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Short Communication

Chipping to Destroy Egg Masses of the Spotted Lanternfly, *Lycorma delicatula* (Hemiptera: Fulgoridae)

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Abstract

A chipping study was conducted during the winter of 2015 in Berks County, Pennsylvania, to determine efficacy against field collected egg masses of the spotted lanternfly, *Lycorma delicatula* (White) (Hemiptera: Fulgoridae). Infested *Ailanthus altissima* Swingle (Sapindales: Simaroubaceae) trees in eastern Pennsylvania were felled and egg masses were counted. Sections were either chipped or allowed to remain intact as controls. Chipped material and intact wood controls were placed in screened barrels and monitored for emergence. No *L. delicatula* nymphs were found in the chipped treatment, as opposed to hundreds of nymphs per barrel in the intact control treatment. We conclude that mid-winter chipping, using the standard 1-inch in 2-dimension chip size, is a quarantine safe mitigation method suitable for treating wood infested with *L. delicatula* egg masses.

Key words: commodity treatment, quarantine, invasive species, Lycorma, chipping

The spotted lanternfly, *Lycorma delicatula* (White) (Hemiptera: Fulgoridae) is a polyphagous phloem feeder from China which was first detected in North America in 2014 (Barringer et al. 2015). Its primary host plant is tree of heaven, *Ailanthus altissima* Swingle (Sapindales: Simaroubaceae) (Sapindales: Simaroubaceae), but it is known to attack over 70 species of woody plants, vines, and trees in 25 families (Dara et al. 2015). In South Korea, where it is also invasive, it has become an urban nuisance and a serious pest of grape (Park et al. 2009, Kim et al. 2011). Feeding causes copious amounts of honeydew to shower down, coating plants, promoting the growth of sooty mold which blocks photosynthesis, and causing plants to wilt and die (Park et al. 2009). Such damage in an organic vineyard in Korea resulted in 80.8% of grapes being unsuitable as table grapes (Song 2010). In a greenhouse study, even three or five *L. delicatula* per potted grapevine was enough to significantly reduce growth (Song 2010).

On 22 September 2014, the Pennsylvania Department of Agriculture (PDA) received its first report of this insect on a property in Berks County, Pennsylvania, and further investigation revealed other properties in the area were infested. After official verification of its identification by the USDA, a New Pest Advisory Group (NPAG) was formed and an initial delimiting survey was conducted. Information from the NPAG and the delimiting survey prompted the implementation of a state quarantine restricting movement of live *L. delicatula* and conveyances from a six township area surrounding the known infested area. This quarantine now extends to 13 counties, and the population continues to expand.

Because egg masses are deposited on trees, woody debris, as well as numerous other substrates, a mitigation method for egg masses on woody debris is required for landscapers, roadside crews, and other affected businesses and individuals that handle woody debris. The initial recommendations were incineration or chipping combined with deep burial (2 m), which is often impractical for a variety of reasons (e.g., local clean air restrictions, added permitting). A mitigation alternative was sought that would consider quarantine security while not overly burdening staff responsible for treatment and disposal. Chipping to a predetermined chip size (1 inch in 2 dimensions) is an industry standard that has been adopted as a quarantine safe mitigation measure for existing APHIS programs such as Asian longhorned beetle *Anoplophora glabripennis* Motschulsky (ALB) (Coleoptera: Cerambycidae) and emerald ash borer *Agrilus planipennis* Fairmaire (EAB) (Coleoptera: Buprestidae) based on a number of successful experiments on insect life stages (Wang et al. 2000, Mccullough et al. 2007). Our experiment was designed to evaluate the efficacy of industry standard chipping process on survival of *L. delicatula* egg masses.

Materials and Methods

The PDA worked with landowners in the infested area to allow a study to be conducted and *A. altissima* trees to be felled on a private property. Trees were scouted for egg masses using binoculars, and infested trees flagged. On 4 February 2015, 11 of the most heavily

infested trees were felled and cut into sections. Infested branches were sawed into bolts roughly 1.5 m in length and averaged 5 cm in diameter, but ranged from 1 to 15 cm in diameter. Each branch section was carefully inspected and the number of *L. delicatula* egg masses was marked on the sawn end. Branches were then sorted evenly based on number of egg masses and placed into 16 plastic barrels (46 cm diam. × 84 cm tall) so that each barrel of branches had on average 34 egg masses (range 32 to 37). Branches were handled with care to avoid scraping off or damaging the egg masses. Because the density of egg masses on branches varied, the amount of wood in each barrel also varied, whereas the number of egg masses was standardized between barrels. The contents of five barrels were assigned as unchipped "controls", and those of the remaining 11 barrels as "chipped".

A Bandit XP150 disc-style chipper was operated at 1,800 rpm and settings adjusted to produce 1-inch (2.54 cm) chips in two dimensions, the regulatory standard used in both the ALB and EAB programs (USDA-APHIS 2014, 2015). The chipper was equipped with a standard metal chute that directed the chips into a large metal hopper. The branches in one barrel were chipped, and the wood chips were then collected from the hopper using shovels and a broom and transferred back into that barrel. This procedure was repeated for each of the 11 chipped barrels. The depth of the chips was recorded for each barrel. All barrels were then transferred into a storage room on the property with a heater that maintained a temperature of 18.8 ± 0.16 °C (range 15.6 to 26.7 °C). The higher temperature was intended to stimulate early emergence of nymphs in order to determine chipping efficacy before spring hatch. A compost thermometer (REOTEMP Instruments, San Diego, CA) was inserted at least 10 cm into the center of the chips in each chipped barrel weekly to monitor inner chip temperatures. Control barrels had temperature data loggers, and ambient room temperature was also recorded.

Each barrel was covered with nylon mesh screening (500 microns opening) attached with a large (38 cm) rubber band. A band of brown sticky paper (Korea Beneficial Insects Lab Co., Ltd., Ansung, Korea) (20.3 cm width) was attached to the inner circumference of each barrel, just below the inner rim, and secured with duct tape to catch emerging nymphs crawling toward the barrel opening. Barrels were inspected visually through the mesh screening weekly for 15 wk. Barrels remained screened for 6 wk after initial emergence, allowing stragglers to emerge and ensuring all nymphs were dead. After 15 wk, barrels were opened and nymphs were quantified, and their location in the barrel noted. A subset of three barrels containing wood chips was selected for a thorough examination of all the chips to determine if any nymphs had emerged and were trapped beneath the decaying chips.

Analysis

We tested the hypothesis of whether the depth of wood chips played a factor in observed mortality as opposed to the chipping alone. To do this, we postulated that if chip depth negatively affected egg survival, the top 2.5 cm of chips would be most likely to contain viable eggs. Assuming even distribution, the number of egg masses expected to have randomly ended up in the top 2.5 cm ($m_{exp(2.5\ cm)}$) of wood chips was calculated by dividing the number of egg masses (m) in the barrel by the depth (d) of the wood chips in the barrel (cm) and multiplying by 2.5 cm.

$$m_{exp(2.5\ cm)} = m / d \times 2.5\ \text{cm} \quad (1)$$

The expected hatch rate (h) was calculated by dividing the number of nymphs (n) by the number of egg masses (m) in control barrels.

$$h = n_{control} / m_{control} \quad (2)$$

The expected (exp) number of nymphs in chipped barrels assuming only eggs in the top 2.5 cm were viable ($n_{exp(2.5\ cm)}$) and was calculated by multiplying the expected number of egg masses calculated in equation 1 for the top 2.5 cm in chipped barrels by the hatch rate (h).

$$n_{exp(2.5\ cm)} = m_{exp(2.5\ cm)} \times h \quad (3)$$

Expected values were compared to observed values of nymphs captured in chipped barrels using a paired t-test (α = 0.05). The numbers of nymphs per barrel in chipped and control treatments were compared using a two-tailed t-test with unequal variance. The relationship between chip depth and temperature was evaluated using a linear regression model (JMP 10.0.0; SAS Institute, Cary, NC).

Results

An average of 559.0 ± 51.6 nymphs emerged per control barrel, with 442.4 ± 36.6 captured on the sticky paper, and 116.6 ± 36.0 found

Table 1. Mean observed numbers of emerged nymphs (±SE) from chipped and control barrels, and average temperatures (±SE) in those barrels over a period of 15 wk

Chip depth per barrel (cm)	Estimated no. egg masses in top 2.5 cm	No. nymphs per barrel			Avg. wood temp. until emergence (°C)	*N*
		Expected from top 2.5 cm	Expected from whole barrel	Observed		
58.4	1.5	24.3	559.0	0.0	25.2	2
55.9	1.5	25.4	559.0	0.0	24.7	1
53.3	1.6	26.4	553.5	0.0	23.7	3
50.8	1.7	28.0	559.0	0.0	22.5	1
43.2	2.1	34.8	591.9	0.0	22.7	1
38.1	2.5	40.6	608.3	0.0	20.9	1
25.4	3.5	57.5	575.4	0.0	19.4	1
20.3	4.0	65.8	526.1	0.0	18.9	1
Mean for chipped barrels	2.1	34.5	563.5	0 (±0)	22.8 (±0.4)	11
Mean for control barrels	34.0	559.0	559.0	559 (±51.6)	13.2 (±1.3)	5

The expected numbers varied depending on the number of egg masses and depth of wood chips in each barrel.

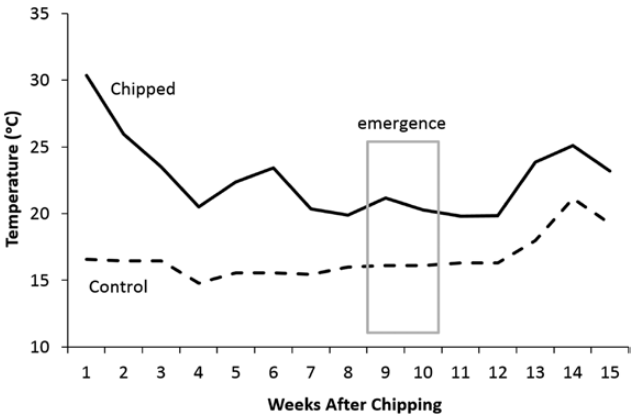

Figure 1. Average temperatures beneath chips in barrels compared to controls. Barrels were held at 18.8 (±0.16) °C for 15 wk. Emergence occurred only in controls during weeks 9 and 10.

on the branches or on the bottom. Therefore, in control barrels, the hatch rate was 16.4 ± 1.5 nymphs per egg mass, and the capture rate by sticky bands was 80.2 ± 4.9 %. No nymphs emerged in chipped barrels, and numbers of nymphs emerging in chipped and control barrels were significantly different (*t*-test; *t*-ratio = 10.84, df = 4, $P = 0.0004$).

Emergence from only the top 2.5 cm of chips was expected to be 34.5 ± 4.3 nymphs per chipped barrel. The expected number decreased from 65.8 to 24.3 with increasing chip depth (Table 1). In chipped barrels, the difference between the expected and observed numbers of nymphs was significantly different (paired *t*-test; *t*-ratio = −76.3, df = 10, $P < 0.0001$).

Average temperature within chips was positively correlated with chip depth ($R^2 = 0.8962$, intercept = 15.27 ± 0.88, slope = 0.16 ± 0.02, $P < 0.0001$, $N = 11$). The average temperature within chips was 3.9 ± 0.4 °C above ambient, and that difference grew with increasing chip depth. All chipped barrels spiked in temperature 1 wk after chipping (Fig. 1). After 1 wk, average chip temperature was 30.4 ± 1.1 °C, whereas ambient temperature was 16.6 °C.

Discussion

High-speed chipping of soft-bodied insect life stages to support regulatory programs has been successful in several instances (Wang et al. 2000, McCullough et al. 2007). Bark and ambrosia beetles have been identified in the literature as the primary groups capable of surviving high-speed chipping due in part to the small size and hard exoskeleton of adults (Spence et al. 2013). *L. deliculata* egg masses are quite soft and vulnerable, and chipping should be an excellent mitigation strategy for this insect. In this experiment, no nymphs were found emerged in chipped treatments, whereas controls produced on average 559 nymphs per barrel. From this study we conclude that during the *L. delicatula* egg stage (in eastern Pennsylvania this is between late November and early April), chipping of egg-infested wood using the chipping parameters described in our methods was sufficient to destroy all *L. delicatula* eggs. At higher moisture contents, wood chip depth promotes decay and higher temperatures, and these factors may also have an impact on emergence. In all likelihood, however, the combined physical forces (accelerative, concussive, etc.) found in the chipping chamber during the chipping process are sufficient alone in causing complete mortality of *L. delicatula* egg masses (R. Mack, personal communication).

The addition of a proven mitigation method that destroys *L. delicatula* egg masses by chipping will aid regulatory officials in developing compliance agreements and best management practices (e.g., winter chipping) for businesses and individuals who work with woody debris and operate in areas where *L. delicatula* is present. Having additional tools for the mitigation of egg masses on materials like woody debris that is at risk for spreading *L. delicatula* will greatly benefit the effort to contain and mitigate this pest.

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