Trap Height Affects Capture of the Pecan Nut Casebearer (Lepidoptera: Pyralidae)[1]

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Abstract The pecan nut casebearer, *Acrobasis nuxvorella* Neunzig (Lepidoptera: Pyralidae), is a monophagous pest attacking pecan, *Carya illinoinensis* (Wangenh.) Koch. Pheromone traps attractive to adult males are used to monitor this pest in orchards by placing them in the lower canopy. However, some insects exhibit vertical stratification in tree canopies as does occur for some beneficial and pest species associated with pecan. The objective of this study was to assess vertical stratification of the pecan nut casebearer in the canopy of tall pecan trees when sampling with pheromone traps. Traps were placed at three heights in orchards (1.5, 7.6, and 13.7 m) above ground. In one experiment, only one trap was placed at one of the three heights at a tree. In the other experiment, three traps, one at each height, were placed in the canopy of the same tree. Results from both experiments reveal that the pecan nut casebearer does stratify within the pecan canopy. Significantly more moths were captured in the highest trap than in the traps at the other heights. These results provide information useful for developing pecan nut casebearer management strategies such as mating disruption in pecan orchards with tall trees.

Key Words *Carya illinoinensis*, *Acrobasis*, integrated pest management, monitoring, pheromone

Pecan, *Carya illinoinensis* (Wangenh.) Koch, is the most economically important native nut crop in North America (Cottrell and Wood 2008). It is commercially grown for nut harvest in all states of the southern United States from North Carolina to California and in Arkansas, Oklahoma, Illinois, Kansas, and Missouri (Wood 2003). Pecan nuts are attacked by numerous insect species, including several lepidopteran pests such as the pecan nut casebearer, *Acrobasis nuxvorella* Neunzig (Lepidoptera: Pyralidae). This pest occurs throughout much of the United States where pecan is grown; *A. nuxvorella* has not been detected in California, but was recently detected in Arizona (T.E.C. unpubl. data; Knutson and Ree 2019).

Acrobasis nuxvorella is monophagous, completing its life cycle within the pecan tree canopy. During autumn, *A. nuxvorella* larvae construct a hibernaculum on a pecan branch near a bud and overwinter. During early spring, these overwintering larvae emerge from the hibernaculum and feed on developing buds and shoots. They pupate within the shoots where they feed, or under bark. Emerging adults

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oviposit first generation eggs on pecan nutlets. Nutlets are susceptible to feeding by *A. nuxvorella* soon after pecan pollination, and there are two to four generations during a season. It is the first generation, however, that typically does most damage because a single larva may destroy all nutlets in a cluster (Knutson and Ree 2019). Monitoring is by using traps baited with the female-produced *A. nuxvorella* sex attractant (9*E*,11*Z*)-hexadecadienal that capture adult males of the species (Knutson et al. 1998, Millar et al. 1996). As nuts grow during the season, later generations of *A. nuxvorella* are generally supported in their development by one or two nuts rather than damaging all nuts in the cluster (Knutson and Ree 2019).

Trees in mature pecan orchards are tall and may grow to heights of ≥25 m (Bock et al. 2013, 2023), leading to the potential for vertical stratification of insects associated with pecan. Although numerous studies have shown the seasonal capture of male *A. nuxvorella* in pheromone traps, no studies have reported whether this pest is vertically stratified in tall pecan trees. From the literature, it is known that numerous insect species, including those in the Lepidoptera, stratify within the canopy of tropical rain forests (de Souza Amorim et al. 2022, Schulze et al. 2001) and temperate forests (Botero-Garcés and Isaacs 2003, Ruchin 2023). In pecan orchards, vertical stratification of insects has been documented for beneficial species of Coccinellidae (Coleoptera) (Cottrell 2017) and pest species of Pentatomidae (Hemiptera) and Aphididae (Hemiptera) (Cottrell et al. 2023, Slusher et al. 2022). Fruit pests such as the codling moth, *Cydia pomonella* (L.) (Lepidoptera: Tortricidae), and grape berry moth, *Paralobesia* (*Endopiza*) *viteana* Clemens (Lepidoptera: Tortricidae), are known to stratify within tree canopies (Botero-Garcés and Isaacs 2003, Weissling and Knight 1995).

Unequal stratification of a pest population in tall pecan trees can present an issue for pest management. For example, Bock et al. (2013, 2023) have demonstrated that ground-operated airblast sprayers used to apply pesticides to pecan do not achieve equal spray distribution to the canopy of tall pecan trees; less spray reaches the upper canopy of treated trees. In addition, the implementation of mating disruption in orchards may be affected by tree height and target pest stratification (Muegge and Knutson 2012, Weissling and Knight 1995).

The objective of this multiyear study was to monitor first-generation emergence of adult male *A. nuxvorella* in pecan orchards when traps were vertically stratified within an orchard. This was done by using three traps in the same tree, each at a different height, or only one trap per tree, at one of three heights.

Materials and Methods

This study was conducted in mature pecan orchards, Stuart and Schley cultivars, at the USDA, Agricultural Research Service, Southeastern Fruit and Tree Nut Research Laboratory in Byron, GA (32°39′29.86′′N, 83°44′18.75′′W) from 2013 to 2016. Trees used in this study were from 18 to 21 m tall and were planted on an 18 × 18-m spacing. Routine orchard management practices were followed, except no insecticides were applied (Wells 2016).

Wing traps with a plastic top and a replaceable adhesive-coated paperboard bottom (Scentry Biologicals Inc., Billings, MT) were used for sampling *A. nuxvorella*.

Traps were baited with a rubber septa lure (L835) containing the attractive pheromone of *A. nuxvorella* (Scentry), suspended from the plastic top just above the adhesive-coated bottom. Lures were replaced monthly. A rope and pulley system was used to suspend traps at heights of 1.5, 7.6, and 13.7 m above ground in a pecan orchard. A length of rigid, straight wire was attached to the rope and jutted out perpendicular (i.e., horizontal with the ground), approximately 25 cm, to the vertical rope. This served as the attachment point for a trap allowing it to hang freely from the rope. This was done for each trap height on the rope.

During 2013–2015, three traps were placed on the same rope at the 1.5-, 7.6-, and 13.7-m heights. A rope with three traps was set up on 12 trees, and these trees were separated by at least two trees, that is, 36 m. Each of the 12 trees with three traps was considered a replicate. Traps were placed on the ropes in orchards on 24 April 2013, 28 April 2014, and 22 April 2015. Traps were sampled weekly through 22 May 2013, 02 June 2014, and 08 May 2015. Traps did not contact foliage or limbs, but were suspended within the tree's canopy.

This same sampling design was used during 2015 and 2016 when only one trap was used per rope. A replicate consisted of three traps suspended at 1.5, 7.6, or 13.7 m on a tree, and four replicates were used each year. Traps within a replicate were separated by at least two trees, that is, 36 m, and replicates were separated by $>$100 m. Traps were randomly placed at one of the three heights on the ropes in each replicate on 04 May 2015 and 20 April 2016 and sampled weekly through 25 May 2015 and 01 June 2016.

For the experiments using three traps per rope or one trap per rope, cumulative *A. nuxvorella* trap capture, by year for one or three traps per rope, was subjected to one-way analysis of variance to determine whether trap height affected capture. If a significant effect of height was detected ($P \leq 0.05$), Tukey's honestly significant difference test was used to separate means (JMP 1989– 2023).

Results and Discussion

The vertical stratification of insect species within the canopy of trees has been documented in numerous studies (Botero-Garcés and Isaacs 2003, Cottrell et al. 2010, de Souza Amorim et al. 2022, Ruchin 2023, Ruchin and Egorov 2021, Schulze et al. 2001, Teulon and Penman 1987). Herein, we document that adult male *A. nuxvorella* stratify vertically within the pecan canopy when captured using pheromone traps early in the season. Whether one trap was placed at one of the three sampled heights within the tree canopy, or three traps were stacked at the three heights within the same tree canopy, more moths were captured in the highest trap across the trapping period (Fig. 1A, B). For example, when only one trap was used per rope at a tree during 2015 and 2016, significantly more moths were captured in traps placed at 13.7 m than at 7.6 or 1.5 m ($F = 10.67$; df $= 2, 11$; $P = 0.0106$ and $F = 30.26$; df $= 2, 11$; $P = 0.0007$, respectively) (Fig. 2A, B). Capture of male *A. nuxvorella* followed a similar pattern when three traps were positioned at the same tree. During 2013, 2014, and 2015, significantly more moths were captured in traps placed at 13.7 m than at 7.6 or 1.5 m ($F = 92.87$; df $= 2, 35$; $P < 0.001$, $F = 50.38$; df $= 2, 35$; $P < 0.0001$, and $F = 82.28$; df $= 2, 35$; $P < 0.0001$, respectively) (Fig. 3A–C). Ruchin (2023) reported that

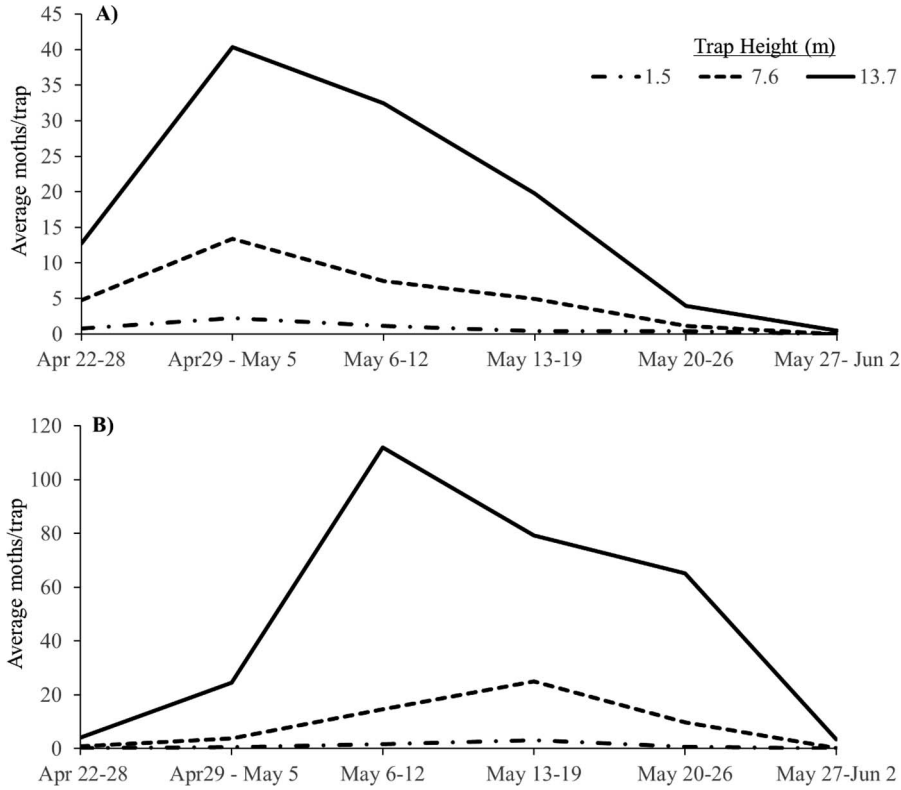

Fig. 1. First-generation capture of male pecan nut casebearer in pheromone traps placed at 1.5, 7.6 or 13.7 m in pecan orchards when (A) one trap was placed at one of the three sampled heights (combined data from 2015 and 2016) within the tree canopy, or (B) three traps were stacked at the three heights within the same tree canopy (combined data from 2013–2015).

cumulative abundance of captured Lepidoptera was greatest at 12 m and lowest at 1.5 m in forest ecosystems of central European Russia. It was interesting that regardless of a single trap or multiple traps at the same tree, as used in the current study, the vertical stratification of male *A. nuxvorella* remained consistent. Botero-Garcés and Isaacs (2003) trapped the grape berry moth also using stacked traps and reported greater capture in higher traps. For that study and the current study, this likely indicates that vertical proximity of the stacked pheromone traps does not interfere with capture in traps at the different heights. Cottrell et al. (2010) showed that captures of males *Synanthedon exitiosa* (Say) and male *Synanthedon pictipes* (Grote and Robinson) (Lepidoptera: Sesiidae) were greater within the canopy of peach trees than above the canopy of peach trees. This indicates that the attractiveness of the pheromone traps was limited to the activity zone for those two species, that is, the pheromone lure did not attract the

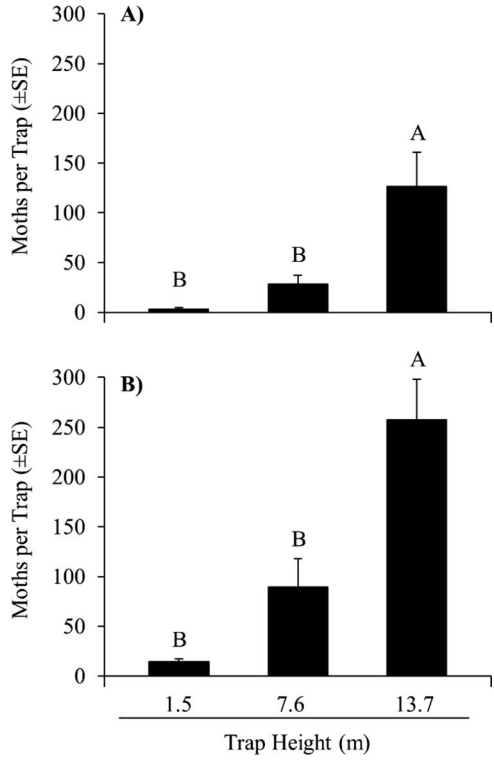

Fig. 2. Cumulative capture of first-generation male pecan nut casebearer during (A) 2015 and (B) 2016 when pheromone traps were placed at 1.5, 7.6 or 13.7 m in pecan orchards by using only one trap per tree at one of the three sampled heights. Within each year, different letters above columns indicate significant difference (Tukey's honestly significant difference test, $P < 0.05$) between treatments.

moths away from the host tree. Given the monophagous habit of *A. nuxvorella,* males likely behave similarly.

Although many studies have used pheromone traps to sample for *A. nuxvorella* (Hartfield et al. 2012, Knutson and Ree 2019; Morales-Olais et al. 2019, Muegge and Knutson 2012), this is the first report concerning the vertical stratification of this insect within pecan orchards. Why the male moths are more abundant higher in the canopy is not known, but could be related to their mating behavior. It is not known whether female *A. nuxvorella* stratify vertically within the tree canopy at any point during their life cycle, but nut damage samples indicate that oviposition is uniform throughout the canopy (T.E.C. unpubl. data). Mating disruption studies against this pest successfully have shutdown capture of males in traps but a reduction in crop damage was unsuccessful (T.E.C. unpubl. data). The results of this study are the beginning of a further understanding of this pest's biology that may be useful toward implementing advanced management practices such as mating disruption in tall pecan orchards.

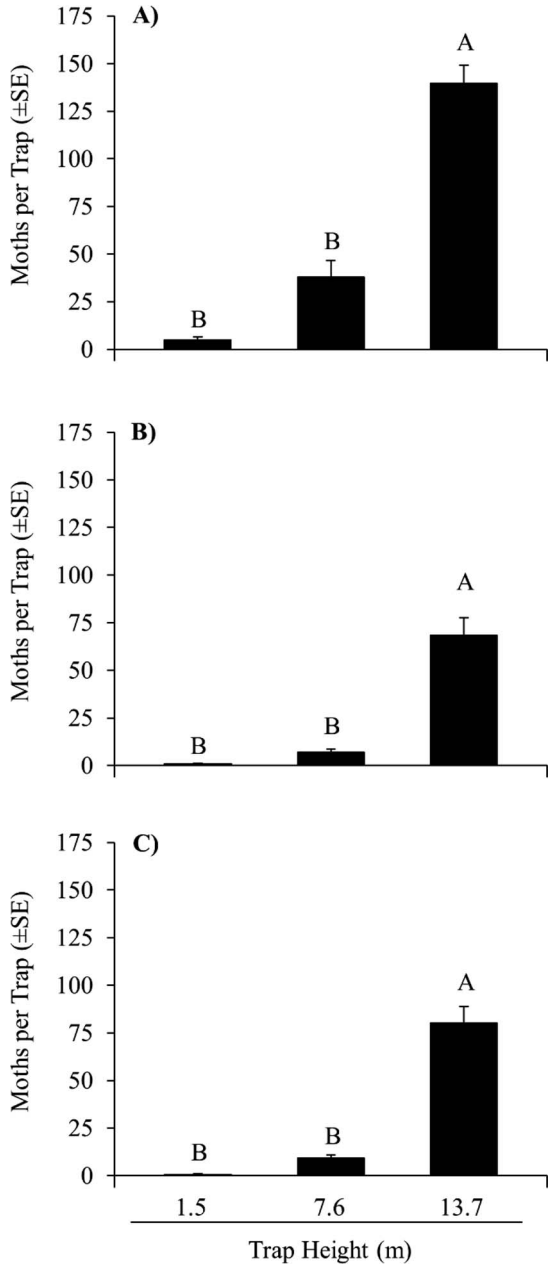

Fig. 3. Cumulative capture of first-generation male pecan nut casebearer during (A) 2013, (B) 2014, and (C) 2015 when pheromone traps were stacked at 1.5, 7.6 and 13.7 m at the same tree in pecan orchards. Within each year, different letters above columns indicate significant difference (Tukey's honestly significant difference test, $P < 0.05$) between treatments.

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