


2014

The Inky Story of the Dinky Oak Gall

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Sulak, Ken, "The Inky Story of the Dinky Oak Gall" (2014). *USGS Staff -- Published Research*. 1066.
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Volume 31: Number 1 > 2014

The Quarterly Journal of the Florida Native Plant Society



Palmetto



The Inky Story of the Dinky Oak Gall ● A Native Celebration ● The Rebirth of Cape Florida



Pea galls on live oak leaves (*Quercus virginiana*) induced by *Belonocnema treatae*, a gall wasp.

The Inky Story of the Dinky Oak Gall

Article and photos by Ken Sulak

Spring in North Florida – and all those magnificent live oaks are sporting a bright new flush of green leaves. Last year’s old clothes, those worn out leaves now lie dry and brown on the forest floor. But look closely and you will soon notice that many of those leaves are decorated with rows or clusters of little round woody galls on their underside, like little brown pearls.

Belonocnema treatae, live oak pea galler wasp (3 mm long).



Maybe you have noticed these little spheres before – but did not give them much thought. Or maybe, you puzzled: What are these wooden pearls? How did they get there? Well, a tiny wasp, called the pea galler wasp or gallfly, *Belonocnema treatae*, is the culprit. The diminutive female gallfly (one of nearly a thousand species in the gall wasp family Cynipidae), about the size of a fire ant, lays eggs on a freshly budded live oak leaf in spring. When the larva hatches, it produces a chemical that induces the oak to enclose it in a protective and nurturing gall: nifty chemical subterfuge, producing a durable little house for the gall wasp larva – no house of bricks, but nearly as good – indeed maybe even better. It comes equipped with a food supply as well. At the chemical direction of the larva, the gall provides an inner layer of nitrogen-rich pulp, similar to seed tissue. A tough lignin-rich¹ outer layer protects the larva from predators, and a chemical shield of anti-microbial tannic acid is concentrated within. Tannic (or gallotannic) acid concentrated in the gall is the tree’s way of isolating the parasitic larva. Ironically, however, the same phenol-rich barrier helps deter predators and disease. Perhaps the bitter taste of tannins and phenols may also discourage predation of gall larvae by birds.

Each gall (called a pea gall or smooth oak gall) is a small wonder, a complex world unto itself, typically less than the size of a pea. Gall wasp larvae transform within leaf galls, one gall per customer, and emerge as winged adults after drilling a tiny circular hole through the protective shell. Only female gall wasps

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Microwasp parasitoids of pea gall wasp larvae. Left to right: *Synergus* sp. and *Ormyrus* sp.



Microwasp parasitoids with long ovipositors used to penetrate pea galls. Left to right: *Torymidae* sp. and *Sycophila* sp.



The Inky Story of the Dinky Oak Gall (continued from page 5)

emerge from leaf galls. Pea gall wasps alternate between an asexual (parthenogenic) all-female generation hatching from leaf galls, and a sexual generation hatching females and males from multi-chambered galls on live oak roots. However, death often comes prematurely to larval females while still in their leaf gall houses. In the natural scheme of things, countermeasures often evolve to defeat even the strongest defenses like a tough, tannin-filled gall. So, many species of tiny parasitic wasps (called ‘parasitoids’ because they eventually kill their host) have evolved as the nemesis of gallfly wasps. These parasitoid wasps (families Eurytomidae, Torymidae and Chalcidae) use a long slender ovipositor like a needle to penetrate the gall and deposit an egg on the gallfly larva. When the egg hatches, it devours the larva and/or the gall pulp and takes over its house as its own tiny pupal chamber. Incredibly, there are still other wasps, called hyperparasitoids, which parasitize the initial parasite – dishing out the same treatment over again! Not the end of this intricate story - however. Defying the tannin barrier, certain fungi can attack the gall, digesting its resident larva. Many other insects, called inquilines, have evolved to dispossess the gall wasp, resulting in a brief period of co-occupancy. Unfortunately, this is not a peaceful coexistence. Eventually, the unwelcome guest larva outpaces its host, growing rapidly and crowding out or smothering the gall wasp larva. As a result, what emerges from a pea gall is quite often not its original inhabitant. And, to add one final twist in the story of evolutionary tit-for-tat, the gall wasp egg may never get beyond square one to begin with. It seems some live oaks have developed their own elegant countermeasure to prevent energy theft by pea gall wasps. Certain live oak trees can detect a gall wasp egg deposited on a leaf, recognizing it as a pathogen. Then, chemical defenses are mobilized to kill off leaf cells surrounding the egg, halting formation of a gall.² Even when the pea gall wasp survives such defenses and the lethal gauntlet of parasitoids and inquilines, life as an adult female will be brief, 3-5 days at most – just long enough to lay eggs in live oak rootlets, setting the stage for the sexual generation that will hatch as both females and males.

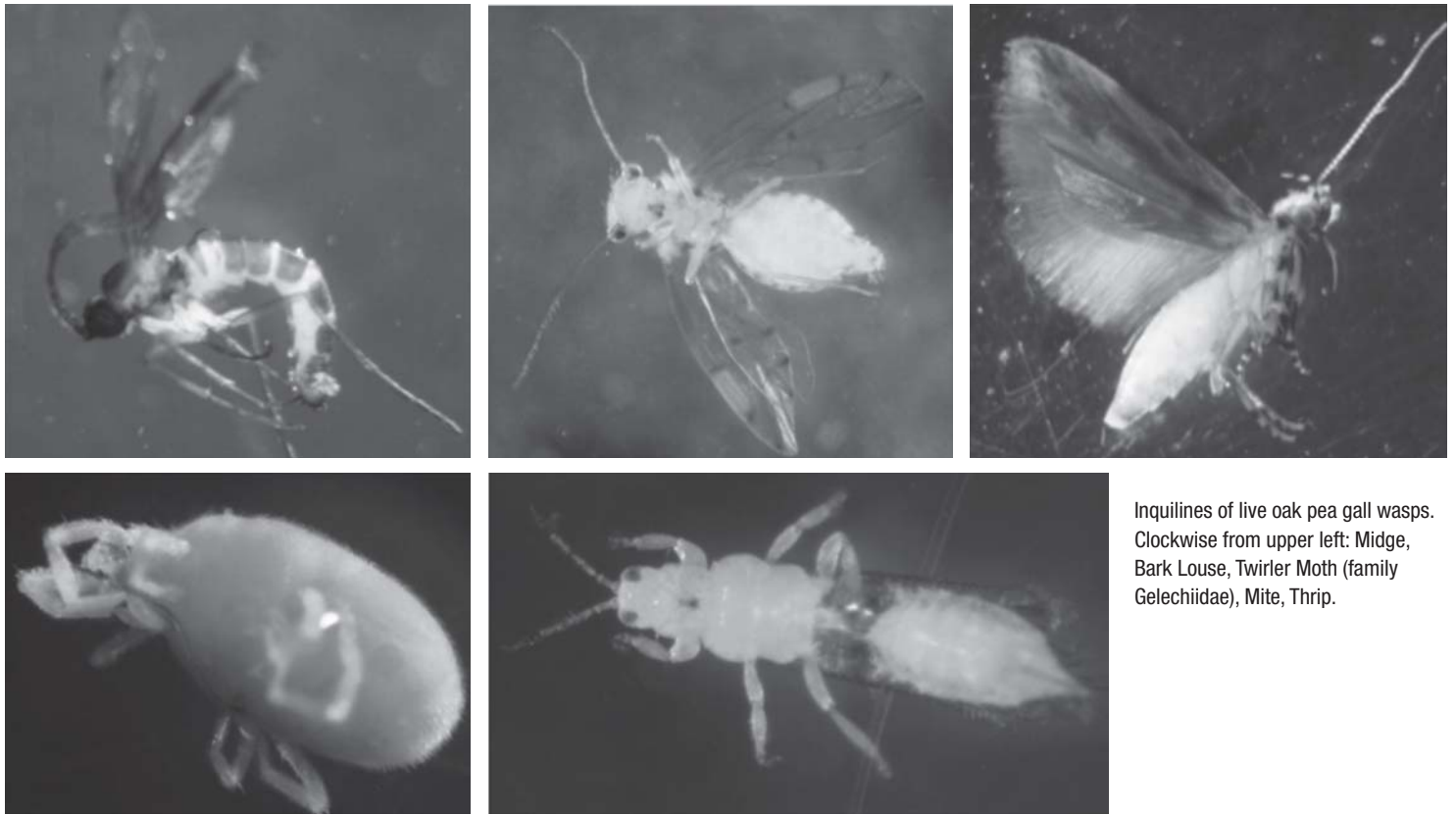
Many species of oak trees are victimized by different gall wasps, but each wasp species prefers a certain species of oak.^{3,4} In Florida, the pea gall wasp only parasitizes the southern live oak (*Quercus virginiana*) and the closely-related sand live oak (*Q. geminata*). Look for galls on the undersides of green leaves while still on the tree. Or, better yet, scan fallen brown leaves in October and November (when the pea gall wasps first emerge) or in February and March when the annual big leaf fall occurs (when parasitoids and inquilines predominate). When you find a gall-bearing leaf, look for others nearby. If a gall has a tiny hole, its resident has already emerged. If not, place collected galls in a sealed jar or plastic bag, set in a sunny window, and wait for tiny insects to emerge – you will need a microscope to get a close look. Mysteriously, gall wasps

will favor one individual oak tree (and often one side of that tree), leaving its close neighbors lightly or totally unparasitized. Scientists are closing in on why that happens.⁵ By the way, those irregular knotty swellings on oak twigs (called ‘gouty galls’, ‘potato galls’, ‘horned galls’, and ‘bullet galls’) are yet a further chapter in the gall wasp story – each gall with a different gall wasp species, each with a different story.

But who really cares about dinky little brown oak galls and their diminutive parasitic wasps? Well, humans have cared very much for about 2,000 years. Back in ancient times, some clever person discovered that those galls concentrate tannic acid, and tannic acid makes a fantastic ink – but only when combined with iron sulfate. From the early days of the Roman Empire, right up to the mid-20th century, nearly all written words put to paper in Europe, and later its colonies worldwide, were penned with oak gall ink – also called iron-gall ink. Indeed, the Declaration of Independence and the first drafts of the Constitution of the United States were penned in iron-gall ink. So were the ancient Dead Sea Scrolls and almost all medieval and Renaissance documents, including Leonardo da Vinci’s mechanical drawings and Johann S. Bach’s symphonies. This ink is simply made, is incredibly permanent, cannot easily be erased (tannin binds to the paper fibers), and does not fade over hundreds of years. In fact, it gets darker over time. In some European countries, laws specified (some still do) that iron-gall ink must be used for original legal documents.

Recipes for gall ink go way back in time, the earliest passed down from the Roman naturalist and philosopher, Pliny the Elder. Galls are gathered, their juice extracted, boiled, sometimes fermented, and mixed with iron particles or iron sulfate – the iron reaction turning the ink darker. Then gum arabic, or the resin of hemlock or pine, is added as a binder. The result is a nearly black ink that binds very tightly to papyrus, parchment, or vellum, the plant fiber and animal skin forerunners of modern cellulose fiber paper. Oak gall ink was the dominant ink of the feather quill pen and inkwell era, used by ancient scribes, and by all of our Founding Fathers. A free bounty of nature, oak galls still had to be gathered, a tedious task. Pity the poor page or apprentice whose job it was to wander the forest, bent over for unending hours, scanning millions of fallen leaves, seeking out enough oak leaf galls to make a few ounces of ink. But, oak gall gatherers were spared when wood pulp paper replaced parchment and rag bond papers, and as the fountain pen replaced the quill pen. Gall ink does not bind well with the cellulose fibers in modern paper. Even more critically, acidic gall ink corroded metal fountain pen points, bringing the age of iron-gall ink to a close. However, gall ink continues to be used by artists and enthusiasts of the ancient arts, and for certain official purposes.

The small natural wonder of the magic oak gall and its curious inhabitants continues to stimulate scientific inquiry, sometimes leading in rather unexpected directions. Gall



Inquilines of live oak pea gall wasps. Clockwise from upper left: Midge, Bark Louse, Twirler Moth (family Gelechiidae), Mite, Thrip.

wasps inhabiting a certain live oak for generations become genetically isolated from their neighbors on other host trees. The acorn does not fall far from its mother tree – nor does the gall wasp. So, each tree is like an island with its own inbred population of wasps. Wasps inhabiting adjacent ‘islands’ differ in small ways and provide a readily-studied genetic model of fine-scale evolution in action. Recent research also indicates that gall extract has powerful anti-oxidant properties.⁶ However, this should come as no surprise – gall extract has a long history as a traditional anti-inflammatory and astringent medicine in Asia. Indeed, dried oak galls as a folk remedy for numerous ailments are readily available at street markets in India. Modern research confirms that tannins do have many important pharmaceutical applications.⁷ But oak galls may possess even more mysterious powers. Too much exposure to oak galls may have unexpected consequences. A noted entomologist, Dr. Alfred Kinsey spent most of his scientific career researching gall wasps, then suddenly switched to the study of human sexuality, authoring the ground-breaking books: *Sexual Behavior in the Human Male* and *Sexual Behavior in the Human Female*. Such are the twists and turns in the long and intricate story of evolutionary and social interaction between gall wasps, oak galls, and humans!

Making your own gall ink

A gall ink recipe can be found online at: http://www.ehow.com/way_5251227_oak-gall-ink-recipe.html. You can make up your own iron solution from rusty nails and vinegar, or

you can find iron sulfate (ferrous sulfate) available as an inexpensive, readily-dissolved, dietary supplement in health food stores or from online vendors. 🌱

Notes and References Cited

- ¹ Lignin is the resilient biopolymer that strengthens wood in trees by linking cellulose molecules into a tight matrix.
- ² Cristina M. Campbell, Glen R. Hood, and James R. Ott 2009. Hypersensitive-like defense in Live Oak: Discovery and efficiency against a host-specific gall former. Presented at 94th meeting of the Ecological Society of America, Albuquerque, NM. <http://eco.confex.com/eco/2009/techprogram/P18803.HTM>
- ³ Abrahamson, W. G., G. Melika, R. Scrafford, and G. Csoka. 1998. Gall-inducing insects provide insights into plant systematic relationships. *American Journal of Botany* 85:1159-1165.
- ⁴ Abrahamson, W. G., M. D. Hunter, G. Melika, and P. W. Price. 2003. Cynipid gall-wasp communities correlate with oak chemistry. *Journal of Chemical Ecology* 29:209-223.
- ⁵ Scott P Egan, and J. R. Ott. 2007. Host plant quality and local adaptation determine the distribution of a gall-forming herbivore. *Ecology* 88(11):2868-2879.
- ⁶ Hamid, H., G., Kaur, S. T. Abdullah, M. Ali, M. Athar, and M. S. Alam. 2005. Two new compounds from the galls of *Quercus infectoria* with nitric oxide and superoxide inhibiting ability. *Pharmaceutical Biology* 43(4):317-323.
- ⁷ Chung, K. T., T. Y. Wong, C-I. Wei, Y-W Huang, and Y. Lin. 1998. Tannins and human health: A review. *Critical reviews in food science and nutrition* 38(6):421-464.

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