# GROWTH AND YIELD FOR A 7-YEAR-OLD YELLOW-POPLAR PLANTATION IN NORTHERN WEST VIRGINIA

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**Abstract.**—Results for several major stand level variables from a 7-year-old yellow-poplar (*Liriodendron tulipifera* L.) plantation established in a converted pasture in northern West Virginia were summarized based on initial planting densities of 1,517 trees/ac, 972 trees/ac, 765 trees/ac, and 602 trees/ac. Stand basal area/acre at age 7 was greatest (54.7 $ft^2$/ac) for the 4 ft spacing and least (22.1 $ft^2$/ac) for the 10 ft spacing. Average total height for all trees was similar for all spacing treatments except for the 10 ft spacing which was approximately 6 ft shorter at age 7. Based on locally fit logarithmic weight and volume equations, total aboveground green weight and dry weight decreased with an increase in planting density, with the greatest being the 4 ft spacing treatment averaging 26.3 and 10.8 tons/ac, respectively. Outside bark bole volume ranged from 228 to 769 $ft^3$/ac, while bole green weight ranged from 6.4 to 22.7 tons/acre, depending on planting density.

## INTRODUCTION

In the central Appalachian region, few experimental results have been reported for hardwood plantations due to the natural coppice regeneration common to this region. Even less information is available for stand level growth and yield data from successful plantings. Some historical information is available for yellow-poplar (*Liriodendron tulipifera* L.) plantations in Monongalia County, West Virginia (Fithian 1979), Jackson County, West Virginia (Faleru, 1983), Clarion County, Pennsylvania (Grisez 1968), Noble County, Ohio (Funk et al. 1974), and Smith and Trousdale Counties, Tennessee (Clatterbuck 2004). The purpose of this study was to report and develop growth and yield data for planted yellow-poplar in the central Appalachian region based specifically on a planting density study. Stand level growth and yield data are reported for a 7-year-old plantation planted at four different spacings: 4 by 11 ft; 6 by 11 ft; 8 by 11 ft; and 10 by 11 ft.

The study area is located in north central West Virginia near the city of Morgantown. The area is approximately 4 acres in size and was pastured for at least 5 years prior to planting. The site has a northerly aspect and approximately a 30 percent slope. The soils in the study area are classified as Westmoreland silt loams of 25-35 percent slope which are characterized as well drained with a soil depth of 40 inches to bedrock.

## METHODS

In late September of 2003, a 4 acre pasture was cut, and 2 weeks later, planting rows were sprayed with a 0.5 percent solution of glyphosate mixed with water. The spray unit utilized was a 50 gallon portable sprayer powered by a 3.5 horsepower motor installed on the back of an all-terrain vehicle (ATV). Planting rows were aligned parallel to the contour and spaced 11 ft between row centers.

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Within each row, planting density treatments (within row densities) were assigned at random at 4, 6, 8, and 10 ft between trees. Planting density treatments were replicated in two blocks, with one planting block located on the lower slope and a second planting block occurring higher on the slope. Seedlings were 1-0 bare root improved yellow-poplar seedlings obtained from the West Virginia Division of Forestry state tree nursery at Clements, WV. Seedlings were hand planted in mid-March 2004 at predetermined planting locations indicated with colored pin flags. During the second and third growing seasons, late spring backpack applications of a 0.5 percent solution of glyphosate mixed with water were applied to provide some herbaceous weed control. During the spring of the fourth growing, an ATV mounted sprayer was used to apply a shielded spray application of a 0.5 percent solution of glyphosate adjacent to each row. No additional herbicide treatments were applied.

Within each density treatment, for both replications, a rectangular fixed area plot was established made up of 5 rows within each treatment area. Average plot size was 0.0733 acre with plot boundaries buffered by at least two additional planting rows. Tree positions were mapped by planting space location, and the first tree in each row was marked with a metal stake to permit individual tree identification through time. At the end of the first, third, and fourth growing seasons, total height to the nearest 0.1 ft using a height pole and diameter at breast height (d.b.h.) to the nearest 0.0001 inch using an electronic caliper were measured for each tree. At the end of the seventh growing season, all trees were remeasured, using an Impulse laser to measure heights. Average number of trees/plot ranged from 115 (4 ft spacing) to 50 trees/plot (10 ft spacing).

To determine accurate estimates of total aboveground green weight, dry weight, green weight of the main bole, and bole $ft^3$ volume, equations were developed based on the destructive sampling of 57 trees obtained from outside the measurement plots and at nearby even-aged regeneration sites of similar densities on the West Virginia University Research Forest. All live limb segments (excluding leaves) were cut flush with the main stem and weighed as one group. Weights were recorded to the nearest 0.001 g with an electronic scale. The main bole was cut into approximate 1 ft segments with a bow saw and weighed. Tree sections and tops were dried at 70 °C for 1 week and reweighed. Tree $ft^3$ volume was based on the end diameter measurements of each 1 ft section using Smailian's equation as there was no indication of lower stem butt swell with these small tree sizes. Dry weight was obtained from only 33 of the 57 sample trees. Descriptive statistics for the sample trees are displayed in Table 1. To facilitate stand level estimates of bole green weight (B_GWT), total aboveground green weight of stem and branch wood (TGWT), total aboveground dry weight of stem and branch wood (TDWT), and bole $ft^3$ volume (B_CUFT), prediction equations were developed using SAS NLIN procedure (SAS Institute Inc., Cary, NC). Prediction equations were of the logarithmic form:

$$Y = \beta_1 D^{\beta_2} H^{\beta_3} \qquad [1]$$

Where Y is the tree level parameter to be estimated, D is d.b.h. in inches, H is total height in ft, and $\beta_i$ are parameters to be estimated from the data.

**Table 1.—Weight and volume sample tree statistics for a yellow-poplar plantation in West Virginia**

| | n | Mean | Min | Max | SD |
|---|---|---|---|---|---|
| D.B.H. (in) | 57 | 0.756 | 0.210 | 2.340 | 0.500 |
| THT[a] (ft) | 57 | 9.1 | 4.5 | 23.2 | 3.9 |
| Bole GWT[b] (tons/ac) | 57 | 2.667 | 0.158 | 25.147 | 4.408 |
| Total GWT (tons/ac) | 57 | 3.525 | 0.170 | 30.080 | 5.579 |
| Total DWT[c] (tons/ac) | 33 | 2.283 | 0.064 | 12.924 | 3.090 |
| Bole ($ft^3$/ac) | 57 | 0.048 | 0.003 | 0.419 | 0.077 |

[a] THT is total height
[b] GWT is green weight
[c] DWT is dry weight

**Table 2.—Weight and volume equation parameter estimates and model root mean square error (RMSE) for a yellow-poplar plantation in West Virginia**

| | Beta 1 | Beta 2 | Beta 3 | RMSE |
|---|---|---|---|---|
| Total DWT | 0.2738 | 1.2914 | 0.8586 | 0.473 |
| Total GWT | 0.4976 | 1.4966 | 0.8795 | 0.893 |
| Bole GWT | 0.0914 | 1.1864 | 1.4474 | 0.644 |
| Bole CUFT | 0.0026 | 1.2595 | 1.2676 | 0.006 |

## RESULTS

Nonlinear tree weight and volume equations were fit to the sample data in both weighted (weighted by $D^2H$) and nonweighted form. The nonweighted parameter estimates were selected since weighted forms showed no improvement in explained error or residual analysis. Parameter estimates and fit statistics are listed in Table 2. All models and model parameters were significant at the p=0.0001 level. Individual tree weights and volumes were estimated for each sample tree and summed by plot for per acre estimates.

Based on the age of these plantations, stand level variables behaved as expected with the greatest density possessing the largest volumes and basal area values. Average (average of the two blocks) planting densities ranged from 1,517 trees/ac with the 4 ft spacing to 602 trees/ac for the 10 ft spacing treatments. Density values are based on actual field counts following planting for each plot. At age 7, percent survival ranged from 86 percent with the 10 ft spacing to 94 percent with the 6 ft spacing. Few survival differences were observed between the 4, 6, and 8 ft spacing treatments. Total basal area/ac ranged from 22 $ft^2$/ac for the 10 ft spacing to 55 $ft^2$/ac for the 4 ft spacing treatment. Very little difference was observed in terms of quadratic mean diameter (QMD) between treatments, with the 8 ft and 6 ft treatments showing the largest average diameter at this young age. With respect to total stand height (average height of all trees), little difference was observed between the 4, 6, and 8 ft density treatments, while the 10 ft spacing treatment averaged approximately 6 ft shorter at age 7. Stand development in these variables is shown in Figure 1.

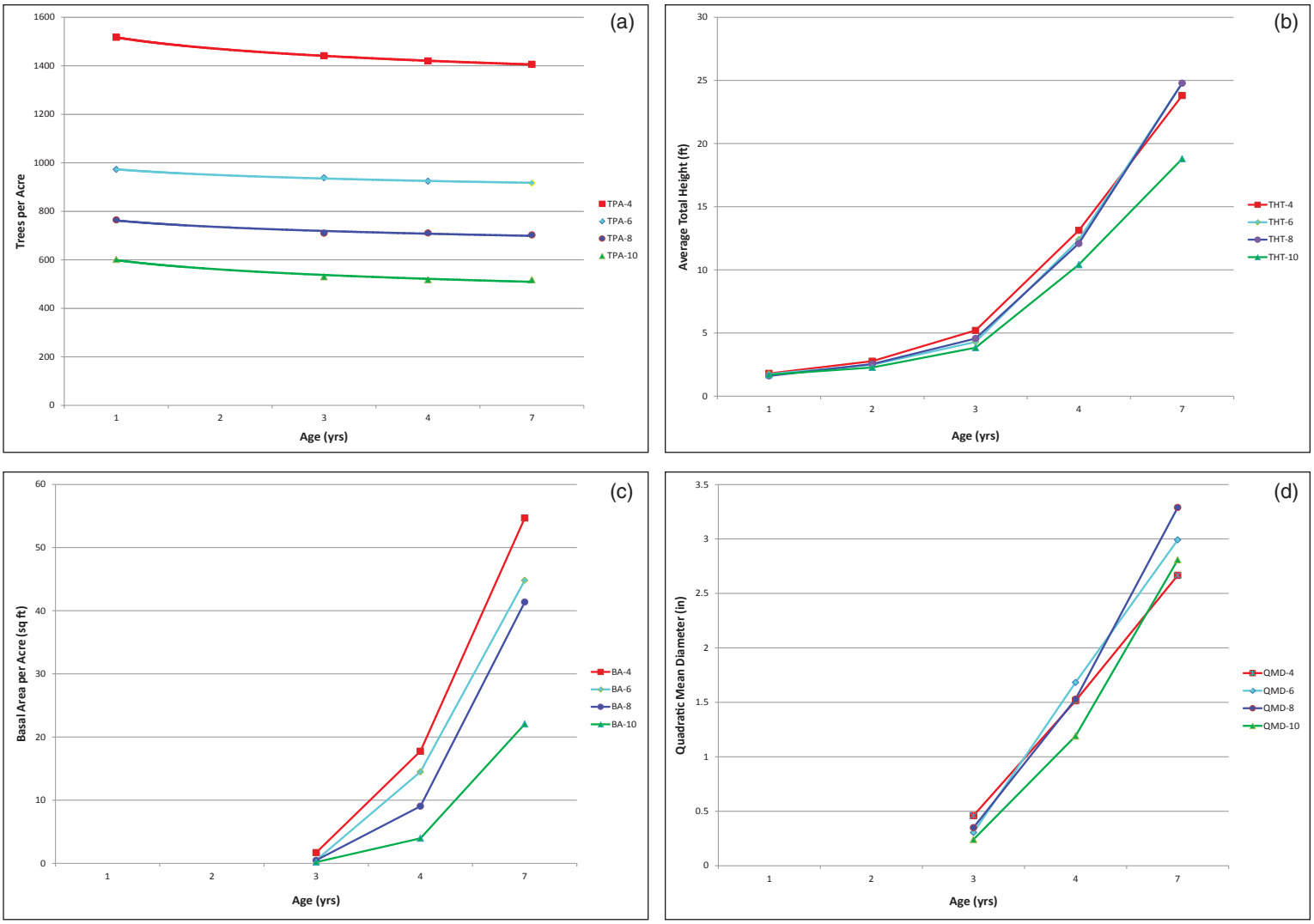


Figure 1.—Average stand trees per acre (a), total height (b), basal area per acre (c), and quadratic mean diameter (d), by age and planting density for planted yellow-poplar in West Virginia.

When considering aboveground weight of stem and branches, both TGWT and TDWT exhibited the same patterns with the 4 ft spacing treatment having the greatest total volume and the 10 ft spacing treatment having the least. Little difference was observed between the 6 ft and 8 ft density treatments. Similar stand development was observed for B_GWT and B_CUFT. At age 7 the greatest volume development was observed with the 4 ft spacing treatment having a TGWT of 26.3 tons/ac, a TDWT of 10.8 tons/ac, a B_GWT of 22.7 tons/ac and a B_CUFT of 769.3 $ft^3$/ac. Stand development in these parameters are shown in Figure 2.

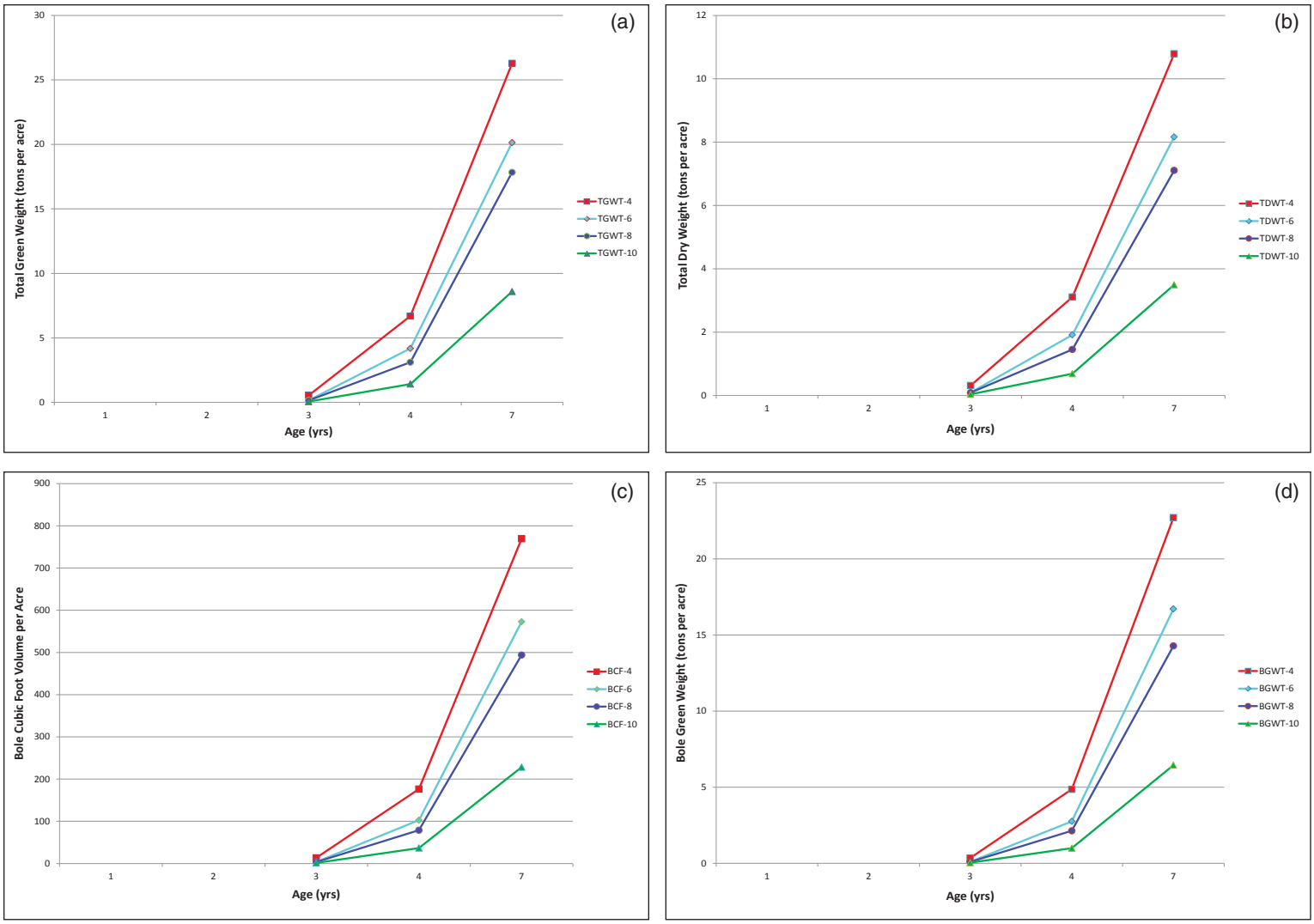


Figure 2.—Average total aboveground green weight per acre (a), total aboveground dry weight per acre (b), bole cubic foot volume per acre (c), and bole green weight per acre (d), by age and planting density for planted yellow-poplar in West Virginia.

## DISCUSSION

Although not directly comparable due to different sites, seed sources, ages, and climatic conditions, results from this yellow-poplar density study are similar to those published by Clatterbuck (2004) in Tennessee and Funk et al. (1974) in southeastern Ohio. With proper site selection and herbicide treatments, successful plantations can be established on existing pastures. Although early results can be misleading, the author suggests that planting spacings of 6 ft by 11 ft and 8 ft by 11 ft provide good growth characteristics and good early volume development. Planting at spacing near 10 ft by 11 ft had less volume and average height than other planting densities. The higher density plantings also provide some insurance should planting mortality exceed those achieved in this study.

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