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WOODLAND MANAGEMENT

Black Walnut Plantation Management

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This report is a state-of-the-art manual for black walnut plantation management based on findings of many individuals over the past 20 years. There are alternatives to some of the recommended practices, but the purpose is to give the landowner a straight-forward set of guidelines that have provided good results under most circumstances. Alternative practices are mentioned where appropriate, but the author's opinion is the determining factor in cases where one practice is recommended over another. Aggressive black walnut plantation management will produce rapid growth, good form, and marketable products much faster than plantations allowed to grow without intensive culture. A brief summary of black walnut plantation management activities is provided in Table 1.

Site Selection

Site selection should be the first consideration in deciding where to plant walnut. Professional help is a must; black walnut should not be planted without first seeking the assistance of an Indiana Division of Forestry District Forester, a Soil Conservation Service (SCS) professional, or consulting forester. In general, soils should be deep (at least 36 inches), well-drained, and have good moisture-holding capacity. Fertile loams and sandy loams with high organic matter and pH from 6.5 to 7.2 are usually best. Bottom land soils often meet these requirements, but you should be aware of possible detrimental factors in such soils because of flooding, poor internal drainage, and bedrock or gravel deposits close to the surface. Flooding can kill young walnut trees during the growing season. If water remains over the tops of trees for more than 2 days, the trees usually die. Flooding for 3 to 5 days during the dormant season is tolerated, but logs and other debris will often break or bend trees. Young trees recover rapidly from such treatment, but older trees may sustain permanent damage to bark, providing an avenue of entrance for decay.

Ridgetops, south- and west-facing slopes, and swampy areas usually are poor walnut sites. A soil producing good yields of corn or soybeans may or may not be a good walnut soil, since walnut's extremely deep taproot utilizes a much greater proportion of the soil profile than does corn or beans.

Some level upland fields may be suitable walnut sites if internal drainage is good. A mottled appearance (alternating spots of gray and brown or orange color) indicates poor internal drainage. In many parts of Indiana and the Midwest, heavy clay layers and fragipans are common in level upland soil. These layers impede drainage and root penetration. On some of the clay-loam soils walnut will grow well with intensive management, particularly weed control. The better Indiana soil types for walnut plantations are listed on page 2.

You should realize that even though a soil type is listed as suitable for walnut, individual fields vary considerably in terms of past soil management, including erosion, compaction, fertilization, liming, drainage tile, etc. Also, other soil types covering fewer than 5 acres might occur and not be listed in county soil surveys. These "inclusions" might be unfavorable for black walnut. Care should be taken to have a soil scientist identify these soils in a potential black walnut planting area. Walnut may be growing in a nearby fence row or woods, but

Table 1. Summary of black walnut management activities

Activity	Date	Rate or instructions	Comments
Lime	Fall-Winter	Maintain pH between 6.5 and 7.2. Requires 2 tons/acre once every 3 to 4 years.	Incorporate if possible or apply before planting. Use pulverized agricultural limestone only.
Pruning	Feb.-April	Annually after trees are 2 years old.*	Maintain a central stem. Side branch pruning should begin when trees reach 6 to 8 feet tall.
Fertilize	April	After age 3. 100 to 200 lbs./acre/yr. of urea or 400 to 800 lbs./acre/yr. of 12-12-12.	Broadcast over entire area just before rain or incorporate. Do not fertilize the growing season of outplanting.
Weed control	May-June	Roundup at 2 qts./acre in 25 gal. water/treated acre.**	Roundup must be directed so that it is not applied to young bark or green foliage. Until trees are 10 to 12 feet tall, leave weed or legume strips 4 to 6 feet wide between rows. Strips should be mowed occasionally. When trees are more than 12 feet tall, total weed control over the entire area should be maintained unless erosion is a problem. After trees are 30 feet tall, weed control can be discontinued or greatly reduced. Tall fescue and goldenrod should be eradicated from all plantings.
Weed control	Late July-August	Roundup at 2 oz./gal. water. Roller applied or carefully directed spray.	Some grasses and perennial woody plants will survive early weed control and will need a fall application or careful mowing.

*Beineke, W. F., 1982. *Corrective Pruning of Black Walnut for Timber Form.* Purdue University Cooperative Extension Service FNR-76, 7 pp.

**Zimmerman, D. and H. Holt., 1983. *Use of Herbicides in Establishing Woody Plants.* Indiana Department of Natural Resources, Management Series No. 1, 13 pp.

Suitable Soils for Black Walnut in Indiana*

Alford, Allison, Alluvial, Alvin, Armiesburg, Ava, Ayr, Barce, Baxter, Beanblossom, Backville, Belmore, Berrien, Bewleyville, Billett, Birkbeck, Bobtown, Bonnell, Boyer, Branch, Bronson, Bruno, Cadiz, Camden, Cana, Carmel, Carmi, Celina, Chagrin, Conotton, Coolville, Corwin, Crider, Cuba, Dana, Dearduff, Deputy, Door, DuPage, Ebal, Eel, Eldean, Elkinsville, Elston, Foresman, Fox, Frederick, Genesee, Gessie, Glenhall, Glywood, Grayford, Griffin, Griswold, Hagerstown, Haney, Hanna, Haymond, Hickory, Hillsdale, Huntington, Huntsville, Jasper, Jules, Kalamazoo, Kaskaskia, Kinderhook, Kosciusko, Landes, Lindside, Linkville, Lobdell, Lomax, Longlois, Losantville, Lucas, Lydick, Manlove, Markham, Martinsville, Medora, Medway, Mellott, Miami, Miamian, Monitor, Montmorenci, Morley, Muren, Negley, Nineveh, Nolin, Oakville, Ockley, Octagon, Oldenburg, Onarga, Ormas, Oshtemo, Otterbein, Owosso, Parke, Parr, Pekin, Philo, Piankeshaw, Pike, Plano, Princeton, Proctor, Rainsville, Rawson, Riddels, Roby, Rockfield, Ross, Rush, Russell, Ryker, Seward, Sidell, Simonin, Sisson, Skelton, St. Clair, St. Charles, Steff, Stonehead, Stonelick, Strawn, Swanwick, Switzerland, Sylvan, Symerton, Taftown, Tama, Tilsit, Tippecanoe, Tracy, Trappist, Troxel, Tuscola, Uniontown, Varna, Warsaw, Waupecan, Wawasee, Wea, Wellston, Wheeling, Whitaker, Wilbur, Williamstown, Wingate, Wirt, Woodmere, Woolper, Wynn, Xenia

***Guide to Selecting Soils for Black Walnut Planting Sites in Indiana**. Ponder, F. Jr., P. Johnson, and W.F. Beineke. 1989. Purdue Agricultural Experiment Station Bulletin. (in press)

just because it is "surviving" does not necessarily mean that the particular field is a good one for walnut. After all, the trees you see may be very old and growing very slowly.

Site Preparation

Site preparation refers to activities necessary to get the land ready to plant the trees. Generally your site will fall into one of the three following categories: 1) cropland, 2) brush and perennial weeds, or 3) cutover woodlands or woods openings. Each site should be treated differently depending upon the type and amount of existing vegetation and soil conditions.

Before you plant, alter soil pH to 7.0. If pH is below 7.0, add lime before planting since it can be applied easily at this time and can take effect before trees are planted. Rates vary according to soil type and present pH, but in general if the pH is 6.0 or less, apply 3 tons per acre; if 6.0 to 6.7 apply 2 tons per acre; and if 6.7 to 7.0 apply 1 ton per acre.

Cropland

Land under cultivation is the easiest to convert to black walnut production since perennial weeds usually will not be present. Application of simazine (Princep) before weed seeds germinate, and before or at the time seedlings are planted, will accomplish site preparation and weed control in one operation. Simazine should be applied in strips or spots where the trees are to be planted (see the section on weed control for specifics on herbicide applications).

Brush and Perennial Weeds

Sites that have not been in agricultural crops for several years should be prepared the summer before walnut is to be planted. Brush should be mowed or cut and allowed to resprout and then sprayed in September with a nonselective herbicide such as Roundup. In particular, woody brush such as multiflora rose, black locust, sassafras, blackberry, poison ivy, and grapevines must be controlled using herbicides to prevent vigorous root sprouting that would interfere with the walnut. Also, Princep should be applied for residual grass and broadleaf control as discussed in the section on cropland.

Cutover Woodlands or Woods Openings

The summer before planting, fresh-cut stumps should be treated with Roundup to prevent sprouting. Young trees, brush, and sprouts should also be cut and herbicide-treated.

Cutover woods and openings require special care and present some unusual problems. Black walnut is a species that requires full sunlight and cannot stand much competition. Therefore, it is extremely important to kill all woody vegetation that could compete with newly planted walnut seedlings and to have openings large enough to provide light. Generally, walnut should not be planted in circular openings smaller than an acre (larger for elongated openings), or the surrounding trees will simply grow over and shut out much needed light. Root competition is also a large factor in small openings. Consult a professional forester before woodland openings are planted to be certain that the openings are adequate in size and shape.

Source of Seedlings

Most state divisions of forestry maintain a state-owned nursery system to provide seedlings to landowners for reforestation. The Indiana Division of Forestry has two excellent nurseries that sell black walnut seedlings for a very nominal price. Seedling quality is generally very good, and all seedlings are grown from walnuts collected in Indiana. However, there is no effort to collect from only the highest quality trees, so you are buying unselected seedlings of unknown genetic quality. Genetically improved walnut seedlings from the Indiana Division of Forestry seed orchards are available, and a small percentage of each order includes improved seedlings.

If run-of-the-mill nursery seedlings are purchased, it is suggested that you buy at least 50 percent more trees than you need. Sort and plant only the larger seedlings with healthy root systems. In this way you will be providing some genetic improvement through selection.

Order forms and price lists are available from the Indiana Division of Forestry, county Extension agents, Extension foresters, and SCS offices. Orders should be placed in November or December before the spring in which you intend to plant. Seedlings are shipped in March or April and are bare-root, dormant, and about 1 to 2 feet tall.

Grafted trees from patented superior black walnut trees are available from a private com-

pany in Indiana. The grafts are relatively expensive but provide a known, reproducible, genetic improvement over nursery seedling stock [2].

Plantation Establishment

Planting Season

April and May are generally the most desirable months for planting bare-root walnut seedlings in Indiana. They should be planted after danger of late freezes that might penetrate the soil more than an inch deep around the roots. Soil frozen to greater depths may cause frost heaving, which will push the carrot-like taproot of the walnut seedling upward and can even thrust it completely out of the ground, killing the tree.

Spring planting allows the seedling time to establish a root system before winter. Fall planting (September, October, November) has proven successful under certain conditions. However, bare-root seedlings approaching the winter with little root growth and without adequate snow cover or mulch often suffer winter kill. Containerized, actively growing seedlings or grafts can be planted throughout the growing season—if adequate water is available.

Layout and Spacing

Recommended spacing for walnut plantations is 12 x 12 feet (300 trees per acre). This allows for mortality and thinning of undesirable trees during the course of the rotation.

Plantation layout is crucial to future ease of management operations. Rows must be perfectly straight in at least one direction to facilitate mowing, spraying, and other cultural operations. Maximum utilization of the land area is achieved with straight rows, and a perfectly squared field gives a neat, attractive appearance. Plantation layout does not require a transit and a knowledge of land survey. The only equipment necessary is a tape measure or a measured rope and stakes.

First determine which edge of the field you want to run rows parallel with. Measure in from the edge, fence, or road at several points to establish the first row. Then, at the corner where you want to begin, establish a right angle by using the 3, 4, 5 right triangle. Measure down the established row 40 feet and put in a stake. Then return to the corner and estimate a right angle and measure 30 feet down the other side and place a stake. Measure across the corner between the two points to form the hypotenuse of the triangle. Adjust the location of the 30-foot-long side until the length of the hypotenuse is exactly 50 feet, and the right angle will be established. By sighting along the rows and measuring from these rows you can lay out the rest of the field in a square grid. The best way to do this is to mark a rope or heavy twine at 12-foot intervals with brightly colored tape. If you have a long steel tape with foot markings, you will still want to mark 12-foot intervals to save time. If large areas are to be planted, row markers attached to a tractor may be used to cross-hatch the field. Spots where trees are to be planted can be marked with wire stakes with plastic flags or small wooden stakes. Trees should be planted consistently on one side of the stake, and stakes should remain in place after the planting is complete to mark the spots where trees should be.

Planting

Bare-root seedlings can be planted with a planting bar, chain saw auger, tree planting machine, or shovel. For the landowner establishing a small plantation, a planting bar is an excellent investment. Planting bars consist of flat, tapered, and pointed steel blades welded to steel pipes with a T-handle. By working the bar back and forth an opening is created in the soil for the root. The opening is closed by inserting the bar 3 inches or so behind the hole and forcing the bar forward to close the opening around the seedling. Foot pressure should be applied on 2 sides of the seedling to firm the soil insuring that the hole is closed and the seedling is secure and without air spaces around the roots [8].

Augers are sometimes used to plant tree seedlings, either chain saw or tractor mounted. But they aren't recommended for planting walnut. Holes are often made too deep and the trees settle causing the root collar to be buried to levels that cause dieback and/or death of the seedling. Growth is often slowed in soils having clay content because of the "scouring" or slicking effect of the auger on the sides of the hole. Root penetration through the soil side walls compacted by the auger is impeded and the entire root system may be contained in the auger hole for many years. This is not a problem on sandy or loamy soils.

Seedlings often require root pruning before planting. Long lateral roots that will not fit in the hole without curling or a taproot too long for the planting hole must be cut back or seed-

lings could eventually be strangled by their own roots. Taproots forced into the planting hole and bent upward form J-roots which often result in windthrow many years later because of the weakened root system. However, taproots should not be pruned to less than 8 inches.

Plant seedlings at the same depth as they grew in the nursery. This can be seen as a color change between the stem and root just above where the swollen taproot begins to take shape. Keep seedlings cool and moist and out of direct sun prior to planting [8].

Interplanting

Interplanting, or multicropping is the planting of some species other than walnut on the same site. This co-mingling of species theoretically provides several advantages depending on the species planted with the walnut. For example, wheat, corn, or hay crops provide income to pay the bills early in the life of the plantation; black locust, autumn olive, vetch, and European black alder fix atmospheric nitrogen in root nodules and provide shade and improve form through side branch pressure; and Christmas trees or ornamental shrubs provide income after a few years.

However, a crucial question must be asked. Why are you growing walnut? If short term gain is your desire, walnut certainly is not the crop. Do you want to farm the land for annual crops? Do you want to grow Christmas trees? If so, do it.

Annual crops require expertise and expensive, specialized equipment. Usually the alternative of renting the land or share cropping is more attractive. However, then you must deal with a tractor driver who would rather the trees were not there and whose income depends on how much land area he can glean from your walnut trees.

Christmas trees require another kind of management and marketing expertise. The combination of walnut and Christmas trees has been successful, but herbicides used on walnut may not be compatible with Christmas trees and vice versa. Management may suffer since as the base of the Christmas tree expands and becomes valuable, the area at the base of walnut becomes smaller since lower limbs are pruned off. As you prune young walnuts, you tend to step on Christmas trees and vice versa.

The best interplanting species is European black alder. The others present special problems. Black locust outgrows walnut and quickly smothers it. Autumn olive, a thorny shrub, spreads out into the rows and restricts passage after a few years. It is also becoming another "multiflora rose" spread widely by birds across the landscape. Various lespedeza and vetch species are being investigated as possible companion plants providing weed control and nitrogen fixation [17]. But they must be kept under control near the walnut trees and do not provide stem shading.

European black alder has an upright growth habit, fixes nitrogen, grows rapidly, and provides side branch competition for the walnut. It should be planted between each walnut within the row. That is if walnuts will be spaced at 12 x 12 feet, then one direction will still provide a 12-foot passage and in the other direction trees will be 6 feet apart. Alder is usually killed by the walnut toxin, juglone, exuded from the walnut roots in about 12 to 15 years. That is about the time alder must be removed because of crowding anyway. The alder may provide some fast-burning firewood but otherwise has no economic value.

On marginal walnut sites, alder will provide considerable growth stimulation for the walnut. On good walnut sites the effect of alder is less pronounced. However, alder can be killed or damaged by rates of Princep normally used in walnut plantations. Alder also tends to leaf out earlier than walnut, making earlier spring application of Roundup necessary. To avoid these conflicts, cultivate or wick-apply Roundup for the first 2 or 3 years.

Under no circumstances should livestock be grazed in a black walnut plantation. They will eat young trees; the bark of older trees may be stripped; and soil compaction will reduce walnut growth. Deer and rabbits will provide you with enough animal problems.

Tree Shelters

Recently, plastic tubes or squares have become available to protect young trees from animal predation and herbicide damage, and to provide growth stimulation. The shelters are manufactured in two-, four-, and six-foot heights and must be staked for support. A greenhouse-like environment is created within the shelter and the trees tend to grow too late into the fall. This lack of winter hardiness often causes dieback. Therefore, if you invest in shelters, it is recommended that they are opened up, raised up six inches on the stake, or removed from the stake from late August until May. This should provide the winter chill

necessary for the trees to go dormant. The shelters should last from five to seven years and gradually disintegrate.

Weed Control

Without weed control black walnut plantations invariably fail or do not grow nearly to their potential.

Three possible methods of weed control are available to most growers: herbicide, cultivation, and mulches.

Herbicides

Herbicides used to control weeds in walnut plantations are safe, effective, and the most popular method of weed control. New herbicides and techniques of application are introduced frequently, and you should attempt to keep up to date on developments.

At the present time, the only herbicide legally registered for use on black walnut is Roundup, a relatively expensive herbicide that kills all green plants. Thus, if applied to walnut leaves, it will kill the walnut or cause dieback. However, it will not harm the brown or mature bark of walnut. Roundup sprayed on 2-year and older bark should not cause problems. Roundup should be applied after perennial weeds or grasses have emerged. May and June are the best months for application of Roundup in Indiana. In July, August, or September spot treatments may be necessary to control some woody perennials such as poison ivy and multiflora rose, and late germinating grasses such as the foxtails. One- to 3-year-old trees need special protection if Roundup is used after they have leafed-out. Shields of stovepipe, cardboard, or roofing felt should be used to prevent spray contact with leaves. Spraying must not be attempted on windy days. Once the tree leaves are 1 1/2 to 2 feet above the ground, directed spray toward the base of the tree will eliminate cumbersome shielding. Any leaves or low branches accidentally sprayed by Roundup should be broken off immediately to keep Roundup from being absorbed.

Roundup can be applied by backpack sprayers (e.g., Solo), garden sprayers, or large farm tractor-mounted sprayers. Also, Roundup may be applied by various wiping techniques which eliminate spray drift and shielding. The easiest and cheapest method is to mix 2 ounces of Roundup in 1 gallon of water in a plastic bucket and use a paint roller on a long handle to roll the weeds around the trees. This is an excellent method to control weeds around newly planted seedlings since there is little danger of Roundup getting on the tree leaves.

Sprayers must be calibrated to ensure that proper amounts of herbicide are applied to a given land area. Excellent instructions and details on herbicide rates, sprayer calibration, and other products can be obtained from the publication: *Use of Herbicides in Establishing Woody Plants*, Department of Natural Resources, Division of Fish and Wildlife, 607 State Office Building, Indianapolis, IN 46204 or Department of Forestry and Natural Resources, Purdue University, West Lafayette, IN 47907 [18]. Read all product labels and brochures carefully for information concerning proper rates and methods of application.

Newly planted trees need only a 3-foot diameter circle of weed control around each tree. However, if herbicides are applied by tractor sprayer it is easier to spray stips. As the trees grow, circles, squares, or strips must be enlarged. After 3 years most plantings should have strips sprayed 6 to 8 feet wide down the row of trees leaving an untreated strip 4 to 6 feet wide between the rows. The purpose in leaving the strip untreated is to prevent soil erosion. You will probably want to mow the strips occasionally. After tree crowns grow close together (trees 15 to 30 feet tall and 10-15 years old), only mowing and occasional spot weed control may be necessary.

Cultivation

Cultivation with hoe, rototiller, rotovator, or disk is an acceptable alternative to herbicides. However, it must be emphasized that cultivation will be required several times during each growing season when weed height reaches 6 inches or so. The area cultivated and duration of weed control should be the same as described with herbicides. Depth of cultivation must be very shallow (2 inches) because many walnut feeder roots are in the upper layers of the soil and are easily damaged. Care must also be exercised to keep away from the base of the trees. Surface roots and bark on the lower stem of the tree may be easily damaged providing avenues of entry for disease.

Mulches

Weed control may be accomplished by organic mulches or black plastic. Any organic material may be used—leaves, hay, straw, bark, chips, sawdust, etc. Generally, if you have more than a few trees, obtaining sufficient tonnage of materials and applying them is not cost effective. Also, the tendency is to apply them

too thin over too small an area to be as effective as they should be. Another problem is that mulches create ideal habitat for mice during the winter, and trees are often girdled. Some evidence exists that both organic and plastic mulched trees grow slower than those treated with herbicides or are cultivated. However, mulches are more desirable than doing nothing at all.

Mowing

Mowing is not a weed control method and has mostly a cosmetic effect. The root systems of the weeds are still intact, and the weeds resprout using additional moisture and nutrients. In fact, in numerous plantations, mowing has done much more harm than good. The tendency is to mow too close to the trees and cause a serious disease known as tractor or mower blight. By bumping or scraping the bark, pockets of decay develop beneath the bark — even if the bark remains intact. These areas provide ideal points of infection for various canker and wood rotting diseases, which can lead to wind breakage at that point or severely degrade the log at harvesttime. If you must mow, at least use herbicide or hand pull weeds from around the base of the trees *before* you mow so that you won't be tempted to mow too closely.

Severe Weed Problems

Several weed species pose particular problems for plantation black walnut. For instance tall fescue has been shown to reduce walnut growth by two-thirds [15], and it is suspected that smooth bromegrass may do the same. Goldenrod appears to have a detrimental effect on black walnut growth and has been shown to greatly reduce growth and survival of several other tree species [11]. These weed species appear to have an antagonism toward black walnut that inhibits growth through allelopathy (the exudation of growth inhibitors through root systems or decaying leaves). Therefore, under no circumstances should these competitive weeds and grasses be allowed in your walnut plantation.

Pruning

Next to weed control, the most important cultural activity you can do to improve the quality and future value of your black walnut is pruning [3].

The purpose of pruning is to develop a straight single stem which will ultimately become a high value veneer log. Pruning to develop straightness in young trees is usually called corrective pruning and should begin when the trees are 2 years old. A publication, *Corrective Pruning of Black Walnut for Timber Form* (FNR-76) is available from the Cooperative Extension Service, Department of Forestry and Natural Resources, Purdue University, West Lafayette, IN 47907, and explains pruning procedures in great detail [4]. Basically, corrective pruning is removing forks and branches that compete with the main stem for dominance. Black walnut has an overwhelming tendency to produce multiple shoots caused by insect or frost injury to the terminal bud. These shoots, if not reduced to the single straightest and/or tallest, will produce forks that limit the length of the future log.

On the other hand don't overdo pruning. Any reduction of potential leaf area may reduce growth. Also trees completely stripped of side branches grow too spindly and tend to bend over or break during windstorms.

Even fast-growing trees that have been pruned properly may be wind damaged during the early part of the growing season. You may want to snip off 3 or 4 inches of the ends of new growth in late June or early July to remove weight and allow branches to become woody. Prune only lateral branches and not the terminal or central stem that is to become the log. Small trees bent by wind may be straightened by tying to stakes or steel fence posts.

As trees reach 6 to 8 feet tall, you should begin side branch pruning to reduce knots in the future log. Branches should not be allowed to grow more than 1½ to 2 inches in diameter before removal. Otherwise the area of the pruning wound is too great to heal over rapidly, and decay could enter. Branch stubs should not be left when pruning, but branches should not be pruned perfectly flush with the bole either. A small collar indicates where the branch is beginning to seal off naturally and should be left to encourage healing [13]. Wound dressing is not necessary, since it seldom promotes healing and may, in fact, promote decay.

Recent studies show that proper pruning is one factor that a grower can use to greatly increase tree quality and hence the economic value of a walnut plantation. In fact, pruning may double the value of a plantation at harvest age [3].

Fertilization

Most studies have shown that fertilization of walnut provides little growth improvement [6]. On very good sites nutrient levels are probably

adequate for optimum walnut growth, at least while the trees are young. Soil tests seldom help since optimum nutrient levels for black walnut are unknown. However, severe deficiencies or improper pH may be detected by soil tests.

Under no circumstances should seedlings be fertilized the year of planting. Walnut root systems, not yet well established, are easily damaged by sudden increases in nitrogen levels.

The nutrient most often at low levels in soils is nitrogen, and some additional nitrogen should be provided if optimum growth is to be maintained [10]. Nitrogen in urea form provides a source usable by the trees. If phosphorus and potassium are also low, a balanced fertilizer such as 12-12-12 should be used.

As a general recommendation, 100 to 200 pounds of urea per acre should be applied annually after age 3. After age 10, treatments may be made biennially. If phosphorus and potassium are low, 400 to 800 pounds of 12-12-12 per acre should be used for several years rather than urea.

Maintenance of proper pH and calcium levels is probably as important as nutrient availability. As emphasized in the section on site preparation, pH should be maintained between 6.5 and 7.2 and is best corrected during site preparation. However, if periodic tests indicate a drop in pH, add sufficient lime to raise the pH for your soil type. Most walnut soils require 2 tons per acre every 3 or 4 years.

Insect, Disease, and Other Problems

At the present time, no known insects or diseases are capable of destroying large portions of a black walnut plantation. However, it is inevitable that some pest problems will occur when many walnut trees are planted near each other. Most of the effects observed, while looking drastic, are cosmetic and probably not life threatening to the tree. Several excellent publications are available on insect and disease pests of walnut and should be consulted when damage occurs [9, 17].

Insects

One of the few insects capable of killing entire walnut trees is the oyster shell scale. Of all the insect pests, it is the least noticeable until the tops of trees die back, and by that time, the trees are often nearly dead. Scale looks like tiny oyster shells less than ⅛ inch long closely pressed to the twig singly or in groups. Color ranges from gray to dark brown. Entire branches and trees may become so encrusted that no bark can be seen through them. Scale is difficult to treat with insecticides and for most growers the quickest remedy is to cut and burn the infected trees. If many trees are infested, malathion can be applied in mid-May in southern Indiana to about the first week in June in northern Indiana. Spray should be repeated the third week of July. This spray schedule will kill the crawler stage of the insect, which is easier to kill than the adult [12]. Highly refined horticultural oils applied at low dosage and only during the dormant season should kill most scale.

Tiny ambrosia beetles tunnel into young walnut stems and carry fusarium disease spores with them. The disease usually kills trees 2 to 4 years old back to the ground. Resprouting occurs from the root-collar, and the tree then develops normally, though several years of growth may be lost. Cutting and burning infected trees is the only effective control.

Pecan casebearer and walnut shoot moth larvae eat or bore into developing terminal buds and shoots. This causes lateral buds to grow, deforming young walnut trees. Either frost or these insects will destroy a large percentage of the terminal shoots in a given plantation every year; these are the principal reasons walnut must be correctively pruned. Insecticides applied in mid-April or just before bud break controls the insects, but little can be done to control frost damage.

Walnut caterpillar and fall webworm are the insect problems most growers notice and become concerned about. Actually, they do less damage than most other insects since defoliation by caterpillars and webworm occurs late in the season after most growth is complete. Webs or masses of caterpillars can be removed from small trees and burned or smashed.

Diseases

Fusarium canker is one of the few diseases that can kill walnut trees. However, root systems usually survive and sprout back. In fact sprouts from the base of a normal looking tree often indicate a fusarium infection has begun. Cankers appear as dead, dark brown areas beneath elongated splits in the bark. These are often associated with old pruning wounds or mower damage. Cankers sometimes completely girdle the tree, and the only treatment is to cut and burn the tree and train one of the basal sprouts to become the new central stem. On larger trees, cankers eventually heal over,

but valuable wood is stained, rotted, and degraded. Recently, studies have shown that to avoid fusarium infection, pruning should be done from January through May and never from August through December, since the latter period coincides with spore flight, and wounds will not heal properly.

Bunch disease is a serious and little recognized disease problem in black walnut. Bunch is caused by a virus-like organism, which is carried from tree to tree by sucking insects such as aphids and tree hoppers. It is slow acting, often infecting only one branch and requiring several years to move through the sap stream to other parts of the tree. Symptoms include cupping of leaves, upright leaf rachises, proliferation of short shoots, and weak wood prone to wind breakage. Bunch leaves and shoots tend to go dormant very late and leaf out very early causing dieback from cold injury. Slow growth, decline, and sometimes death occur over many years. When bunch is recognized, infected branches should be pruned. If bunch sprouts occur on the stem or at the base of the tree, the entire tree should be removed and the root system killed. Pruning usually stimulates latent bunch development in infected trees, and bunch often becomes visible after pruning or wind damage.

Anthracnose, a leaf disease that causes spotting and premature leaf fall is the disease most often noticed by growers, but it is a disease that seldom causes much real damage. Trees may be defoliated in August and September, but most growth has already occurred, and studies indicate that growth is not reduced by anthracnose [14].

Animals

Deer have become the most severe animal problem in Indiana and most midwestern states. It is difficult to imagine why deer would relish the taste of black walnut foliage and stems over other surrounding food, but they do. They browse on new growth during June and July and often nip branches and terminal shoots during the winter. Deer browsing can be distinguished from rabbit damage by the torn or irregular cuts made on the twigs. Rabbit damage is characterized by sharp slanting cuts that appear to be made by a knife. Little permanent damage is done by browsing, but it necessitates increased pruning to remove multiple shoots.

Young trees, 5 to 10 feet tall, are also favored for removal of "velvet" from newly grown antlers. Damage occurs in the fall and appears as long strips of bark torn away or shredded. Sometimes the tree may be entirely girdled. Damaged trees may overgrow the wound, but these wounds provide excellent openings for fusarium and wood rotting infections. Trees usually sprout at the base, and a new sprout can be trained to replace the damaged one.

Browsing damage occurs from May through July on new growth, and trees are rubbed from September through November. Sporadic nipping of dormant twigs may occur during the winter months, but this is usually minor.

Many commercial and "homemade" deer repellents have been tested. Most seem to work for a time — usually until the first heavy rain. They must be replaced or replenished after every rain. Several commercial repellents are on the market. Also, dried blood in small cloth bags tied to trees; human hair; and a spray containing raw eggs are repellents. The best, easiest, and least offensive repellent found so far is small bars of deodorant soap. Holes can be made with an electric drill and the soap tied loosely to the tree, preferably on a branch that will not be girdled. Soap must be replaced every 2 months or so, depending upon rainfall, but one application in spring and another in fall seem to minimize browsing and rubbing. A new repellent, Ropel, has provide good protection, is easy to apply (hand spray bottle), and requires no mixing. Actually the only sure repellent is a 12-foot-high fence or an electric fence built to exacting specifications [7].

Rabbits often are blamed for deer damage, and it isn't until the grower notices damage to 4-foot trees that he realizes the "rabbits" have grown taller than normal. Rabbits usually clip newly planted trees or 1-year-old seedlings. Damage is restricted to winter and early spring. They seldom, if ever, nip new green growth. Chicken wire exclosures 2 feet tall and 18 inches in diameter are effective but expensive. The same repellents that are effective on deer also repel rabbits most of the time.

Mice may be a problem, even in older plantations. Mice tend to nest or burrow at the base of trees. If the winter is difficult with deep snows, mice may gnaw away the bark at the ground line, and trees usually basal sprout the following year. Plantations with good weed control very rarely have this problem since the natural cover of the mice is removed.

Groundhogs have been observed eating new growth of black walnut and often construct burrows which can cause equipment damage. Groundhogs are easily discouraged by trapping or placing 12-12-12 fertilizer in their burrows.

Frost

Frost damage has been mentioned in other sections of this manual, but it deserves a space of its own since this is often the first damage a grower encounters in a young walnut plantation.

Walnut leafs out late compared to most tree species, but often not late enough to avoid late spring frosts. Black walnut is very susceptible to light freezes, and since it is often planted in bottom lands where cold air drainage occurs, frost damage is likely at sometime in the early years of a plantation.

Frost damage appears as suddenly blackened new leaves and shoots. Secondary buds will break and begin growth up and down the stem within a few days after frost. No permanent damage is caused except for the growth of multiple stems that require careful pruning.

Frost protection is unnecessary and impractical for most growers unless a nut crop is of great value. Since frost also kills flower buds, nut crops often fail because of frost. Over tree sprinkling systems, while very expensive, will protect nut crops from most frost damage [5].

Thinning

As your plantation grows and matures, the trees will become crowded and growth will decrease. At some point you will have to face the difficult task of removing some of the trees to allow the remaining trees to continue rapid growth.

Therefore, an important part of your management program should be to obtain accurate growth information. Diameter should be measured at 4½ feet above the ground. Height is not as important and is difficult to measure accurately once the trees grow above 15 feet or so. If the plantation is less than an acre, every tree should be measured annually. In larger plantations measurement plots should be established and accurately mapped so that the same trees can be remeasured annually. Plots should be scattered over the entire plantation and may be rectangular or portions of rows. Three or four plots per acre containing 10 trees each should be sufficient to give satisfactory growth information.

One-thinning recommendation for black walnut plantations has been devised [1]. However, it is based on crown closure, relatively slow growth, and poor management. If rigidly followed, too many trees will be removed from plantations on good sites with good weed control, fertilization, and rapid diameter growth. Managed plantations will be able to support more trees per acre than unmanaged stands since nutrients and water will be utilized by only the desired tree crop.

Either through mortality or thinning, about 90 to 110 of the original 300 trees per acre should remain for the final harvest. Therefore, trees will be spaced at an average of 20-foot intervals. Of course, in some places trees may be 12 feet apart and in others 36 feet apart.

The first thinning should be made at about 12 years and is the easiest. Poorly formed trees with no potential for straightening, diseased, and very slow-growing trees should be removed. Stumps will resprout but should not be sprayed with a translocated herbicide since root grafts could link the stump to adjacent trees and kill them also. Sprouts should be mowed frequently until dead.

Once crown closure occurs and diameter growth begins to decrease, light thinnings should be made frequently. At this stage you will probably need the advice of an experienced forester to ensure that thinning is properly done. If diameter growth has been averaging .4 inch per year and drops to .25 over a 2- or 3-year period, thinning is probably necessary. Of course, that is an average growth rate. In some cases initial growth may be faster or slower. Drought conditions, or poor weed control could be factors in reduced growth and should be considered. Remember that your goal is for your planting to produce as many trees per acre of large size and high quality as possible.

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