Black Walnut Allelopathy in a 28-Year-Old Loblolly Pine Stand and Implications for Initial Plantation Establishment

Coleman A. Doggett, Michael J. Perry, and William R. Doggett

Forest Health Section Head (retired), North Carolina Division of Forest Resources, Raleigh, NC; President, Forestry Services Inc., Cary, NC; Project Statistician, Poquoson, VA

Abstract

Damaged and dying loblolly pine trees (*Pinus taeda* L.) were found around black walnut trees in a 28-year-old plantation in Chatham County, NC. The damage and mortality are attributed to disease caused by walnut allelopathy. Damage is first evident by the presence of resin exudation on the lower trunks of affected trees. As damage progresses, resin exudation occurs higher on the trunk, eventually reaching heights of more than 10 ft (3 m). The phloem and sapwood beneath the resin exudation are killed thereafter leading to termite invasion and bird predation. Affected trees eventually die. Sampling of black walnut trees and the affected pines in their vicinity indicated the following: most of the resin exudation (95.6 percent) is found on the side of the pines facing the black walnut tree, pine mortality increases as resin flow height increases, larger diameter black walnut trees result in farther damage extent, and damage extends beyond the dripline of the black walnut tree. Before establishing loblolly pine plantations, the planting area and vicinity should be surveyed for the presence of black walnut trees. It is recommended that no pines be planted within 35 ft (10 m) of driplines of established black walnut trees. If black walnut trees are found in the vicinity of a pine plantation, the plantation should be surveyed at least every 5 years to locate and eliminate any newly established black walnut seedlings.

Introduction

Black walnut (*Juglans nigra* L.) is an extremely valuable hardwood tree found in Eastern North America from southern Ontario, Canada, in the north to northern Florida in the south (Burns and Barbara 1990). Wood from this species is used in furniture manufacture, both as solid boards and veneer, and in gunstock manufacture. Black walnut is shade intolerant and develops best on moist, deep, well-drained soils, although it can survive and grow on a wide variety of other soils.

Black walnut is an allelopathic species. *Allelopathy* is defined as "any direct or indirect harmful effect by one plant on another through production of chemical compounds that escape into the environment" (Rice 1974). Allelopathy was first documented in the United States in Wisconsin in the late 19th century (Hoy and Stickney 1881) when black walnut was reported to cause adverse effects to other plants. Davis (1928) identified the causative allelopathic agent produced by black walnut as juglone (5-hydroxy-1, 4 napthalenedione). Appleton et al. (2009) summarized information on production of juglone and included a list of known susceptible and resistant plant species. Juglone is produced in walnut husks and leaves and is exuded by the roots. Once exuded, juglone remains in the soil around walnut roots and can injure roots of susceptible plant species within 0.25 to 0.5 in. (0.64 to 1.27 cm.) of a root. Injury to susceptible plants can include wilting, chlorosis, necrosis, or mortality. Pine (*Pinus* spp.) is a susceptible genus (Appleton et al. 2009).

Several studies have confirmed the allelopathic effect of black walnut on other species. Gabriel (1975) studied the allelopathic effects of walnut on white birch (*Betula papyrifera* Marsh) and observed that mortality of birch seedlings planted near walnuts began the first year after they were planted. He also noted that, as surviving seedlings grew older, their vigor increased as their distance from walnut trees increased. Fisher (1978) conducted a field study in a 22- to 25-year-old mixed plantation of red and white pine (*Pinus resinosa* Ait. and *P. strobus* L.) and black walnut in Ontario, Canada. The study compared pine growth and survival in the mixed pine-walnut stand between well-drained Brant soils, imperfectly drained Toscola soils, and poorly drained Colwood soils. The pines growing adjacent to the walnuts on the Brant soil showed no significant effect from walnut allelopathy, but the pines growing on the Brant soil had significantly poorer survival and growth. The pines on the Colwood soil that were adjacent to the walnuts all died.

Funk et al. (1979) conducted laboratory studies on the effects of juglone on seedlings of Japanese larch (*Larix kaempferi* [Lam.] Carrière), Norway spruce (*Picea abies* [L.] Karst.), white pine, and Scots pine (*Pinus sylvestris* L.). The seedlings

were grown in a hydroponic system for 8 to 10 weeks in various juglone concentrations. At high concentrations, juglone was toxic to all species. At moderate concentrations, no visible injury to white pine was observed, but seedling growth was inhibited. Appleton et al. (2009) summarized information on production of juglone and included a list of known susceptible and resistant plant species.

The objective of this study was to determine if black walnut allelopathy caused observed damage to a 28-year-old loblolly pine plantation growing in proximity of black walnut trees and to document damage symptoms.

Materials and Methods

A 115-ac (46.5-ha) loblolly pine (*Pinus taeda* L.) stand was planted in Chatham County, NC, in 1986. The plantation site included an abandoned homestead surrounded by several black walnut trees and also scattered black walnut trees along a small stream. These black walnut trees were not removed before the pines were planted so they and the walnut seedlings established from their nuts competed with the pines. Because walnut seedlings were found at distances well beyond the driplines of the parent trees, the long-distance movement was probably caused by gray squirrels burying nuts resulting in randomly scattered walnut trees of various ages throughout the pine stand. Before the pines were planted, most of the property was in fescue pasture, which was furrowed before planting to reduce vegetative competition. The pine stand was thinned for pulpwood in 2001 and 2014. Before the 2014 thinning, an examination revealed that pine trees were dying and that the mortality appeared to be associated with the presence of black walnut trees. Affected pine trees had notable resin exudations on their boles.

To determine if walnut allelopathy was the causal agent of the observed pine damage, 29 black walnut trees and 97 affected loblolly pines around them were located and measured. Because the black walnut trees were randomly scattered throughout the stand, a considerable amount of searching along transects was required to locate trees for inclusion in the study. Pine trees along the transect lines were carefully examined to determine if symptoms around the walnut trees also occurred away from the influence of those trees.

Walnut trees were measured for diameter at breast height (DBH) determined in 2-in (5.1-cm) diameter classes, tree height, and distance to the nearest and farthest affected pine trees. Pine trees were measured for DBH, distance to the nearest walnut tree, number of resin exudations, and height of resin exudations from ground level.

During initial sampling, it appeared that most resin exudation occurred on the side of the pine tree that faced the nearest black walnut tree, which may further indicate that the walnuts are the damage source. Because of this observation, a subsample of 9 walnut trees, each associated with 10 living pine trees, was measured for total number of resin exudations versus number of resin exudations facing the nearest walnut.

For statistical analyses, individual tree data were entered into a curve-fitting program (The MathWorks, Inc. 2014) to determine relationships among variables measured. Linear and second-order polynomial curves at 95-percent confidence level ($\alpha < 0.05$) were evaluated, and the curves with the best r^2 values are presented.

Results and Discussion

Resin exudation on the lower trunks of pines, thinning crowns, and mortality was found only in the vicinity of black walnut trees. Extensive searches in the pine stand found no similar symptoms on trees that were not associated with walnut trees. This finding indicates that the damage was related to the presence of the walnut trees and was likely caused by walnut allelopathy.

In the subsample, to determine whether resin exudation faced black walnut trees, the affected pines had a total of 45 points of resin exudation, with 43 of these (95.6 percent) on the side of the pine trunks that were facing the walnut tree at the center of the plot. This observation further confirms the black walnut trees as the focal point of the pine tree damage.

Based on our observations, we determined that the general progression of damage to loblolly pine trees begins with a few small areas of resin exudation on the lower bole (figure 1). As damage progresses, more areas of resin exudation appear higher on the bole and the phloem and sapwood beneath die. This progressive damage is followed by termite invasion into the dead wood, with accompanying termite soil tubes and bird (probably woodpecker) predation on the termites (figure 2). Advanced damage continues upward on the bole and may extend to 10 ft (3 m) or more. In the advanced stage, damage appears similar to lightning damage on the side of a tree. In our study, height of resin exudation on the bole was negatively correlated with the number of living, affected trees (figure 3), indicating that fewer trees survive as damage increases upward on the bole.

The damage pattern within a pine may be explained by pine roots in close proximity to walnut roots absorbing juglone along with water and nutrients. As water and nutrients

Figure 1. Resin exudation evident on the lower bole of a live 28-year-old loblolly pine tree. (Photo by Coleman Doggett, 2015)

Figure 2. This recently dead loblolly pine tree has advanced symptoms of damage from walnut allelopathy, still visible on the side of the bole facing the walnut tree. The decayed area on the lower bole is riddled by termites. Above this area are holes through the bark caused by bird predation on the termites. Resin exudation is visible near the top of the photograph. (Photo by Coleman Doggett, 2014)3)

travel through the pine roots and upward in the bole, the juglone could cause the observed damage. It would be interesting to test the needles of damaged pines to determine if juglone is present in the needles and may contribute to further damage after needle fall.

Positive correlations existed between black walnut tree DBH and distance to the nearest and farthest damaged pine trees (figure 4) and also the number of trees affected (figure 5). These data indicate that larger black walnut trees have a greater and farther allelopathic effect than smaller black walnut trees. From a practical standpoint, the forest manager is probably most interested in the maximum distance from a black walnut tree that allelopathic damage may occur.

Although black walnut is classified as a shade-intolerant species, small black walnut trees were present in the understory of our study and were adversely affecting pines. This understory presence may be due to the thinning operations, which are normally done in pine stands one to three times before stands are harvested. Each time a stand is thinned, light is admitted to the understory, which may allow for the small walnut trees to survive.

Recommendations for Plantation Establishment

When establishing loblolly pine plantations in areas where black walnut trees grow, we recommend surveying the plantation area for the presence of walnut trees before planting. The survey area should include not only the plantation area

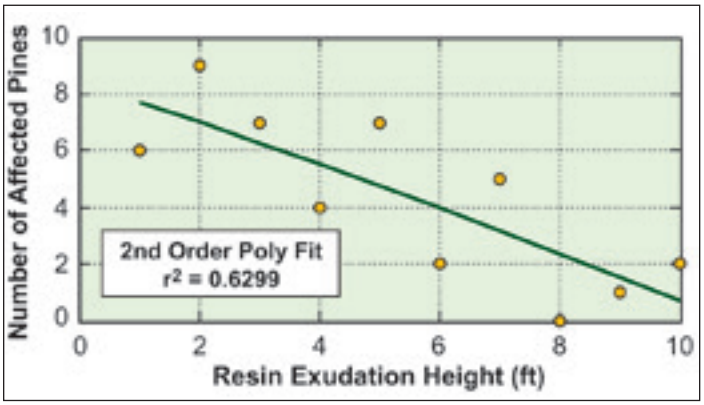

Figure 3. Height of resin exudation on the pine bole was negatively correlated with the number of living, affected trees.)

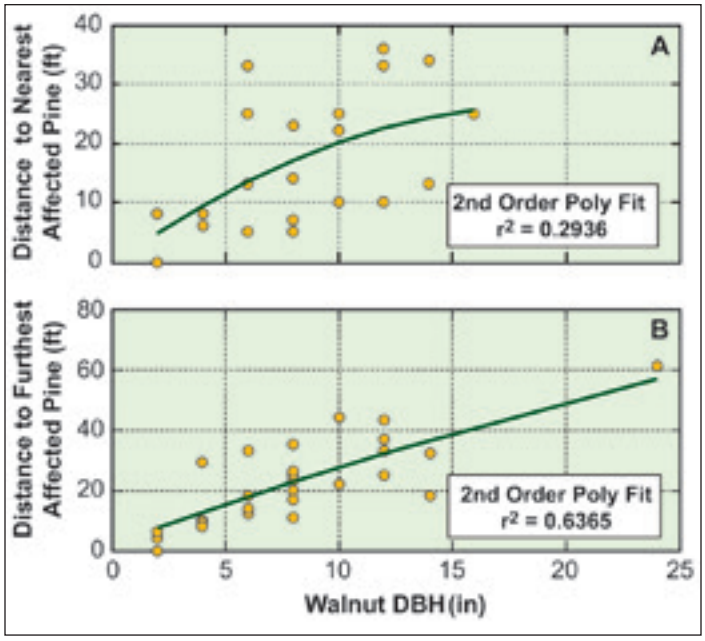

Figure 4. Black walnut tree diameter at breast height was positively correlated with the distance to the (A) nearest and (B) farthest affected pine trees.

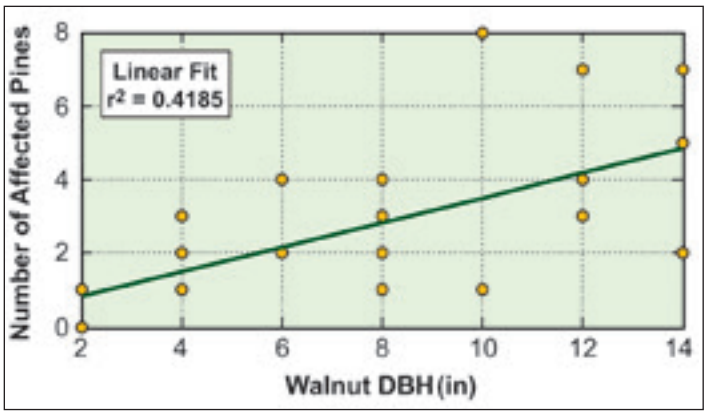

Figure 5. The number of pine trees affected around a black walnut tree was positively correlated with the walnut's diameter at breast height.

itself, but also areas along nearby streams, because the deep, moist soils along streams often support walnut tree growth. Any old homesites in or near pine plantation should also be carefully surveyed, since walnut trees have traditionally been planted near homes for both their nut production and lumber. If walnut trees are found, the forest manager must decide whether to remove or leave the walnut trees. If walnut trees are left in the vicinity of pine plantations, pines planted near established walnut trees will be adversely affected. To be conservative, no pines should be planted within 35 ft (10 m) of the driplines of existing black walnut trees. Although pine trees may survive for a period of time when planted near walnut trees, the roots of the pines and walnut trees will grow together prior to the pines' harvest age, resulting in mortality or degraded wood values.

After planting, the pine plantation should be surveyed at least every 5 years for the presence of black walnut seedlings established by nuts falling from trees or being carried and buried by squirrels. Any walnut seedlings found should be removed.

Address correspondence to—

Coleman Doggett, 217 Rosecommon Lane, Cary, NC 27511

Acknowledgments

This article is dedicated to Mike Burke, who is retiring from Duke Forest, the 7,060 acre research and educational forest that adjoins the Duke University campus. Mike Burke's keen understanding and knowledge of Duke Forest will be missed by everyone who has known him, especially the Duke faculty, staff, and students.

REFERENCES

Appleton, B.; Berrier, R.; Harris, R.; Alleman, D.; Swanson, L. 2009. The walnut tree: allelopathic effects and tolerant plants. Virginia Cooperative Extension Service Bulletin. 430-021. College of Agriculture and Life Sciences, Virginia Polytechnic Institute and State University. 4 p.

Burns, R.M.; Barbara, H.H. 1990. Silvics of North America. Vol 2: Hardwoods. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture, Forest Service. 877 p.

Fisher, R.F. 1978. Juglone inhibits pine growth under certain moisture conditions. Soil Science Society of America Journal. 42(5): 801–803.

Funk, D.T.; Case, P.J.; Rietveld, W.J.; Phares, R.E. 1979. Effects of juglone on coniferous seedlings. Forest Science. 25(3): 452–454.

Davis, E.F. 1928. The toxic principle of *Juglans nigra* as identified with synthetic juglone and its toxic effects on tomato and alfalfa plants. American Journal of Biology. 15:62 (abstract).

Gabriel, W.J. 1975. Allelopathic effects of black walnut on white birches. Journal of Forestry. 73(4): 234–237.

Hoy, P.R.; Stickney, E.F. 1881. Comments on walnut. Transactions of the Wisconsin State Horticultural Society. 11: 166–167.

Rice, E.L. 1974. Allelopathy. New York: Academic Press. 353 p.

The MathWorks, Inc. 2014. MATLAB and statistics toolbox. Release 2014b. Natick, MA.