

CHESTNUT CULTURE in CALIFORNIA

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The chestnut is a delicious nut produced on large magnificent trees on millions of acres of native habitat in the Northern Hemisphere, particularly China, Korea, Japan, and Southern Europe. The entire Eastern half of the USA was once covered with native chestnut trees until a blight fungus introduced from Asia destroyed them in the early 1900's. The fleshy nut is sweet with a starchy texture and a low fat content resembling a cereal grain. The nuts are eaten as traditional foods in much of Asia and Europe where they are consumed fresh, cooked, candied, and as a source of flour for pastries.

The chestnut tree (*Castanea sp.*) is in the same family as the beeches and oaks (*Fagaceae*). The formidable, spiny chestnut burr is the equivalent to the cap on an acorn. Chestnuts belong to the Genus: *Castanea*, with four main economic species: *C. dentata* (North American), *C. mollissima* (Chinese), *C. sativa* (European), and *C. crenata* (Japanese). It is not related to the horse chestnut (*Aesculus sp.*). The tree has a gray bark and is deciduous with leaves 5-7 inches long, sharply serrated, oblong-lanceolate, and pinnately veined. Domestication of the chestnut is still progressing with much of the world's production collected from natural stands.

SPECIES

Four species of chestnut are grown in North America. They exist as pure species or, more commonly, as hybrids of the various species because they readily cross with one another. In many cases, it is difficult to distinguish species and almost impossible to determine the parentage of the hybrids visually.

SPECIES	COMMON NAME	HEIGHT	NUT SIZE	NUT FLAVOR	BLIGHT RESISTANCE
<i>C. dentata</i>	American	60-100'	Small	Excellent	None
<i>C. sativa</i>	European	60-80'	Large	Good	Very Little
<i>C. crenata</i>	Japanese	40-60'	Varies	Fair	Some
<i>C. mollissima</i>	Chinese	30-50'	Med.	Good	Very Resistant

Castanea dentata: the American chestnut was native to the Appalachian forests of the United States from Maine to Georgia and as far west as Michigan and Louisiana. The trees are huge timber types tall, straight, and columnar, reaching heights of over 100 feet with trunk diameters of three to five feet. The nuts are small, about 35 to the pound, and covered with thick pale fuzz. Two or three are compressed in one burr. They are said to be the sweetest and most flavorful of all the chestnuts. The species was virtually wiped out in the early 1900s by a fungus originally called *Endothia parasitica*, but renamed *Cryphonectria parasitica*, or the

chestnut blight. The alien disease swept through the forest and caused one of our nation's worst ecological disasters, however a few isolated stands still exist. American chestnuts are believed to be resistant to oak root fungus.

Castanea sativa: the European chestnut is native to the temperate mountains of western Asia, Europe, and North Africa. Chestnuts growing in these areas seem to be quite tolerant of less than ideal conditions. The trees are large and spreading with a compact head; the nuts are much larger than the American species. Nut quality is quite variable depending on the individual variety. These make up most of the imported nuts commonly seen in U.S. supermarkets.

Castanea mollissima: the Chinese chestnut is the smallest tree of all the species (about 40 feet tall). It is native to northern and western China. The nuts are generally medium in size and of good eating quality. Trees bear at a young age (3 years) and are the most resistant to chestnut blight. Nuts from *Castanea mollissima* average about 30 nuts/pound. There are some exceptionally large cultivars (18 nuts/lb.) but these are not common. Average yield is three tons/acre, with up to 5.5 tons/acre reported with dense plantings (10' x 6') and high yielding cultivars.

Castanea crenata: the Japanese chestnut is native to China and Japan where it grows into a dense slender tree attaining a height of about 50 feet. The tree is very resistant to most known diseases, but nut flavor is considered inferior to other species.

VARIETIES

There are several varieties that have been selected in each species group and recently, breeding programs have produced many hybrids. Currently in California, the principal cultivar is 'Colossal' grown with 'Silverleaf', 'Nevada', 'Eurobella', or 'Colossal Seedlings' as a pollinizer. 'Okei' is a promising new pollinizer for 'Colossal' as it is vigorous, produces an abundance of pollen, has large nut size, but it is a light bearer. Two new cultivars, 'Fowler' and 'Montesol' produce excellent quality nuts that are very large and are being investigated for commercial planting. The following is a list of some of the varieties grown in the U.S. and their purported characteristics. (A = American, C = Chinese, E = European, J = Japanese)



Colossal Chestnuts

Silverleaf Chestnuts

- **Belle Epine:** (E) Pollenizer variety, resistant to root rot.
- **Borra:** (E) Large, high quality Italian variety.
- **Bouche de Betizac:** (E x J) Standard of quality in France, resistant to root rot.
- **Castel Del Rio:** (E) Large high quality Italian variety.
- **Colossal:** (E x J) Produces uniformly sized, very large, sweet nuts (average 18 per pound) with a thick pellicle and some multiple embryos. Productive trees modestly susceptible to blight. The current industry standard.
- **Crane:** (C) Nuts average 32 per pound, shell is dark red, good keeper, excellent flavor.
- **Douglas hybrid:** (C x A) Good size nuts, late flowering and blight resistant.
- **Doyle:** (E x J) Selected Colossal seedling of excellent quality.
- **Dunstan hybrids:** (C x A) Medium sized nuts of very good quality; trees are blight resistant.
- **Eurobella:** (E x J) Pollenizer for Colossal. Nuts are smaller than Colossal.
- **Fowler:** (E) Chance seedling of excellent quality and size with a Marrone type nut (dark shell and papery pellicle rarely invaginated into the cotyledons).
- **Gellatly #1:** (C) Productive tree with sweet early nuts that fall free of the burr.
- **Ginyose:** (J) One of the best Japanese types, large nuts, resistant to gall wasp
- **Layeroka:** (C x E) Early, productive, medium sized, timber type, blight resistant, pollen sterile.
- **Maraval:** (E x J) Excellent nut quality, slow to bear.
- **Marigoule:** (E x J) Pollenizer, productive, resistant to blight & root rot.
- **Marrone di Lucerna:** (E) High standard of quality, resistant to root rot, large size.
- **Marrone di Maradi:** (E) A large, high quality nut grown in Italy east of Florence.
- **Montesol:** (E) A seedling selection that produces an abundance of very large nuts with good quality.
- **Myoka:** (C x E) Good producer of medium size nuts that stick in the burr but the pellicle peels easily. Good pollen producer, blight resistant.
- **Nevada:** (E x J) Pollenizer for Colossal that is very productive; nuts are smaller than Colossal.
- **Okei** (E): Open-pollinated seedling of Silverleaf. Pollenizer for Colossal; a light bearer of very large nuts (16/lb.) with invaginated pellicle; shell tends to split at maturity. Produces abundant pollen.
- **Precoce Migoule:** (E x J) Excellent, large stripped nut, resistant to root rot.
- **Primato:** (E x J) Early leafing, bloom, and harvest.
- **Silverleaf:** (E) Large very sweet nut that peels easily, but the shell has a tendency to crack; used as a pollenizer for Colossal.
- **Skookum:** (C x E) Cross of Layeroka and Myoka, vigorous tree with medium sized sweet nuts.
- **Skioka:** (C x E) Produces 35 to 40 nuts per pound of good quality. Productive, sterile pollen.
- **Sleeping Giant:** (C x A x J) Sweet large nuts that fall free of the burr, vigorous, blight resistant.
- **Tsukuba:** (J) Large nut, good production, resistant to gall wasp
- **Willamette:** (C x E) produces 18-22 nuts per pound that are sweet and easy to peel; timber type habit.

FLOWERING AND BEARING HABIT

Chestnuts are monoecious, bearing both staminate (male) and pistillate (female) flowers on the same tree. They have mixed buds, which break dormancy relatively late in the spring. As the shoots elongate from one-year wood, staminate catkins emerge from lower nodes and a few bisexual catkins grow from near the shoot tip. These bisexual catkins will have one or two pistillate flowers at their bases, the remaining flowers being staminate. Each pistillate flower differentiates into three pistils within the burr or involucre. If pollinated, the ovaries of all three will develop into nuts; the middle one will be flattened. In some cultivars, two pistillate flowers fuse resulting in 4-6 small and poorly shaped nuts.



Male and female flowers



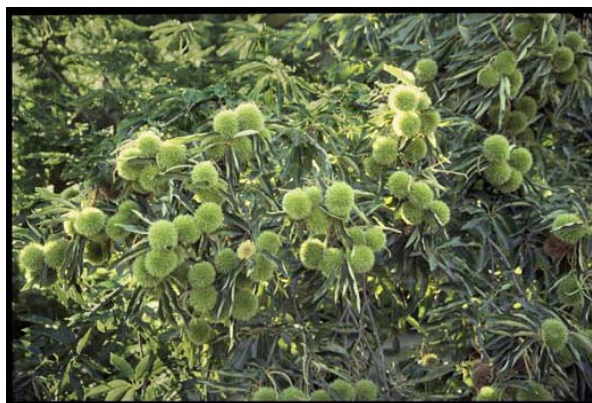
Close up of chestnut burr

Blossoming from mid-June to mid-July, the flowers evade spring frosts so that most cultivars will bear annually. Catkins of some commercial cultivars, e.g. Colossal, produce only a few or no staminate flowers, and other cultivars with staminate flowers may shed their pollen before the pistillate flowers are receptive, therefore requiring cross-pollination. Bees and other insects are attracted to chestnut pollen, which has a distinct odor, but they do not seem to visit the pistillate flowers, presumably because the flowers lack nectar. Therefore, for the most part, chestnuts are wind pollinated. Some research has demonstrated that the pollen parent can have an influence on the pollinated nut, especially with respect to size; a phenomenon called metaxenia. That is, pollen from a tree with large nuts could impart better size to its recipient than pollen from a tree with small nut size.

In the Central Valley of California, the burrs of the Colossal cultivar will begin to dehisce in mid-September, shedding the nuts. On the North Coast of California, harvest does not begin until early October. Nuts will continue to drop for the next 3 – 5 weeks with or without the burr.



Chestnut burrs beginning to dehisce



Good crop of Colossal nuts

NUT CHARACTERISTICS AND USES

The fruit of the chestnut is a large starchy nut with cream-colored cotyledons (meat) covered with an astringent membrane called the pellicle, which ranges in thickness from papery to a relatively thick woody tissue. Some pellicles tend to adhere to the nutmeat or intrude into the fissures and cracks in the cotyledons making peeling more difficult. The nut, with its leathery shell is encased within a spiny burr called the involucre. The color of the shell ranges from black to brown to a stripped golden yellow color. The burr splits at maturity usually exposing one to three nuts, but may contain as many as seven. Nut size, degree of burr separation from the shell, ease of pellicle removal, and flavor are all very important quality characteristics.

The chestnut is a “grain” growing on a tree. The nut contains about 40% carbohydrate, 40% water, 5-10% protein and less than 5% oil. It is similar to other starchy foods such as potatoes, rice, or cereal grains. Nutritionally, chestnuts are receiving recognition as a health food unlike other nuts, which are well over 50% fat. Consisting mostly of starch, chestnuts also contain a very high quality protein.

FOOD VALUE OF CHESTNUTS: (from USDA Ag Handbook #8-12,1994)

FORM	%WATER	%PROTEIN	%FAT	%CARBOHYDRATE	CAL/OZ.
Fresh	44	4	1	49	64
Dried	9	7	2	80	103
Boiled	62	3	1	34	44
Roasted	40	4	1	52	68

Traditionally, the main use in the United States has been for eating raw, boiled, or roasted as in “chestnuts roasting on an open fire.” The nut is very flavorful and sweet and can be used as an

ingredient in turkey stuffing, sweet breads, cakes, soups, stir fry, cereals, and ice cream. Candied nuts, Marrone glacé, are common and prized in Europe. Dried nuts can be ground into flour and used in diets for people with allergies to grains. In countries where a chestnut culture is well established, chestnuts are used commonly as a staple food, much as Americans might use potatoes.

Chestnuts with shell removed; pellicle is still attached to cotyledons



HISTORY

Chestnut is probably the most important nut crop in the Temperate Zone. It ranks behind only coconut and peanut in importance. With species indigenous to all three continents of the Northern Hemisphere, the chestnut has long been cultivated throughout China, Korea, Japan, and the Mediterranean basin. In Asia, the Japanese chestnut (*C. crenata*) has been cultivated since the 11th century and the Chinese chestnut (*C. mollissima*) possibly as long ago as 6,000 years. In the Mediterranean region, chestnuts have been cultivated for at least 3,000 years. The ancient Greeks are thought to have been among the first Europeans to cultivate the nut, introducing the European chestnut (*Castanea sativa*) from Asia Minor, via Turkey, to Southern Europe and North Africa.

The importance of chestnuts in past civilizations cannot be overemphasized. The nuts served as year-round food for humans and animals. In the colonization of America, the American chestnut (*Castanea dentata*) was the premier tree, providing wood for railroad ties, house framing, barns, fences, and fuel, tannin for leather processing, and, of course, the highly palatable nuts for human and wildlife consumption.

In the early 1900's, chestnut blight was introduced into this country, apparently from the Orient. The blight-susceptible American chestnut was all but eliminated by 1950. With it went the image of a way of life and dependence on a single tree species for so many important uses. Many of the present generation of Americans therefore do not know what chestnuts are. While no wood has replaced the versatility and durability of the American chestnut, the larger, imported European chestnut (*C. sativa*) has replaced the native chestnut in the marketplace. Some people think it is an inferior substitute for the sweeter American chestnut of years past.

WORLD CHESTNUT PRODUCTION

Current production worldwide is about 500,000 tons which is distributed as follows: China 40%; Korea 15%; Italy, Turkey, Japan, around 10% each; France, Spain, Greece about 4% each and the USA, Australia, New Zealand, Chile, and Argentina less than 1% each.

Asia

China is currently the world's largest producer and exporter of chestnuts with an estimated production of 100,000 to 240,000 metric tons annually. About one-third of the annual harvest is exported to Japan. From southern to northern China, 300 different cultivars are grown under diverse and variable climatic conditions and environments, but only about 50 cultivars are produced commercially. China is the low-cost producer that sets the market price in Asia. Chinese cuisine uses chestnuts in high-class dishes. Most of the nuts are consumed fresh-roasted in October, November, and December when they are first available. The popular dragon-boat festival around May uses up most of the dried chestnuts.

The world's second largest producer of chestnuts is Korea with up to 80,000 tons/year, of which up to 30,000 tons are exported to Japan; some are also exported to the USA. Yields of 0.72-3.6 tons per acre are reported from plantings of about 160 trees/acre with one-third pollenizers. Most production is by *Castanea crenata* (Japanese cultivars) grown on seedling rootstock.

Japan is a large chestnut producing and consuming country and certainly the biggest chestnut importer. Japan has a long history of chestnut cultivation. The domestic production is fresh chilled and consumed throughout the winter, especially around the New Year. Another method is to boil the nuts, cut them in half, and eat the nut "meat" with a teaspoon. Japanese chestnut prices range from \$3.00-4.00/lb. for ordinary cultivars. The very best varieties can sell for \$7.00-8.00/lb.

Europe

Most European chestnuts are produced from managed native forest. Italy is the largest chestnut producer in the European Community at over 50,000 tons/year. Italy is also the world leader in the production of marrone glacé and other processed chestnut products. For marrone glacé, the nut is stored for a period (chilled) which allows the shell and pellicle to be removed more easily from the nut by steam blasting. The nut is then stored frozen, thawed, and preserved with sugar liquor to a candied consistency. A box of marrone glace chestnuts is more expensive than a box of fine chocolates.

Within Italy, the traditional use of dried chestnuts and chestnut flour in cooking is declining, but overseas, the popularity of these and similar products are increasing, especially in the United States. High prices for processed, peeled, and frozen chestnut products in the U.S. (fetching more than \$ 2.75/lb) have prompted moves to expand the chestnut industry.

The chestnut industry in France, that produces about 25,000 tons per year, has declined considerably from what it once was mostly due to conversion to other more valuable crops and

urbanization. Within the European Community, France is now the biggest chestnut importer, mostly from Italy, but also from Spain and Portugal.

Spain produces about 20,000 tons that serves a large local market along with some exports to Italy and France. Wood production is also a major consideration, with some chestnut cultivars specifically selected for timber rather than nut production. Root rot (*Phytophthora*) is a major limitation of chestnut production throughout much of Europe.

Southern Hemisphere

Australia, New Zealand, Argentina, and Chile have recently begun to produce chestnuts primarily for export. Australia has even established a growers association. Production is for both nuts and timber. Harvest begins in March and is complete by April. Stored nuts are shipped from March through May.

US Production

In the United States, the first settlers found extensive native forests of the American chestnut (*Castanea dentata*) from Main to Georgia. European chestnuts were introduced in the early 1700's, Japanese chestnuts by 1860, and Chinese chestnuts in the late 1800's. In the early 1900's however, the accidental introduction of chestnut blight destroyed almost all *C. dentata*, and most introduced *C. crenata* and *C. sativa* plantings by the 1950's. Because chestnut blight killed almost all the native trees, extensive efforts are underway to re-establish the natural chestnut forests of the country. This has been the main concern of most chestnut researchers and supporters east of the Rocky Mountains where most growers have planted the blight-tolerant Chinese chestnut (*C. mollissima*) or its hybrids. Planting stock is predominantly open-pollinated seedlings. Michigan growers have also planted several Korean varieties of chestnuts and Colossal for trial.

There are an estimated 300 acres of trees in Oregon and Washington State. Most of the plantings are less than ten years old. The plantings are primarily the Colossal variety, but some growers are trying Dunstan Hybrids and varieties like Skookum, Layeroka, and Myoka. Growers have formed a Chestnut Growers Association to foster information exchange and marketing.

Chestnuts were brought into California by immigrants during the Gold Rush of 1849 mostly as seed of the European chestnut, but some of mixed origin and grafted varieties. Small old plantings still exist in the Sierra Foothills as well as the North Coast and Central Valley. Within the last 15 years, there has been an increase in the plantings of chestnuts to an estimated 600 acres, about half of that acreage bearing. Most of the planted trees are either Colossal or its seedlings. Most of the plantings are under 5 acres in size, with a few in the 6 to 20 acre size range and a few ranging in size from 21 to 80 acres.

The original Colossal tree is still standing in Nevada City. It was planted by Benjamin Tonella, a Swiss-Italian who also planted apples, pears, and walnuts on the property, which he purchased from Felix Gillet, the owner of Barren Hill Nursery. Mr. C. E. Parsons bought the nursery in 1908 after Gillet died and renamed it the Felix Gillet Nursery and introduced seedling and grafted chestnuts from the original Colossal tree. The tree today is 70 feet tall with a trunk circumference of 14 feet and an annual production of 300 pounds of nuts.

Numerous small colossal seedling-tree orchards have also been planted which have produced several named selections.

PER CAPITA CONSUMPTION OF CHESTNUTS

Although worldwide demand for chestnuts exceeds the demand for walnuts or almonds, the absence of a domestic industry after the disastrous loss of the native chestnut has seen chestnuts fade from common use in North America. A majority of contemporary Americans has never tasted a chestnut, but everybody has heard of them. Eagerness to sample that first chestnut is almost universal. Most people including children like them and some consumer tests indicate ready and enthusiastic acceptance by the American consumer. The United States has the greatest potential for expanding new chestnut plantings of any area in the world.

Country – Region	Approximate Per Capita Consumption
China	0.5 pound
Korea	4.0 pounds
Japan	1.2 pounds
USA	0.1 pound
Europe	1.0 pound

The U.S. currently imports some 10 to 20 million pounds of European in-shell chestnuts, primarily from Italy, annually, at a retail cost of \$30 to \$40 million. The annual value of imported processed chestnuts is estimated to be \$500,000. Import prices range from \$1.50 to \$3.00/lb. (average \$2.10/lb.). The United States would need to produce chestnuts on 5,000 acres just to displace imports. Should the domestic consumption level rise to only one pound per capita the U.S. would require over 100,000 acres of mature production to meet that demand. Such an industry could be worth \$600 to \$800 million annually.

ECONOMICS

Very large sized California chestnuts, in the 1990's were commonly selling for \$3.00/lb wholesale; organically produced nuts for an even higher price. The range in price is between \$1.20 to \$5.00 per pound wholesale, depending on the grade, market season, and location. Retailers commonly double the wholesale price and pay the best prices for the largest sizes. The size of the individual chestnuts is important in the more choosy fresh markets. Large nuts (16-28 grams each) may well command a premium as high as \$6-7.00 per pound at retail markets.

Production costs vary greatly depending on site and management practices. On a good site, a mature orchard should yield 3,000 pounds per acre. It is expected that as knowledge and experience accrue on chestnut production in North America in the coming years, and with the development of improved cultivars and cultural practices, per acre yields will rise.

Assuming a wholesale price of \$2.00 per pound for large sized chestnuts, the gross return to growers would be \$6,000 per acre per year. Full commercial maturity (30-80 pounds of nuts per tree) project positive cash flow by years 10-15 if land costs are not too high. The length of productive commercial life of trees can be over 100 years.

Anyone considering an investment in a chestnut orchard should evaluate production costs, earning potential, and tax consequences, and make comparisons with alternative investments.

MARKETING

California chestnut harvest and sales begins about mid-September to the first week of October in most years, later in cooler locations. Most of these nuts are sold by Thanksgiving. Thanksgiving through the New Year is the time of the highest demand, which is then filled by imported nuts mostly from Italy and Korea. Italian chestnuts are sold for about \$2.00/lb, wholesale, and have been consistently available throughout the holiday season.

Some buyers prefer Italian chestnuts because of the consistent quality (large sizes & ease of peeling) to the inconsistent quality of California chestnuts (mixed sizes, different colors, and varieties that do not peel easily). Recently with the introduction of uniformly large sized and high quality nuts from California that image is changing.

Sales are mainly to specialty ethnic markets, health food stores, farmers markets, and from roadside stands. Ethnic markets make up the greatest number of consumers of chestnuts, perhaps as high as 80% in some locations. Most of the remainder are sold to up-scale consumers for a special recipes during the holidays. Chestnuts are an expensive food item and complicated to prepare for most people not familiar with them. Most are sold fresh in the shell, but some Italian delicatessens also sell dried, peeled chestnuts. There is likely a potential to increase consumption through marketing and promotion programs especially since chestnuts are considered a health food that is delectable and can be easily grown organically. These positive aspects appeal to many of today's consumers.

Since freshness is a sales factor in chestnut appearance, domestic production has a definite advantage due to early ripening compared to Europe and Asia. When pre-holiday sales become saturated, the next logical step is to store the nuts for sales between Thanksgiving and Christmas in direct competition with imported nuts. Storage conditions are very important to prevent molding of the nuts. There have been problems reported with chestnuts molding and drying on the store shelf especially nuts that have been shipped by sea from Europe due to poor storage conditions during transport.

CULTURAL PRACTICES

In Europe and Asia, peasant cultures have harvested from the chestnut groves and forests for thousands of years. Chestnut production there is virtually a harvest-only system, with herds and flocks of livestock grazing the chestnut stands for all but the annual harvest period. In

many climates chestnuts are survivors and will continue to produce fruit with no soil cultivation, no pesticide sprays, and no fertilizer inputs.

Given the original range of the American chestnut and the broad range in Europe and Asia, it is fair to say that the range of commercial plantings in North America could be diverse geographically. Variety selections and cultural practices will likely vary throughout this huge area. Land ideally suited to chestnut production is plentiful throughout much of the United States. In California, however, the production of economically competitive yields and large size nuts will require management that is much more intensive. Getting the trees off to a vigorous start is the first step.

Site Preparation:

Chestnut trees thrive on a variety of site and soil conditions and have traditionally been grown on hilly land that is unsuitable for row crops. Light, well-drained soils are optimal since chestnut trees are intolerant of wet soil conditions. Standing water during any part of the season depletes soil oxygen and a saturated soil condition is very conducive to *Phytophthora* root rot infection, which is the most common disease problem in chestnuts. Chestnuts will tolerate low pH soils very well, but not highly alkaline soils.

Soil tests for potassium, phosphorous, calcium, magnesium, and pH should be conducted prior to planting trees. Alkaline soils can be acidified by the addition of sulfur or aluminum sulfate to a desirable pH of slightly below neutral (below 7.0). Soils that are extremely acid (below 5.5) should be amended with the addition of lime to a pH of approximately 6.5. Soil and irrigation water tests for micronutrients might need to be conducted if there is a suspicion of an excess nutrient problem. Choices of liming materials, the need for gypsum and subsequent leaching of sodium salts, or special circumstances with high magnesium or low calcium soils should be corrected before planting the trees. Contact your local farm advisor for specific recommendations.

The orchard site should be properly prepared before planting. Ripping and breaking up of subsoils by mechanical means has proven very helpful to the development of strong root systems if there is an existing subsoil or compaction problem. Leveling or proper installation of drainage for low areas is very important. Mounding and planting trees on top of a soil berm or windrow will allow for better drainage at the tree crown and help prevent root and crown rot. Fumigation or solarization is recommended if oak root fungus is present.

The ground should be free of any perennial weeds because once the trees are established weed control is more complicated and costly. A cover crop planted the previous year, cultivation, or herbicide application can help remove noxious or problem weeds.

Planting and Training Young Trees:

Care should be taken to spread the young roots in the planting hole, and to achieve the proper depth of planting. Plant the trees at the same depth they were in the nursery or slightly higher, but not too deep. Watering the tree in will ensure good soil to root contact and subsequent weekly irrigations once growth begins are necessary to keep the soil moist and the young tree actively growing.



New chestnut orchard - closely spaced



First growing season - trained to a single leader with no branching below 42 inches

Chestnut trees need to be trained during their formative years to develop a desirable structure e.g. a modified central leader system used for walnuts (See Division of Ag & Natural Resources Publication # 3373 *Walnut Production Manual*). Cut back the top of the tree to approximately 36 to 48 inches to compensate for roots lost during digging in the nursery. A single new leader is typically trained up a stake the first growing season. If the grower anticipates mechanical harvest with shakers, the trunk should be, at least, 42 inches high to the first scaffold branch. Branches originating below that can be removed during dormant pruning at the end of the first growing season. The scaffold branches are selected during the second through the sixth growing seasons with good spacing between branches on the main trunk.



Eight year old orchard - trees are just beginning to touch - very closely spaced

Tree Spacing:

Trees can be planted from 14 to 40 feet apart, depending on the grower's willingness to remove every other tree when crowding occurs. The closer spacings will eventually require thinning of trees in order to maintain high yields and bearing throughout the tree. Crowded trees tend to create excessive shading on lower branches and bearing only on one plane in the tops of the trees limiting production. Severely shaded lower branches will die out.

Without topping or shaping, chestnut trees will eventually grow to a height of 35-40'; some timber-form trees will reach 100 ft. The large timber-form trees are not desirable because they are more difficult to manage and much of the tree's energy goes into wood production rather than nut production. A management strategy calling for little pruning or tree thinning should plan on a minimum of 30' to 40' spacing on all sides (27-48 trees/acre). Denser chestnut plantings with tree spacings of between 14' to 25' have been popular (about 70-200 trees/acre) because they will provide greater return per acre in the early years, but they require tree thinning as the canopy's begin to touch. The hedgerow system of trees, closer within the row than between rows, is more efficient for floor management and irrigation layout.



12 year old orchard with crowded trees and excess shading on lower branches



15 year old orchard with every other row removed

Pollenizer trees should be planted at a ratio of one tree for every eight to ten trees of the principle cultivar. If the nut of the pollenizer cultivar is different in size, color, or maturity date than the main cultivar, they should be planted in separate rows to facilitate harvest and separation. Small orchards should have the pollenizer trees planted up-wind from the main cultivar.

Weed Control & Orchard Floor Management:

No other single cultural practice is as important as controlling competing vegetation during the establishment phase (first 3-4 years) of a chestnut planting. A competition free zone extending three to six feet in all directions from the trunk to the drip line on young producing trees has proven very beneficial. Once a tree has reached 6-8 years of age and is producing regularly, weed control is somewhat less essential; many weeds become shaded out underneath the trees.

Although chestnut trees start out with a taproot, soil conditions will dictate the extent of the root system. The majority of the essential fine feeder roots are within 2 – 3 feet of the surface. Cultivation, mulching, herbicides, and mowing are used in various combinations to assure young trees the advantages they need to start and stay strong. As trees mature and reach bearing age a clean, hard-packed surface from the trunk to the drip-line of the tree is essential for nut harvest. Weed or cover crop vegetation can be mowed closely with a flail mower prior to harvest to obtain a nice clean surface.

Both pre-emergent and post-emergent herbicides are available for use in chestnut orchards. Consult your local Cooperative Extension office for information on the safe use and handling of herbicides. Synthetic fabric mulches are also very effective for weed control and an alternative to herbicides. Other alternatives include the use of various cultivation devices such as hydraulic rotating weeders, reciprocating roto-tillers, or cutting blade devices.

Fertilization:

Nitrogen is usually the element most needed by chestnut trees; studies have shown that nitrogen supplements have positive benefits for production and nut quality. The amount of nitrogen required varies according to size and age of the tree as well as soil conditions. Limited growth in the terminal and yellowing leaves indicate nitrogen deficiency. Fertilizer programs should be used in conjunction with periodic soil tests. No standards for leaf analysis have been established.

Care should be taken not to apply fertilizers in the planting hole since this can cause root burn. Fertilization programs should begin as growth begins in the spring. The application of about 100 pounds of actual nitrogen per acre, per year is adequate for a mature chestnut orchard. Young trees should receive a fraction of the mature rate based on estimated fill-in of the orchard (trees shading 40% of the orchard floor should receive 40 lbs. of actual nitrogen per acre per year). For trees planted 30' x 30' (48 trees/acre), apply two to three ounces of actual nitrogen to each tree per year. Increase this rate of application by two to three ounces of actual nitrogen to each tree every year until 100 pounds of actual nitrogen are applied per acre. Closer tree spacings with more trees per acre will require lower amounts per tree. Apply the fertilizer from the dripline to within two feet of the trunk before irrigation. For drip irrigated orchards, small amounts of fertilizer can be placed under emitters periodically; do not exceed one ounce of conventional fertilizer material per application per emitter.

Since most soils in California have an adequate supply of phosphorous, it is usually not needed as an added nutrient. Potassium, however, is a common element that is often missing and when needed, it should be applied in large quantities (500 lbs. of potassium sulfate/acre) in a band just inside the dripline of the tree. Large quantities are applied to a concentrated area because small quantities of potassium normally become tied up by the soil and are rendered unavailable to plant roots.

Fertilizer materials such as compost, feather meal, blood meal, manure, and mined minerals classified as organic can also be used to fertilize chestnuts. They typically contain a low concentration of several nutrients that become available for plant uptake as they slowly break down. Their rates should reflect the application of approximately 100 pounds of actual nitrogen per acre in a mature orchard. Young tree rates are calculated as a percentage of the leaf cover of the orchard.

Leguminous cover crops can also be grown to provide nitrogen fixed in their root nodules and to make available other nutrients from the lower soil profile. Cover crops should be seeded in the fall of the year right after harvest when soils are still warm in order to get good seed germination and early growth. Cultivation each year is required to prepare a seed bed prior to

planting and in the spring to incorporate the organic material for large seeded legumes such as vetch or bell beans. Another method is to use self-seeding legumes such as subterranean clover, or rose clover and just mow the cover crop in the spring. These cover crop types need to be established in a well prepared seed bed the first year, but come back on their own with fall and winter rains. Cover cropped orchards usually require more irrigation water.

Irrigation:

Chestnut trees are remarkably drought resistant, but water stress can lead to smaller nut size and lower yields. Trees can become easily water stressed in the dry California summers, especially if grown on light-textured or shallow soils. Irrigation of chestnut trees should be based on the evapotranspiration rate for the time of the growing season. Sprinkler or surface irrigated orchards, on sandy loam soils usually require a deep irrigation every 2 – 3 weeks to a depth of 3 - 4 feet from May to September. Drip or micro-sprinkler irrigated orchards need a moist soil continuously maintained in order to foster good tree growth and nut size. For drip irrigation, this means daily or every-other-day applications; micro-sprinklers are usually run twice per week.

Diseases & Pests:

Chestnuts are very susceptible to *Phytophthora* crown and root rot, which is the most prevalent disease of chestnuts in California. Infected trees usually collapse as hot weather begins in the springtime (leaves turn yellow–brown followed by death of the branches and trunk). Brown to black streaking can be observed in the water conducting vessels of the wood, just under the bark. This fungus disease can be prevented by selecting planting sites with good internal soil drainage and using irrigation management strategies that avoid prolonged periods of saturated soil conditions. Modifying the drainage by providing good surface drainage, underground tile systems, and planting on raised mounds can also help. The soil immediately surrounding the tree trunks should be kept as dry as possible at all times of the year.

The most notorious chestnut disease is the chestnut blight (*Endothia parasitica* renamed *Cryphonectria parasitica*). This fungal bark disease is very threatening to the European (*C. sativa*) and American (*C. dentata*) chestnut trees. Fortunately, our best orchard selections are hybrids involving *C. mollissima*, the most blight resistant of the *Castanea* genus, having co-evolved with the blight organisms for thousands of years in Asia. Chestnut blight is present in California but is not spreading under our climatic conditions. Colossal trees infected with chestnut blight in California are not dying even after years of infection. This indicates that the trees are not immune but tolerant of the disease without much ill effect. For Propagation, West Coast nurseries and growers are using American, Asian, and European hybrids. They are relying on varietal tolerance, their isolation, and quarantines of plant material to prevent introduction and spread of the blight into their orchards.

Oak root fungus (*Armillaria mellea*) has been known to kill chestnut trees. Preventing this disease through soil fumigation and planting in areas free of the disease is the current means of control. Ultimately, the use of resistant rootstocks is the best biological control tactic, but research must be conducted to evaluate the level of resistance in potential rootstocks.

The worst insect problems associated with chestnuts are the shot hole borer, chestnut weevil, clearwing chestnut moth, gall wasp, and filbert worm, none of which is currently a significant problem in California. Chestnut weevils and shot hole borer have been identified as minor pests. Maintaining adequate vigor in the trees through irrigation management and reducing stress factors on the trees prevents shot hole borer infestation, which has been a problem in other growing areas. Chestnut weevils are controlled through sanitation and storage conditions that prevent their introduction. There are very few pesticides registered for use on chestnuts in California. At present, spray programs are not required in chestnut groves so there is a good opportunity to grow the trees organically.

Young chestnut trees are very vulnerable to attack by deer and gophers. The orchard must be fenced to exclude deer if they are present. Gopher baits and traps are the only sure way to eliminate damage from underground feeding. Wild pigs love chestnuts and should be controlled, fenced out, or nuts must be harvested daily to minimize losses.

Pruning:

Chestnut production comes from flowers borne on current season's growth originating from last year's shoot growth, much like the walnut varieties such as Hartley and Franquette. Heading-type pruning cuts can be used to develop more branching in the early years, but as the trees come into bearing it will reduce yield. Mature trees should be pruned to remove dead or weak branches, water sprouts, and those branches that hinder cultural operations. Some branch thinning may be necessary to allow sunlight exposure down into the tree and maintain fruiting wood. Heavy pruning will invigorate vegetative growth, but will diminish and delay production. Alternate-year pruning as conducted with some other tree species with similar bearing habit may be feasible.

HARVEST

Chestnuts are hand harvested in the major production areas of Europe and Asia with methods little changed over the past 2,000 years. The scarcity of farm labor and the changing cost structure in agriculture dictate, however, the need for mechanically assisted harvesting options. The simplest harvesting method is to let the nuts fall to the ground naturally, step on the burrs to separate the nuts, and then pick them up by hand. New, low cost polypropylene net tarps can help reduce collection costs for small-scale operations. A multi-acre orchard would have a natural nut drop period of 10-15 days in most years, but may range up to 30 days in some years, depending on environmental conditions. During these extended harvest periods, the nuts are subject to fungal infection and drying out. Fallen nuts should be picked up at least every two days.



Pick-up machine picking up nuts in burrs from windrow



Pick-up machine conveyor belt loading nuts into a bin

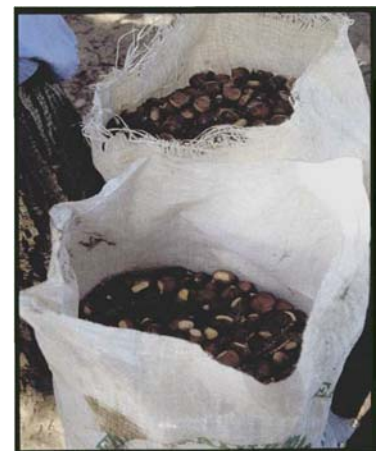
The splitting and opening of the burrs is a sign that the nuts inside are mature (mid-September to mid October). Chestnuts add much of their final weight during the last two weeks on the tree. If mechanical shakers are to be used, it should be done as late as possible in order to maximize yield and nut quality. Mechanical harvest (shaking) may need to be done more than once and should not be done before natural nut fall begins. No mechanical system of chestnut harvest has been completely perfected to lower labor costs, however, some existing harvesting techniques for other crops, such as walnuts or filberts may be adaptable to chestnuts. It is easy enough to pick up the nuts and burrs with conventional almond, walnut, filbert, or pecan sweepers, but the main problem is separating the nuts from the burr.

Roller drums have been used that are similar to walnut hullers but separation is not complete and many of the nuts are scratched. One California grower has developed a wringer type separator made from tires. It squeezes and twists the burrs to pop out the nuts without scratching the shell. In Italy, some growers use a large vacuum that is pulled through steep terrain to gather the nuts. The nuts are sucked into a rotating drum that separates the burrs from the nuts.



Left: Chestnut wringer made from tires, used to remove nuts from burrs.

Right: Sized chestnuts stored in sacks for transport to market



On small orchards and for young trees, hand harvest is the most viable option. It is estimated that one person could harvest a ten acre planting consisting of 1,000 trees by hand. Hand harvest also assures the highest quality since nutshells are not scratched.

STORAGE OF CHESTNUTS

It is anticipated that most growers will sell their production as soon as the harvest is gathered fresh from the grove, thus eliminating any storage concerns. For short-term storage, chestnuts should be treated more like apples than other nut crops, i.e. walnut, filbert, or almond. Chestnuts should be washed thoroughly and cooled as soon as possible to 32 - 33°F for storage. Relative humidity should be as high as possible. Chestnuts dry out, even at high humidity, so protective packaging is needed. Mold-inhibiting fungicides and controlled atmosphere storage would most likely improve chestnut quality in long term storage.

For long term storage, in some locations growers place fresh nuts in a cool water bath for 7-9 days, and then into cold storage at 28-33° F and 70-80% humidity. Chestnuts held under these conditions will remain in excellent condition for up to 3 months when they will begin to germinate (embryos with emerging radicals are still edible).

PROPAGATION

Seedling trees are quite variable in size, shape, and vigor. They are definitely not acceptable for commercial production. Each seedling tree is different, and seedling orchards produce mostly small nuts, some large nuts, but several sizes, shapes and colors. Many of those nuts will also be very difficult to peel due to differences in pellicle thickness and adherence to the shell or cotyledons. There will also likely be flavor differences. For the production of a commercial crop with uniform size and quality characteristics, grafted trees are necessary.

Commercially, trees are produced by grafting a scion of the desired cultivar onto one-year old seedlings grown from nuts of the same cultivar. Graft incompatibility can develop when seedling rootstocks and scions are from different cultivars.

Nuts to be planted for seedling rootstocks should be stored in moist (not wet) peat moss inside plastic bags. Generously puncture the bags using a toothpick or other device. Make sure each nut is surrounded by peat moss and does not touch other nuts or the side of the bag. Store at 34° F until planting time.

Grafting a scion cultivar onto random seedlings from other cultivars may result in delayed incompatibility and eventually death of the tree 1 to 10 years later. Incompatibility usually is indicated by weakened collapsing trees with a dark necrotic area at the graft union. Incompatible trees sometimes break cleanly at the graft union. The normal grafting methods used on other woody species (T-bud, chip-bud, whip grafting, etc.) are generally also successful with chestnut. Self-rooting the trees through layering, cuttings, or tissue culture is possible, but very difficult.

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PHOTOS

All photos by Paul Vossen

1. Colossal Chestnuts (variety section)
2. Silverleaf Chestnuts (variety section)
3. Male and female chestnut flowers (choice of 3 different slides) (flowering & bearing habit section)
4. Good crop of Colossal nuts (flowering & bearing habit section)
5. Close up of chestnut burr (flowering & bearing habit section)
6. Chestnut burrs beginning to dehisce (flowering & bearing habit section)
7. Chestnuts with shell removed; pellicle is still attached to the cotyledons (flowering & bearing habit section)
8. First growing season tree trained to a single leader with no branching below 42 inches in height. (planting and training young trees section)
9. New orchard closely spaced (tree spacing section)
10. Eight year old orchard as trees are just beginning to touch (tree spacing section)
11. Twelve year old orchard with crowded trees and excess shading of lower branches (tree spacing section)
12. Fifteen year old orchard with every other row removed (tree spacing section)
13. Chestnut sweeper moving nuts into a windrow (harvest section)
14. Pick-up machine for chestnuts (harvest section)
15. Conveyor belt from pick-up machine loading chestnuts into a bin (harvest section)
16. Chestnut wringer made from tires, used to remover nuts from the burr (harvest section)
17. Sized chestnuts stored in sacks for transport to market (harvest section)