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PAULOWNIA: A GUIDE TO ESTABLISHMENT AND CULTIVATION
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Paulownia (Paulownia tomentosa), or kiri, was introduced into the US during the 1800s. It quickly became naturalized over much of the eastern states. Except for its ornamental qualities, it was generally ignored or considered a weed tree. However, since Japanese buyers have begun to buy US grown logs, Paulownia is now considered a premier timber species. Prices paid for Paulownia logs often exceed those paid for black walnut, recognized as "The King" of the hardwoods.
This publication contains specific information for the paulownia grower on site selection, seed collection and storage, planting stock development and early plantation care. A recent publication from the University of Kentucky, Department of Forestry, Paulownia Plantation Management: A Guide to Density Control and Financial Alternatives (3) gives specific information on spacing and growth characteristics necessary for the production of high quality logs.

Site Selection

A large portion of the US has soils and climatic conditions favorable for paulownia production. This area lies below the curved line shown in Figure 1 that stretches from southern Maine to the state of Washington. The region having the best combination of growth conditions, for the production of high quality logs, is illustrated by the shaded area. Kentucky and Tennessee lie in the center of this prime production area.
Scattered small areas in the north also can produce paulownia. However, growth is usually restricted by inadequate precipitation, cold temperatures, poor soils or combinations of these factors. On the other hand, extremely fast growth leading to reduced log quality is typical of paulownia grown in the Gulf States. However. growth can be slowed in plantations by maintaining high plantation densities.
Since paulownia growers must concentrate much of their effort on planting stock development and seedling care, choosing the proper planting site is often neglected. Much of the paulownia plantation's success, however, depends on location. While little is known about specific growth potentials for paulownia on US soils, several general criteria can help determine proper plantation location.
Topography and soil quality are two factors affecting the potential success of paulownia plantations. Sloping land is generally better than poorly-drained flat land, and lower slopes are superior to upper slopes. The best site is a sunny slope facing southeast. In gently rolling topography plantings may be made on all slope positions. In extremely hilly or mountainous topography, little success can be expected on any north facing slope. The site should be relatively well protected from prevailing winds and have a well-drained soil at least 25 inches deep. Generally soils with high clay content should be avoided. Loamy soils (ones having only a moderate clay content) with a pH of approximately 6.0 are optimum.

Production of Planting Stock

Planting stock refers to plant material used to establish a plantation. Root stocks or root cuttings arc the preferred paulownia planting stocks. Root stocks arc the entire root systems of 1- to 2-year-old seedlings. Root cuttings arc 4 to 5 inch sections of roots approximately 1 inch or greater in diameter. With special care and techniques, containerized and bare root seedlings, and direct seeding can also be used successfully. Options may be limited if the grower can not produce his or her own planting stock since few types arc commercially available (normally containerized seedlings). This, coupled with few local suppliers, provides advantages for growers able to grow their own planting stock. Planting stock is grown in nursery beds established from seed or root cuttings for 1 or 2 years, after which it is transplanted to the plantation.

Seed Collection and Storage

Seed for nursery beds must be either bought from a seed warehouse or gathered from local trees. Collecting seeds from local trees provides some assurance that the trees you produce arc capable of surviving and growing reasonably well in your area. If possible, collect seed from the best looking trees.
Paulownia usually begins to produce seed 'after 8 or 10 years. There are nearly 3 million seeds per pound. Under favorable conditions a large tree may produce as many as 20 million seeds in one year.
Generally the best time for seed collecting is early September. Gather the pods after they ripen but before they open.

They should be predominantly brown. After collection allow the pods to air dry. A good way to remove seed from the pods is to put them in burlap bags and gently crush the contents. The seed can be easily separated from the heavier trash by hand or with a blower.

Put the seeds in cold storage at a temperature of 38° to 40° F for maximum longevity. They may be stored dry in sealed containers or stratified between moist layers of a mixture of sand and peat. Stratification seems to reduce the very' high light requirement that fresh seed exhibit and hence shortens the germination time. Both methods allow you to store seeds for as long as 4 years before germination declines sharply. For best results, however, use seeds during the first or second year.

Nursery Beds

Nursery beds can be used to produce bare root seedlings, cuttings, or root stocks which can be used for plantation establishment. While more intensive methods such as greenhouse production are available, nursery beds offer several advantages including affordability proximity to outplanting site, and the opportunity to grow large seedlings for outplanting or for developing large root systems for cuttings.

The procedures outlined here arc general guidelines for nurser)., bed production of paulownia planting stock and arc essentially the same as those used for tobacco plant beds. Individual situations may necessitate minor changes or additions to these procedures. However, the techniques for germinating the seed should produce adequate results over a wide geographical range. Specific details of this method can be found in A Practical Method for Production of 'Paulownia tomentosa" (4).

Locate nursery beds in areas with good drainage. Since young plants arc susceptible to waterlogging and disease, a sandy or loamy soil is helpful in maintaining healthy beds. Soil pH is not critical but should be maintained between 6 and 7.5. Avoid locating beds in frost pockets. Early autumn frosts in these low lying areas will prematurely injure the succulent foliage, shortening the growing season. Extreme winter cold can lead to root collar wounding and root-stock mortality.

Cultivate the beds in late winter or early spring and cover them with plastic (4 mil). Apply a soil fumigant, like methyl bromide, to kill unwanted seeds, nematodes and fungi harbored in the soil. Many local fertilizer suppliers in the southeast now provide tobacco plant bed fumigation services, simultaneously applying methyl bromide and covering the bed with plastic. After the danger of frost has passed, the plastic can be removed.

While methyl bromide kills all pests at the time it is applied, it is only effective while the bed is covered with plastic. Therefore incorporate a fungicide (like Captan 50 W) to a depth of 2 to 4 inches to ensure continued control of fungus. Rake the beds to produce a relatively smooth surface. Also apply fertilizer at this time.

While detailed fertilizer requirements are not known for paulownia, the following regimen has proved successful in research beds: a slow-release NPK fertilizer such as Osmocote (14-14-14) at 1 lb/sq yd, a slow-release micronutrient additive such as Micromax at 4 oz/sq yd, and gypsum and dolomite at 8 oz/sq yd each. In most "fertile" soils, strict adherence to this recommendation may not be critical. if you use a slow release fertilizer, a single application is enough for the entire growing season and should not produce any significant problems during seed germination.

Moisten the bed and then seed at about 1 level tsp/sq yd. Scatter the seed by hand on a windless day.

Maintaining a moist environment during germination and initial seedling development is important. The small seeds on the soil surface can support only one attempt at rooting, so the microenvironment surrounding them is critical. Desiccation even for short periods can be fatal during the root's early development. Emerging roots can dry out even between irrigations during afternoons with high temperatures and low relative humidities. Use a straw mulch or a covering over the bed to maintain adequate moisture. Trials with soil amendments and mulch have had sporadic results, because mulch shifts position and seeds get buried by wind and rain.

You can maintain the proper environment, while avoiding problems, by covering the nursery bed with a spunbonded polyester or nylon canvas, commonly called a "tobacco plant bed cover". This covering suspended above the bed lets light (necessary for paulownia seed germination) filter through while alleviating the adverse effects of excess water and wind. The covering disperses incoming water droplets, letting only a fine mist reach the soil surface. It provides a warm, moist and undisturbed environment for germination. Light-weight cotton or cheesecloth can also be used to cover the beds, but the synthetic material is much less expensive and is readily available.

Don't let the covering contact the soil because the plants will grow through the cover and you will damage the seedlings when you remove it. To avoid this contact, you can suspend the covering over the soil surface by a series of arched wires placed along the bed's center line; you can attach it to a wooden frame surrounding the plant bed, or you can spread a very small amount of straw over the soil. Remove the covering when the seedlings are 2 inches tall. Continue watering, keeping the soil moist but not saturated.

Proper control of seedling density is critical for producing vigorous planting stock. Wait until the plants average 6 inches tall and then do the first thinning. But don't wait too long. Postponing the thinning leads to small spindly plants. Thinning is necessary for proper seedling growth, but specific seedling density depends on the type of planting stock being grown.

Do the thinning by hand, leaving the most vigorous seedlings intact. At first, thin seedlings to about 100 plants/sq yd. When they are 12 inches high, thin them to 20 to 50 seedlings/sq yd. They normally can be kept at this density if you are producing one-year-old seedlings or root stocks for outplanting the following year. If you plan to develop 2-year-old plants, thin the beds to 10 seedlings/sq yd. At the beginning of fall, reduce the watering schedule and let the plant bed dry between watering.

Normally, use either root stocks or root cuttings as planting stock. Do not use bareroot seedlings (i.e. the entire seedling including the top). In the fall after the leaves have died, prune the main stem at the ground line and discard the tops. Root stocks should overwinter in the beds, covered with an inch or two of a mulch such as sawdust. The next spring you have the following choices for these rootstocks:

(1)Outplant them,

(2)Let them grow a second year in the nursery bed,

(3)Move them to a transplant bed.

However, leave the root stocks in the plant bed until planting time.

Plantation Establishment

Root Stocks and Root Cuttings

Very careful handling is required when planting paulownia rootstocks or cuttings. Roots are fragile and can be easily desiccated or damaged. If you purchase them, follow all the instructions provided by the nursery. Grade the root stocks to eliminate disease and root prune them if necessary. If signs of rot are present, you can spray a fungicide on the root stock before packing them in moist sphagnum moss. Apply 50% Captan® fungicide at 1 tsp/5 gal of water.

Keep root stocks cool and moist while processing. Bundles of root stocks can be wrapped with moss in heavy paper or put in cardboard boxes. If you put them in buckets or other containers which hold water, be careful not to let water stand around the roots. Then store them at 35 to 40° F until they are outplanted. While they can be kept in storage for up to 2 months, it is better to pull them from the plant beds just before planting.

Check the roots periodically for mold and rotting ends if you are going to store them 'for an extended period. You can get 4 to 5 inch root cuttings from roots greater than 1 inch in diameter. Let the ends of the cuttings air dry before planting. Doing so normally may take 1 to 3 days and helps to "seal" the cutting and reduce rot.

The actual planting of root stocks and root cuttings can vary. One good procedure is described by Arnold and Gertner (1) in an Illinois study using zero till and herbicides. Another, discussed by Beckjord (2), has root stocks planted in a hole where the soil has been loosened in a circle about 1 ft across. The Japanese use an intensive procedure, digging a 3 ft deep hole, 3 ft across, filled from the bottom up with 1 ft of topsoil, 4 inches of compost and 8 inches of prepared soil. The final 12 inches of the same prepared soil is then carefully packed around the roots. If you cannot use prepared soil, it is essential to pack excavated soil firmly around the roots and to leave no air spaces in the planting hole.

Regardless of the method used, plant a root stock's cut end at ground level, but root cuttings are put 1 to 2 inches below the surface. Planting on windless, overcast days is always best to avoid root desiccation. Initial irrigation may improve survival in the first month after planting if the soil dries.

Direct Seeding

Bare soil, sufficient moisture and direct sunlight arc required for seed germination. Fresh, unstratified seed may require up to 150 hours of light for germination. For this reason, field germination may take as long as 2 weeks. Because of their small size and high light requirement, seeds should be surface-sown and mulched with a material that light can penetrate.

Paulownia should be hydro seeded at a rate of 1/2 lb or more with a mixture of less than 800 lb/acre of wood fiber mulch. However, attempt hydro seeding only on an area completely bare of vegetation that has been treated with a moisture-retaining mulch like processed hardwood bark. Apply at least 45 cu yd/acre of hardwood bark. Frequent light watering protects the seed from desiccation.

Delay establishing ground cover until after the paulownia seedlings become established and can compete with other vegetation. The time necessary for seedlings to become established varies from a minimum of 2 years up to 5 or more. During that time, control encroaching vegetation by mowing or by applying herbicides near the plants.

Containerized Seedlings

Containerized seedlings are plants growing in a container of growing medium that can be directly outplanted to the field. The growing medium furnishes nutrients and moisture to the plant during early development. Several commercial nurseries produce such planting stock. However, you can produce your own. Choose a suitable, biodegradable container and fill it with a mixture of sand, vermiculite and peat moss. Put a pinch of seed on top of the planting medium. Cover the seeds with a patch of cheese cloth or tobacco plant bed net to hold them in place.

Water them enough to keep them moist but not saturated. As the seeds begin to grow, remove the cheese cloth and thin them until you only have one per container. Seeds can also be germinated in a flat and the seedlings carefully transplanted to containers when they are 1/2 inch tall.

When the seedlings are 10 to 14 inches tall, they are ready for outplanting. Because of their succulent nature, paulownia seedlings should be well hardened before outplanting. To do so, either plant them when they are dormant or let them sit in a shady, moderately protected area for 3 to 5 days before planting. Larger seedlings are prone to wind damage. Do not plant containerized seedlings until well after the last killing frost date.

Do the actual planting on a vegetatively bare area with either a tile shovel or backpack auger. Make a hole slightly deeper than the container. Insert the container and then fill the area around it tightly with the removed soil. If the area being planted has a stand of existing vegetation, treat it with a herbicide like Roundup® before planting. For best results use a 2 ft square, 2" X 4" frame. Put processed bark around each seedling for moisture and for protection against vegetation encroachment (Figure 3). Do not leave the frame around the mulch.

Cultivation Methods

You must cultivate paulownia intensively during the early years if it is to produce high quality logs. No matter how you establish them, the trees need competition control for at least the first several years. To do so, mechanically remove vegetation at least 3 ft from around the seedling's base. Herbicides can also be effective. Consult with your local forester, county agent or other qualified professional on the proper use of herbicides in your plantation.

Unattended plantation trees generally are poorly formed and do not normally develop a bole of sufficient length and form for high grade logs. Therefore, pay special attention to coppicing and pruning paulownia seedlings.

After one to three years in the plantation, the root system has had time to develop and you must cut the trees just above the ground line. During the root system's development, do not be concerned with the tree's form and do not branch or top prune. Cutting the tree at the bole and removing the tree's aboveground portion promotes resprouting that yields tall, equal sized trunks on all the plantation's trees. This situation is preferable to having seedlings varying in height or poorly formed. These tall, straight sprouts, often attaining heights of 8 to 16 ft, are also easier to prune than 1- to 3-year-old seedlings which are the same height.

If possible, cut the bole with a slight slant to the south. Make the cut smooth and treat it with lime water. When the tree begins to sprout, remove all but the most vigorous sprout when they arc about 6 inches tall. When choosing equally vigorous sprouts, keep the one furthest from the stump. You can safely leave two equally vigorous sprouts if you remove one the next year.

Figure 4 shows what can happen if the sprout selected is just adjacent to the old stump. As the sprout grows, much of the new tissue develops over the old stump which can lead to rot and a weak stem. The sprout in Figure 5 is better because it allows more development adjacent to the stump rather than on top of it.

The best method is illustrated in Figure 6:

Carefully remove the soil from the stump's roots after the bole has been severed.

Strip the bark from the roots about 6 inches from the stump and cover it with the excavated soil.

Several sprouts should develop beyond the stripped areas. Leave one vigorous sprout and remove all others.

Fill around this sprout with fertile soil or mulch.

This method can also be used to regenerate the plantation after it has been harvested. The old stump may be removed later if desired.

If left to grow without intensive cultural operations, paulownia tend to develop branches that spread on all sides and most likely will have a bent trunk. To avoid that tendency much training and trimming is required during the early years.

Paulownia culture in Japan presently recognizes 4 basic tree configurations suitable for plantation grown trees (see Figure 7). The preferred "one step" method produces a long, single stem before the first limbs and the slow growth necessary for high quality logs.

For the "one step'" method remove the buds from the joint of the leaf stalk and the bole several times during the first

year after resprouting, before they become woody (Figure 8). Leave only a few well developed buds at the top for the next year's growth. Figure 9 shows the new growth's beginning as it would occur from buds left directly below the top. Keep removing buds until the tree is the height you desire. While this method of pruning is different from the branch pruning normally used in the US, it is the method of choice in the Orient and could be used quite effectively in the US as well.

The "two step" method produces 2 short logs, one below and one above the first limbs. The "2 fork" method produces one short log before the fork. Both methods yield faster growing, short logs usually lower grade than those produced by the "one step" method. Two step trees are produced similarly to one step trees except that they retain their buds 7 to 10 ft above the ground.

The "3 fork" method produces only one short, low grade log. However, it is used when the area being planted is subject to strong winds. Since it also affords the greatest protection against sunscald, you can use it for planting west slopes subject to strong afternoon sun.

Selecting one or a combination of growth configurations depends on the paulownia grower's goals and the plantation's topographic conditions. Use the "one step" method on optimal southeast slope sites not adversely affected by wind or sun. A plantation high on a west slope probably requires the use of the "3 fork" method. Use the other methods on sites between the two extremes. Beckjord (2) suggests that paulownia growers use either the "one step" or the "two step" method. Sun scald problems can be overcome by either wrapping the stem with paper or painting the south facing part of the trunk with white latex paint applied with a long handled paint roller. Early wind throw problems could be minimized by using landscape anchor wires.

Summary

Producing plantation-grown paulownia is a relatively new enterprise in the US. The only existing markets are in Japan. Much uncertainty exists concerning its growth characteristics on a wide variety of soils and climatic conditions. However, intensive cultural practices in the early years and proper density control through planned thinnings can yield very high returns for the serious producer.

To be a Successful Paulownia Producer:

1.Select your planting site carefully.
2.Produce or acquire high quality planting stock.
3.Ensure that the planting is done correctly.
4.Maintain competition control for a least 3 years.
5.Follow the recommended coppicing and pruning procedures.
6.Refer to "Paulownia Plantation Management: a guide to density control and financial alternatives" for information on plantation density control.
7.Work with your forester for technical help.

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About the Authors

Don Graves has been in UK's Department of Forestry since 1964. Specializing in revegetation systems and surface mine reclamation, he has been working with paulownia since about 1975. During those years he has conducted field tests of paulownia on surface mine sites, in nurseries and other places. He has studied seed storage problems, direct seeding techniques, greenhouse methods, etc. He has worked directly with growers in Maryland and is in touch with people all over the US who grow paulownia.

Jeff Stringer specializes in hardwood silviculture in UK's Department of Forestry. His involvement in paulownia research since 1982 has included developing techniques for germination and seedling production and determining drying properties of paulownia lumber. He has helped landowners in Kentucky and the southeast produce paulownia seedlings for plantation culture.

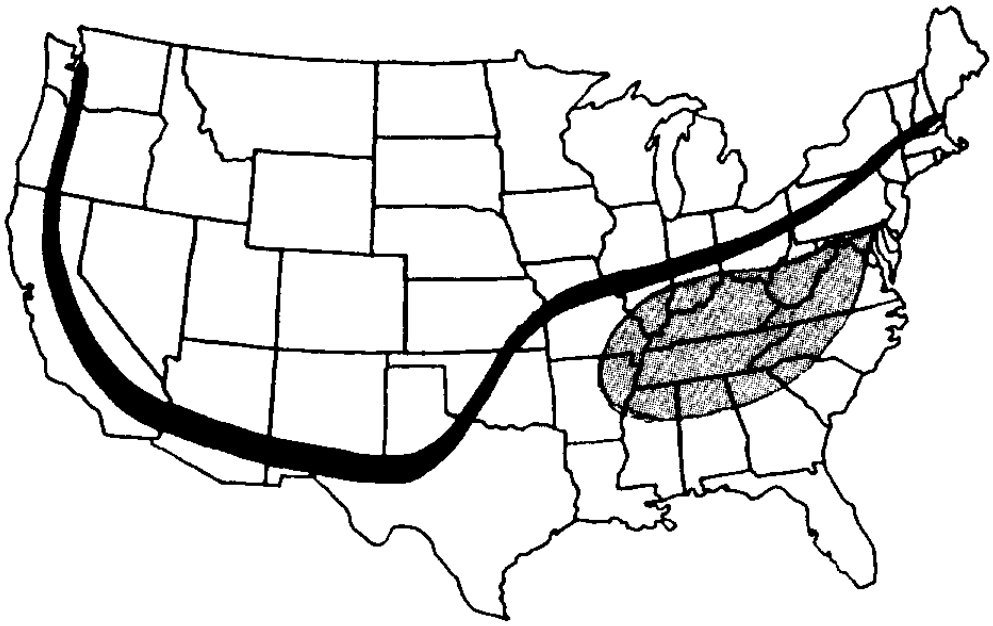

FIGURE 1. — The area below the curved line has soils and climate favorable for paulownia production. The shaded area has the best combination of growing conditions.

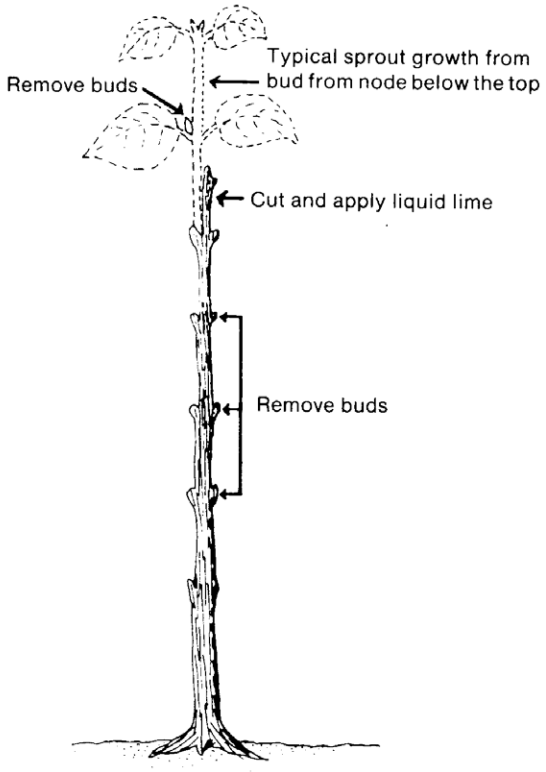

FIGURE 9. — Elongation from bud below terminal.

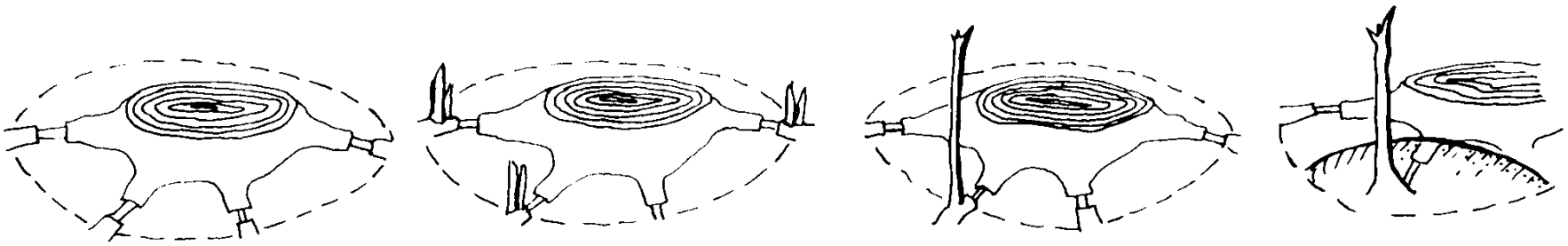

FIGURE 6. — The best situation: this sprout comes from roots disconnected from the stump.

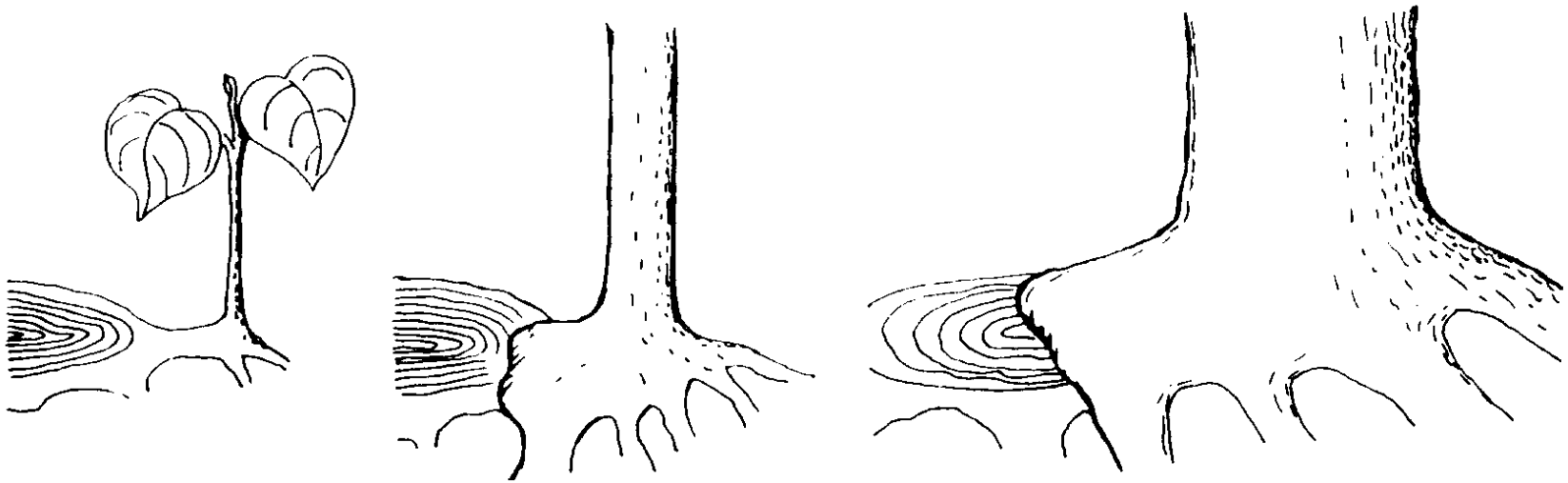

FIGURE 5. — A sprout further away from the old stump fares better.

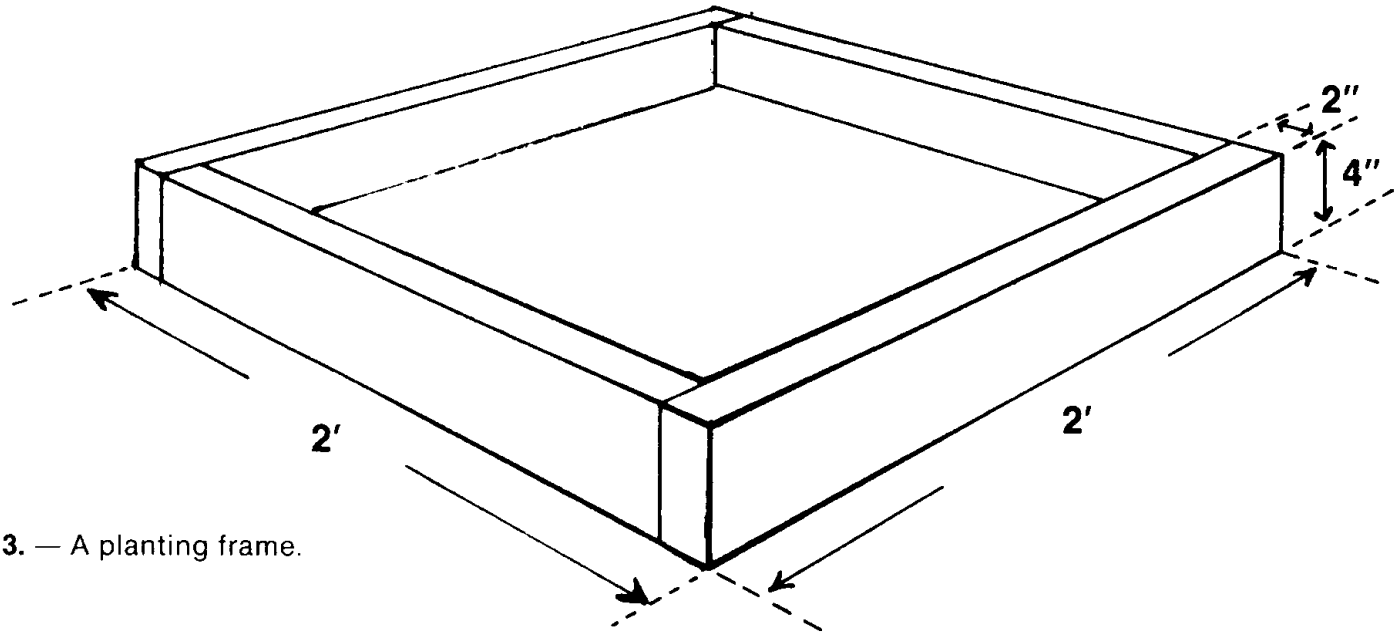

FIGURE 3. — A planting frame.