PLANTED WHITE OAK (*QUERCUS ALBA*) RESPONSE TO SPACING DENSITY AND ORIENTATION IN GAP OPENINGS IN THE BLUE RIDGE MOUNTAINS OF NORTH CAROLINA

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EXTENDED ABSTRACT

White oak (*Quercus alba*) trees are difficult to sustain in many stands across the Central Hardwood Region because natural and anthropogenic processes are failing to establish advance reproduction (Schweitzer and others 2019). Large-scale shifts in species composition result in mesophication of hardwood forests that can lead to lower biodiversity and reduced fire and drought tolerance (Woodbridge and others 2022). Artificial regeneration (i.e., planting) contributes to localized restoration targets with an immediate input of advance reproduction (Clark and Schlarbaum 2019). The goal of our study was to determine how white oak seedlings respond to the effects of planting density and planting orientation in an irregular shelterwood.

We implemented the study in the Blue Ridge ecoregion on the Pisgah National Forest in North Carolina to examine artificial regeneration responses within an uneven-aged irregular shelterwood. The shelterwood was initially implemented as 0.25-acre or 1.0-acre gaps through commercial harvesting in 2019. The gaps will be expanded in approximately 10-year intervals on an area basis to create multiple age classes. Planted seedlings were bareroot (1-0) from 10 pedigreed sources in eastern Tennessee and were planted in six of the 0.25-acre gaps. Trees were randomly assigned into treatments consisting of planting spacing (2 feet by 2 feet or 12 feet by 12 feet), gap location (center, edge, forest matrix), and gap direction from gap center (north or south). Groups of 10 to 30 trees were planted within each gap along the north and south axis extending from gap center at the three gap locations: center (2 to 13 feet from gap center), edge (6 feet inside and outside of the gap edge), and forest matrix (20 to 30 feet outside the gap edge). The 2-foot-by-2-foot-spacing trees were planted in five rows of six trees each, and the 12-foot-by-12-foot-spacing trees were planted in two rows of five trees for each treatment combination. Across all treatments, tree height ranged from 6 to 34 inches

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with an average of 13.1 inches at the time of planting. Trees were measured for survival and height after the third growing season. Data were analyzed using general linear mixed modelling to test fixed effects of spacing (2 feet versus 12 feet), direction from gap center (north versus south), and location within the gap (center, edge, and matrix). Spacing was the whole plot treatment, and direction and location were subplot treatments; replication (n = 3) was a random effect in the model. A 0.05 α-level was used to denote significant differences.

Third year survival was 77 percent across all gaps, and treatments ($F_{1,4}$ ≤1.51, P ≥0.29) and interactions ($F_{2,16}$ ≤1.64, P ≥0.23) were not significant effects. Seedlings planted in gap centers were 2.5 feet tall after three growing seasons, 0.9 to 1.0 feet taller than trees on the gap edge or in the forest matrix, respectively ($F_{2,16}$ = 20.1, P <0.0001) (fig. 1). The effect of spacing ($F_{1,4}$ = 0.10, P = 0.77) and direction ($F_{1,4}$ = 0.60, P = 0.48) did not significantly affect height, and interactions were not significant ($F_{2,16}$ ≥1.38, P ≥0.27). Deer browsing on terminal stems was negligible (<3 percent of trees browsed).

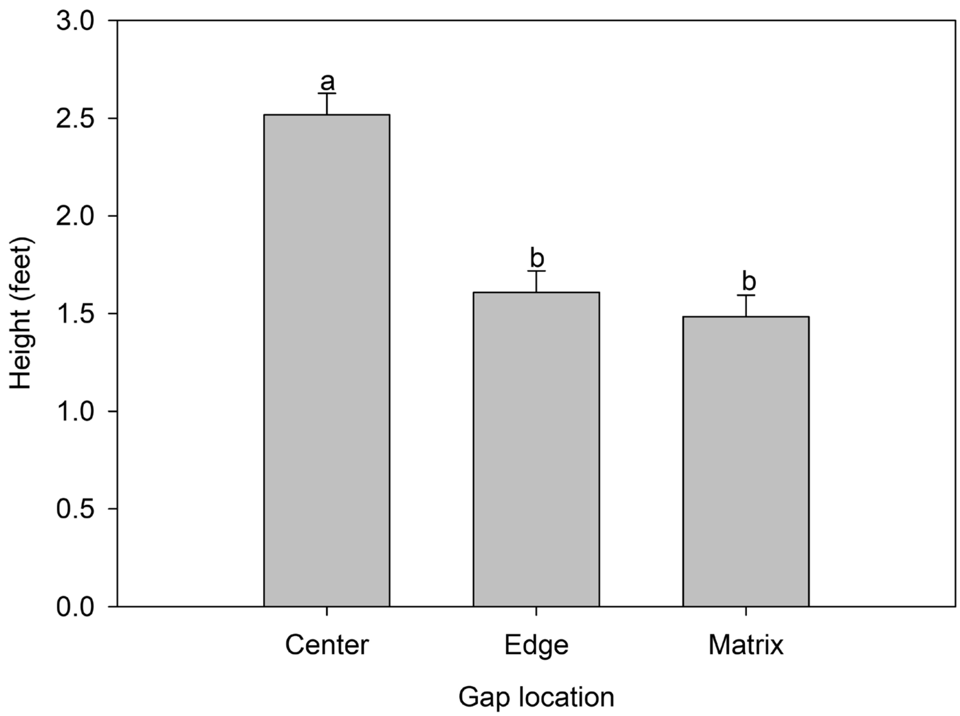

Figure 1—Third-year height (least-squares means) of white oak seedlings planted in 0.25-acre gaps in western North Carolina.

This study was relatively novel for the Central Hardwood Region by incorporating artificial regeneration into an irregular shelterwood. Unlike more traditional regeneration systems (e.g., clearcut, shelterwoods resulting in low basal area) that have received more research and management attention in the Region (c.f., Brose 2010, Schweitzer and Dey 2011), the smaller-sized and irregular-shaped shelterwood was designed to mimic natural disturbances, but its efficacy has not been adequately tested for oak forests. Artificial regeneration of white oak has been historically difficult, owing to poor seedling quality, deer browse, and lack of competition control (Dey and others 2008), but planting and nursery protocols have been better refined in the last 3 decades to improve planting success (Clark and Schlarbaum 2019, Kormanik and others 1994).

Planted white oak seedlings did not grow appreciably in height, even in the gap centers (17 inches of stem growth over 3 years), especially compared to competition, dominated by yellow-poplar (*Liriodendron tulipifera*) (data not shown). Future gap expansions are predicted to benefit established seedlings in the gap edges and forest matrix, where oak seedlings should maintain their physiological demands in intermediate light environments (Patterson and others 2022). Planting density and gap direction did not affect seedling performance in the first 3 years, but seedling growth dynamics are expected to change over time as the root systems for seedlings become better established and the gaps are expanded, resulting in an increase in light. Despite the limited biological implications related to planting density, the higher density plots required less establishment time because trees were grouped together in relatively small areas, which simplified planting logistics. Higher planting density may also simplify future tending practices (i.e., reduction of the treated area around seedlings).

A similar study in eastern Tennessee showed that a proportion of white oak seedlings planted into gap edges grew into competitive canopy positions 7 years after planting, and these seedlings are now in a favorable position for recruitment into the canopy following gap expansion (Clark and others, In press). In this study, seedling quality was comparatively lower. Seedling quality varies from year to year due to weather, and nursery and management schedules that can disrupt timely sowing, lifting, and seedling storage. Seed quality impacted by insects and seed storage (Rink and Williams 1984) can also degrade seedling growth in the nursery, and delayed sowing time may have reduced overall seedling size in this study. Despite the relatively common challenges, we increased the overall oak regeneration potential of the forest and improved chances for oak recruitment by establishment of new age classes through gap expansion.

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LITERATURE CITED

Brose, P.H. 2010. Long-term effects of single prescribed fires on hardwood regeneration in oak shelterwood stands. Forest Ecology and Management. 260: 1516–1524. https://doi.org/10.1016/j.foreco.2010.07.050.

Clark, S.L.; Schlarbaum, S.E. 2019. Artificial regeneration in the Southern Appalachians. In: Clark, S.L.; Schweitzer, C.J., eds. Oak symposium: sustaining oak forests in the 21st century through science-based management. e-Gen. Tech. Rep. SRS-237. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 95–100. https://doi.org/10.2737/SRS-GTR-237.

Clark, S.L.; Schlarbaum, S.E.; Schweitzer, C.J. [and others]. In press. Planted white oak (*Quercus alba*) and natural regeneration response to even- and uneven-aged silviculture in the Ridge and Valley ecoregion of Tennessee. In: Proceedings of the 22nd central hardwood forest conference. Gen. Tech. Rep. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station.

Dey, D.C.; Jacobs, D.; McNabb, K. [and others]. 2008. Artificial regeneration of major oak (*Quercus*) species in the Eastern United States—a review of the literature. Forest Science. 54(1): 77–106. https://doi.org/10.1093/forestscience/54.1.77.

Kormanik, P.P.; Sung, S.J.S.; Kormanik, T.L. 1994. Towards a single nursery protocol for oak seedlings. In: Lantz, C.W.; Moorhead, D.J., comps. Proceedings of the 22nd southern forest tree improvement conference. Sponsored Publ. No. 44. Atlanta, GA: Southern Forest Tree Improvement Committee: 89–98.

Patterson, C.P.; Hackworth, Z.J.; Lhotka, J.M.; Stringer, J.W. 2022. Light and regeneration patterns following silvicultural gap establishment in *Quercus* dominated stands of the northern Cumberland Plateau, USA. Forest Ecology and Management. 505: 119871. 12 p. https://doi.org/10.1016/j.foreco.2021.119871.

Rink, G.; Williams, R.D. 1984. Storage technique affects white oak acorn viability. Tree Planters' Notes. 35(1): 3–5.

Schweitzer, C.J.; Dey, D.C. 2011. Forest structure, composition, and tree diversity response to a gradient of regeneration harvests in the mid-Cumberland Plateau escarpment region, USA. Forest Ecology and Management. 262: 1729–1741. https://doi.org/10.1016/j.foreco.2011.07.020.

Schweitzer, C.J.; Dey, D.C.; Wang, Y. 2019. White oak (*Quercus alba*) response to thinning and prescribed fire in northcentral Alabama mixed pine-hardwood forests. Forest Science. 65(6): 758–766. https://doi.org/10.1093/forsci/fxz031.

Woodbridge, M.; Keyser, T.; Oswalt, C. 2022. Stand and environmental conditions drive functional shifts associated with mesophication in eastern US forests. Frontiers in Forests and Global Change. 5: 991934. 16 p. https://doi.org/10.3389/ffgc.2022.991934.