



Growing Chinese Chestnuts in Missouri

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Chinese chestnut is an emerging new tree crop for Missouri and the Midwest. The Chinese chestnut tree is a spreading, medium-sized tree with glossy dark leaves bearing large crops of nutritious nuts. Nuts are borne inside spiny burs that split open when nuts are ripe. Each bur contains one to three shiny, dark-brown nuts. Nuts are "scored" then microwaved, roasted or boiled to help remove the leathery shell and papery seed coat, revealing a creamy or golden-colored meat. Chestnuts are a healthy, low-fat food ingredient that can be incorporated into a wide range of dishes – from soups to poultry stuffing, pancakes, muffins and pastries (using chestnut flour). Historically, demand for chestnuts in the United States has been highest in ethnic markets (European and Asian, for example) but as Americans search for novel and healthy food products, chestnuts are becoming more widely accepted. The University of Missouri Center for Agroforestry conducts one of the nation's most comprehensive programs for developing the Chinese chestnut into a profitable orchard crop. There are multiple field studies, including a repository with 65 cultivars at the Center's research farm in New Franklin, Mo. Ongoing market evaluation and consumer research is also conducted by the Center.

Chestnut Species

Three *Castanea* species are native to the U.S. – American chestnut (*C. dentata*), Allegheny chinkapin (*C. pumila* var. *pumila*), and Ozark chinkapin (*C. pumila* var. *ozarkensis*), but all three are very susceptible to chestnut

blight. In fact, the devastation caused by chestnut blight (*Cryphonectria parasitica*) stem cankers has reduced American chestnut from a major timber species to a rare understory tree often found cankered in sprout clumps. Major efforts are underway to restore the American chestnut (see www.acf.org/). The Allegheny and Ozark chinkapins are multi-stem shrubs to small trees that produce small tasty nuts and make interesting (but blight susceptible) landscape trees that are also useful for wildlife.



Chinese chestnut is a medium-sized tree with spreading habit and has attractive white catkins late May and through June.

Three species of chestnut provide the basis for worldwide chestnut production—Chinese chestnut (*Castanea mollissima*), European chestnut (*C. sativa*) and Japanese chestnut (*C. crenata*). Chinese chestnuts are a medium-sized (40 ft.) tree, often multi-branched and wide spreading. With both good cold hardiness (-20° F) and adequate tolerance to chestnut blight, Chinese chestnut is the best adapted chestnut for Missouri and surrounding states.



The European chestnut is a larger tree (65 ft.), wide spreading but generally too blight susceptible to grow east of the Rockies and not as cold hardy as the Chinese chestnut. Most chestnuts found in U.S. grocery store chains are imported European chestnuts, primarily from Italy.

The Japanese chestnut is a small- to medium-sized tree (35 ft.) but lacks the blight tolerance and winter hardiness of the Chinese chestnut. European and Japanese chestnuts are grown commercially in West coast states where chestnut blight is not as pervasive and the climate milder. Chestnut species hybridize freely, resulting in many selected hybrid cultivars. Several Japanese x European hybrid cultivars are under test at the University of Missouri Horticulture and Agroforestry Research Center in New Franklin, Mo., but long-term observation will be needed to determine if any have enough blight tolerance and climatic hardiness to be recommended for planting in Missouri.

Site, Soil and Water Requirements

Chinese chestnut trees perform best in well-drained, loamy to sandy loam soils. Heavy, poorly-drained soils, or soils that have a perched water table during wet seasons promote *Phytophthora* root rot, a devastating disease of chestnuts. Soils should be slightly acid (pH 5.5-6.5). Most Chinese chestnuts can tolerate -20° F temperatures when fully dormant, but it is strongly recommended that frost pockets be avoided as planting sites, to avoid injury to swelling buds in the spring. Site selection similar to the requirements for peaches, where summit and shoulder slopes are chosen to allow for good air drainage, would be the best choice to safeguard from winter and early spring frost injury.

Chinese chestnut trees are rather drought tolerant once established, but ample water throughout the growing season promotes good tree growth and regular nut production. Maximum chestnut yields and nut size are obtained only under optimum soil water conditions, therefore irrigation is recommended. A lack of water during mid-August will result in smaller nut size, while a lack of water in September can prevent burs from opening normally. Micro-irrigation techniques (drip and/or micro-sprinklers) are best suited for chestnut orchards.

Nearly all chestnut trees are self-incompatible and require another tree of a different cultivar for pollination.

Flowering, Pollination and Fruit Development

Flower buds are initiated during late summer on shoot growth above the developing burs. During the follow-

ing spring, new shoots emerge from these buds with catkins appearing midway along the shoot (Fig. 1). Chestnuts produce two types of catkins – catkins with only male, pollen-producing flowers (staminate catkins) and catkins that contain both male and female inflorescences (bisexual catkins). The first few (basal) catkins are staminate catkins, producing pollen around 10 weeks after bud break. The last (most distal) catkins to develop along the current season's growth are bisexual, containing one to three pistillate inflorescences at the basal end of a catkin.

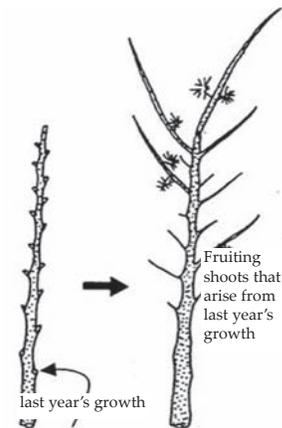


Figure 1: Fruiting shoots arise from previous years' growth.

At the end of May to mid-June, pollen is released from the most basal staminate catkins. Pistillate flowers on bisexual catkins become receptive a few days later and are receptive for one to two weeks. Once pistillate flowers become receptive, the bisexual catkins begin to release pollen. Flowering times of most Chinese chestnut cultivars are similar



Catkins releasing pollen. The distal catkin is bisexual with a receptive female inflorescence (arrow).

enough to ensure that any two cultivars will be able to pollinate each other. Pollinator trees should be within 200 feet of each other to ensure adequate pollination. Numerous insects visit chestnut catkins, feeding on the



A dehiscing bur. The nut in the middle position is flattened on two sides.

Table 1: Recommended Chinese Chestnut Cultivars for Missouri. Revised Fall 2008

Cultivar	Nut Fall	Nuts/lb.	Growth Habit	Comments
'Eaton'	Sept. 24-Oct. 1	32-35	Spreading	Nuts have excellent flavor and sweetness and store well. Ornamental glossy leaves. Nut size can be small if cultural conditions aren't ideal.
'Peach'	Oct. 1-3	23-32	Upright	Good quality nut grown at Empire Chestnut Company in Ohio. Large nuts with "peach fuzz."
'Gideon'	Oct. 3-6	28-38	Spreading	Uniform attractive nuts. More cold hardy than many Chinese chestnuts. Bears consistent, high yields of easy peeling nuts with excellent flavor. Grown at Empire Chestnut Company in Ohio.
'Sleeping Giant'	Sept. 24-Oct. 1	28-35	Upright	Hybrid – Chinese x (Japanese x American). A larger tree with proven blight resistance. Excellent nut quality and flavor. Cultivar is grown and sold as a seedling and requested by people interested in timber form.
'Qing'	Oct. 1-3	21-35	Spreading	Compact crown. Good branch angles. Shiny, medium to dark mahogany nuts. Excellent sweet flavor. Stores well. Heavy producer. Can set too many nuts, causing reduced nut size. NOTE: Delayed graft failure a problem with this cultivar.
'Au (Auburn) Homestead'	Sept. 27-Oct. 3	27-35	Spreading	Consistent, moderate yields. Large burs may drop early in wind storms.

Missouri Growers: Make sure you purchase Chinese chestnuts, not European or Japanese varieties. They may not be cold hardy in Missouri and may get blight. Do not plant American chestnut because they will die from chestnut blight.

abundant amounts of pollen produced by this tree. However, chestnuts are primarily wind pollinated and do not require bees for adequate fruit set.

There are normally three pistils in each bur (involucre). If all three ovaries are pollinated, then three nuts develop in the bur. (See image, previous page bottom right.) The middle nut is flattened on two sides, while the outside nuts are flattened on one side. If only one nut develops, then the nut is round in shape.

Selecting Cultivars (vs. Seedlings)

Chinese chestnut seedlings are widely available in nurseries across the Midwest. (See pg. 11). Although these trees provide adequate nut production for home use, seedlings often produce small nuts of mediocre quality and take longer to come into production. Seedling tree yield can't be predicted. Establishing an orchard of chestnuts with seedling trees will make nut harvest more complicated. Each tree in the orchard will ripen at a different time making quick and efficient harvest difficult. Grafted trees of proven cultivars bear earlier, provide more uniform ripening, have higher nut quality, larger nut size and more consistent yields. The evalua-

tion of chestnut cultivars for the Midwest is underway. University trials in Mid-Missouri have been established and are providing preliminary data. Table 1 lists a few Chinese chestnut cultivars that have shown excellent potential for nut production in Missouri. (See p. 11 for recommended nurseries.)

Methods for Establishing Chinese Chestnut Trees

Chinese chestnuts can be established by planting grafted trees, by planting seedling trees then field grafting one to two years later, or by planting nuts then field grafting two to three years later. Each of these methods has advantages and disadvantages. Prospective growers should choose the method most suited to their skills and economic situation.

Planting grafted trees Transplanting grafted trees of desired cultivars is the simplest way to establish an orchard. Grafted trees come into bearing two or three years following establishment, depending on tree growth rate. Commercial production of grafted cultivars (at least 750 lbs./acre, with 50 trees planted per acre) begins between the sixth and ninth year after the



Properly scored Chinese chestnut shells pop open upon cooking, revealing attractive golden nutmeats. The nutmeat should be easy to extract from the shell while hot.

grafted cultivar is planted. It is reasonable to expect production reaching 2,000 lbs./acre in a well-managed orchard by age 12-15. By providing optimum weed control, proper fertility and ample water, you will ensure vigorous tree growth and early fruiting. Grafted trees can be purchased as bareroot or container-grown trees. Bareroot trees are more widely available but suffer a greater degree of transplant shock. Transplant shock is a major contributing factor in graft failure following establishment.

For this reason, spring planting of grafted trees is preferred. Currently, trees of all recommended cultivars are not widely available from commercial nurseries unless custom ordered a year in advance, making it difficult to obtain grafted trees. (See p. 11 for sources).

Planting seedling trees Seedling Chinese chestnut trees are widely available and are relatively inexpensive compared to grafted trees. Bare root seedling trees survive well, but may grow slowly the first season.

Growth is better the second growing season and in subsequent years. Desired cultivars should be grafted to seedling trees one to two years after establishment. Nut production should begin one to three years after field grafting. Starting a chestnut planting with seedlings offers the advantages of low initial costs and the opportunity to establish cultivars not readily available from commercial nurseries. Disadvantages of establishing a chestnut orchard with seedlings include delaying the onset of profits from nut production and adding the expense of grafting your own trees.

Planting nuts Chinese chestnuts are easily grown from properly stratified nuts. Freshly harvested nuts can be stratified in moist sand by placing them in layers about three inches deep and holding them in a cool room or refrigerator (35° to 40° F) for 60 to 90 days. The nuts also can be stored in resealable plastic bags with slightly moistened sphagnum moss and kept in the vegetable bin of a refrigerator. Stored chestnut seed can be quite prone to rotting so inspect the bag of nuts periodically and remove any spoiled nuts. The taproot (radicle) will slowly emerge during storage, similar to acorns in the white oak family. Care must be taken not to injure the taproot when it is time to field plant the nuts in the spring after the danger of frost passes. Homegrown

seedlings can be grown in a nursery row in your garden and transplanted the following year or planted directly in the final tree location. Soil drainage is critical so mound the soil into a small hill at each seed plant location to help prevent nuts from rotting. Chestnuts can be grafted using the three-flap, bark or arrowhead graft, detailed in the University of Missouri Center for Agroforestry publication "Propagating Pecan and Black Walnut in Missouri," AF 1003. Find this guide online or order by going to www.centerforagroforestry.org

Transplanting Trees

Transplant bareroot stock in March as soon as the soil can be easily worked. When planting bareroot seedlings, care should be taken to keep the roots moist. Prune the top of each tree to a single stem and prune off broken or rotten roots. Dig your planting hole large and deep enough to fit the entire root system. Hold the tree in position and fill soil around the roots, making sure the fibrous roots are spread out in their natural positions. Plant the tree at the same depth as in the nursery. Water in the tree after transplanting and do not place soil amendments or fertilizers in the planting hole.



Containerized grafted 'Qing' trees ready to be fall field-planted.

In central Missouri, container-grown stock can be planted in early October or in late March (although spring planting of grafted trees is recommended). Dig your planting hole twice as wide as the container, but no deeper than the depth of the pot. After removing the tree from the container, gently tap or shake the rootball to remove some of the potting media, then inspect for encircling roots. Gently pull out the encircling roots and spread out into natural positions in the planting

Tree Transplanting Tips

- Transplant bareroot stock and any grafted trees in March
- Water in the tree after transplanting and do not place soil amendments or fertilizers in the planting hole
- Container-grown stock can be planted in early October or in late March



Left: Sunscald injury to a chestnut trunk that has been pruned heavily. Painting the trunk after

pruning with 50 percent interior white latex paint would have prevented the damage. **Above:** Keep all vegetation controlled in a six-foot circle around trees using mulch or herbicides (spread fertilizer evenly over this entire six-foot vegetation-free area).

hole. Fill in the planting hole with topsoil making sure the tree is at the same depth as it was in the container. However, be sure to cover the rootball and potting soil with an inch of soil to retard drying out the rootball.

Care During Establishment

The trunks of young chestnut trees are susceptible to sunscald. To prevent injury, paint trunks white with 50/50 mixture of white latex interior paint and water or wrap the tree with a white, plastic, spiral tree wrap. Keep all vegetation controlled in a six-foot circle around the tree by using mulch or herbicides. If the tree makes several inches of new growth by early June, spread a half-cup of ammonium nitrate fertilizer around the tree evenly over the entire weed-free area. During the summer following tree establishment, it is especially important to keep the soil around the tree moist (but not soggy) at all times. Installing a micro-irrigation system will help provide optimum soil water conditions throughout the life of the orchard. (See pg. 15 for irrigation Web resource.)

Chestnut Culture: Planning Your Orchard

Chinese chestnut is a very adaptable crop. Chinese chestnut can be grown as a backyard nut tree, a small-scale, low-input orchard tree, or an intensively managed, high-density orchard crop. Tree spacing and pruning systems differ under each of these management regimes requiring the grower to choose a cultural system before setting out a single chestnut tree. The three basic cultural systems are described below.

Backyard trees

Chinese chestnuts make an excellent nut tree for home production. Planting at least three trees (different cultivars if grafted trees) will ensure pollination and produce enough nuts for a family. Chinese chestnut trees naturally form wide spreading crowns that grow to a height of 35 to 40 feet. Spacing your trees at least 40 to 50 feet apart will allow ample room for tree growth and allow easy access to all sides of the tree at harvest time. Homeowners should plant their chestnut trees in a location where children and pets can be kept away from the spiny burs that fall to the ground at harvest. Chestnuts require full sun for best nut production so they should not be planted adjacent to large shade trees. Young trees should be trained to the central leader system to develop a strong framework of lateral branches along the main trunk. After the trees come into bearing, begin pruning off lower limbs—one or two each year until there is enough clearance for mowing and harvesting. Once the trunk is developed, allow the tree to develop its natural spreading form. If branches with “narrow crotches” arise, prune them out. Branches with narrow crotch angles tend to form bark inclusions, which can lead to limb breakage under the weight of a heavy crop or ice storm. Mature trees require minimal pruning.



A strong crotch showing pronounced bark ridge for the upper right branch. The lower left branch does not show a pronounced bark ridge and is inherently weaker and should be removed.

Low-input orchard

Chestnut plantings of 50 to 250 trees (1 to 5 acres) are large enough to provide landowners with a reliable source of supplemental income but are small enough to manage with hand labor. For these growers, minimizing capital expenditures for machinery is the key to profitability.

To maximize nut yield, initial tree spacing for the small-scale orchard should be 30 by 30 feet, or roughly 50 trees per acre. As trees grow and limbs of adjacent trees start to touch (age 15+), remove every other tree on the diagonal to leave trees on a 42 by 42-foot spacing (26 trees/acre). *NOTE: A well managed, irrigated, 5-acre chestnut orchard of 250 trees may yield up to 10,000 lbs. of chestnuts by age 12-15.*

A second thinning may be necessary before chestnuts attain their final spacing of 50 by 50 feet (17 trees/acre). Thinning the orchard is crucial to providing optimal sunlight to the trees and ensure maximum nut produc-

tion. Crowded trees create excessive shade on lower branches allowing flower and nut production only in the tops of the trees. Severe shading causes lower branches to die out and compromises general tree vigor.

Young trees should be staked and pruned using the modified central leader pruning system.* Many cultivars do not naturally grow vertical central leaders but must be staked to provide a structure for training the young trees. A strong stake should be placed near each tree and a leader chosen and loosely tied to it. Central leaders grown vertically develop leaves and buds in a spiral fashion allowing good choices for scaffold branches growing in the proper directions. Central leaders allowed to bend over will develop buds on opposite sides of the shoot, not in a spiral fashion. The scaffold branches are selected during the second through sixth growing season, allowing for good spacing between branches in a spiral fashion along the main trunk. The height of the lowest scaffold branch depends on the individual grower's equipment needs.

**(Modified central leader method is used in peach orchards and should work with chestnuts.)*

Intensively managed orchard

Large nut size is one key to profitable chestnut farming. Large chestnuts command premium prices. To maximize the production of premium quality nuts, chestnut trees can be grown as a high-density, intensively managed orchard crop. This level of management requires a skilled grower willing to plant sufficient acres of chestnuts to justify investments in trees and the mechanization of orchard operations. *(Note: The following management practices and pruning strategies are being tested in Missouri; however, proven recommendations are not yet available.)*

A hedgerow system** of chestnut production has been developed in Japan by Dr. Hitoshi Araki and is currently practiced in New Zealand and Australia. Trees are planted 13 feet apart within rows spaced 26 feet apart. The trees are not thinned out over time but are pruned to contain tree size similar to what is done in peach orchard management. In a hedgerow orchard, a micro-irrigation system is critical for providing optimum soil water conditions to maximize nut size.

Research in Japan has shown that chestnuts require high levels of light intensity to be able to set and develop fruit. In addition, there is a direct relationship between the intensity of sunlight within the tree canopy and the number of female flowers per cubic foot of canopy (Fig. 2). High light intensity

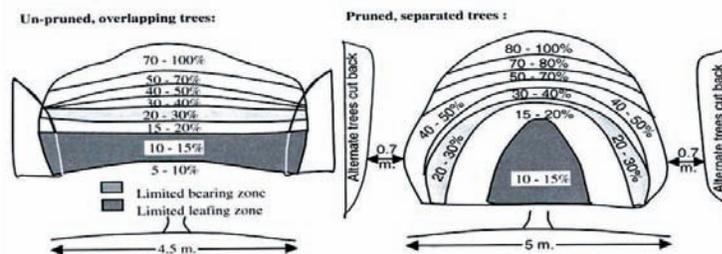


Figure 2: Measurements of relative solar radiation within the tree canopy.

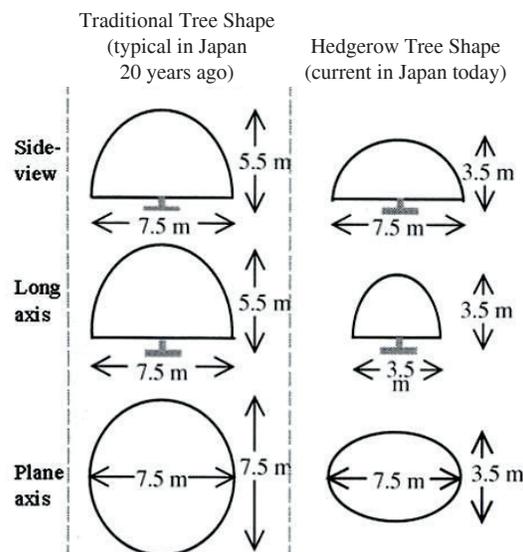


Figure 3: Re-shaping of chestnut trees in Japan.

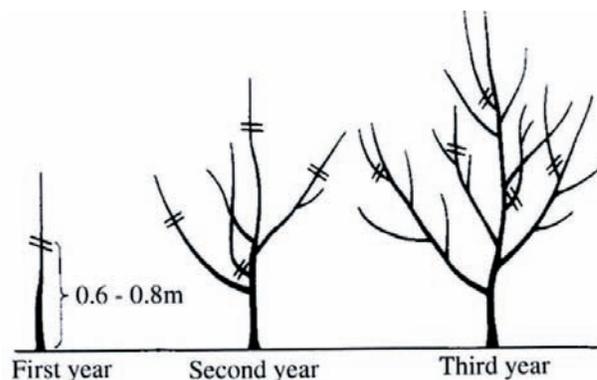


Figure 4: Pruning a young tree in three successive years.

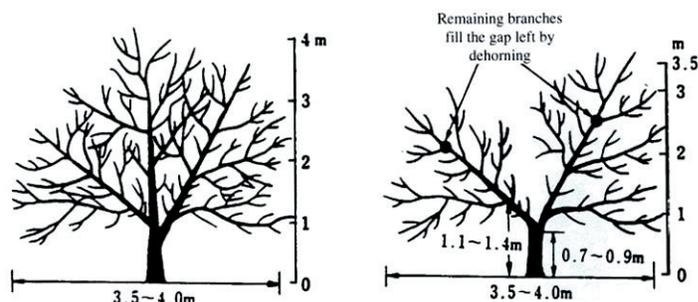


Figure 5: De-horning the central leader.

stimulates nut-bearing shoot growth, which in turn promotes large fruit size. The hedgerow pruning system** strives to maximize light penetration into the entire tree canopy. To achieve these results, the Japanese pruning system limits tree height to 12 to 13 feet and restricts the distance from the edge of the canopy to the center of the tree. Trees are pruned to an elliptical tree shape (Fig. 3)

To achieve needed tree structure, pruning needs to start in the first year and continue regularly throughout the tree's life. The target initially should be to promote a leader and two main branches. The third year, the aim should be to encourage the tree to spread out (Fig. 4). Thinning the inward growing branches is necessary to further encourage branch spreading into the alley. By approximately the fifth growing season, commercial cropping should begin. Cut out the central leader in the winter, leaving the two permanent structural branches that reach out into the alleyways to become the tree's permanent framework. Removing the central leader also reduces tree height (Fig. 5).

*** (Hedgerow pruning system is experimental and unproven in Missouri.)*

Subsequent tree growth will fill the gaps left by removal of the central leader. From this point forward, thin out interior branches as they begin to crowd, and also remove branches to maintain a reduced tree height and elliptical tree shape. Depending on the cultivar and manage-

ment inputs, time will determine whether the hedgerow system can be maintained in the Midwest. If not, every other tree will need to be removed within the hedgerow to allow light penetration into the canopy.

Portuguese scientists (Gomes-Laranjo et. al.*) are experimenting with pruning European chestnuts into a "vegetative wall" (hedgerow). The hedgerows are on a north-south orientation to take advantage of the morning and afternoon sun movements (Fig. 6). Trees are spaced on 30-foot centers and have been pruned to within 1½ feet of the trunk on the alley side, but the trees are allowed to fan out within the row to form the vegetative wall. Based upon light measurements and studies of leaf and fruit development, researchers have concluded that the hedgerow structure helps eliminate shaded areas in the canopy. They believe this pruning management will allow an overall increased canopy density per unit area that receives adequate solar radiation. Hedgerow style pruning is being used on other nut crops, including walnuts in California and pecans in New Mexico.

At the Horticulture and Agroforestry Research Center, the Center for Agroforestry has established several different tree spacings for studying aggressive pruning methods as compared to minimal pruning. Some of the spacings are 30 x 30 feet and 27 x 27 feet utilizing a modified central leader style of pruning; others are 20 x 30 feet and 13.5 x 27 feet with a hedgerow style of pruning applied. At the present time, a 30 x 30 foot spacing and modified central leader pruning strategy is the recommended approach. *Additional years of study are needed to reach definitive conclusions on chestnut tree spacing and pruning methods under Midwest conditions.*

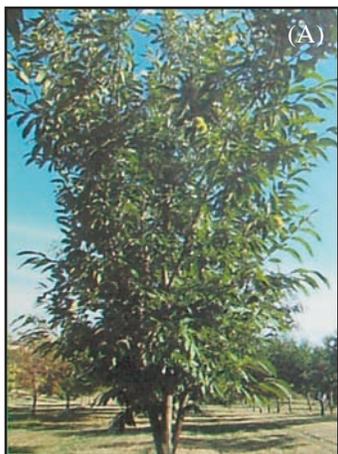
NOTE: The calculated amount of fertilizer should be split into two applications

Fertilization

If needed, fertilizers such as lime, potassium and phosphorous should be incorporated into the soil before planting trees. (CAUTION: Do not incorporate fertilizer directly into the planting hole).

Trees should be fertilized with nitrogen annually. However the optimum nitrogen rate will vary depending on the soil type, orchard floor management, crop load, etc. Soil nitrogen leaches more readily in sandy soils than in heavier types. Thus, nitrogen rates may need to be increased slightly on sandy soils. Sites in which alfalfa was previously grown may contain high levels of residual soil N and require less fertilizer the first year. Sodded orchards may require

Figure 6: Vegetative wall pruning (hedgerow) in Portugal. Trees are pruned within .5 meters of the trunk (A), but limbs fan out within the row (B and C).



*Gomes-Laranjo, J., J.P. Coutinho, J. Ferreira-Cardoso, M. Pimentel-Pereira, C. Ramos, and J. Torres-Pereira. 2004. Assessment to a New Concept of Chestnut Orchard Management in Vegetative Wall. Abreu, C.G., E. Rosa, and A.A. Monteiro, eds. Proc. 3rd International Chestnut Congress. Acta Horticulturae 693:707-712.

20 to 50 percent more N than those where the ground beneath the tree is kept free of vegetation. The nitrogen rates presented in this guide can be used as an initial recommendation, but should be adjusted based on annual new growth and leaf color. Non-bearing trees should produce 18 to 24 inches of new growth annually. In contrast, bearing trees should produce about 12 to 15 inches of new growth each season. To achieve this type of shoot growth, apply 0.1 lb. actual N per tree per year of age. For example, for a 3 year-old tree should receive 0.3 lbs. actual N per tree. To calculate the amount of fertilizer product needed, divide the actual N by the percent active ingredient. Thus, if ammonium nitrate (34% active ingredient) is used, then the amount of this product applied per 3-year-old tree would be $0.1 \times 3 \text{ years} \div 0.34 = .88 \text{ lbs. per tree}$. The calculated amount of fertilizer should be split into two applications. Two-thirds of the calculated fertilizer amount should be applied before bud swell (April 1) and the other third should be applied at the end of flowering (June 20). Apply the fertilizer within the dripline of the tree. The following growing season, if shoot growth is less or greater than the recommended lengths, nitrogen rates can be adjusted based on the site conditions.

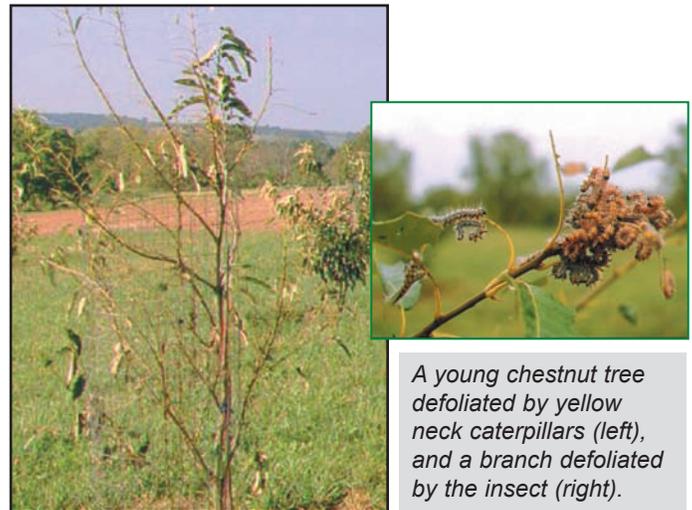
Pest Management

Chinese chestnut is a relatively pest free orchard crop. In carefully managed, well-scouted, small-scale plantings, chestnuts can be successfully grown without pesticides. However, no chestnut tree is safe from insect pests or the browsing of deer, rabbits and voles.

Mammals

When trees are young, the smooth, thin bark of a chestnut tree is especially inviting to rabbits and voles. Place plastic tree guards around each tree, pressing the guard into the soil to prevent voles from digging under them. Remove all vegetation and mulch from the tree during winter. Bare soil provides a beautiful backdrop for hawks and owls to spot daring rabbits and voles trying to attack your chestnut trees. Once chestnut trees develop rough bark, the threat from rabbits and voles diminishes.

Deer not only browse chestnuts, but bucks also often rub all the bark off of trees during late summer and early fall. Installing a permanent fence around your chestnut planting to prevent deer damage can be cost-effective, as it will protect your trees and crop from year one, on. (For specific supply and construction instructions for a chestnut deer fence, see <http://www.centerforagroforestry.org/faq.asp>) These fences require regular maintenance.



A young chestnut tree defoliated by yellow neck caterpillars (left), and a branch defoliated by the insect (right).

Insects

The yellow neck caterpillar (*Datana ministra*) is an occasional pest of chestnuts. These insects feed in large colonies and can completely defoliate a young chestnut tree. Scout your orchard regularly starting in late June and look for newly hatching colonies. Although this pest is frequently kept under control by beneficial insects, an insecticide can be used to control outbreaks of yellow neck caterpillars. Recommended insecticides include carbaryl and *Bacillus thuringiensis*.

Potato leafhopper (*Empoasca fabae*) is a regular pest of many agricultural crops, including chestnut. Leafhoppers feed on the veins on the underside of developing leaves in May and June, causing deformation. Young leaves show cupping and curling and may fall off of the tree. As weather becomes hot and dry the leaf hoppers disappear, but the resulting leaf damage and defoliation may affect nut yield and quality. An orchard spray with carbaryl at the first signs of leaf cupping and curling is recommended.

Oriental chestnut gall wasp (*Dryocosmus kuriphilus*) was accidentally introduced into Georgia in 1974 and has spread north across the eastern United States since (it has not yet been found in Missouri). Adult gall



Galls appear on a chestnut tree. (Above.) Right, adult chestnut gall wasps.

wasps lay eggs in chestnut buds in early summer; larvae remain dormant until buds expand the following spring. Gall wasps induce the formation of greenish red, 1/3- to 1/2-inch leaf and twig galls that suppress shoot elongation, reduce fruiting and cause twig die-back. Adult wasps, 1/8-inch long, then begin emerging from the galls during early summer, continuing the cycle. Severe infestations can result in mortality of young trees. Parasitic wasps move with chestnut gall wasp populations, and have aided in population declines. At present there are no documented chemical control method(s) in the literature.



Exit hole and larvae of the small chestnut weevil. (Photo courtesy R. Bessin, University of Kentucky.)

Two species of weevils pose the greatest risk of injury to a Midwest-grown chestnut crop. These weevils lay eggs inside chestnuts starting in August and continuing until harvest. Larvae of the chestnut weevil are white, legless grubs that can devour the entire contents of a nut. Because native chestnut tree species have been killed by the chestnut blight fungus,

chestnut weevils have become somewhat rare and are infrequently encountered in new chestnut plantings. It often takes 10 to 15 years before chestnut weevils find new chestnut plantings and build up to economically damaging populations.

Small chestnut weevils (*Curculio sayi*) emerge from the soil in late May through July. Adults feed on chestnut foliage until nut kernels enter the dough stage in mid to late August. Although they can lay eggs any time after kernel filling, most eggs are laid after the bur begins to open. The female weevil uses her long proboscis to drill a hole through the shell before turning around and placing her ovipositor into the nut and laying five to seven eggs. Eggs hatch in about 10 days and larval development is completed two to three weeks later. Mature larvae chew a small round hole through the shell, exit the nut, and then burrow into the ground under the chestnut tree. The insect remains in the soil for two to three years before re-emerging as an adult.

Large chestnut weevils (*C. caryatrypes*) emerge from the soil in late July and August. Because of their larger size, large chestnut weevils are more successful in laying eggs in nuts before burs open. The long proboscis of large chestnut weevils enable females to drill oviposition sites among the spines of the bur. Eggs hatch in five to seven days producing large, legless grubs. The life cycle of the large chestnut weevil is similar to that of its smaller cousin but the larger weevil spends only one to two years in the soil.



Above: Mechanized nut harvesting is essential in commercial-sized orchards. (Photo: Bob McEwen, Rural Missouri magazine.) **Inset:** Chestnuts in California are sorted to size, bagged in 25-pound "onion bags" and then stored at 27° F until a full tractor-trailer load is ready to be shipped to a wholesale broker in New York City.

Nut Curculio (*Conotrachelus carinifer*) is a sporadic pest of chestnut. This curculio is primarily an acorn pest but has been observed to invade chestnut orchards when the acorn crop in nearby forests is low. The nut curculio is related to chestnut weevils and the damage inflicted to chestnut kernels is similar. Curculios have much shorter probosci and must wait until the burs open to lay eggs inside the nut. The nut curculio has a one-year life cycle.

Good sanitation practices can help keep weevil damage under control. Prompt harvest followed by a hot water treatment (122° F for 30 minutes, then immediately cool to ~32 to 34° F) will kill weevil eggs before they have a chance to hatch. In large orchards, control weevil populations by making three applications of carbaryl (Sevin®) at 10-day intervals starting in mid-August. The adult weevils can be scouted and monitored for their presence by jarring the tree and counting fallen weevils. (See pg. 15 for resource link on creating hot water bath.)

Harvest, handling and processing

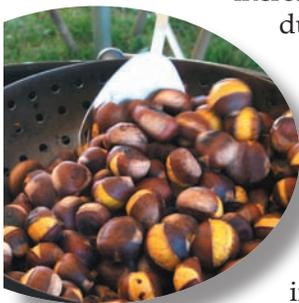
Harvest in the Midwest occurs September and October, depending on cultivar and growing season. Harvest fallen nuts promptly to preserve quality and prevent excessive predation by deer, possums, turkey, mice and other wildlife. Individual trees generally drop nuts for two to four weeks. Use heavy leather gloves when handling chestnuts in the bur. The prick of a chestnut bur can be very painful. In home plantings, roll the bur under your foot until the nuts pop free before picking up chestnuts. In large plantings, mechanical pecan harvesters are somewhat successful; however, the flat side of chestnuts helps them "hug" the ground. Highly efficient large-scale mechanical harvesting equipment is still lacking.

Unlike most tree nuts that are high in oil content and low in water content, ripe chestnuts are high in carbohydrates (49 percent) and water (44 percent) making these nuts subject to molding and decay. Pick up nuts at least every other day to preserve nut quality. Promptly store nuts in a refrigerator (32° F or slightly above) in sealed plastic bags (one to two gallon bags work well) to retard kernel molding. Ventilated plastic bags are needed for larger quantities to allow some air movement while still reducing excessive moisture loss.

Kernels of fully dry chestnuts (to less than 8 percent moisture) are rock hard and inedible. However, dry chestnuts can be ground into gluten-free chestnut flour and used as a substitute for corn meal. Dry chestnuts also can be rehydrated in boiling water much like dry beans. Fully drying chestnuts provides chestnut enthusiasts a way to preserve the nuts if refrigerator space is limited. Although dry chestnuts are not susceptible to molding, they are subject to attack by stored grain pests such as the Indian meal moth and confused flour beetle. Store dry chestnuts in tightly sealed containers to prevent insect attack.

Markets and marketing

The Center for Agroforestry's long-term objective is to create a thriving domestic chestnut industry focusing its efforts on four key areas: production techniques/orchard management; national market research; creating local "grower clusters"; and increasing consumer awareness and demand. The outcome of this effort will be an active program that reaches out to potential producers and establishes a multi-million dollar chestnut industry in the state of Missouri and surrounding states. Through a national market study conducted in 2005 and ongoing consumer research (2003-2008), the Center strives to increase adoption of chestnuts by producers, retailers and consumers.



Consumer research

A longitudinal study (2003-2008) revealed that quality, locally grown and nutrition-diet-health were consistently perceived as the most important attributes influencing chestnut purchase decisions. Another study explored preferences for different

characteristics including nut size, production process and geographic origin. Results suggest consumers strongly prefer locally and U.S. grown compared to imported chestnuts with additional preferences for chestnuts that are medium sized and organically certified. Growers that provide the market with chestnuts meeting these characteristics are like to capture price premiums.

Five years of consumer research show that familiarity with chestnuts increased over time. Compared with people that attended the Missouri Chestnut Roast festival for the first time, repeat visitors demonstrated higher interest and consumption of chestnuts and a gain in knowledge regarding three key chestnut attributes: need for refrigeration, low fat content and a source of gluten-free flour. The Missouri Chestnut Roast provided a forum for interested people to ask questions and receive pertinent written information to take home and read, furthering the education process. These results demonstrate that the Missouri Chestnut Roast is having an impact on consumers' familiarity and interest concerning chestnuts and that public events of this nature are an effective tool to educate consumers and help create a viable chestnut industry in the region.



Describing the U.S. chestnut market – an analysis from the University of Missouri Center for Agroforestry

The following is an excerpt from the survey results. The entire report is published as the Chestnut Market Analysis and Producers' Directory, and is available for viewing or downloading from www.centerforagroforestry.org. (See Publications page).

General information about the respondents, industry

- The majority of U.S. chestnut producers have been in business less than 10 years and are just beginning to produce commercially
- Current production volume is less than 1.5 million pounds nationwide.
- U.S. chestnut producers are mainly part-timers or hobbyists (only 20% of respondents are full-time farmers and only two are 100% involved in the chestnut business).
- Most production operations are small; less than 10 acres. With 50 trees per acre, commercial production (at least 10 lbs./tree) can be reached in 6-9 years after grafted trees are established (under proper management).

Information about the market

- The majority of respondents sell their chestnuts locally, 38% sell regionally and 21% sell nationally.
- 38% sell chestnuts on-farm, 34% sell to farmers markets, 23% sell fresh chestnuts to restaurants and less than 20% sell to different retail locations (e.g., ethnic stores (19%), upscale grocery stores (18%), health and natural food stores (17%), national chain grocery stores (11%)).

- Most respondents produce and sell fresh chestnuts in bulk (77%) or packaged (41%). Some producers act as small nurseries and produce seedlings (21%), grafted cultivars (10%) or chestnuts for seed (20%). Nineteen percent of respondents sell value-added products like chestnut flour, dried chestnut kernels, frozen chestnuts, chestnut honey, soup mix and jam, jellies or preserves while 13% sell chestnut-related products (e.g., roaster, mug, cap, knife).
- Demand for quality chestnuts exceeds supply. Demand for fresh chestnuts is expected to continue to increase by 10% - 25% in the next 5 years.
- Grower retail prices range from 75¢ to \$6 per pound at farmers' markets; \$1.50 to \$6 a pound at on-farm sales; and \$2 to \$7 per pound at restaurants, retail grocers and health food stores.
- Overall, wholesale prices average \$3.10 - \$3.50 per pound to the grower.
- Producers who grow chestnuts from cultivars, grow organically, or sell under a brand name achieve the highest prices.

Further details on these findings were published in Hort-Technology (Gold et al. 2004, 2005, 2006; Aguilar et al., 2009) and the Journal of Extension (Cernusca et al., 2008). See the *Chestnut Resources* section for full citations.



The Missouri Chestnut Roast: A Festival of Culture and Agriculture

The Missouri Chestnut Roast, held annually in October, has quickly become one of the premier family-oriented events for mid-Missouri and the MU College of Agriculture, Food and Natural Resources. The event is an outstanding opportunity to introduce families and landowners to the broad range of possibilities and benefits agroforestry practices can provide. Hundreds of visitors each year enjoy their first sample of sweet, Missouri-grown roasted chestnuts, along with a variety of products including locally grown black walnuts and pecans, recipes and nutritional information to pique interest in purchasing local nut products.

Retail Chestnut Nurseries⁺

****Forrest Keeling Nursery**

PO Box 135
Elsberry, MO 63343
800-356-2401
www.fknursery.com
Note: Also carry Qing and Cropper seedlings

****Nolin River Nut Tree Nursery**

797 Port Wooden Rd.
Upton, KY 42784
270-369-8551
www.nolinnursery.com
john.brittain@windstream.net

****Empire Chestnut Company**

3276 Empire Rd. SW
Carrollton, OH 44615
330-627-3181
www.empirechestnut.com
empire@eohio.net

⁺*Order a year in advance for larger orders of custom-grafted trees*
****Carry recommended Chinese Chestnut cultivars**

Nash Nursery

4975 Grand River Rd.
Owosso, MI 48867
517-651-5278
www.nashfarm.com
nashfarm@shianet.org



NOTE: Caution should be exercised on buying any chestnut plant material from areas of known gall wasp infestation (Georgia, North Carolina, Ohio, Tennessee, for example).

Chinese chestnut tree prices

	1-2 feet	bare-root (1yr - 2yr)	container
Seedlings	\$3.50	\$8.50 - \$13.25	\$17.50
Cultivars	\$17 - \$40		

Chestnut Value-Added Products: Unique Niche Market Opportunities

<i>Product</i>	<i>Description</i>
	Fresh roasted or raw, in-shell chestnuts: Best if sold immediately after harvest. Market opportunities include farmers' markets, local festivals, restaurants and specialty grocers. Attractive packaging – such as a fabric drawstring bag – should include preparation and storage instructions. Roasted or fresh chestnuts can sell for \$4.50 to \$6.50 per pound at the retail or direct customer level. Organic, locally grown chestnuts receive the highest prices.
	Chestnut flour: This gluten-free, finely ground product is a gourmet ingredient in pastries, pastas and desserts. Chefs may purchase chestnut flour for these purposes; consumers with gluten allergies or special diets also are increasing demand for chestnut flour. Due to the starchy consistency of chestnuts, specialized equipment may be necessary; this chestnut flour product is milled with imported equipment at Allen Creek Farm in Washington (www.chestnutsonline.com) and sells for more than \$9 per pound. Other chestnut flour producers: Chestnut Growers, Inc., Michigan, http://www.chestnutgrowersinc.com/ordering.shtml ; Ladd Hill Orchard, http://www.laddhillchestnuts.com/ ; and Empire Chestnut Company, http://www.empirechestnut.com/produce.htm#kernel
	Mixes/gift packs: Dried chestnuts, chestnut flour and other gourmet ingredients are featured ingredients in specialty food mixes, such as chowder, bread, scone, wild rice, pasta, cornbread and pancake mixes. These mixes are attractively packaged by Allen Creek Farm (www.chestnutsonline.com) and Ladd Hill Orchards (http://laddhillchestnuts.com/), for example.
	Sweet chestnut puree/marron glacés: Sweet chestnut puree is used in desserts like crepes, for example. Marron glacés are candied chestnuts that are eaten on their own or used as a garnish for other desserts. Both are common in Europe and imported here, but rarely produced in the United States and might be an interesting niche for a grower. (This Michigan-produced chestnuts in maple syrup product, left, is a twist on traditional sweet chestnuts: http://www.earthy.com/Earthy_Delights_Michigan_Chest_P892.cfm)
	Dried chestnuts: Dried chestnuts are excellent for long-term storage and can be rehydrated to be ground and used as a base for pasta, breading for fish or sprinkled on your potato for a sweet topping. Chestnut Growers, Inc., Michigan, has developed a freeze-dried chestnut slice that's shelf-stable for up to two years and can be rehydrated in only 15 minutes. They sell for about \$20/8 oz. (8 oz. doubles when reconstituted) and can be purchased online (http://www.chestnut-growersinc.com). Empire Chestnut Company also sells dried chestnuts – http://www.empirechestnut.com/produce.htm#kernel
	Chestnut snack packs: Green Valley Chestnut Ranch sells this unique Chestnut Snack Pack, a 50 gram pack of peeled, whole-roasted and ready-to-eat chestnuts – a delicious and nutritious snack. (www.chestnutranch.com)
	Chestnut honey: Chestnut honey is a popular and high-demand product in France, Italy and other European regions. Made from chestnut flowers, the honey is delicious in flavor and excellent in color. Many U.S. growers also are producing this gourmet product. Chestnut honey from Nutquacker Farms, pictured here, sells for approximately \$10 per 12 oz. jar. (www.nutquackerfarms.com/). Ladd Hill Orchards also sells honey, in different quantities, at http://www.laddhillchestnuts.com/
	Chestnut beers, wines and liquors are enjoyed across Europe, with small-scale production existing in the U.S. Available chestnut beers include "Fuego del Otoño," a seasonal beer produced by Jolly Pumpkin Artisan Ales, Michigan (see http://www.jollypumpkin.com/beers.htm). In addition, Lee Williams of Trails End Chestnuts, Washington, provides roasted chestnut chips and instructions for anyone wanting to brew their own chestnut beer (http://www.chestnuttrails.com/)
	Frozen, peeled chestnut meats: The Australian Chestnut Company (www.cheznuts.com.au) sells frozen, peeled chestnut meats under the "Cheznuts" brand name with the tagline: "Chestnuts made easy." The product is quick and convenient for everyday cooking. Peeled Frozen Chestnuts are also available from Michigan's Chestnut Growers, Inc. See http://www.chestnut-growersinc.com

Chestnut Orchard Establishment Costs

Supplies for Orchard Establishment (1 acre, 50 trees, 30' x 30' spacing)

<u>Item</u>	<u>Cost</u>	<u>Quantity</u>	<u>Total</u>
*Drip irrigation (1,250' tubing, shutoff valve, filter, pressure regulator, air vent, pvc manifold, risers and fittings)	\$445.50	1	\$445.50
Fertilization costs (ammonium nitrate)	\$45	1	\$45
Herbicide strip at base of trees	\$120	1	\$120
Grafted chestnut trees – 50 wholesale	\$16.95	50	\$848
Shipping costs	\$0.75	50	\$38
10' support stakes	\$5	50	\$250
**Fencing – 100' welded wire fence 60" tall – cut to make tree cages	\$68.36	5	\$342
Rebar for staking cages down	\$195	1	\$195
Leaf analysis – 3 samples	\$40	3	\$120
Year 1 Orchard Establishment supplies total:			\$2,403.50
Fertilization costs (ammonium nitrate)	\$90	1	\$90
Herbicide strip at base of trees	\$120	1	\$120
Leaf analysis – 3 samples	\$40	3	\$120
Year 2 supplies total:			\$330
Fertilization costs (ammonium nitrate)	\$135	1	\$135
Herbicide strip at base of trees	\$120	1	\$120
Leaf analysis – 3 samples	\$40	3	\$120
Year 3 supplies total:			\$375
Total costs for orchard establishment (1 acre, 50 trees, 30'x30' spacing)			\$3,108.50

**Does not include costs to establish water source (well or pond) or pumps.*

***Another option for fencing is to forego tree cages and fence the entire chestnut planting. One acre of fencing will run about \$1,992. See <http://www.centerforagroforestry.org/faq.asp> for the list of supplies and a construction description.*

Chestnut Grower's Calendar

Attention to your markets is a year-round activity. National Chestnut Week, typically the third week in October, is a great opportunity to promote your crop through festivals, retail sales, farmers' markets or on-farm events. Learn more about National Chestnut Week at Chestnut Growers of America (CGA) online, www.chestnutgrowers.com

Month	Non-bearing Trees	Bearing Trees	Pest Management
January	Plan grafting efforts	Maintain equipment	Maintain equipment
February	Collect scionwood Prune trees	Prune orchard	
March	Fertilize trees Plant bare-root or grafted trees	Prune orchard Fertilize trees	
April	Apply weed control	Apply weed control	
May	Graft trees to recommended cultivars	Keep groundcover mowed	Field survey for potato leafhopper damage; apply carbaryl as needed
June	Water newly planted trees Stake new grafts	Keep groundcover mowed	Field survey for caterpillars
July	Prune off suckers below new grafts	Keep groundcover mowed	Field survey for caterpillars Install protection at planting
August	Make sure newly planted trees have adequate water	Keep groundcover mowed Irrigate as needed	Scout for weevils Apply carbaryl as needed
September	Establish cool season cover crops	Harvest promptly Clean and market nuts Irrigate as needed	Refrigerate nuts to retard mold development/Hot water treatment for weevil infestation
October	Plant container-grown trees	Finish nut harvest Market crop	Install rabbit and vole protection
November		Market crop	
December		Market crop	



Chestnut Resources

In the Library

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On the Web

- **University of Missouri Center for Agroforestry:** Chestnut Market Analysis Producers' Perspective and Market Directory; chestnut nutrition information and recipes; Chestnut Roasting 101; current research; orchard irrigation layout example; chestnut weevil hot water bath treatment parts and assembly
www.centerforagroforestry.org
- Agricultural Marketing Resource Center: Chestnut Market Opportunities - Assessing Upscale Restaurant Interest in Value-added Chestnut Products, www.agmrc.org/agmrc/commodity/nuts/chestnuts/
- The American Chestnut Foundation, www.acf.org
- Connecticut Agricultural Experiment Station: Chestnut Fact Sheets
<http://www.ct.gov/caes/cwp/view.asp?a=2826&q=378168>
- University of California, Davis: Chestnut Culture in California
<http://anrcatalog.ucdavis.edu/pdf/8010.pdf>
- University of Kentucky: Nut Weevils
www.uky.edu/Agriculture/Entomology/entfacts/fruit/ef206.htm
- University of Tennessee, Chattanooga: The Chattanooga Chestnut Tree Project
www.utc.edu/Faculty/Hill-Craddock/chestnutlinks.html#general
- Michigan State University: Growing Chestnuts for Commercial Markets
www.plantpathology.msu.edu/fulbright/Pages/MNPCpages/growingchestnuts.html

Informative Growers' Web Sites (selected)

- **Chestnut Growers of America** (a national network of growers): <http://www.chestnutgrowers.com/>
Chestnut Growers of America represents chestnut growers, researchers and others throughout the United States and Canada involved in the chestnut industry. The organization advocates the delivery of high quality chestnuts to the marketplace and the family's table. A membership directory, information forum and access to the quarterly newsletter *The Chestnut Grower* are included with membership.
- Chestnut Charlie (KS), <http://www.chestnutcharlie.com/>
- Allen Creek Farm (WA), www.ChestnutsOnLine.com
- Delmarvelous Chestnuts (DE), www.delmarvelouschestnuts.com/grow.htm
- Empire Chestnut Company (OH), www.empirechestnut.com
- The Northern Nut Growers Association, www.icserv.com/nnga/
- Red Fern Farm (IA), www.redfernfarm.com
- The Australian Chestnut Company, www.cheznuts.com.au

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Visit www.centerforagroforestry.org to learn about the Center's current chestnut research and view or print these resources:

- *Chestnut Market Analysis: Producers Perspective and Market Directory*
- *Why Chestnuts? (Nutritional Guide)*
- *Chestnut Roasting 101*
- *Chestnut Recipes*
- *The Missouri Chestnut Roast page - learn about this successful annual event that is building the chestnut industry*
- *Orchard irrigation layout example*
- *Chestnut weevil hot bath treatment parts and assembly*
- *Orchard fencing supplies, design and pricing*



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