The Asian Chestnut Gall Wasp in North America

Carol C. Mapes

The Asian chestnut gall wasp (ACGW), *Dryocosmus kuriphilus* Yasumatsu, 1951 (Hymenoptera: Cynipidae) is an invasive gall-forming cynipid wasp that is a global pest of *Castanea* spp. Mill. (Gibbs et al. 2011; Borowiec et al. 2014). Native to China, the ACGW spread to Japan in 1941, Korea in 1958, the United States in 1974, Nepal in 1999, Italy in 2002 with subsequent spread to many other countries in Europe, Canada in 2012, and Russia in 2016 (Avtzis et al. 2019). Galls caused by the ACGW in North America are found on the Chinese chestnut (*Castanea mollissima* Blume), Japanese chestnut (*C. crenata* Siebold & Zucc.), and European chestnut (C. sativa Mill.), as well as on the American chestnut (*C. dentata* (Marshall) Borkh.). ACGW galls are rarely found on native Allegheny chinquapins (*C. pumila* (L.) Mill.) and native Ozark chinquapins (*C. ozarkensis* Ashe) (Rieske 2007; Anagnostakis 2014).

Life History of the ACGW

Larvae of the ACGW spend the winter "hidden" in buds of *Castanea* spp. After overwintering in the buds, the larvae form green and/or red galls (Figure 1) that are 5 to 20 mm (sometimes up to 30 mm) in diameter, on developing petioles, leaves, and stems (Figures 2 and 3) of *Castanea* spp. (EPPO 2005; Cooper and Rieske-Kinney 2007). Galls contain from 1 to 25 larval chambers or locules (Figure 4) (EPPO 2021).

Larvae pupate in the galls (Cho and Lee 1963), and adult female wasps emerge from fully formed galls in late spring or early to mid-summer. The time of emergence is site-specific and is affected by factors such as latitude and altitude (Bosio et al. 2010, EPPO 2021).

There are no male wasps, no sexual reproduction, and females develop from unfertilized eggs (Zhu et al. 2007). Adult ACGWs (Figure 5) are only 2.5 to 3.0 mm long and live from 2 to 10 days (Yasumatsu 1951; EPPO 2021). Female wasps lay unfertilized eggs in *Castanea* spp. buds, and each female wasp can lay up to 300 eggs (EPPO 2021).

It takes just one female to start an infestation (EFSA 2010). Individual buds can contain up to 30 eggs that are 0.1-0.2 mm long (Payne 1978, EPPO 2021). Larvae hatch from eggs in the buds in 30 to 40 days, and larvae overwinter in the buds.

It is not possible to visually determine which buds contain eggs or larvae without the aid of a stereomicroscope (EPPO 2021). Molecular techniques (PCR) can however, be used to detect the presence of the ACGW in buds (Sartor et al. 2012).

After overwintering, larvae become active again in the spring and induce gall formation (Borowiec et al. 2014). After galls are fully developed, adult female wasps emerge from the current season galls, and the cycle repeats. Interestingly there is a newly described species, *Dryocosmus zhuili* Liu & Zhu, 2015 that has been shown to form galls on Chinese chinquapins (*C. henryi* (Skan) Rehd. & Wils.) that are morphologically indistinguishable from ACGW galls. Unlike the case for the ACGW, there are both male and female wasps of *D. zhuili*. As of yet, *D. zhuili* has only been reported in China and only on Chinese chinquapins (Zhu et al. 2015).

Damage Caused by the ACGW

Infestation with ACGW galls results in inhibited shoot elongation, reduction in flowering and fruiting/nut production, premature leaf death (Figure 6), premature leaf abscission resulting in leaf area loss, twig dieback, reduction in winter bud development, reduction in shoot and tree vigor and in some cases tree mortality, particularly of smaller trees when other stressors are present (Payne 1978; Avtzis et al. 2019). Heavy infestations of the ACGW have been implicated in making European chestnuts (*C. sativa*) trees more susceptible to blight (Turchetti et al. 2010).

Dispersal of the ACGW in North America

Since its initial introduction in Georgia in 1974, *D. kuriphilus* has been reported in 16 additional states: Alabama, Tennessee, South Carolina, North Carolina, Kentucky, Virginia, West Virginia, Ohio, Maryland, Pennsylvania, New York, New Jersey, Delaware, Michigan, Connecticut and Massachusetts (USDA Forest Service 2019; Mapes et al. 2020). *D. kuriphilus* was reported in Niagara-on-the-Lake, Ontario, Canada in 2012 (Huber and Read 2012).

The ACGW disperses by natural and artificial means. Natural means consist of dispersal by active flight and transport by the wind (EPPO 2021). ACGWs are not strong flyers; they are induced to fly at low wind speeds but at high wind speeds, the wasps are blown by the wind. The direction of the prevailing winds plays an important role in dispersal (Oho and Shimura 1970, EFSA 2010).

Artificial means of dispersal include human transport of infested plant material (EPPO 2021) including seedlings, saplings, or scionwood. Early range expansion in the Eastern United States was reported at rates of about 23 km/year, with a range of 15.2 to 25 km/year (Rieske 2007) and 15 miles/year (24.1 km/year) (Payne 1981). The early expansion of the range of the ACGW in the Eastern United States was thought to be due to natural means (Rieske 2007), with some of the more recent dispersal events most likely due to the introduction of infested plant material (Cooper and Rieske 2007; Mapes et al. 2020).

Figure 1. *Galls of the Asian chestnut gall wasp (Photo: Mark Giambrone).*

Figure 2. *A stem gall of the Asian chestnut gall wasp (Photo: Carol Mapes).*

Figure 3. *A leaf gall of the Asian chestnut gall wasp (Photo: Carol Mapes).*

Figure 4. *The interior of a gall of the Asian chestnut gall wasp showing two larval cavities/locules (Photo: Mark Giambrone).*

Figure 5. *The Asian chestnut gall wasp, Dryocosmus kuriphilus (Photo: Gregory Setliff).*

Figure 6. *Premature leaf death caused by a gall of the Asian chestnut gall wasp (Photo: Carol Mapes).*

Control of the ACGW

Resistant Japanese chestnut (C. crenata) cultivars that were developed after the introduction of the ACGW into Japan in 1941, were grown successfully for many years until the 1960's and 1970's when galls were found more and more frequently on those cultivars (Moriya et al. 2003). Additional resistant Japanese chestnut cultivars have subsequently been developed. In Europe, the Japanese chestnut (*C. crenata*) × European chestnut (*C. sativa*) "Bouche de Bétizac" hybrid cultivar that was developed, is used by growers as it is resistant to the ACGW (Dini et al. 2012). In North America, crosses have been done using native Ozark chinquapins (*C. ozarkensis*) that are rarely galled or Chinese chinquapins (*C. henryi*) that also show some resistance. Offspring of crosses of American chestnut with Ozark chinquapin x Chinese chestnut have shown some resistance to gall formation (Anagnostakis 2014), and research involving crosses of commercial chestnuts with Chinese chinquapin or Ozark chinquapin are also showing promise (Anagnostakis 2019).

The use of insecticides against the ACGW has not been considered a particularly suitable control option for several reasons. Larvae are well protected within the galls early in the season, and bud scales provide protection of larvae within buds later in the season (Moriya et al. 2003; Aebi et al. 2007; Bosio et al. 2010). Use of insecticides against emerging adults would require precise timing and would also require potentially large quantities of insecticides adding to other environmental and toxicity concerns (Bosio et al. 2010; Avtzis et al. 2019; EPPO 2021).

Another avenue of control that has been investigated is hot water treatment (HWT) of dormant buds to kill the ACGW larvae within buds. Immersion of Qing Chinese chestnut scions in water at 52°C for 10 minutes was shown to kill *D. kuriphilus* larvae in buds and resulted in successful grafts. It was shown that conditions need to be carefully controlled as slightly higher temperatures (53°C for 10 minutes) caused injury and much lower graft union success (Warmund 2014). Immersion of European chestnut (*C. sativa*) scions in water at 49°C for 10 minutes killed *D. kuriphilus* larvae in buds and resulted in a high percentage of successful grafts (Ciordia et al. 2020). More research is needed to determine the effectiveness and parameters required for HWT of scions of other *Castanea* spp. and cultivars, as well as more research on HWT of seedlings.

Biological control with the parasitoid *Torymus sinensis* Kamijo, 1982 (Hymenoptera: Torymidae) (Figure 7) is considered the most effective method of ACGW control. Populations of *T. sinensis*, native to China, are now established in Japan, Europe, and North America (Avtzis et al. 2019). The life cycle of *T. sinensis* is closely aligned with that of the ACGW. *T. sinensis* adults emerge from overwintering ACGW galls in the spring. After mating, females lay eggs on ACGW larvae or on the

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Figure 7. *The biological control parasitoid Torymus sinensis* (Photo: Gregory Setliff).

walls of larval chambers in developing galls. A larva of *T. sinensis* feeds on an ACGW larva, eventually killing it. Larvae of *T. sinensis* overwinter and pupate in ACGW galls, and adults emerge in the spring (Quacchia et al. 2008).

Pruning of branches with newly formed galls in the spring before adults emerge, and disposal of the galls in a manner that kills the wasps, is a practice that can provide control on a small scale (Payne and Johnson 1979). Removal of current season galls after ACGW departure will result in the removal of *T. sinensis* parasitoids that are still present in the galls. Therefore, if one wishes to help maintain levels of the parasitoid *T. sinensis*, recently vacated current season galls (Figure 8), should not be removed, as *T. sinensis* overwinters in the galls.

The states of Michigan and Oregon have issued quarantines for *D. kuriphilus* (MDA 2010; Oregon Administrative Rule § 603-052-0075, 2014). Michigan's Chestnut Gall Wasp Quarantine was established in 2010. Among other things, it prohibits importing *Castanea* spp. plants and scionwood from infested states unless the place of production has passed inspections as specified and is certified "pest free". *Castanea* spp. plant material must be enclosed when transported through an infested county between May 1 and July 1 (MDA 2010). The Oregon Administrative Rule § 603-052-0075 (2014) protects against chestnut blight and all chestnut pest insects including the

Figure 8. *Galls after the emergence of adult Asian chestnut gall wasps (Photo: Carol Mapes).*

chestnut gall wasp. *Castanea* spp. & *Castanopsis* spp. plant material as specified, is not allowed into the state from defined eastern states, except by special permit. For defined western states, plant material and the site of production need to be certified disease and pest free as specified (Oregon Administrative Rule § 603-052-0075, 2014). Warmund et al. (2017) have proposed that additional states consider implementing quarantines to delay what may be the inevitable spread of the ACGW into non-infested states.

Summary

The Asian chestnut gall wasp, a global pest of *Castanea* spp., has spread throughout much of the Eastern United States since it was first inadvertently introduced into Georgia in 1974. The ACGW spreads by natural means (by flight and wind) and by artificial means through the transport of contaminated plant material. The ACGW "hides" in dormant buds in late summer and through the winter, making it easily spread through contaminated plant material. Hot water treatment (HWT) of buds has shown promise in treating contaminated buds. Some resistant chestnut cultivars have been developed, and there is ongoing research to develop others. The most effective method of control has been biocontrol by the introduced parasitoid *Torymus sinensis*. Two states have issued quarantines for the ACGW, and other states may follow. Greater awareness of the ACGW and additional research are needed to help control the spread of this invasive pest species in North America.

About the Author

Carol C. Mapes is a Professor in the Department of Biology, Kutztown University of Pennsylvania, Kutztown, PA 19530. Her contact information is mapes@kutztown.edu. Her research focuses on cecidology, the study of plant galls. She would not mind at all if someone contacted her with photos of chestnut galls, to get her opinion as to whether the galls were produced by the Asian chestnut gall wasp. She is also willing to help in the identification of photos of galls on other nut trees. However, please do not send actual specimens of galls.

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