Bulletin 319

How to Produce and Market Paulownia

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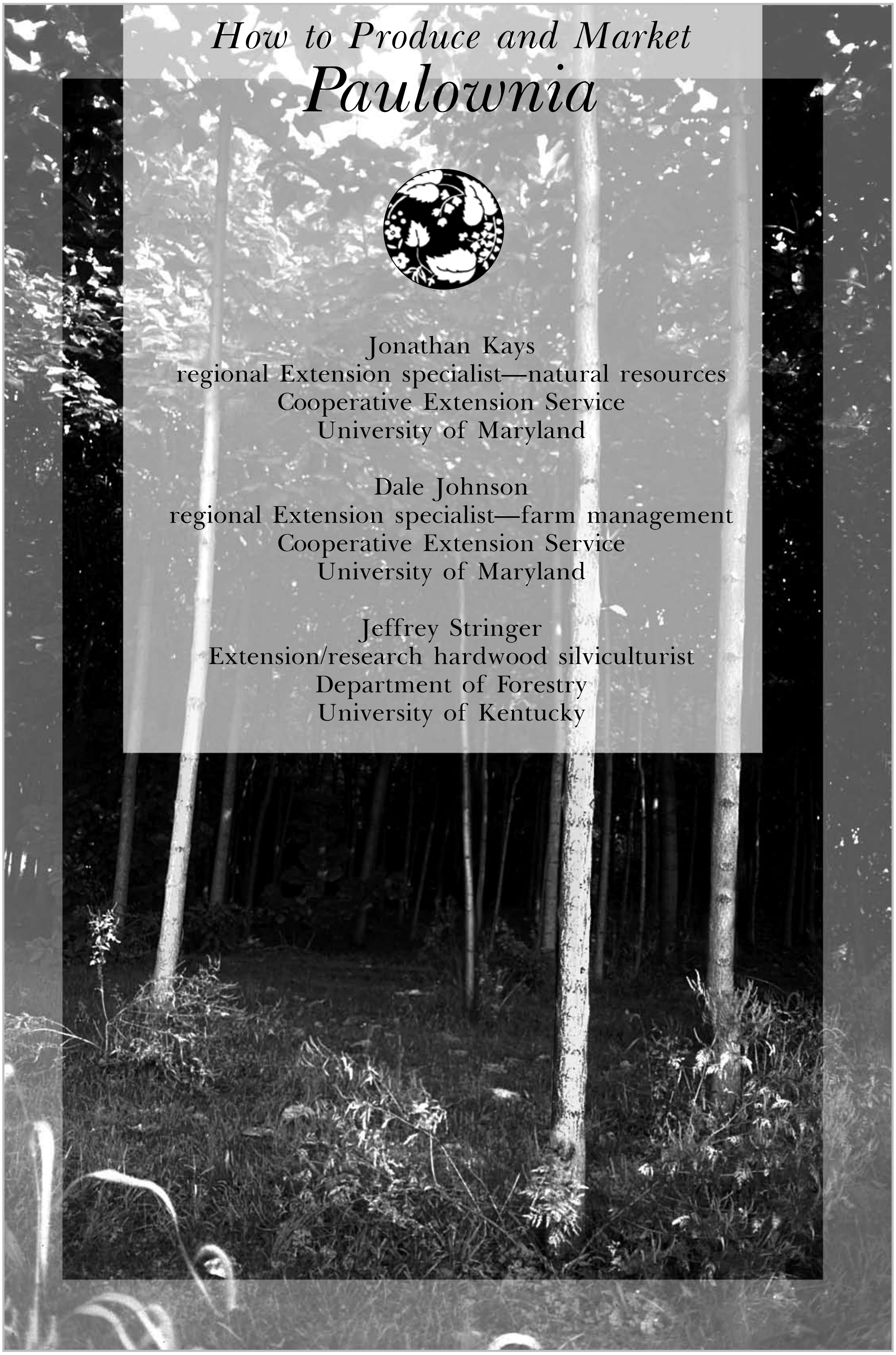

How to Produce and Market

Paulownia

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The establishment of paulownia (*Paulownia* spp.) tree plantations as a cash crop is of great interest to a large number of landowners. Since the 1980s, high stumpage prices have been paid for slow-growing forest-grown trees to supply a limited Japanese market. Plantation-grown trees of similar quality require 35 years, a shorter rotation time compared with other species such as oak, walnut, and ash. Paulownia species are capable of producing sawtimber-sized trees in 15 years, but large commercial markets for fast-growing trees do not presently exist in the United States or Japan. Paulownia culture requires a large amount of care during the first 7 to 8 years to produce high-quality trees, regardless of how fast they grow. Growers need to be aware of the implications of limited markets, cultural requirements, and the reality that prices paid for forest-grown high-quality trees may vary over time.

Paulownia plantations are relatively new in the U.S., with the oldest planted in the early eighties. Therefore, there is much about plantation management, especially in the later phases, that has not been tested and will prove challenging to growers. These challenges will require experimentation and working closely with forestry professionals to take advantage of new information as it becomes available.

This publication provides information on characteristics of paulownia species and how to establish and cultivate them successfully according to different product objectives. Marketing information and a financial analysis are also included.

WHAT IS PAULOWNIA?

The paulownia—also called the kiri tree, princess tree, and empress tree—belongs to the figwort family and is native to China. Many of the native Chinese species are considered subtropical and are not recommended for planting throughout the majority of the U.S. The three species commonly recommended for planting in the U.S. include *P. tomentosa* (Royal Paulownia), *P. fortunei* (white-flowered Paulownia), and *P. elongata*.

Leaves of paulownia species are enormous, especially on juvenile stems; they can measure up to 3 feet across (FIGURE 1). They are heart-shaped (nicknamed "elephant ears") and covered with hair on the lower side. The leaf of *P. fortunei* has a smooth lower side. The twigs are smooth, brown, and dotted with white lenticels. The hollow pith is characteristic of all paulownia. The bark is brownish-gray with shallow fissures. The flowers of paulownia contribute to its ornamental value: flower buds appear in leaf axils in late summer. These buds grow throughout the summer months, mature in October, and are visible as terminal panicles before the leaves fall. In late April, large five-lobed lavender flowers emerge before the leaves.

Paulownia tomentosa was probably introduced into the eastern U.S. more than 150 years ago as a landscape tree. Early colonists used paulownia capsules and seeds to protect shipments from China. The tiny windblown seeds from the discarded packing material may have contributed to the naturalization of paulownia through much of the eastern U.S.

IS THERE A MARKET FOR PAULOWNIA?

The primary market for paulownia is Japan. Since the early 1970's, Japan has not been able to grow enough paulownia to meet its needs. As a result, it has been importing it from China, Taiwan, South America, and the U.S. The Japanese prize our wild *P. tomentosa* tree for its wood color, narrow growth rings, and straight form. When Americans became aware of the Japanese demand in the seventies, wild stocks were harvested and high prices were paid. Currently, the price for paulownia logs is much higher than that paid for the highest quality oak, ash, or walnut. Much of the wild stock has

FIGURE 1. *Large heart-shaped leaf characteristic of young sprouts.*

Table 1. Minimum winter temperature for paulownia species grown in China	
Species	**Minimum Winter Temperature**
Paulownia tomentosa	-4 degrees F
Paulownia elongata	5 degrees F
Paulownia fortunei	14 degrees F

Source: Chinese Academy of Forestry, 1986.

been depleted, but high prices continue to attract the attention of landowners who see the potential for growing it as an alternative tree crop in about 35 years. However, little is known about what prices plantation-grown paulownia will bring in the future.

The Japanese have used paulownia wood since A.D. 200. Presently, most of the wood is used for plywood panels in furniture. The best grade wood is used for musical instruments such as zithers, kotos, guitars, banjos, and harps; and for jewelry, gift boxes, furniture, shoes, paneling, and specialty items. The poorer grades are used as crating material for heavy machinery. Poorer grades are not purchased from the U.S., as sources closer to Japan are capable of satisfying that market. Woodworkers and forest industries in the U.S. are beginning to recognize the excellent woodworking properties of paulownia, as well as its physical properties. It may be possible to develop a domestic market in the future.

Figure 2. *Area below curved line has soils and climate favored for P. tomentosa production. Shaded area has best combination of growing conditions.*

WHAT ARE THE WOOD PROPERTIES OF PAULOWNIA?

Unique wood properties such as lightness, strength, woodworking versatility, and stability under rapid changes in moisture have made paulownia highly desirable. These will be primary reasons for future use in domestic markets.

•Lightness—Paulownia is about 2/3 the weight of the lightest commercial wood in the U.S. The specific gravity of paulownia wood ranges from 0.23 to 0.30 (23 to 30 percent of the weight of water). Average cubic foot weight is 16.55 lbs. The bulk weight of lumber averages 1,382 lbs per thousand board feet compared to yellow poplar (tulip poplar), which weighs 2,190 lbs, or white oak, which weighs 3,337 lbs.

•Strength and stability—Although the wood is light, it is extremely strong and will not split even when spikes are driven into it. Unlike other commercial woods, paulownia does not split and crack with rapid drying.

•Easily worked—Another unique quality is the ease with which it can be worked, especially when green. It is suitable for carving, woodworking, model airplane construction, and peeling for veneer. As it dries, it becomes considerably harder, but not as hard as most domestic woods.

•Easily dried—Paulownia will air dry in about 30 days with no warping. This reduces the cost of kiln-drying.

•Papermaking qualities—Paulownia is not suitable as a source of pulp for papermaking because of its low specific gravity, relatively large amount of extractives, and short fiber lengths.

WHAT IS THE REGIONAL DISTRIBUTION OF PAULOWNIA?

A large portion of the U.S. has soils and climatic conditions favorable for several paulownia species. The species best adapted to the Mid-Atlantic and upper southeast region is *P. tomentosa*. It is found growing wild on field edges and disturbed sites with poor soils. Research on two other paulownia species is ongoing; their ability to survive is based primarily on minimum winter temperature. *Paulownia fortunei* and *P. elongata* lack the tolerance of cold winter temperatures characteristic of *P. tomentosa* (Table 1) and are best adapted to warmer regions. *Paulownia tomentosa* can be grown below the curved line shown in Figure 2, which stretches from southern Maine to the State of Washington. The shaded area is the region with the best combination of growth conditions for the production of high-quality logs. Kentucky, Tennessee, and large

Table 2. Paulownia plantation guidelines for two different product objectives			
Objective	**Rotation Time**	**Initial Spacing**	**Thinning Guidelines**
Slow-growing wood for Japanese market.	30-35 years	10 ft x 10 ft 8 ft x 8 ft	Maintain diameter growth at less than 1/2-inch per year after crown closure by thinning around crop trees. Select trees based desired growth rate and on form, not size.
Maximize volume growth for domestic market use.	10-15 years	10 ft x 10 ft 12 ft x 12 ft	Maximize diameter growth by releasing best 100 crop trees per acre.

portions of West Virginia, Virginia, N. Carolina, and Maryland lie within this prime production area.

Production of paulownia species north of this area is usually restricted by inadequate precipitation, cold temperatures, poor soils, or a combination of these factors. Paulownia grown in many of the Gulf States tend to grow extremely fast, which results in poor quality wood. However, growth can be slowed in plantations by maintaining high plantation densities. Rapid growth can be useful only if domestic markets develop.

MANAGING FOR DIFFERENT PRODUCT OBJECTIVES

Paulownia species can grow at very fast rates and produce sawtimber-size trees in 10 to 15 years, or they can grow at slower rates to produce tight-grained trees in 30 to 35 years (Table 2). The quality of the site and the spacing of trees affects growth rate. However, on the same site, diameter growth can be controlled by the number of stems per acre and the amount of thinning performed as the trees compete. Therefore, it is critical that growers develop product objectives before establishing plantations, to guide management actions.

Some common product objectives and associated plantation establishment guidelines are provided in Table 2.

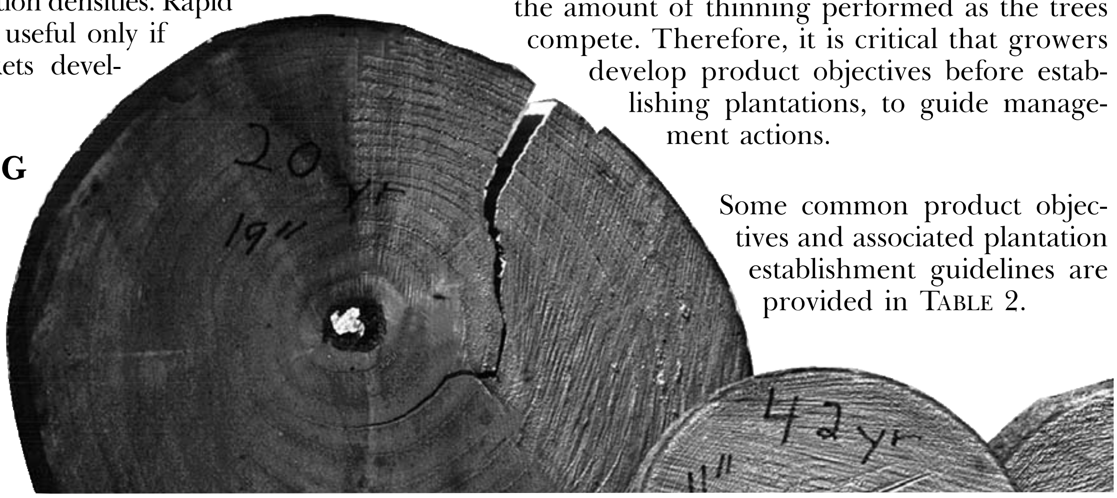


Figure 3. *Product value in current markets is highest for slower growing trees. Tree on left grew 19 inches in diameter in 20 years; tree on right grew only 11 inches in 42 years and has high export value.*

SELECTING A PLANTING SITE

Topography and soil quality are two site factors that will affect plantation success. Paulownia trees will not tolerate wet sites or land with a high water table (water table should be 3 feet or more below the surface). Well-drained, slightly sloping land without a hardpan or rocky impervious layer is generally better than poorly drained flat land. Lower slopes are better than upper slopes (FIGURE 4). If possible, select a site protected from prevailing winds, since the thin bark makes the trunks susceptible to sunscald and winter cold damage.

The soils should be loamy in texture, at least 25 inches deep, and should have a pH range of 5.5 to 7.0. Soils with high clay content (more than 30 percent) should be avoided. Information on soil characteristics for potential planting sites can be determined from county soil surveys available at your county Natural Resources Conservation Service office and verified by soil testing.

FIGURE 4. *All trees planted in this area failed to survive due to poor drainage.*

FIGURE 5a. *Site prepared to remove competing vegetation prior to planting seedlings.*

FIGURE 5b. *Same area during first growing season.*

TREE PLANTING

Planting density is expressed on a per-acre basis and should be high enough so that a forest-like competitive stand will develop quickly. As the crowns of the trees close, competition will limit growth and improve log quality. Given the cost of establishing seedlings and the time required to culture trees, it is best to plant as few seedlings as possible, while providing a margin of at least 10 percent for trees that will die or be of poor quality. Planting density may range from 300 to 680 trees per acre (tpa). Tree spacing of 10 ft by 10 ft (435 tpa) is recommended, but spacings of 8 ft by 12 ft are common (FIGURE 5, a, b).

PREPARING A SITE

The growth of paulownia is favored by a weed-free environment, where the soils do not seriously hinder root development. Site preparation treatments must often be administered to provide these conditions.

Some growers have tried to establish paulownia in cutover areas with varying degrees of success. If competing vegetation is controlled, plantings can be successful.

The best time to prepare a planting site is in the fall or in the spring before planting. There are four different methods for preparing planting sites:

1. Applying chemical herbicide. Herbicide to control competing ground cover, grasses, or broadleaf herbaceous weeds, is the least labor-intensive and most cost-effective. Contact your local forester or county agricultural agent for specific information regarding herbicide use. To ensure establishment success, it is recommended that competing vegetation be eliminated within 1 1/2 to 2 feet of each tree. This can be done by spraying a broad-spectrum translocated herbicide (for example, Roundup or Accord) in the early fall. This generally kills all existing vegetation, but will not control weed seeds that germinate during the spring and early summer or fall months. This is common if the surface soil has been disturbed by disking or rototilling. Since seedlings are planted late in the spring after frost, another application of herbicide may be needed before planting. Maintenance sprays will be required the first 2 years or longer to remove competing vegetation from young planting stock. When spraying herbicides for vegetation control after trees have been planted, use a hood over the nozzle or other method to protect the thin-barked stem from damage from spray drift.

2. Plowing. Plowing, disking, or rototilling the land in the fall or early spring is more expensive than using herbicides and requires more labor. Furthermore, it exposes the soil and stimulates weed seeds to germinate. However, it provides permeable soil conditions that aid in root development. You will have to weed by hand around each tree for the first year or carefully apply an herbicide to remove competing vegetation to allow paulownia seedlings to develop properly.

FIGURE 6a. *Common types of planting stock include container-grown seedlings.*

3. Mulching. This requires the use of black plastic, newspapers, weed barriers, heavy tar paper, or natural bark. Mow the area close to the ground before planting. After planting the seedlings, apply mulching material in a 3-foot-wide band at least 18 inches on each side of the tree. If using film or tarpaper, be sure the hole around the tree is large enough so the stem is not pinched or bruised. Anchor the sides of the film so wind will not lift the mulch and destroy the seedlings. Mulch can be used in conjunction with plowing and herbicides; however, it is costly in time and materials. This technique may cause problems with voles.

4. Subsoiling. Many planting locations may have compacted soils from years of farming or have a hardpan layer that will inhibit deep root growth. Subsoiling involves the use of a subsoiler or ripper plow that penetrates 14 to 18 inches into the ground. The effect is short-lived unless organic matter is incorporated, with the soil settling back within a year. Subsoiling is usually done in the tree rows so roots can penetrate deep into the soil. Subsoiling is best done when soil is dry and at least a month before planting so the ground can settle and air pockets collapse. The ground can be disked to smooth the surface and ease planting. Check with local farmers or your Cooperative Extension Service agent for sources of equipment rental.

FIGURE 6b. *Common types of planting stock include root cuttings.*

WHAT TYPE OF PLANTING STOCK SHOULD I USE?

The most common types of planting stock are (1) bare root seedlings, (2) root cuttings, and (3) container-grown seedlings (FIGURE 6, a, b). Planting stock can be grown by landowners or private nurseries and should be ordered early to ensure an adequate supply.

1. Bare-rooted plants are grown from seed in a nursery bed for one growing season. After the plants are dug, tops and lateral roots are pruned. Bare root seedlings resemble a carrot when planted.

2. Root cuttings are 4- to 5-inch-long sections of roots approximately 1/2 inch or greater in diameter. When planted, the cuttings produce new shoots and roots. Cuttings are planted directly in the ground but need to be watered after planting. Survival of root cuttings after planting has been poor; however, production techniques are still being researched, and improved techniques should result in acceptable outplanting.

3. Container-grown seedlings are generally greenhouse-grown in containers such as tubes, peat pots, and paper or plastic cups. Seeds are generally sown in late winter or early spring and are quite succulent when outplanted. Care is required to protect seedlings from drying out during the outplanting process. They are widely used but must be watered immediately after planting.

HOW DO I COLLECT SEED?

Growing your own planting stock starts with seeds. The following steps will help you in collecting and storing seed:

1. Collect seed from local trees that have good form for timber (straight trunks) to provide some assurance the seeds you collect will survive and grow well in your area. Preferably, collect seed from trees growing in a group of other paulownia trees. Paulownia usually begin to produce seed after 5 years. The seed pods are round and grow in clusters; each pod contains 800 to 1,000 seeds (FIGURE 7).

2. The best time to collect seed is when the green pods turn brown but before they open and are dispersed by the wind. This usually occurs in September or October. Paulownia are most frequently seen growing along roadsides, field edges, and railroad tracks. Potential seed sources can be found in the spring by looking for the characteristic large and numerous lavender flowers of *P. tomentosa*. After you collect the seed pods, place them in a warm, dry place until they crack open. Gently crush the pods over a flat surface or in a bag and pour the seeds over a screen to remove extraneous material.

FIGURE 7. *Paulownia seed pod with hundreds of windblown seeds.*

3. Store the cleaned seeds in a glass jar with a sealed lid, in the refrigerator, at 34 to 36 degrees Fahrenheit until you are ready to use them. Paulownia seed does not need to be stratified; however, for best results, use fresh seeds.

4. If you wish, test the seeds for germination by placing a wet paper towel on the bottom of a square lasagna pan. Place 100 seeds on the towel and cover the pan with clear plastic wrap. Place the pan near a northern window, and in 9 to 11 days viable seeds will germinate. The germination percentage will be equal to the number of seeds that sprouted. If germination is less than 50 percent, discard the seeds.

HOW DO I GROW MY OWN CONTAINER-GROWN SEEDLINGS?

Paulownia seeds need light to germinate and moist conditions for emerging root growth. The following recommendations will produce quality seedlings:

1. Choose a suitable container—biodegradable, if possible. Many types of commercially made products are available: tubed trays, Styrofoam blocks with depressions, peat pots, or Styrofoam cups with several holes in the bottom. Use a light soil mix consisting of two parts perlite, two parts peat moss, and one part high-quality potting soil. The mix will hold water while providing good root aeration and soil drainage. Fill the containers and moisten thoroughly.

2. Begin seeding mid-February to early March for planting in May, or wait until after the frost-free date. Germinate seeds on light soil in a tray or directly in the container. Both sunlight and warm, moist conditions are essential for germination in 9 to 11 days. For best results, do not cover the seeds with soil. Place the container in a mist room or cover it with a clear plastic film, polyspun fabric, or cheesecloth to help keep the soil surface moist. Check moisture daily. If you are using a clear plastic film, avoid placing the germinating seeds in full sunlight until the cover is removed. *Do not allow the seeds to dry out. Once the germination process has started, if they dry out for as little as 1 to 2 minutes, they will die.*

3. The ideal germination temperature is approximately 85 degrees Fahrenheit. Remove the cover as soon as seeds have sprouted. Water the new seedlings sparingly to keep them moist. Do not saturate the rooting medium; too much water will cause the roots to rot. After the seedlings are 1/2 inch tall, carefully transplant them to a growing container with a light soil mix, if they were not germinated in the growing container.

TABLE 3. *P. tomentosa* growth summary schedule (years 1-5)

Year	Months	Treatment	Suggestions
0 year	June-August	Select a planting site.	Choose a location with well-drained, fertile soil on a lower slope.
	September-October	Apply contact herbicide in 3-ft bands at desired spacing at selected planting site.	Contact local forester or Extension agent for advice.
	April	Final preparation of the planting site.	Subsoil down planting rows if soil is compacted. Apply herbicide again if necessary.
1st year	May	Plant seedlings, rootstocks, etc.	Plant in cleared area using planting bar, auger, shovel, etc.
	All through growing season	Water trees with 5 gallons of water unless it rains 1/4 inch per week.	Use a water tank, garden hose, or irrigation system if available.
	June-September	Mow vegetation between trees.	Use a bush-hog or lawnmower 2-4 times/season, if possible.
1st to 3rd year		Examine trees at least once a month for possible disease, insect, or animal damage.	Walk through plantation and check leaves, buds, stems, and ground around trees.
2nd and 3rd	February-April	Measure trees to determine average height. Unless all stems are over 8 ft tall, let them grow another year before coppicing.	Usually best to wait 2 years years to allow root system on all trees to develop. Coppicing taller trees first year shades younger trees.
	February-April	If all trees are over 8 ft tall, coppice all trees in plantation.	Cut trees 1 inch from ground level. Select sprouts that are on windward side of stump- and farthest from cut stump, if possible.
	May	Remove all but the best sprout on each stump.	Pinch off excess sprouts.
	June	Prune branch buds in leaf axils on 1st year's growth. Do not remove leaves.	Pinch off buds by hand or use pruning shears.
	July-August	Prune lower branch buds again if necessary.	Use same method as in June.
3rd and 4th years	February-April	If all trees are over 8 ft tall, coppice. Also coppice trees damaged by animals or disease.	Cut trees 1 inch from ground level.
	April-May	For trees coppiced last year, train the top elongated sprout if necessary.	Tie lateral top sprout to dead top.
	May-August	Continue to prune branch buds.	Pinch off buds by hand or use pruning shears or paint roller.
	June-August	Cut off dead terminal sprout.	Cut diagonal above

4. When the seedlings are 6 to 10 inches tall and roots are growing from the bottom of the container, they are ready for outplanting. Because of their succulent nature, seedlings should be well hardened before planting; place them in a shady, moderately protected area outdoors for 3 to 5 days before planting. Large seedlings are prone to wind damage. Remember to plant *after* the last spring frost.

How do I plant container-grown seedlings?

In general, the larger the planting hole, the greater the success, since digging loosens the soil structure, which will allow new roots to penetrate more easily. Although you may use a planting bar, trowel, shovel, or bulb planter, a power-assisted soil auger on a tractor or portable unit is more efficient. Mechanical planters also can be used. Whatever the method, it is essential to plant the seedlings at the same depth (FIGURE 8) and pack excavated soil around the roots to eliminate air spaces. Water the plants immediately after planting to settle the soil and provide adequate moisture.

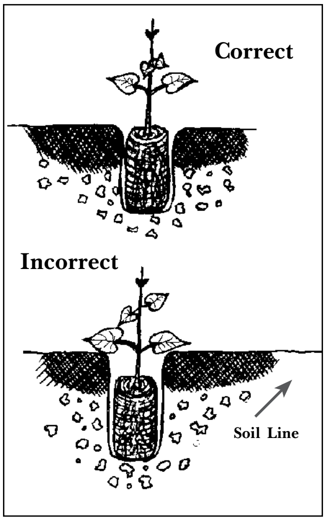


FIGURE 8. *Proper depth to plant a container-grown seedling.*

HOW DO I CARE FOR PAULOWNIA AFTER PLANTING?

The plantation will require a significant amount of care and labor for the first several years to control growth and produce quality logs. If left unattended, the trees are likely to be crooked, with low side branches. This is especially true for *P. tomentosa*, which does not naturally grow as straight as *P. fortunei*.

Watering planted containerized seedlings

Adequate water is essential to ensure survival, especially in the first growing season. Once the roots are well-established, the plants can cope with normal weather conditions. Water all seedlings immediately after planting and weekly thereafter during the first growing season, if less than 1/4 inch of rain per week falls. Mulching will help conserve water and minimize the need to water.

Controlling weeds and animals

Paulownia seedlings will not grow under shaded conditions. Good weed control during the first year is critical. You may control weeds with herbicides, by mowing, or by hand-weeding. Weeds also provide cover for voles and mice that can girdle young stems and roots in winter. Browsing can be a problem, but the rapid growth of paulownia quickly puts the growing point out of reach of deer. Rubbing damage by deer is a problem when trees are sapling size. Rubbing and tearing of the thin bark will render a tree useless for future harvest. The use of a one- or two-wire baited electric deer fence is cost-effective for plantations up to 3 acres and may be useful on larger plantations. Suspending a bar of soap from the bottom branch of each tree from mid-August to early-December is also an option (see Kays, 1995, in References for more information on deer control options).

Coppicing

A realistic objective is that each tree produce a single high-quality log, 10 to 16 feet in height. "Coppicing" refers to the removal of the existing stem after 1 to 3 years, when the root system has become well-developed (FIGURE 9). The purpose of coppicing is to produce a fast-growing sprout from the root collar that will form a straight, high-quality log. Coppicing will produce a stem 8 to 18 feet long the first year. When the sprout continues growth the next year, the new main leader

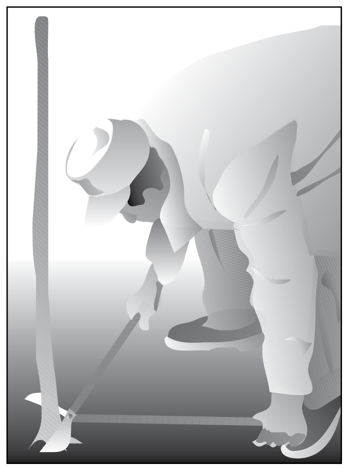


FIGURE 9. *Coppicing of stem near ground with saw or shears.*

normally develops from the side of the stem, forming a crook (FIGURE 10). It is important to allow the root system enough time to develop, so a tall sprout will be produced. Coppicing is more important for *P. tomentosa* because of its bushy habit of growth.

The right time to coppice can be determined by the height of the existing stems. Almost all stems in the plantation should have a minimum height of 8 feet before coppicing. This allows the development of strong root systems. A good rule of thumb is to wait at least two growing seasons before coppicing. While the stems of some trees may reach 8 feet the first year, if you coppice these and not others the stems coppiced the second year will be shaded, and their growth will be reduced. All coppicing should be done at one time, in late winter or early spring before spring growth.

Cut the stems 1 inch above the ground with a slight slant to the south. When new sprouts are 6 inches tall, remove all but the most vigorous. If possible, choose the sprout growing farthest from the stump on the windward side. Selecting sprouts close to the stump will grow new tissue over the old stump, which can result in rot developing later. FIGURE 11 shows how sprouts away from the stump develop a stronger base.

FIGURE 10. *Crook in stem reduces log quality. As tall a sprout as possible needed after coppicing.*

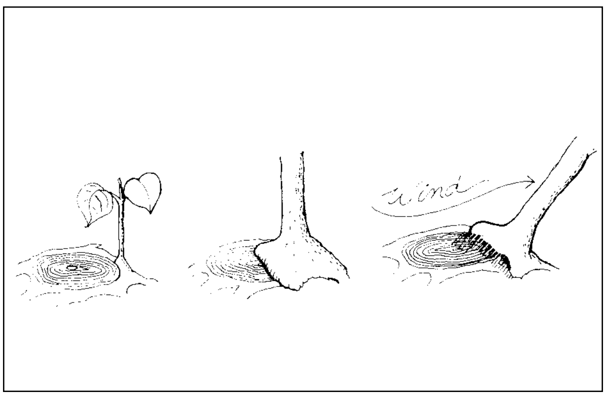


FIGURE 11. *Sprout farther away from old stump fares better.*

Pruning and trimming

Pruning is limited to removing lateral buds and branches to promote the development of growth and straight, smooth stems. At the point of leaf attachment, there is a hidden bud that can form a branch. Removing these buds before they develop will allow the stem to remain branchless until it has reached the desired height for a log. When a 16-foot-tall clear stem is developed, all branches above this height are allowed to grow. No pruning is necessary until after the stems are coppiced. It is generally necessary to prune all buds and branches several times each year for 3 to 5 years after coppicing.

FIGURE 12. *Buds in branch axils should be removed before becoming woody.*

Remove lateral branches from the joint of the leaf stalk and the tree stem if they start to elongate during the first year after coppicing (FIGURE 12). These laterals should be removed before they become woody; however, do not remove the leaves. The following spring, allow only a few well-developed buds along the top 3 to 4 feet of the stem for new growth. (FIGURE 13) shows the new growth beginning as it would occur from buds below the top of the stem. The second year after coppicing, and thereafter, new branches will grow vigorously from the lateral buds and must be removed before they become woody. As the diameter of the tree increases, the canopy of the plantation closes, and lateral bud growth decreases. Nonwoody branches and

FIGURE 13. *Lateral bud growth can easily be removed at this size.*

FIGURE 14. *Removing woody lateral branches with pruning shears.*

elongating buds can easily be removed by rolling a paint roller, without the cover, up and down the stem. Woody stems can be pruned with shears (FIGURE 14).

Paulownia trees do not form a true terminal bud in the fall like many tree species; thus, one of the side buds near the end must develop into the new leader each year (FIGURE 15). This creates a crook in the stem that degrades the quality of the bottom log and leaves a dead stub that can allow decaying organisms to enter. To avoid these problems, tie the topmost expanding shoot, when it is 6 to 10 inches long, to the dead top stem. Once the new shoot starts to harden, later in the growing season, cut the dead terminal with a sharp pair of shear cut pruning shears close to the point where the new leader is growing on the main stem (FIGURE 16). Do not cut through the woody diaphragm between the leaf scars. The wound will heal completely in 1 to 2 years. This operation would only be done the second year after coppicing.

FIGURE 15. *Terminal leader that commonly develops on paulownia.*

Thinning

Once the trees have developed up to a clear 10- to 16-foot stem and no new side branches are developing, no further pruning is necessary. As the trees grow, they will start to crowd each other and the growth rate will decrease. Thinning recommendations do not exist at this time since most plantations are presently too young for this practice. Product objectives will determine if trees should be thinned to maximize growth or not thinned to produce slow-growing crop trees.

Diameter growth will be very fast until the crowns of the trees close. To produce slow-growing, high-value trees for the current market, it is reasonable to set an objective of six growth rings per inch of wood or a diameter growth of 1/3 inch per year after crown closure. Depending on planting density, it may take 5 years after coppicing before the growth declines to this level. Early rapid growth does not create a marketing problem, since paulownia buyers measure log value for the Japanese market based on the outer 1/2 to 2/3 of stem diameter.

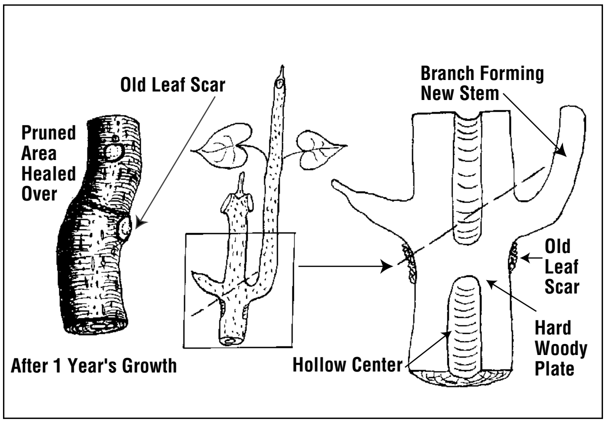


FIGURE 16. *Proper cutting lines for pruning terminal growth.*

When to thin

You will need to monitor the growth of selected crop trees to detect changes in diameter. Three to 5 years after coppicing, crop trees can be selected. Measure the diameter of at least 10 crop trees per acre from throughout the plantation. Mark the trees with paint or ribbon at 4 1/2 feet above the ground. Measure the same trees each year at the mark and chart diameter growth. When diameter growth on the crop trees decreases to a rate less than that desired, it is time to thin the plantation. Trees are usually thinned on 2 to 4 sides, depending on the amount of release desired.

It is best to be conservative in thinning, since removal of too many trees will stimulate excessive growth and reduce log quality. Ask your local forester for assistance in marking the trees to be removed.

[redacted]

	Inch	Diameter (inches)	Clearfaces (number)	Length (feet)	Prices (1996 $)
AA	8	16	4	6.5	10.00
A	6	12	4	6.5	6.00
B	6	10	4(*1 knot*)	6.5	2.50
C	4	8	3	5	2.00
D	4	8	2	5	1.50
E	4	6	0	5	1.00
	Log Position			**Pith Location**	
AA	butt			center	
A	butt			center	
B	butt or upper			undefined	
C	butt or upper			undefined	
D	butt or upper			undefined	
E	butt or upper			undefined	

(See pages 12-13 for explanation of grading specifications and subjective criteria.)

HOW DO I MARKET MY TREES?

Harvesting trees involves cutting the trees, bucking them into logs, skidding logs to a central landing, loading logs on trucks, and transporting them to a mill. The more harvesting you can do yourself, the greater the return. However, inexperience can also lead to a loss of value if felling and initial storage are not done correctly. Timber is usually sold "on the stump," with the buyer incurring all the harvesting costs. Factors such as access of the trees for harvesting, volume of wood to be cut, distance to the mill, and quality of trees will all affect harvesting costs and prices paid on the stump.

Most trees presently being harvested are exported to Japan. The price for high-quality paulownia grown in the wild exceeds that paid for quality oak and walnut timber. Japanese imports increased 161 percent from 1982 to 1989. Higher prices are paid for trees with more growth rings per inch, indicating slower growth—and requiring a longer growth time. The prices given in TABLE 4 are those paid for wood delivered at the mill. The price paid for trees on the stump will generally be about 1/3 less.

Paulownia log grades

The following grade specifications can be used as a guideline for determining the relative value of paulownia logs. While there is no recognized standard for paulownia log grading in the U.S., these specifications are widely used throughout the central and southeastern states for buying logs. Pricing is sensitive to grading specifications, market fluctuations, and subjective criteria such as color, number of growth rings per inch, length of log, ring shake, and stain.

With individual trees worth thousands of dollars, the theft of paulownia trees has become a serious problem. Trees have been stolen from lawns, parks, and woodlands. If you have been approached to sell trees, the security of those trees must be considered. If you cannot adequately protect the trees from theft, consider selling them.

Predominant uses

AA Koto (high-priced stringed musical instrument)

A Tansu (furniture)—show parts and Koto

B Tansu—show parts

C Tansu—generic parts (backs, interior parts)

D furniture—generic parts

E common use—bowls, shoes, boxes, etc.

Grading specifications

Rings per inch: The minimum number of allowable growth rings per inch of log diameter. Normally this value is averaged across the entire cross-sectional diameter (see increment variability).

Scaling diameter: Diameter inside the bark at the small end of the log.

Minimum clear faces: The outside circumference of the log is divided into quarters; a face is a section of the outside of the log that is 1/4 of the circumference running the entire length of the log. B grade logs may have only one knot on the log surface.

Log length: The minimum length required for a grade.

Relative price: Average price paid per board foot for each grade in 1996 (Doyle Log Rule). While the absolute value may fluctuate, the relative difference between grades should remain stable. Note: In some instances, lower grade logs (D and E) may not be marketable.

Log position: Butt denotes main stem logs next to the ground. Uppers are any logs above the butt in the main stem or branches.

Pith location: For grades AA and A, the pith is required to be in the center of the log; all other grades may have an uncentered pith.

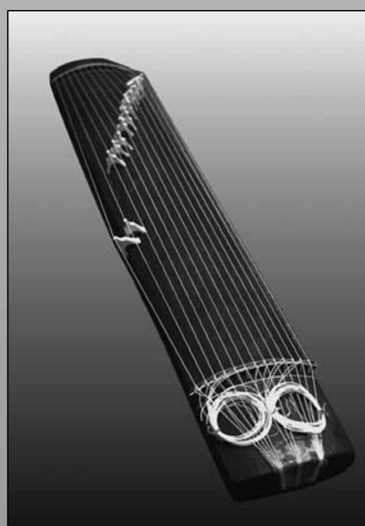
Subjective criteria

The following criteria are not included in the grading specifications but may affect price. The relative impact of these criteria on price

Products from Paulownia Wood

Common Use—bowls, boxes, etc.

Tansu (furniture)



Koto
(high-priced stringed musical instrument)

depend on the buyer and market conditions.

Color: While paulownia logs are generally white, they can be tinted yellow, green, or a medium gray. Whitish logs are preferred, especially in the higher grades (AA, A, B).

Increment variability: For AA logs, the ring width must be consistent across the log. Small variations in ring width can be tolerated in A and B logs. However, higher prices are paid if ring width is constant, especially in the outer 1/2 to 2/3 of the diameter.

Ring shake and stain: Paulownia logs can contain a relatively high amount of ring shake and stain. Ring shake results in separation of wood layers, usually at annual rings. Stains in logs, when cut (primarily purple stain), devalue the log. Do not cut paulownia trees in the late spring or summer as the logs can develop a tan stain that decreases their value. Higher grades are more sensitive to staining.

It is difficult to predict future market prices. Paulownia wood is associated with the cultural traditions of Japan and the demand for slow-growing trees is expected to increase modestly in the future. Because of high prices being paid for wood, large plantations are being established in China, Australia, and the U.S. If the supply of high-quality wood greatly increases, prices may decrease in the future. Presently, there is no demand by Japan for fast-growing trees grown in the U.S., and none is expected in the future.

Domestic markets for paulownia must be developed to use fast-growing trees. Niche markets for carving decoys, woodworking, model planes, boat construction, and crafts are developing, but large-volume markets are not presently available. This is partly because large-volume supplies of paulownia are not presently available. Utilization studies for the U.S. of fast-growing paulownia wood provide the following information:

- It can be peeled to 1/16 of an inch for veneer by domestic hardwood veneer mills.
- It provides excellent structural and strength characteristics to laminated plywood.
- It is good for dimension lumber products (for ex., 1 x 4, 2 x 4).

Paulownia flowers

- The lumber planes well and dries quickly with little shrinkage, warping, or splitting.
- It is a poor source of pulp for paper and unprocessed fuel.

As growers consider different product objectives, managing for fast-growing trees will likely provide a source of supply for high-volume domestic markets as they develop. However, growers should realize that these markets are not available at this time.

CAN PAULOWNIA BE GROWN WITH OTHER CROPS AND TREE SPECIES?

In China, paulownia is a choice tree for intercropping with agricultural crops such as corn, wheat, and vegetables. Crop systems in China use *P. elongata*, not *P. tomentosa*. *Paulownia tomentosa* is not used because it is a relatively slow-growing species with a large, dense crown and has a low trunk compared to other species.

Paulownia has a deep root system. Studies from China indicate an average of 76 percent of absorbing roots at a depth of 16 to 40 inches. Paulownia has late leaf emergence and leaf fall, with a branching and leaf arrangement that is sparse and allows sunlight to penetrate. In China, intercropping with paulownia has been shown to improve the microclimate for crop plants and increase yields. The tree cover reduces wind speed and evaporation rate, thus reducing soil moisture loss.

The density of the trees can vary from 17 to 167 trees per acre, depending on the objective of the intercropping system. In addition to the timber produced, the branches, leaves, and flowers are rich in nutrients and suitable for feeding to pigs and sheep. A single 8-to-10-year-old paulownia tree normally produces 220 pounds of fresh leaves per year.

Intercropping with paulownia in the U.S. is not practiced; however, results from China indicate that intercropping with *P. elongata* is successful. *Paulownia tomentosa* is the primary species that will grow in a cooler climate, and little work has been done in China or the U.S. with intercropping using this species.

The trend in plantation establishment in the U.S. is toward mixed species planting to improve biodiversity and reduce potential insect and disease problems. Intercropping paulownia with other fast-growing pine and hardwood species may have promise. Mixed planting of paulownia with hybrid poplar may be possible since they have similar growth rates.

Mixed planting with fast-growing conifers, such as loblolly pine and white pine may help to shade and protect the thin-barked paulownia trees from sunscald and winter cold damage, especially in colder climates and unprotected planting areas. More applied research is needed in this area.

EVALUATING YOUR INVESTMENT

When deciding whether to establish a stand of paulownia and which product objective to manage for, it is important to consider the financial impact of various alternatives. This long-term decision will affect the land for many years. Therefore, it is useful to evaluate different scenarios and estimate the value of the crop in economic terms.

Deciding whether paulownia production is a good investment will require careful consideration of production costs, expected returns, and how much your time is worth. Trees take much longer to grow than traditional crops, and your money will be invested for many years.

A method used by Johnson et al., 1992, (see References) illustrates a “commonsense” approach for paulownia financial analysis. Returns must be discounted because a dollar to be received tomorrow is not worth the same as a dollar received today. Whether a bird in the hand today is worth more than two (or even three) in the bush tomorrow depends on your time preference for money and your risk evaluation. In doing your investment analysis, choose the discount rate to reflect your preference for dollars today rather than dollars in the future. Using an annual discount rate of 10 percent indicates that you would be just as pleased to receive a dollar today as one dollar and ten cents next year.

Three measures to analyze an investment:

1. Net present value (NPV) is similar to “profit.” The effects of inflation on expected returns over costs are removed, and returns are discounted to the present. An investment with an NPV greater than zero is profitable.

2. Annual equivalent value (AEV) is net present value expressed as a constant annual return throughout the investment period. The AEV can be used to compare tree crop enterprises with more traditional annual field crop returns on the same site.

3. Internal rate of return (IRR) is the rate at which discounted revenues equal discounted costs. An investment has potential if the IRR exceeds rates from alternative investments with similar risk, timing, and capital outlay.

The Webster family

Objective 1: Produce slow-growing trees for the Japanese market (See Appendix for detailed costs and revenue.)

The story of the Webster family illustrates the economics of establishing a paulownia plantation. While everyone’s situation is different, this example provides some insight into the estimated cost involved. The Webster family owns 15 acres of land, including an 8-acre cornfield that has not been cropped in 3 years. They first contacted their State forester and applied for cost-share assistance under the Forest Stewardship Program that would pay up to 65 percent of the establishment cost. However, the costs below do not reflect any cost-share reimbursement.

They decided to plant 3 acres in paulownia. In the fall before planting, they mowed the field and applied a contact herbicide with a backpack sprayer. The chemicals and application cost $25 per acre. They hand-planted 435 container-grown seedlings per acre on a 10-ft by 10-ft spacing. Each seedling cost $1 and they valued their labor at $35 per acre. The Websters also had the option of producing container-grown seedlings at a cost of $0.10 each. Rainfall was unreliable the first growing season, so they irrigated once a week when necessary at a cost of $30 per acre.

Weed control was necessary for the first 5 years. They mowed once a year for 5 years between the rows with their farm tractor. The cost to run the machine plus labor was $35 per acre per year. To avoid mower damage to the base of the trees, a contact herbicide was sprayed 3 feet around each stem once a year for the first 3 years. The chemical and application cost was $25 per acre.

All trees were coppiced the winter after the second growing season. The labor cost was $25 per acre. The coppiced trees were pruned years 3 through 6 at a cost of $175 per acre per year. Deer rubbing would have been a problem, so a double-strand polywire baited electric deer fence was installed at a total cost of $277. This cost was not included in the analysis because the materials would be used in a few years to protect the family garden.

After 6 years, much of the Websters' work was completed. The Websters selected about 10 crop trees per acre and marked them permanently so they could be remeasured each year to determine changes in diameter growth and the need for thinning. While some of the thinned wood was sold, the thinning operation cost $100 per acre in years 12 and 20.

What can the Websters expect for timber yield and price?

Expected timber yield tables are not available for paulownia. Some studies have indicated a 15-year-old plantation will yield 10,000-14,000 board feet per acre. This assumes 100 trees that are 17 to 19 inches in diameter. However, it is likely this would produce the lowest log grade (E) according to the present market. To produce grade B and C logs, with harvested logs averaging 10 to 15 inches in diameter, trees should be grown for 30 to 40 years. Given this scenario, the Websters can expect about 8,000 board feet per acre of grade B and C logs for a 35-year rotation.

What about timber price? In 1993, log prices varied between $2 and $8 per board foot, depending on the grade. The Websters' estimate is a conservative $2 per board foot, or a return of $16,000 per acre.

Was the Websters' investment a profitable decision at the time of planting? The analysis assumed a 4 percent inflation factor for both cost and return, and a 28 percent marginal tax bracket. The actual internal rate of return the Websters will realize depends on the yield per acre, price per board foot, and whether labor costs are included. Using our assumed price of $2 per board foot and 8,000 board feet per acre, the investment will provide a 10.8 percent internal rate of return. All the estimates include labor cost.

TABLE 5 shows how the internal rate of return can change based on different yields

TABLE 5. Internal rate of return (IRR) for various prices and yields of a 35-year-old plantation after income taxes (labor included)

	Yield in Board Feet Per Acre		
Price per Board Foot	**6,000**	**7,000**	**8,000**
$0.50	5.6%	6.1%	6.6%
$1.00	7.9%	8.5%	8.9%
$2.00	10.3%	10.8%	11.3%
$3.00	11.7%	12.2%	12.7%

Note: *If labor for tree planting, irrigation, coppicing, pruning, and thinning are not included, the IRR will increase about 2.5 percent. If the grower raises container-grown seedlings at a cost of $0.10 each, the IRR will increase about 1 percent.*

and price per board foot. The IRR can vary from 5.6 percent for a yield of 6,000 board feet per acre sold at $0.50 per board foot to 12.7 percent for a yield of 8,000 board feet per acre sold at $3 per board foot.

Many growers do not include the cost of their labor in culturing paulownia. Others may be interested in how their return is affected if they raise their own container-grown seedlings instead of purchasing them. The note in TABLE 5 indicates that if labor costs for tree planting, irrigation, coppicing, pruning, and thinning are not included in the analysis, the IRR will increase by about 2.5 percent. For example, the 10.8 percent in TABLE 5 would increase to 13.3 percent. If the grower raises container-grown seedlings at a cost of $0.10 each, the IRR will increase only about 1 percent. In this case, raising your own seedlings may not be a cost-effective option in the long run.

TABLE 6. Net present value and annual equivalent value per acre for various discount rates of a 35-year-old plantation yield 7,000 board feet per acre at $2 per board foot after income taxes

Discount Rate (%)	Net Present Value	Annual Equivalent Value
5	$5,610	$343
10	$ 282	$ 29
10.8	$ 0	$ 0
15	($ 638)	($ 96)

TABLE 6 allows the Websters to analyze the investment based on their desired return or discount rate. If their desired return was 5 percent, the net present value at planting time was $5,610 per acre, after accounting for all the costs and future income. Given the long period between planting and harvest, the profit expressed as NPV is very sensitive to the discount rate. As the desired rate of return increases, the profit gets lower and finally breaks even at 10.8 percent. This is the same as the IRR discussed above. The annual equivalent value shows that the return per acre per year at a discount rate of 10 percent averaged $29 after Federal income taxes. This is considerably lower than most row crops.

Objective 2: Produce fast-growing trees for a future domestic market (See Appendix for detailed costs and revenue.)

Let's assume that the Webster family decided to maximize the growth of the trees in their plantation by managing for a 15-year rotation that will yield 12,000 board feet per acre of grade E logs in the current market. It is unlikely any of this material would be exported to Japan, so we will assume that the trees will be sold domestically using a reasonable rate currently paid for hardwood timber on the stump: $0.25 per board foot. What would be the profitability of their investment making these assumptions?

TABLE 7 shows that the investment would yield an IRR of 8.7 percent. However, IRR can vary from -1.4 percent at $0.10 per board foot and 10,000 board feet per acre yield to 23.1 percent at the higher yield of 14,000 board feet at $1 per board foot. The analysis shows that for the lowest price of $0.10 per board foot and all yields, this is not an attractive investment.

TABLE 7. Internal rate of return (IRR) for various prices and yields of a 15-year-old plantation after income taxes (labor included)

	Yield in Board Feet Per Acre		
Price per Board Foot	10,000	12,000	14,000
$0.10	-1.4%	0.3%	1.7%
$0.25	7.0%	8.7%	10.1%
$0.50	13.4%	15.0%	16.5%
$1.00	19.9%	21.6%	23.1%

Note: *If labor costs for tree planting, irrigation, coppicing, pruning, and thinning are not included, the IRR will increase about 6.5 percent. If the grower raises container-grown seedlings at a cost of $0.10 each, the IRR will increase about 3 percent.*

The note in TABLE 7 indicates that if labor costs for tree planting, irrigation, coppicing, pruning, and thinning are not included in the analysis, the IRR will increase by about 6.5 percent. If the grower raises container-grown seedlings at a cost of $0.10 each, the IRR will increase only about 3 percent. In this case, excluding your labor and raising your own seedlings can increase your IRR by an average of 9.5 percent.

TABLE 8. Net present value and annual equivalent value per acre for various discount rates of a 15-year-old plantation yielding 12,000 board feet per acre at $0.25 per board foot after income taxes

Discount Rate (%)	Net Present Value	Annual Equivalent Value
5	$591	$ 57
9	$ 0	$ 0
10	($438)	($ 18)
15	($449)	($ 77)

TABLE 8 shows that if the Websters had chosen a discount rate of 5 percent, the net present value of this investment at the time of planting would be $591. The annual equivalent value indicates that the return per acre per year, after Federal taxes, for a 10 percent discount rate would be minus $18. This would mean the crop would actually be costing you money.

Caution should be exercised in directly comparing the returns from the 15- and 35-year plantations because the rotation lengths vary. Two 15-year rotations could be produced in the time it takes to produce one 35-year rotation. New knowledge about marketing and production of paulownia will likely be available after the first 15-year rotation. This may allow for greater returns in the second 15-year rotation, which cannot be anticipated at this time.

FEDERAL AND STATE COST-SHARE PROGRAMS

Federal and State cost-share programs are available that will pay part of the cost of forestry activities, such as site preparation, tree planting, timber stand improvement, deer control, and fire control. To find out what is available, contact your county forester, Extension agent, or local Consolidated Farm Services Agency (CFSA) office. Federal programs include the Agricultural Conservation Program, Forestry Incentives Program, and Conservation Reserve Program. The Forest Stewardship Program can be used to implement a long-term natural resource management plan on your property and provide cost-sharing under the Stewardship Incentive Program.

Cost-share funds reduce the cost to you of forestry activities. Cost-share activities must be approved before they are carried out. Your State forester is the best source of information on cost-share programs for tree planting.

OTHER BENEFITS OF GROWING TREES

This bulletin has focused on the financial considerations of growing paulownia trees. Other benefits of growing trees are harder to measure. Planted forests provide wildlife habitat for game and nongame species. Trees prevent soil erosion, which enhances land productivity and water quality. And trees filter the air and serve as a natural noise barrier. They provide all this besides their natural beauty. Paulownia trees provide a beautiful display of lavender flowers in the spring. When planning your paulownia plantation, consider all these factors. In many cases, ways can be found to enhance nontimber benefits without sacrificing wood production.

EVALUATING YOUR TREE CROP OPTIONS

Dollar returns and rates of return should not be the sole criteria in deciding whether or not to plant paulownia. Other factors such as farm resources, available time, investment capital, labor resources, and your own abilities need to be considered. Risk should also be considered. Tree crops take a long time to grow and factors such as insects, disease, weather, and markets vary widely. Decide if you can risk losing this investment as a result of unforeseen circumstances. Consider possible scenarios and learn more about the enterprise you are considering from the reference list that follows.

SOURCES OF INFORMATION

American Paulownia Association—formed in 1992 for growers and others interested in the production and marketing of paulownia in the United States. The $20 annual fee includes membership and subscription to a quarterly newsletter. The association holds an annual meeting in the southeastern U.S. each year. For information, contact the American Paulownia Association, Route 3, Box 1600, Sweetwater, TN 37874, (615) 337-3275.

Cooperative Extension Service—Your Extension forester or natural resources specialist with the Cooperative Extension Service can usually provide a list of seedling suppliers and information on herbicides for site preparation and weed control.

Paulownia Production and Cultivation—A 20-minute video is available for $20 from Mark Eclov, Ag Communications Services, College of Agriculture, University of Kentucky, Room 131 Scovell Hall, Lexington, KY 40546-00643. Checks should be made payable to the University of Kentucky.

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Information Sources for Growing and Marketing Paulownia

Site Selection	County Forester
Local markets, initial investment cost, time and effort required, soil conservation and disease control, animal damage control	• County forester • Extension agent
Cost-share programs	• County forester • CFSA Office
Harvesting and marketing	• Private consultant foresters • County forester • Extension agent

Close-up view of Koto instrument made from Paulownia wood

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Appendix

Assumptions Used for Websters' Financial Analysis

Item	Objective 1	Objective 2
	Produce slow-growing trees, 35-year rotation	*Produce fast-growing trees, 15-year rotation*
Site preparation—herbicide application with backpack sprayer	$25 per acre	$25 per acre
Planting density	10 ft x 10 ft spacing	10 ft x 10 ft spacing
Seedling cost	$1 per seedling if purchased $0.10 if home-grown	$1 per seedling if purchased $0.10 if home-grown
Planting cost	$35 per acre	$35 per acre
Mowing (years 1-5)	$35 per acre	$35 per acre
Chemical weed control (years 1-3)	$25 per acre	$25 per acre
Coppicing (year 3)	$40 per acre	$40 per acre
Pruning (years 3-6)	$175 per acre	$175 per acre
Thinning	$100 per acre (years 12 and 20)	$100 per acre (years 5 and 10)
Age at harvest	35 years	15 years
Sale price	$2 per board foot	$0.50 per board foot
Yield	7,000 board feet per acre	12,000 board feet per acre
Harvest expense	5% of sale price	5% of sale price
Marginal income tax rate	28%	28%
Inflation rate	4% per year	4% per year
Tax treatment	Reforestation tax credits credits for planting, all else ordinary income/expenses	Reforestation tax credits credits for planting, all else ordinary income/expenses

Note: *Cost per acre for various expenses are from Johnson et al., 1992,* Tree Crops for Marginal Farmland, *and the authors of this publication.*

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