Identification & Silvics of Ginkgo

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Looking closely at Ginkgo biloba reveals many interesting and unique features of this eldest of trees. Ginkgo has reproductive features which are advancements on relatives called cycads, the cone bearing, fern or palm-like gymnosperms. Ginkgo shares many primitive structural traits of other relatives like conifers. Ginkgo lies between the cycads and conifers in genetically adjusting and dealing with the world containing mainly highly advanced plants and a host of pests. For additional information regarding ginkgo taxonomy and natural history, see Coder, 2003, Ginkgo: Eldest Tree Survivor, University of Georgia School of Forest Resources publication FOR03-18, 5pp.

What is a ginkgo? What are the features which differentiate a ginkgo from other trees? This publication will list the unique botanical characters which set ginkgoes apart from other trees. Although identification of ginkgo is usually not a problem because of its striking attributes, there are many peculiarities which have interest and help people appreciate ginkgo as an ancient tree whose family members have sheltered man and dinosaurs for hundreds of millions of years. Note the following descriptions are not intended to be taxonomically comprehensive but educational.

Leaves

Ginkgo leaves are bright green with a touch of grey in color. Leaves area simple, flat and broad. See Figure 1. Under high fertilization levels or flooded conditions, leaves can be dark green. Ginkgo can be considered generically a "deciduous broad-leaf" even though ginkgo is a gymnosperm. Leaves are fan-shaped, with a smooth surface except for rare tricombes (plant hairs) in axils of vein splits. Leaves appear to be highly ribbed from the clear veination lines, but veins are but slightly raised. All leaf veins can be traced from the initial two veins at the blade base outward always splitting into two veins and widening the leaf blade. Veins have an open, non-interconnected or crossing architecture. The leaf surfaces is waxy.

Leaf shape is highly variable. The wide end of the leaf can be complete (entire) or have a variety of clefts and splits. A single cleft leaving two partially separated lobes is by far the most usual (i.e. species name biloba or two-lobed.) Next most common is two clefts through the leaf blade. Leaves are 2.0 to 3.5 inches long with the leaf blade about 1.3 times wider than long (2.5 to 4.5 inches wide). Stomates are recessed and almost completed concentrated on the underside of the leaf.

Leaves are attached to the tree with long flexible leaf stems (petioles), up to three inches long, which has a small groove running its length. Leaves tend to flutter and turn in small breezes generating a unique rustling sound. Leaves absorb the usual chlorophyll wavelengths of light, but relatively large amounts of both usable and unusable light pass through leaf and canopy. Total canopy light filtering and blockage are reduced by petiole flutter, loose open crowns, and limited absorption giving ginkgo an open, light-filled understory. One of the most desirable and noticed attributes of ginkgo leaves is the golden-yellow to clear solid yellow fall leaf colors. Leaves and seed coats of ginkgoes contain several serious insecticides, toxins, and physiologically active compounds which reduce insect, fungi, and bacterial pests. Fallen leaves decompose fast because of the residual nitrogen, phosphorus, and other elements remaining in the discarded leaves.

Leaves are deciduous and tend to senescence and abscise all together in one event. Leaves, flowers and seeds all grow from thick, short spurs (modified short branches with extremely short internodes) which occur alternately along branches and twigs. Each spur usually carries 3-5 leaves. Terminal growth which has not developed spurs, carry leaves alternatively along the newly expanded shoot.

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Flowering

Ginkgo is a dioecious tree, meaning each tree is either a male or a female. Tree sex can have serious implications when female trees begin to heavily flower and generate seed. Approximately 0.5 % of all male trees can bear some female fruit (monoecious – both sexes on same tree). Both male and female flowers dangle on long stems growing from short branch spurs. In rare natural events, which now have been accentuated by breeding, the flower stem is sometimes formed as part of a leaf blade or can be described as winged. There are no means for easily distinguishing male from female embryos or seedlings until they become sexually mature and start to generate flowers. A DNA test for sexing ginkgo is difficult and not usually completed. Diploid chromosome number is 24 (2n).

Male flowers are soft greenish-yellow, short catkin-like cones which appear in Spring near the end of branches on short leaf spurs. There are usually 3-6 cones per spur which are 0.5 to 0.75 inch in length on long slender stems. Male cones ripen to release pollen when female flowers are receptive – usually in March to early April. Ginkgo pollen is a light, buoyant spindle shape when released. Ginkgo pollen can generate a number of allergy problems during the short time it is on the wind. Upon pollen capture and enclosure by the female flower, the pollen grain swells to a spherical shape. One male tree is needed in close proximity to every five female trees for good pollination and viable embryos.

Pollination is by wind blowing pollen to the wet end of a female flower. Once pulled into the female flower on the droplet surface, the pollen rests among the female cells until late summer. As the pollen rests, the female tissues grow rapidly in preparation for fertilization and embryo development. Female tissues pass through four primary stages of development: a rapid growth period until the first of July; a resting phase till mid-August when the hard seed coat is hardened; a slow growth stage until early September when fertilization is taking place; and, rapid embryo development through seed abscission in late September to early October (with seeds falling before the leaves.)

Fertilization of the egg cell buried in the seed occurs in late Summer. Once the female tissues are ready, a passageway develops and is filled with liquid connecting the pollen holding chamber and the entrance to the egg. The pollen produces two swimming sperm cells (a highly unusual cell type in plants). The sperm cells swim to the fertilization entrance, one pulls its way through the portal, swims to the egg, and fertilizes the egg. Embryo development is rapid and can be sustained either on the tree or on the ground. Pollination, fertilization and embryo development occur in the same growing season, with seed germination readied for the following Spring.

Female flowers have a long (two inches long) slender stem and grow from short spur branches in March to early April. Each flower stem has 2-3 female flowers at its end. Under stressful conditions only one flower succeeds in generating a seed. Under good conditions paired seeds can develop. There are 2-5 flower stems per spur. Female flowers are about 1/4 inch long, light whitish-green, round and held 1-3 flowers on the end of a flower stem. Female trees are not sexually mature until about 20 years of age (the range is 17 to 40 years of age before flowering). There is one female cited as not commencing to fruit until 45 years old. Grafted female branches tend to flower in 1/5 the time as female seedlings.

Because of the revulsion many Westerners have to ginkgo seed coat odor, female trees are usually not planted in the United States. Because of this preference for male trees, few people have seen a female tree or a seed of a ginkgo. Ginkgo is usually propagated by male cuttings grafted onto seedling root stocks. Where viable seed are needed, male branches are grafted onto female trees in various places to assure pollination. Ginkgo can asexually reproduce by expansion of short shoots and root initials generated on the underside of large lower branches as a drooping burl. This burl or aerial root can expand in diameter and grow downward to the soil. These aerial roots will form true roots in the soil and release shoots on the top of the branch. Long term survival of ginkgo on poor sites hostile to seed germination or seedling growth can be facilitated by these aerial roots.

Seeds

Ginkgo seeds are composed of three functional parts: a fleshy outer coating comprising 75% of green seed weight; a hard, smooth, cream-colored, shell-like inner coating; and, farthest within a seed, an embryo with 2-3 cotyledons surrounded by a large amount of nutritive materials which will support seedling establishment and growth. To many people the fresh seed looks like a small drupe (apricot or cherry) or a ripe olive from an angiosperm. Ginkgo does not generate a fruit but a seed with a fleshy coating. The term "fruit" should not be used for the reproductive unit of the ginkgo. Note Figure 2.

The seed is smooth, oval, and approximately 1 to 1.5 inches long and 0.9 to 1.1 inches in diameter. There are usually 1-2 seeds generated on each 3.5 inch long, greenish-orange, seed stem (peduncle). One vegetative type in ginkgo cultivated for its strangeness is where seed stems and leaves are morphed into one unit. The immature seed coat is greenish with casts of orange and a white waxy surface coating. When ripe the seed coat is greenish-yellow with tan and orange streaks or patches. The white waxy surface coating (bloom) covers the seed coat and is easily removed with your fingers. The seed coat has a small apical scar or dot on it far end. Seeds produced tend to be evenly distributed between male and female.

The fleshy seed coat of ginkgo is malodorous and messy. The smell is similar to canine feces, rancid butter, vomit, and/or rotting flesh. The chemicals responsible for the smell and the corrosive qualities of the seed coat on flesh are butyric and hexanoic acids. These acids can cause skin damage. The fleshy seed coat also contains several serious allergenic compounds which cause skin dermatitis similar to poison ivy. The chemical names, formulae, and proportion of total allergenic chemical concentration percent in the fleshy seed coat are: ginkgolic acid ($C_{21}H_{32}O_3$ = 80%); bilobol ($C_{21}H_{30}(OH)_2$ = 18%); and, ginkgol ($C_{20}H_{32}OH$ = 2%). The fleshy seed coat completely surrounds the seed and minimizes oxygen flow to the embryo. As the seed coat decays, oxygen is kept from the embryo preventing germination. Seed germination and seedling growth require moist but well-drained mineral soil and full sunlight after the seed coat is removed.

The seed coat odor developed to attract reptilian carnivores to consume, scarify, and transport seeds to new locations. Today animals which make use of ginkgo seeds as a food source are opossums, squirrels, raccoons, skunks, large fruit eating birds, and rodents. Some of the seeds consumed will survive to germinate after passage through the animal's digestive system.

As the whole seed grows through summer and into the fall, remember pollination has already occurred and pollen is positioned to develop and fertilize the egg. As late Summer and early fall arrives, fertilization is completed and the embryo rapidly develops. Seeds found on the ground and on the tree in late Summer may or may not contain a fertilized egg. By early Winter fertilization is complete in most seeds. The female initials which generate the embryo are unique among trees in being photosynthetically active in the seed. The embryo also can harbor symbiotic simple algae cells which function to stimulate germination under the proper light conditions.

Seeds begin to fall in early Fall with both unfertilized eggs and rapidly developing embryos inside. Usually, any naturally abscised mature seed with mature male trees in the area will have developing embryos present. From early Fall to late Fall, the embryos develop. This development and growth period for the embryo is essential for seed viability. Seed selection for viability should be made from either the tree or the ground beneath in early Winter. Ginkgo usually bears a heavy seed crop every other year with some seed produced every year. Heavy seed crops weight branches to the breaking point under good fertilization and soil health, leading to branch damage. Seeds are abscised in September to October, falling just before the leaves.

To plant seeds for seedlings, gather seeds hanging from the tree or on the ground in early Winter. Scrub the seed coat off with water and rinse multiple times. Allow seeds to air dry for several day to a week. The cleaned seeds can be stored dry at 40 to 45^{o}F until early Spring. Seeds can germinate in 8-10 weeks after a late fall or early winter collection. About 90% of all cleaned, undamaged seeds from females trees which have male trees in close proximity will germinate the following spring if they were collected no earlier than early winter. Survival rate the first two years should be 40-50% of all germinating seeds.

Fungal attack, seed predation by animals, and drying of newly elongated roots and shoots generate significant mortality. Plant seeds in a well aerated seedbed of mineral soil and cover with an inch of mineral soil.

A thin layer (<1 inch) of organic mulch can be applied over the top of the soil. The seedbed must be protected from animal thieves. For further information on collecting and handling seeds, see the publication by Coder, 2003, Ginkgo Seed Collection & Preparation, University of Georgia, School of Forest Resources, Publication FOR03-21, pp. 2.

Seed Coat Dangers: The seed coat chemicals producing the putrid smells are high levels of butyric and hexanoic acids. Butyric acid ($C_4H_8O_2$) is a thick, colorless, water soluble liquid which is flammable in pure form. It is a natural fatty acid which can be synthesized and used in manufacturing some types of plastics. Butyric acid is found chemically bound in animal generated products like butter or in human sweat. As bacteria free the acid, it generates the distinctive scent. Symptoms of being exposed to the odor are: nausea; skin, eye, and lung burning; and, severe respiratory tract irritation. The acid is easily absorbed through the skin. Personal safety demands the use of gloves, eye protection, and protection of bare skin from contact. Respirator use is recommended for prolonged diffuse exposure and in sensitive individuals.

Hexanoic acid ($C_6H_{12}O_2$) is a thick, oily-looking, colorless liquid, which is flammable in its pure form. This acid has a distinct, unpleasant odor like butyric acid. Hexanoic acid is corrosive to the skin, an irritant to the respiratory system, and can cause burning pain in the eyes. It is harmful to aquatic system health. Ginkgo seeds should not be allowed to fall into or collect in ponds, streams, or pools.

The fleshy seed coat also contains several serious allergenic compounds which cause skin dermatitis similar to poison ivy. The chemical names are ginkgolic acid, bilobol , and ginkgol. The chemicals are absorbed onto the skin surface and initiate an itching and burning reaction. Because the chemicals are unique to ginkgo, a person not sensitive to poison ivy / poison oak / poison sumac allergenic chemicals can still be sensitive to this ginkgo allergen mix.

Twigs / Buds / Bark

Ginkgo has thick twigs with many short, thick, greyish-tan spurs 0.5 to 1.5 inches long. Spurs generate the leaves, flowers, and seeds. Buds are brown and rounded with scruffy looking scale edges. Leaf scars are half round. Ginkgo bark is light brown to brownish grey. The bark is corky, low density, and deeply furrowed with flattened shiny ridge tops. The bark contains many druses or crystals of calcium oxalate.

Large lower branches on some older ginkgoes can develop (primarily in response to wounding) drooping bulbous burls or wood masses on their undersides generically called “chichi” (lignotubers). The literal translation of this term and this growth trait is teats, tits, nipples, breasts, or stalactites. These growths are aerial roots derived from dormant shoot growing points, which grow downward and reach the soil generating roots. The top then generates shoots. This development process can lead to expanded support of the tree top and serve as an asexual propagation means. This trait has also been selected for use in cultivars. These growths have in the past been used to generate bonsai plantings by cutting the growth off of the branch, inverting the section and placing it in moist soil. New roots and shoots are generated and an old mature-looking ginkgo is produced on a small scale.

Wood:

Ginkgo wood is light, soft-textured, fine-grained, flexible, and lustrous with a pale yellowish color. Ginkgo wood handles water exposure better than most woods as it does not easily warp or check through many wet and dry cycles. There are many intercellular spaces in the wood, making it much less dense than many other gymnosperm woods. Tracheids are thin-walled and rays are narrow. Ginkgo wood has primary and bordered pits in xylem on radial walls like conifers. The wood contains scattered druses or calcium oxalate

crystals. These crystals in the living portions of the tree are physiologically active surfaces for warehousing excess calcium, especially in high pH / high calcium soils. Sapwood is easily and quickly colonized by wood staining fungi around wounds or when harvested. Lumber should be promptly dried. Use of antifungal agents may be required to preserve wood appearance. Ginkgo wood is used for trinkets, paper making frames, cutting boards, brewing vessels, furniture parts, lacquerware, household items, carvings, handicrafts, and bowls.

Special Uses

In modern life, most people first hear of ginkgo through marketing of herbal food supplements and medicines. Ginkgo leaf extracts are a large health chemical business. Pacific rim nations tend to use the medicinal values of ginkgo as found in the seeds, while Western nations tend to concentrate on medicinal extracts from leaves. The compounds taken from ginkgo have been cited through testimonials (Note: there is a lack of clinical trials supporting a number of claims) to help alleviate symptoms or cure causes of everything from cancer to asthma. A ginkgo leaf production plantation, similar to a mechanically harvested tea plantation, is located near Sumter, SC.

Based on the number of different claims, digestive and urinary tract problem solutions and increased blood flow are the most common medicinal citations. Receiving less publicity on the internet and within the general public information systems are a number of negative side-effects, some extremely serious. Some ginkgo parts extracted or treated in one way may have different impacts on health than the same part treated in another way. Dosage and content of active ingredients (and carriers) can be a problem. Deaths from poisonings and allergic reactions have occurred.

One use of ginkgo seldom highlighted in the United States is seed production for food. Ginkgo seeds have been cited as human food for more than 2,100 years. The first food uses were reserved for the elite and wealthy. Ginkgo seed consumption was not considered common until about 700 years ago. Cleaned ginkgo seeds can be boiled, baked, roasted, or steamed. Ginkgo seed are similar to pistachios in the fleshy seed coat discolors the hard seed coat requiring bleaching or colorants be used to hide stains (or the seeds be harvested promptly and the seed coat immediately removed). The seed splits open slightly after cooking. The thin papery inner seed coat inside the hard shell can be easily removed like a peanut skin. Cleaned seeds have been eaten raw in extremely limited quantities for medicinal purposes, but this is considered dangerous and life-threatening.

Many people have allergic reactions (similar to peanut allergies) to both raw and cooked ginkgo seeds. Ginkgo seed in any form should not be given to children under six. Children are susceptible to ginkgo seed poisoning (gin-nan poisoning) caused by ginkgotoxin ($C_9H_{13}NO_3$) within the seeds. In accidental consumption, over indulgence, or times of food shortages, ginkgotoxin has caused a strychnine toxicity. Of the patients reported, 74% were children and total mortality was 27%. Most of the mortality data is old as recent poisonings with prompt medical attention showed no death or no permanent disability. A quick treatment is available.

When the hard seed covering of a roasted seed is cracked open, the seed meat inside is similar in taste and texture to a starchy pine seed (nut) or a chestnut. Ginkgo seeds are most often purchased without the fleshy seed cover and lightly roasted. The cleaned roasted seed is most commonly served salted with rice wine (sake) or other alcoholic drinks, or as part of desert foods. The cleaned seeds can be dyed red and treated like pistachios for celebrations and weddings. The seed has about 4% protein, 2.5% fat, and 35% carbohydrate primarily as starch. The seed is a good source of niacin (vitamin B complex).

Removing the seed coat is critical for proper roasting and safe consumption. The fleshy seed coat carries an unpleasant or repulsive odor. The same chemicals which are responsible for the odor cause serious skin dermatitis and skin corrosion. These chemicals, and the associated brew of allergens and other compounds in the seed coat, can be left to rot away or mechanically removed from the seed. Always use long latex or vinyl gloves, with full eye protection, for collection and cleaning.

Collect seeds in a plastic bucket, fill with water, and then squeeze and rub the seed coat off of the seeds. Seeds can be left in the water for many days to allow the fleshy seed coat to rot away. The water and

the seeds should not be allowed to touch unprotected skin or soak into clothing. Once all of the seed coat is removed, allow the seeds to dry in the sun for at least a couple of days to a week. Consider the seeds a skin and eye hazard until completely cleansed of the seed coat remnants and fully sun dried. For further information see Coder, 2003, Ginkgo seed Collection and Preparation, University of Georgia School of Forest Resources FOR03-21, 2pp.

Conclusions

Ginkgo is a witness to Earth's ecological history. Ginkgo represents the oldest seed plant lineage common in our surroundings. Ginkgo forests sheltered the beginning and the end of the dinosaurs, and the rise of many genetic dynasties. Across the ages, ginkgo has declined until it now serves as a pet, companion, and service provider for people – not domesticated, just driven into ecological submission. Ginkgo is worth cultivating and appreciating for its ancient and modern values.

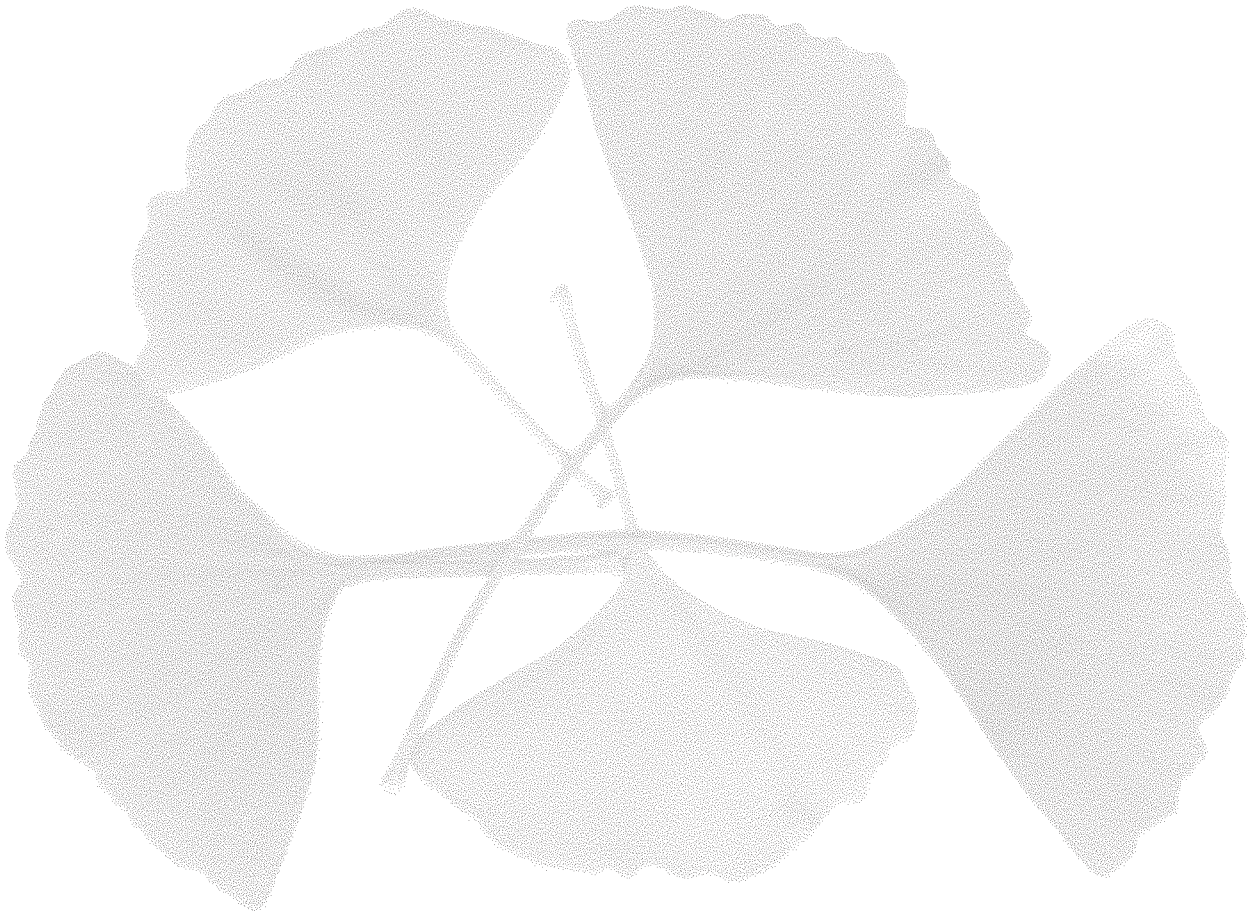

Figure 1: Silhouette of assorted sexually mature female ginkgo leaves harvested on September 1. Note variability in leaf stem (petiole) length.

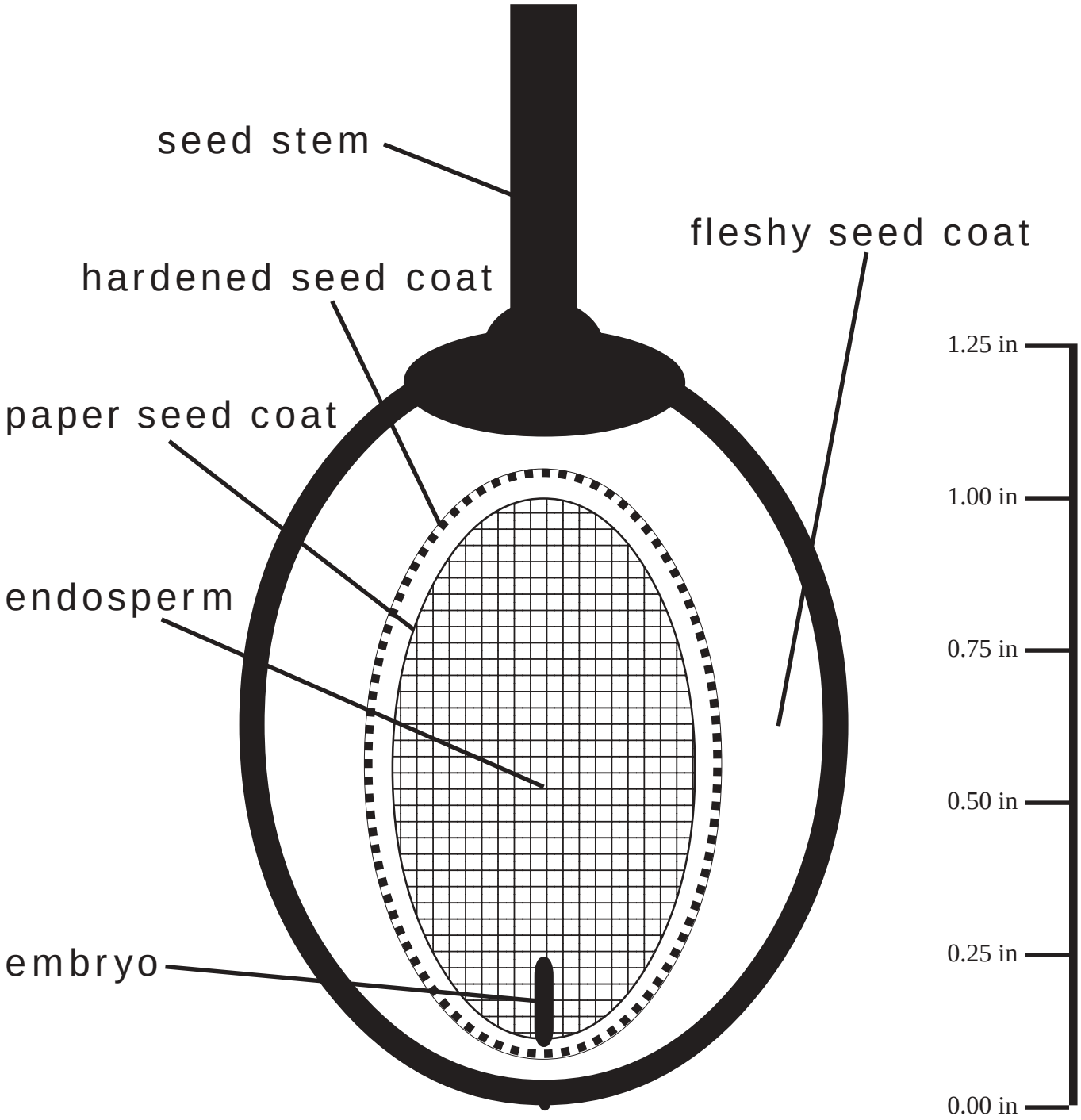

Figure 2: Ginkgo seed cross-section through the long axis showing various protective coats of the seed.
(seed harvested September 1)