Progress in juvenile Douglas-fir plantations with respect to the "Crossover" effect

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In 1991, the Stand Management Cooperative (SMC) Silviculture Project began establishing permanent plots in a series of spacing trials (Type III SMC installations), which were planted in the mid-1980's to early 1990's. The permanent plots are expected to provide information about the effects of initial spacing on the growth and development of juvenile stands of pure Douglas-fir, pure western hemlock, and 50-50 mixtures of the two species. The geographic scope of the project includes western Oregon, Washington and southwestern coastal British Columbia, Canada. These installations include widely contrasting spacings covering a large range of soil and climatic conditions. They are further intended to provide sites for a variety of future research needs which include understanding growth dynamics, estimating growth and yield, modeling, and studying of wood quality.

It is known that many plant species reap benefits from neighbors during juvenile growth (*e.g.*, Scott, *et al*. 1998). This has been referred to as the crossover effect. The initial measurements on the Douglas-fir plots in Type III installations showed strong signs of crossover effects when the attained dimensions (DBH and height) of the 100 largest diameter trees per acre were previously analyzed (Turnblom 1998). We now have two more measurements, two-years apart on most of these same plots. The response variables examined were net increment in QMD, in basal area, in dominant height (avg. height of 40 largest trees by DBH), increment in QMD of survivors and the increment in QMD of the 40 largest diameter trees per acre. The basal area growth is largely correlated with density (stems per acre) at this age (the more stems there are, the more basal area growth there is) and so is omitted from this report. This report focuses on increment in QMD of survivors.

Growth curves (e.g., Current Annual Increment, Periodic Annual Increment, Mean Annual Increment, etc.) are peaked in form or shape, while the corresponding cumulative growth (yield) curve is sigmoid in shape. Before the growth curve peaks, attained tree and stand dimensions are increasing at an increasing rate (or accelerating, *i.e.*, the cumulative growth curve is concave upward). When the increment curve is at its peak, the cumulative growth curve is at its inflection point. Beyond the peak of the increment curves, attained dimensions of the tree are still increasing, but at a decreasing rate (i.e., decelerating).

The existence and position of the inflection point on the sigmoid cumulative growth curve depends on species, density and site quality. While it is recognized that the inflection point will occur eventually even in open-grown trees, it is well recognized also that with all else being equal, denser stands will peak in growth at younger ages than less dense stands (Clutter, et al. 1988). This study examines whether the densest Type III stands, which exhibit faster early growth have reached or passed

their growth peak, or reached or passed the point of inflection in terms of cumulative growth. If growth in dense stands slows down sooner than in the less dense stands, we can expect that the cumulative growth curve exhibited by the dense stand may cross over the cumulative growth curve for the less dense stand at some point in the future (see Figure 1).

Data and Methods

For this study the data were grouped into six density classes and two site classes. Density classes used were 100 stems per acre (SPA), 200 SPA, 300 SPA, 440 SPA, 680 SPA, and 1210 SPA, which are identical to the classes used by Turnblom (1998). Site classes used were less than or equal to 110 feet at 50 years breast height age, or greater than 110 feet.

Turnblom (1998) found a difference between the average QMD attained by the 100 largest trees per acre due to planting density; but found no correlation between QMD and planting density when all trees were considered. To investigate the possibility of density induced differences in QMD growth of survivors appearing at a later stage; a preliminary analysis is performed here to examine growth that occurred in periods not included in the previous study. There were 124 observations available for analysis in the first two-year growth period and 97 observations available in the second two-year period.

To detect if and when the effect of density on growth in QMD of survivors ("growth" in the sequel will implicitly refer to "growth in QMD of survivors") changes from positive to negative, consecutive growth rates are compared. Since the consecutive pairs of two-year growth periods actually occurred over a ten-year time span due to the staggered plot establishment dates for all installations, we expect that the effects of climate will be somewhat ameliorated, or "averaged out." Hence, we simply compared the growth in period 1 to period 2. In the absence of thinning, as in these stands, if the amount of growth occurring in the first two-year period is less than the growth in the second period, it can be said that growth has not peaked yet. If growth in the first two-year period is equal to the second, growth has either peaked or very nearly peaked. Similarly, if growth in the first two-year period is more than in the second, growth has most probably already peaked.

The negative effects of density are hypothesized to occur sooner in the more dense stands and will be detected by growth peaking sooner than in less dense stands. This hypothesis was tested using the following procedures. First, the total growth in QMD of survivors occurring over the entire 4-year period was calculated, and then the proportion of that total occurring in the first and second two-year periods was derived. Next, the significance of density and site as an effect on the proportion of growth occurring in the first period was tested. ANOVA allows testing for the significance of these differences and allows determining if covariates are needed. The ANOVA used density and site classes as factors and tested the following covariates: years as seedling, years as transplant, total planting stock age, and total age from

seed. Total age from seed was the only significant covariate. Therefore, in the sequel, results have been adjusted for slight differences in total age.

Results

The preliminary ANCOVA on growth showed that only the 100 SPA class in the first growth period was different from all others. In the second growth period no significant difference in growth due to density was found. Therefore, it seems that when examining any particular two-year growth interval, density either does not have an effect on growth, or variation in growth within a particular period is large compared to variation in growth between density classes, thus disabling our ability to detect differences that might actually exist.

Next the growth in the first two-year period was compared with the growth that occurred in the second two-year period. Figure 2 displays the mean proportion of total four-year growth occurring in the first two-year period for each combination of density and site class. (Note that the proportion of growth occurring in the second two-year period is just one minus the displayed first period proportion for any particular density and site class.) The ANCOVA on proportion of four-year growth occurring in the first two-year period shows both site and density to be significant at the $\alpha = .05$ significance level, but their interaction is not significant. As can be seen there are differences among the groups: the proportion of growth occurring in the first period increases with density. Also, since the proportion of four-year growth occurring in the first period exceeds 50%, the highest density plots for both site classes appear to have passed the point of inflection on the cumulative growth curve. Further, the 440 and 680 density classes on low sites appear to have reached the inflection point also, while the same density classes on high sites have not.

Other pertinent information for a siviculurist might be the age when a density class has hit (or already passed) its inflection point on the cumulative growth curve. Unfortunately, the 1210 SPA density class has only three observations, a very small sample size. For this reason we supply age statistics for the low site 440, 680 and 1210 density classes combined in Table 1.

Table 1:

Approximate age of growth peak on low sites for 440, 680 and 1210 stems per acre density classes.

Mean Total Age	13.0
Standard Deviation	1.234
# of Observations	16
Maximum	15
Minimum	12

Conclusions

This study has revealed several considerations germane to management options. Except in the lowest density class, density did not significantly affect increment in QMD of survivors during the first period of growth, a result consistent with Turnblom (1998). Growth in QMD of survivors was apparently unaffected by density during the second growth period as well. However, proportion of total four-year growth that occurred during the first period was affected by density. For the low site class, the 440, 680 and 1210 SPA density classes seem to be experiencing losses in growth of QMD of survivors when compared with both lower densities on similar sites, and similar densities on higher sites. For the high site stands, only the 1210 SPA density class plots have peaked in QMD increment of survivors.

Literature Cited

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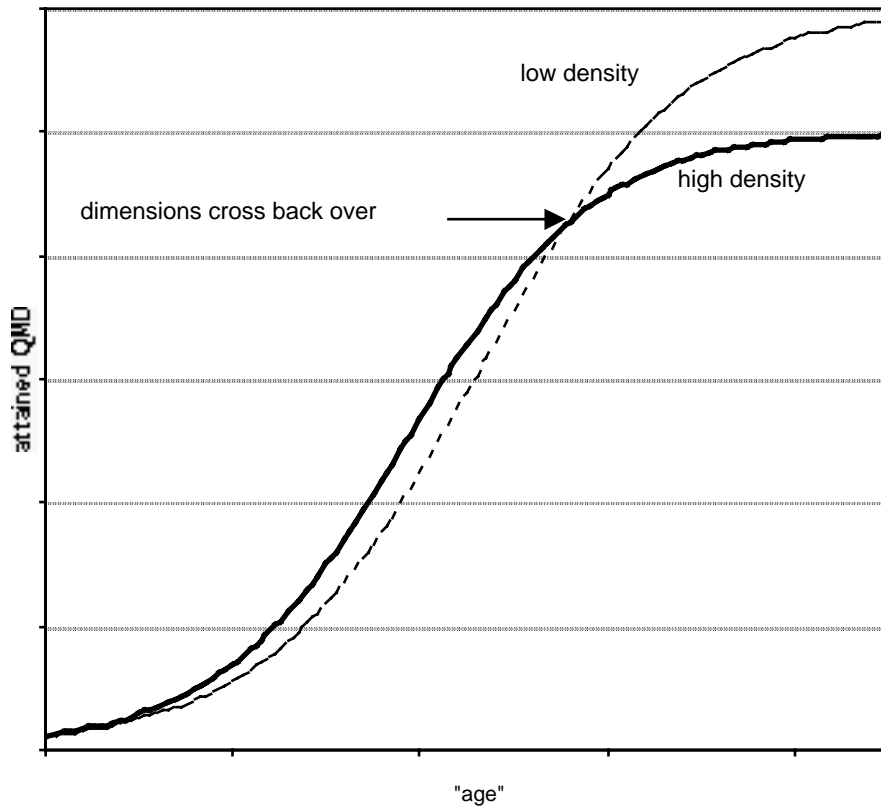
Figure 1: Cumulative growth curves for the average tree in a high-density stand (bold) and low-density stand. Note that the curve for the stand with high density is initially higher, but since crowding and the effects of competition are expected to set in sooner, it will eventually cross over the cumulative curve for the stand with low density. Thus, a smaller attained average dimension is expected in the final evaluation.
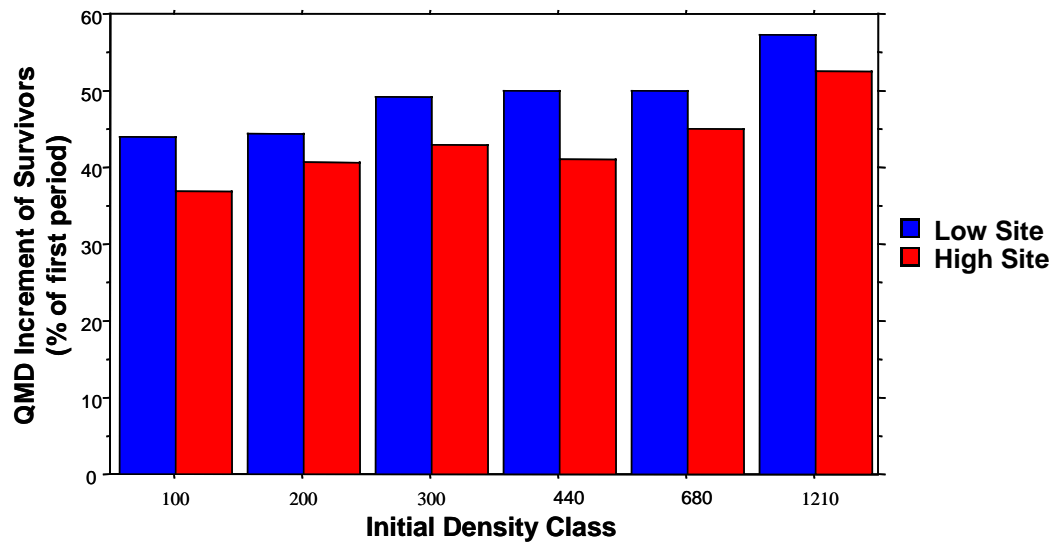
Figure 2: Effect of density and site on the proportion of growth occurring in the first two-year growth period.