Native Species Series

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Tree Root Parasite: *Pyrularia pubera* Buffalonut

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Pyrularia pubera is a parasitic shrub found in the understory of old disturbed forest sites in the Appalachians and foothills. It makes a living using other trees, shrubs and herbs to gather water and essential elements. Pyrularia pubera is a root parasite, connecting with other plant roots. The fruit is unique and the most noticed part of the plant, often being brought in from the woods for identification. This publication is the story of the buffalonut parasite, the cobra of the Appalachian forests of the Southeastern United States.

Common Names

Pyrularia pubera has several common names including buffalo-nut (buffalo nut, buffalonut), oil nut, elk nut, mother-in-law nut, rabbitwood, mountain coconut, crazy nut, and Cherokee salve. The buffalonut and elk nut come from early colonists who witnessed the woodland bison and the woodland / Eastern elk eating the fruit in winter. The oil nut name is derived from the acrid oil in the fruit. The mother-in-law name was derived from veiled poisoning threats. The Cherokee salve name is derived from the plant's herbal medicine uses by native Americans.

Scientific Names

The genus name of Pyrularia is derived from Latin word for "small pear." The species name pubera means "downy or hairy." The scientific name Pyrularia pubera means the downy small pear after the small pear shaped fruit and the small tricombes (hair-like features) on twigs and leaves. Pyrularia pubera is equivilent to the older name Pyrularia oleifera, which means an oily small pear. The genus name Pyrularia is the modern accepted name and replaced a series of old genus names like Hamiltonia, Calinux, and Sphaerocarya.

There are two or three species of Pyrularia around the world. Depending upon the taxonomic division, there are either one or two Pyrularia species in the Himalayan mountains and Tibetan plateau of south-central Asia, which are small trees (i.e. Pyrularia edulus). The other species is Pyrularia pubera, a medium-sized shrub of the central and southern Appalachian mountains of Eastern North American.

Family Ties

Pyrularia pubera is in the sandalwood family (Santalaceae family / Santalales order) of flowering dicot plants. Almost all of the family is composed of parasitic herbs, shrubs and trees. The family name comes from the tropical genus name Santalum which provides the sandalwood oil and incense aroma in the marketplace. The sandalwood family currently has about 38 genera and more than 600 species. Family members are spread around the world primarily in the tropics and sub-tropics. A few members are in temperate and high altitude zones. Four genera of this family are in the Southeastern United States.

Habit & Site

Pyrularia pubera is a straggly, medium to tall shrub standing 4-14 feet tall (average 6.5 feet tall) with its arching stem growing up to 3 inches in diameter. The shrub is considered a hemi-parasite generating most of its own food, but parasitizing surrounding trees, shrubs and herbs to gather water and essential elements. It is one of 29 root parasitic plants identified in the southeastern United States.

Pyrularia pubera is sparsely branched, with twigs concentrated near branch ends. It has a limited, low density, sparsely branched root system. All parts of the shrub contain an acrid oil which can be found most highly concentrated in the fruit. This shrub grows primarily in open cove and ridge sites with forests of mixed deciduous hardwood trees or mixed conifers and hardwoods. Pyrularia pubera occurance in the forest appears to be restricted by seed germination and site constraints, and is not limited by slope, aspect, or surrounding vegetation type. As a root parasite it is not host specific, parasitizing many species. The places where it is most abundant is in open secondary growth forests where there has been disturbance in the past, like fire, logging, road-cuts, storm blow-downs, and extensive litter disruption. It is not an early successional species, but a wide gap-phase species.

Pyrularia pubera can be found growing across many upland sites ranging from moist coves to dry ridge tops throughout the Central and Southern Appalachians and adjacent areas of the Piedmont. This shrub grows between 650 feet in altitude up to 4,400 feet. It was first recorded botanically around 1800 and first cultivated as a curiosity in 1897. It grows in cold hardiness zones 5b to 7b (predominately in zone 6b), and in heat zones 4 to 7. Some consider it to have been a highly successful chestnut parasite before the chestnut forests where destroyed by chestnut blight. It does not grow on wetland soils, clay soils, or soils high in calcium. It is inconspicuous to many people who do not recognize this shrub in the forest understory among the diversity of other plants.

Location, Location

Pyrularia pubera has been identified growing as a native in nine states including Southwestern Pennsylvania (3 counties), East-Southeastern half of West Virginia, Western third of Virginia (5 counties), East-Southeastern Kentucky, Eastern Tennessee, Western North Carolina (33 counties), Northwest South Carolina (4 counties), North Georgia (26 counties), and Northeastern Alabama (3 counties). Pyrularia pubera is suspected to exist but not identified in the extreme Western tip of Maryland. Figure 1.

Eleven states have listed the historic presence of Pyrularia pubera on their territories, and six of these states have an official conservation status or protection priority for the plant. Pyrularia pubera is listed as: imperiled in Alabama; rare in Pennsylvania; secure in Kentucky, North Carolina, and West Virginia; an exotic invader in New York; and, with conservation status not determined in Georgia, New Jersey, South Carolina, Tennessee, and Virginia. The farthest south in the United States the shrub grows as a native is the Pine Mountain area of West-central Georgia, a Southern-most, disjunct outlier of the Southern end of the Appalachians North of Columbus, GA.

Leaves

The simple, deciduous leaves of Pyrularia pubera arise alternately along the twigs with short (0.2 - 0.5 inch) leaf stems growing clustered on short shoots. The leaves are soft, thin, and veiny with tiny transparent dots

visible when held up to the light. The leaves are variable in shape from broadly lanceolate to broadly elliptical or ovate. The leaves are pointed at both ends, with the base tending toward a more rounded or wedge shape. In some deeply shaded leaves both ends can be more rounded. Pyrularia pubera leaf edges are smooth, entire and sometimes appear wavy.

Leaves are usually 2-9 inches long by 1-3 inches wide, but can be up to 11 inches long and 5.5 inches wide. The aspect ratio of the leaves averages 1.9 times longer than wide. Fresh leaves tend to snap when folded in half. The leaf blade surface is slightly wrinkled and dull on the upper surface, downy on the bottom, and dark green to apple-green in color. The downy hairs (tricombes) are small, short, and single pointed.

The leaves vary greatly in appearance and size on the same individual. Flowering branches tend to have a few small leaves up to 5 inches long by 2 inches wide. Non-flowering branches hold many more and larger leaves up to 9 inches long by 4 inches wide. Leaves tend to become smaller in size the farther down the branch they are held. Larger leaves tend to be clustered on short spur-like twigs. Leaves closer to the branch ends are more oblong with pointed ends, while leaves closer to the branch bases are more elliptical with rounded ends.

Leaves come out early in Spring and are held long into Fall, compared with other trees and shrubs in the surrounding forest. The leaves stay on the tree without fall color change until killed by freezing temperatures. Pyrularia pubera has no abscission layer at leaf bases. Once the leaves are dead and are knocked off, they remain visible and undamaged on the forest floor for an extended time. The leaves contain a relatively large concentration of nitrogen, potassium and phosphorus, all gleaned from hosts. Their slow decomposition on the forest floor is due to their oil concentration. They serve as a slow release fertilizer over many months. The leaves and all other parts of Pyrularia pubera contain large concentrations of calcium oxalate crystals, thought to minimize animal consumption. Figure 2.

Good Buds

Pyrularia pubera buds are pointed, greenish in color with reddish tips. The buds are oval in shape and relatively large. The buds form most noticeably on older twigs with no true terminal bud present. Each bud has several short scales at its base with many longer, over-lapping, bright green colored scales above. The buds are without any type of stalk and occasionally appear clumped in older leaf axils. Buds swell early in the growing season, usually before most of the overstory trees. Leaves expand from these buds as the new twig pushes out after the last heavy frost. Figure 3.

Few Twigs

Pyrularia pubera twigs are stout and arching in shape and form. Older twigs are olive-brown in color. Young twigs are green and covered with minute hairs (tricombes), grading into a smooth surface on older twigs. The twigs bear no stipule scars. The leaf scars are round to shield-shaped, slightly raised, and usually contain a single (can occasionally be up to three), round, sunken vascular bundle scar. The twig pith is white in color and spongy. Few twigs are kept on the stem, with most self-pruned early which causes the shrub to look gangly and leggy. There are many twig abscission scars from self-pruning. The twig abscission scars are elliptical.

Stem & Bark

Pyrularia pubera stems are green in color when young, fading to olive-brown to grey-brown after the first year. The twigs, stems, and roots have a noticeable thick green secondary cortex layer. The corky periderm starts to develop after the first year. The younger stems are more greenish-grey with older stems more brownish-grey with white elliptical lenticels. Old stem periderm becomes bumpy and warty with age. The stem wood has a diffuse porous vascular architecture.

Flowers

Pyrularia pubera is functionally a dioecious shrub, with each plant baring either male or female flowers. Some consider Pyrularia pubera to be “sub-dioecious” but no research was found to support this observation.

The sparse flowers are generated at branch tips or in terminal axils of end-most leaves. The flowers are inconspicuous, elongated, small, yellow-green colored, unisex spikes. Flowering occurs in the last half of April to the first half of May. Flowering is completed before the complete canopy of leaves are fully expanded.

The female flowers are few in numbers on branch tips in twin or single short spikes. The female flowers have non-functional male parts present, usually seen as four vestigial stamens. The female flower spikes are 0.4 1.2 inches long with 7-10 flowers. The flowers have a five-lobed, recurving disk with no petals. Male flowers are generated on 0.8-2.5 inch long spikes with 15-32 flowers. Each flower is about 0.16 inch across. The male flowers usually have eight short stalked stamens in two whorls with the inner four stamens much smaller. Male flowers have four to six recurved green sepals with hairy tufts at their base.

Fruit

The fruit of Pyrularia pubera is considered a drupe (dry drupe), like a thin-husked, large seeded hickory. The ripe fruit can split to release the seed. Fruiting is occasional, not abundant, with fruit on the plant from July to September and shed in October. The fruit has a thin pulpy, oily flesh and is light shiny green in color turning a dull yellowish-green when ripe. The fruit is round to pear-shaped tending to be widest near its end. The fruit is approximately one inch in diameter. The fruit stem is about 0.4 inches long. The fruit has a crown-like halo around its end which are the mature remains of five persistent lobes from its flower disk. The base of the fruit has small white-colored raised dots. Figure 4.

Few fruits are generated and grow to maturity, usually numbering only 2-4 per branch and 6-30 per female individual. Figure 5. There are approximately 75 fruit per pound. The fruit contains an acrid oil, similar to olive oil in consistency. The fruit coat prevents oxygen and water from getting to the seed. The fruit coat, and internal seed dormancy, can delay germination for several years in the soil and litter of a woodland area. Figure 6.

The fruit splits along its length to expose a single round seed 0.4 - 0.8 inches in diameter. There are approximately 235 seeds per pound. The seeds are minutely pointed at one end with a small indentation on the other end. Inside the seed is an oily food supply tissue supporting a dormant, small, short embryo, visible upon ripening. The seed coat is smooth, hard, and light tan in color. Seed germination usually occurs in the first and second Spring after fruit fall, if the seed has had ample chilling in the forest litter. Limited third year germination is possible.

The fruit and seed are considered poisonous in quantity when ingested by humans. The fruit has a unpleasant odor and a bland oily taste. Water and alcohol based extracts of the fruit and seed can be lethal. Tasting the fruit can cause severe mouth irritation from interactions with the acrid oil, the large quantities of calcium oxalate crystals present, and the presence of several toxins (one similar in physiological action to cobra venom). A number of animals can safely eat the fruit. Deer heavily browse the vegetative tissue and the fruit. The shrub readily sprouts back after grazing. Fruit and seed transport is by water, gravity, and animal consumption and deposition.

Culture

Pyrularia pubera can be grown by collecting the sparse fruits when ripe in fall (around the first of October.) Immediately remove the fruit coat and place the seed in soil filled pots or in soil beds. The pots or beds should have young host trees already established. Place the Pyrularia pubera seed at the small host (nurse) tree's base. The seeds have a significant dormancy process. Expect approximately 40% of all seeds to germinate if the fruit coat is remove and the seed coat is scarified. The fruit coat must be removed to allow oxygen, moisture, and soil micro-flora to get to the seed coat in order to initiate germination. A cold stratification period of three months has proven effective in dissipating dormancy factors. Once the seedling is well established, the host can be removed. A good program of nitrogen fertilization and watering then must be maintained for survival and growth. Plant the seedlings next to mature host trees where good light resources are available.

Reproduction

Shrub reproduction is by vegetative growth and by seed. Pyrularia pubera spreads and holds forested understory sites primarily through vegetative reproduction. One central stem will generate several thick rhizomes which radiate away from the primary stem, eventually turning upward and forming a leafy shoot at some distance (up to 20 feet) from the parent stem. Rhizomes (which are horizontal stems growing below ground) have small scaly leaves at each node. Rhizomes have all the parts of a stem including nodes, lateral buds, a pith, and a thick cortex. Rhizomes do not have root architectural features like an endodermis. Rhizomes will swell at their ends in the soil providing a food storage organ. Rhizomes actively grow in Spring and Fall.

Root-generated sprouts also initiate new stems up to 3 to 10 feet away from the parent stem. Reproducing primarily by vegetative means allows for large patches of genetically identical stems to be found in forest understories. Seed germination and seedling growth has many problems compared with vegetative sprouting. Seedlings must establish host contacts within 2-3 month, or find a good source of essential elements (especially nitrogen and phosphorus), or the seedling will die.

Root System

The primary root coming from a germinating seed grows downward into well-aerated soil until a minimum oxygen level or some physical constraint is reached. Lateral roots are then generated along the primary root, each growing many yards away from the stem base with little branching. The lateral roots sense proximity of host roots exudates and come up from below to make contact, which can be up to 40 feet away from the main stem. The interface established between the parasite and the host is called a "haustorium."

Pyrularia pubera roots are sparse and not as fibrous as other shrub and tree species on the same site. The advantage of a parasitic lifestyle is the small investment in root tissues. Unfortunately, a limited root system and poor water use efficiency can lead to severe wilting on hot afternoons. Pyrularia pubera can grow well without a host if fertilized. It is clear from artificial and natural regeneration that composted organic matter and a healthy aerobic soil micro-flora and fauna are needed to facilitate effective infection.

Hosts

The parasite / host interface area of Pyrularia pubera is called a "haustoria" (plural) or a "haustorium" (singular). Pyrularia pubera haustoria connect with a large variety of woody and herbaceous plants growing in the same soil. More than 60 species, 50 genera, and 31 families are parasitized. Pyrularia pubera will even parasitize other Pyrularia pubera, but not its own genetically identical roots. Other trees not normally growing in the native range of Pyrularia pubera also have been successfully parasitized in culture. Notably, red and American elm are not parasitized. The haustoria connections take nitrogen, phosphorous, and water from the host. The dryer the site or season, the more haustoria generated.

Native trees parasitized include, but are not limited to: ash, aspen, basswood, beech, birch, blue-beech, buffalonut, cherry, chestnut, dogwood, hazel, hemlock, hickory, ironwood, magnolia, maple, mountain-laurel, oak, persimmon, pine, redbud, rhododendron, sassafras, sparkleberry, sourwood, sumac, tupelo, wahoo, vaccinium, viburnum, witch-hazel, and yellow-poplar. Trees parasitized in the laboratory included: alder, ginkgo, Kentucky coffeetree, sugarberry, and sweetgum. Trees not parasitized (field observations and/or laboratory testing) include: black locust, catalpa, Douglas fir, elm, true cedar, and yellowwood .

Haustoria

The haustoria form quickly on the absorbing roots of host plants 1- 5 months into the growing season. Only the fine (up to one inch diameter) host roots are parasitized. It is difficult to dig and find the haustoria as the Pyrularia pubera roots are brittle and easily broken. The exterior of a haustorium is white to light tan in color, aging to brown. Haustoria appear as flattened, rounded clumps of tissue stuck to the side of a host root. The haustoria do not possess a vascular cambium, generate secondary growth, or have wood. Haustoria

usually exist for less than one year and the roots form new haustoria and reconnect with the same or new host roots every year.

The haustoria attachment can be generically described as a "kiss." The outside tissue of the haustoria varies in size by the host root size and species (i.e. very small on herbaceous plant roots.) The outside tissues form an elliptical to round shaped adhesive seal over the host plant's root, like lips sealing over the host's root surface. The outer tissues help protect the inner vascular tissues. The inner tissues push against and dissolve intercellular materials of the host's root secondary cortex and phloem. The haustorium grows cells to the depth of the cambium and xylem-mother-cells being produced in the host root. Figure 7.

Many xylem connections are established between the host and the parasite, with the parasite tissue aligned beside the host tissue, but not entering cell walls of the host. The haustorium pushes lightly against the host root tissues and uses enzymes and growth regulators to break apart cell connections and control defensive actions of the host. The host tissue grows around and interconnects with haustorium cells. The host will compartmentalize off roots sustaining too much damage or losing too much growth resources to the parasite. By the end of the season, the haustoria leave a sunken, elliptical scar surrounded by wound-wood on woody host roots. The residual damage to the host roots can be significant and lead to root girdling. The haustoria and the parasite's roots are brittle and easily break if pulled upon, providing no hint of root parasitism

Pests

The greatest damaging agent to this parasitic shrub comes from animal grazing, particularly deer. Rabbits and other rodents consume the periderm. The only pathogenic pest cited as significant to Pyrularia pubera is a vascular blight fungi (Trichosphaeria spp.) which causes whole Pyrularia pubera stand to be damaged and die.

Local Relative

A sandalwood family member confused with Pyrularia pubera is in the genus Nestronia in the Southeastern United States. Nestronia is a much shorter shrub with opposite leaves, but it is also a parasite.

Snake Oil Poison

A unique component of Pyrularia pubera is the presence of five different animal-like toxins in its tissues, especially concentrated in the fruit. The shrub contains purothionin, viscotoxin, phoratoxin, crambim, and thionin. A number of these toxins are shared with other sandalwood family members like the mistletoes. Thionin is a small protein which has been proven to be hemolytic (blood), cytotoxic (cells), and nuerotoxic (nerves). Thionin attacks membranes in humans (causing them to be leaky) and red blood cells (destroying them.) Thionin can attack heart muscles. It shares the same form of damage and the same binding site within animal cells as does cobra venom, even though it is not similar chemically.

Different animals have different tolerances for the fruit of Pyrularia pubera and for thionin. Rabbits, pigs and humans all show serious reactions to thionin while horses, cattle, mice, deer, and sheep tolerate the toxin well. After ingestion there is a 1 to 2 hour delay of symptom on-set in people. A severe symptom in humans is convulsions.

Conclusions

The natural history of the Southern Appalachians is represented by many plants and animals. The most successful of these forest systems contain plants which are "free-loaders," reproducing generation after generation on the root investments of others. Pyrularia pubera is one of these plants, an interesting parasite because of its life and its animal health interactions. There is a cobra in the Appalachians and it is the buffalonut.

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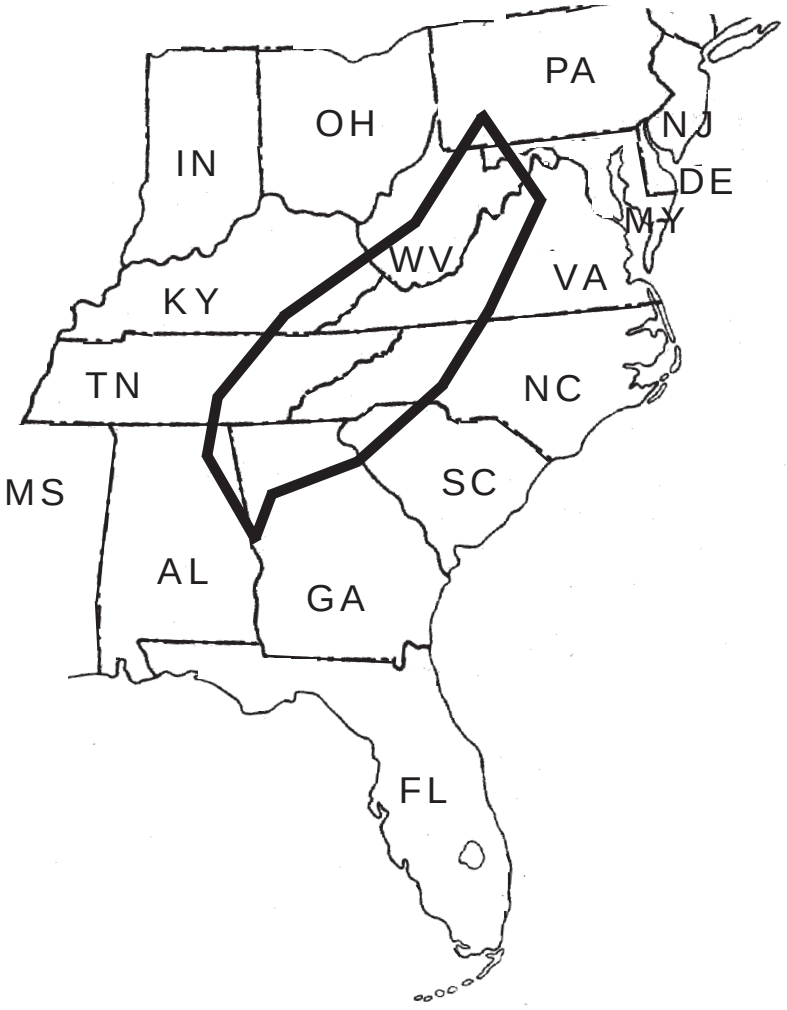

Figure 1: Current native range of ***Pyrularia pubera*** extracted from multiple sources.

Figure 2: *Pyrularia pubera* leaves.
(photographs taken in North Georgia and provided by Daniel Williams)

Figure 3: *Pyrularia pubera* leaf bases and buds.
(photographs taken in North Georgia and provided by Daniel Williams)

Figure 4: *Pyrularia pubera* fruit.
(photographs taken in North Georgia and provided by Daniel Williams)

Figure 5: *Pyrularia pubera* leaves and fruit.
(photographs taken in North Georgia and provided by Daniel Williams)

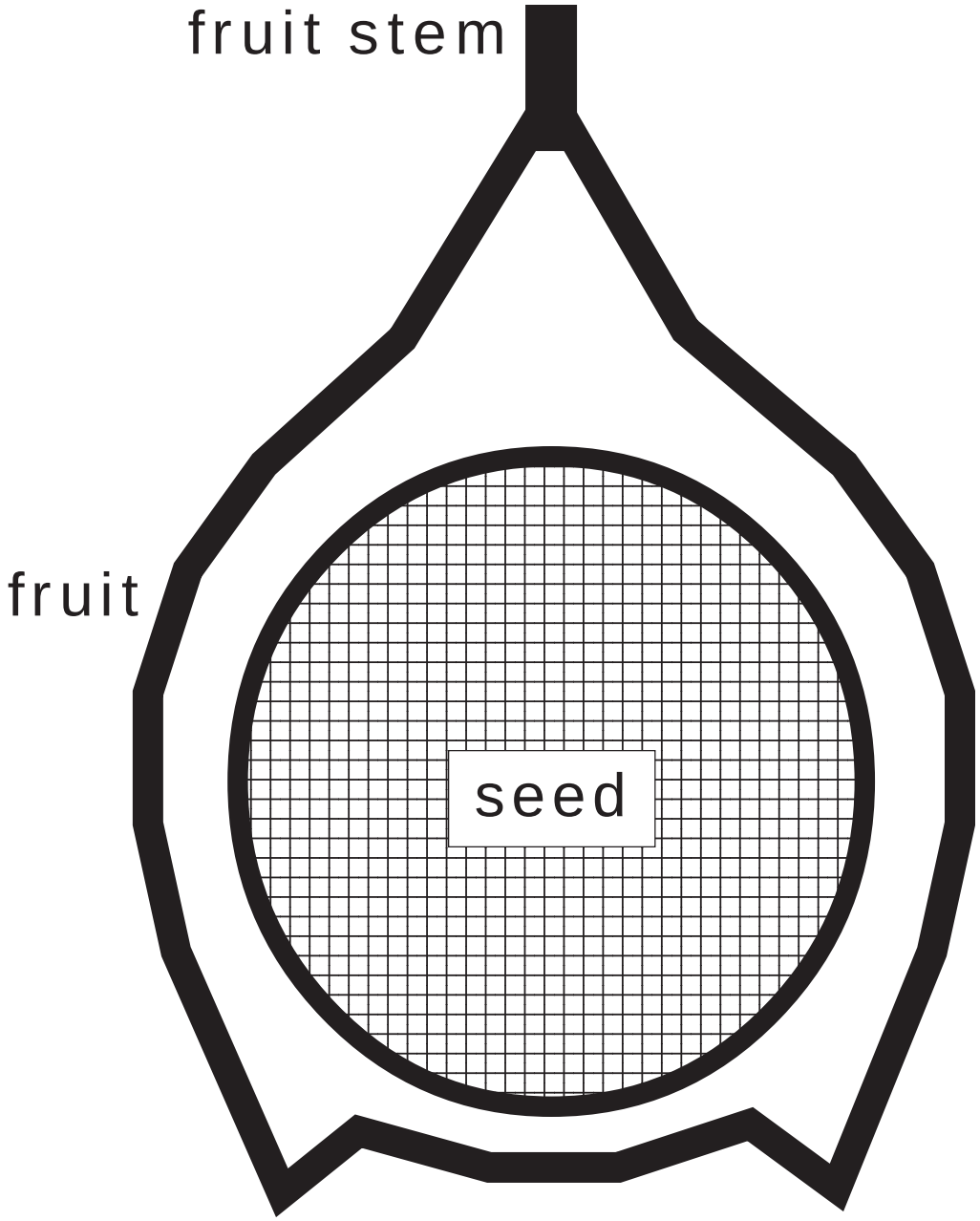

Figure 6: Simplified cross-section view of ***Pyrularia pubera*** fruit and seed.

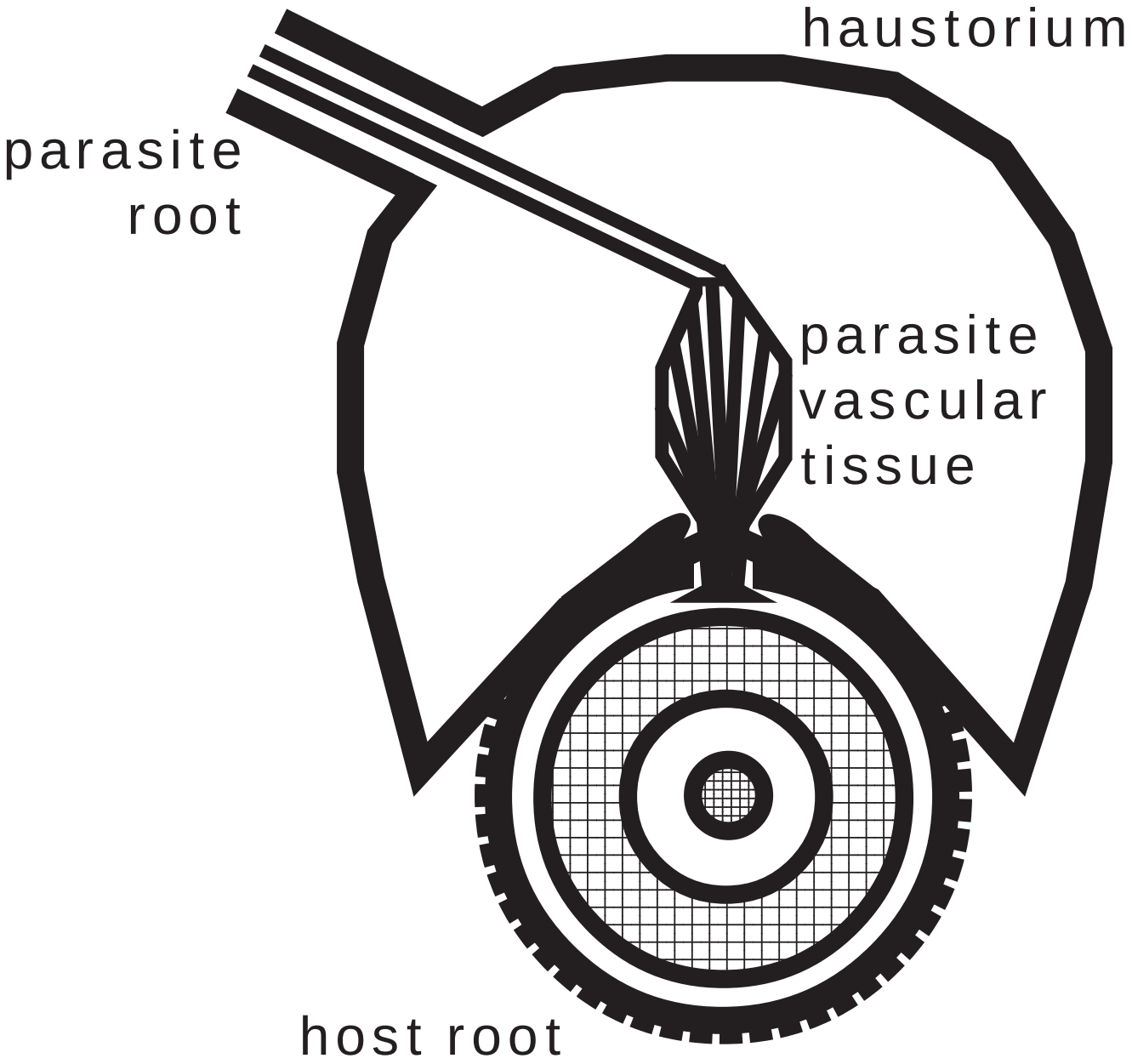

Figure 7: Cross-section view of ***Pyrularia pubera*** haustorium on a host root.