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Half-sib seed source and nursery sowing density affect black walnut (*Juglans nigra*) growth after 5 years

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Abstract The effect of seed source (half-sib family) and nursery bed density on the nursery stock quality and subsequent growth of black walnut (*Juglans nigra* L.) was investigated. Nine black walnut female genitors were selected to represent a range of phenotypes. Seeds were collected, cleaned, cold-treated, and pre-sprouted to ensure that germination was uniform and complete. The pre-sprouted seeds were planted in a randomized complete block design into standard nursery beds in Indiana, USA at three sowing densities, (11.2 plants m^{-2}; 24.2 plants m^{-2}; 29.4 plants m^{-2}). After lifting, the trees were measured for height, ground-line diameter and root volume and then planted into a plantation in a randomized complete block design and re-measured after 1 and 5 years of growth. One year after planting, the effects of family (half-sib seed source) and density were significant or very highly significant for seedling height, and ground-line diameter, although family effects were greater than those for density, especially at moderate and high nursery bed density. After 5 years of growth, the same effects contributed significantly to ground-line diameter and dbh, but only family significantly influenced height. Family was more important than nursery bed density in determining the size of the trees after 5 years. Although there were no significant family × density interactions after 5 years, family variance for all the traits was considerably higher among seedlings grown at moderate and high density in the nursery. Phenotypic correlations among traits within and among years were generally very high ($0.65 < r < 0.90$) and insensitive to planting density in the nursery.

Keywords Seedling quality · Root volume · Shoot height · Ground line diameter · Hardwood genetics · Bareroot nursery production

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