Influence of Plant Direction, Layer, and Spacing on the Infestation Levels of Anthonomus eugenii (Coleoptera: Curculionidae) in Open Jalapeño Pepper Fields in North Florida

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Source: Florida Entomologist, 102(3) : 501-508

Published By: Florida Entomological Society

URL: https://doi.org/10.1653/024.102.0319
Influence of plant direction, layer, and spacing on the infestation levels of Anthonomus eugenii (Coleoptera: Curculionidae) in open jalapeño pepper fields in North Florida

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Abstract
Pepper weevil, Anthonomus eugenii Cano (Coleoptera: Curculionidae), is a most serious pest of peppers in North Florida. To analyze A. eugenii infestation levels on jalapeño peppers as a reference for effectively controlling pepper weevil, we investigated infestation and population dynamics of A. eugenii, and influence of plant direction, layer, and spacing in open fields in North Florida. The results showed that adult pepper weevil infestation started in late Apr when plants started to produce buds and flowers. Three infestation peaks were recorded on 9 Jun, 24 Jul, and 11 Sep. The second peak showed the highest infestation level (14.6 ± 2.7 infested fruits per plant). The density curve of A. eugenii larvae within fruits lagged about 2 to 4 wk behind the curve of infestation level in the field. Three peaks occurred on 10 Jul, 21 Aug, and 25 Sep. Fruits on the eastern part and top third of pepper plants had the lowest infestation levels, as did plants spaced 40 cm apart. This study, focusing on the preferred locations of A. eugenii, will help improve sampling technique and pest management applications, and thus enhance the effectiveness of pesticide application, and ultimately reduce ecological damage.

Key Words: pepper weevil; preference; pest management; population dynamics

Resumen
El picudo de chile, Anthonomus eugenii Cano (Coleoptera: Curculionidae), es la plaga más grave de chile en el norte de la Florida. Para analizar el nivel de infestación de A. eugenii en chiles jalapeños como referencia para controlar eficazmente el picudo del chile, investigamos la infestación y la dinámica de la población de A. eugenii, y la influencia de la dirección, la capa y el espaciamiento de las plantas en campos abiertos en el norte de la Florida. Los resultados mostraron que la infestación de los adultos del picudo del chile comenzó a fines de abril, cuando las plantas comenzaron a producir brotes y flores. Se registraron tres picos de infestación, el 9 de junio, el 24 de julio y el 11 de septiembre. El segundo pico mostró el nivel más alto de infestación (14.6 ± 2.7 frutas infestadas por planta). La curva de densidad de las larvas de A. eugenii dentro de las frutas se retrató aproximadamente 2 a 4 semanas por detrás de la curva del nivel de infestación en el campo. Tres picos ocurrieron en el 10 de julio, el 21 de agosto y el 25 de septiembre. Las frutas en la parte hacia el oriente y en el tercio parte superior de las plantas de chile tuvieron los niveles más bajos de infestación, al igual que las plantas separadas por 40 cm. Este estudio, que se enfoca en las ubicaciones preferidas de A. eugenii, ayudará a mejorar la técnica de muestreo y las aplicaciones de manejo de plagas y, por lo tanto, aumentará la efectividad de la aplicación de pesticidas y, en última instancia, reducirá el daño ecológico.

Palabras Clave: picudo de chile; gorgojo de chile; preferencia; manejo de plagas; dinámica poblacional

Pepper weevil, Anthonomus eugenii Cano (Coleoptera: Curculionidae), is a serious pest of peppers in open fields in North Florida. Originating from Mexico, A. eugenii is widespread throughout Central America, southern USA, and Europe (Berdegue et al. 1994; Speranza et al. 2014). It is a potential risk to other pepper-growing areas due to trade and frequent international shipments. The pest prefers young fruits in terms of feeding and oviposition. Pepper weevils emerge before pepper plant flowering, then infest budding and flowering plants (Seal & Bondari 1999). The infestation rate occasionally reaches 70 to 90% (Rolston 1977). During the post-harvest period when fruits are...
scarce, stamens and pollen are selected as alternative foods (Genung & Ozaki 1972). Larval feeding on internal tissues of fruits is the major damage of pepper weevil, causing the core to become brown and moldy (Brutton et al. 1989; Webb et al. 2014), and more susceptible to decay and disease (Burke & Woodruff 1980). Premature abscission is the most obvious sign of infestation (Riley 1990; Seal & Schuster 1995).

Three to 5 generations of pepper weevil occur each yr and the developmental period of a generation is 20 to 30 d (Elmore et al. 1934; Toba et al. 1969; Capinera 2014). Once infestation by pepper weevil is detected, control with pesticides is difficult (Riley et al. 1992a, b). In addition, natural enemies suffer severe damage from increasing chemical sprays. This study was carried out to determine the infestation level of pepper weevil with respect to locations of pepper plants in open fields, and to access levels of infestation with respect to plant location, direction, layer, and spacing for proper monitoring and management in open fields where suitable pest management plans can be applied.

Materials and Methods

FIELD SITE
Open field experiments were conducted at the IPM demo plots located in the Center for Viticulture and Small Fruits Research, Florida Agricultural and Mechanical University (30.476888°N, 84.172611°W), Tallahassee, Florida, USA. Jalapeño peppers were planted in Mar 2017. Insect monitoring and data collection started twice per wk after planting. All experiments were carried out in pepper fields.

INFESTATION LEVELS OF PEPPER FRUITS IN OPEN FIELDS

In the first survey of pepper weevil infestation and larval density in 2017, 55 samples were examined by collecting samples from Apr to Oct. During sampling, each plant was surveyed every 3 to 4 d. Plant observation times ranged from 10:00 AM to 2:00 PM Eastern Standard Time each d, and all fruits on the plant were examined for weevil infestation. The number of A. eugenii larvae within infested fruits was recorded after dissecting the fruits. The dissected fruits were left in the field to maintain the weevil population.

INFESTATION LEVELS OF PEPPER WEEVIL IN OPEN FIELDS

To determine the influence of plant direction, layering, and spacing on infestation by A. eugenii, pepper fruits were examined in 5 directions (north, south, east, west, and center part of plant), in 3 layers (upper, middle, and lower third of a plant), and at 5 spacing levels (20, 40, 60, 80, and 100 cm between plants). In addition, the wall thickness and single weight of fruits in each location were measured with digital calipers (model 500-474, Mitutoyo, Tokyo, Japan) and an analytical balance (model BS124S, Sartorius, Goettingen, Germany), respectively, to determine the relationship between wall thickness and fruit weight to infestation levels. The larvae were left in the field after data recording.

STATISTICAL ANALYSIS

All data were subjected to 1-way ANOVA analysis and differences between means were calculated by post hoc Tukey's honest test of significance at 5% levels. All statistical analyses were performed with SPSS analysis software (IBM Corp. 2011). Regression analyses were performed with SigmaPlot 12.0 software (SigmaPlot 2007).

Results

INFESTATION LEVELS OF PEPPER FRUITS IN OPEN FIELDS

The different life stages of pepper weevils found on plants, or within fruit, and exit holes made as adults emerged from jalapeño fruits are shown in Fig. 1. Infestation of fruit per plant is shown in Figure 2A. Adult pepper weevils started mating and ovipositing in pepper field at the end of Apr. The infestation did not increase until 2 wk later. The number of infested fruits increased rapidly in the latter half of May and early Jun, reaching a peak (12.0 ± 1.5 fruits per plant) on 9 Jun. After this peak, the infestation level decreased to 3.4 ± 1.1 fruits on 6 Jul, and then increased again during early Jul. The second peak of infested fruits occurred on 24 Jul (14.6 ± 2.7), and was the highest in the season. Fruit infestation decreased to 3.4 ± 0.9 fruits on 14 Aug, followed by the third, and smallest, peak of infestation (9.2 ± 1.4) on 11 Sep. Infestation levels decreased although slight build-up of infested fruit was still detected in early Oct, but by the latter half of Oct the infestation gradually vanished after harvest.

Data on the number of pepper weevils in infested fruits per plant are shown in Fig. 28. During this study, 3 generations of A. eugenii were observed in the open pepper fields in North Florida. The larval population started in early May and showed a peak on 10 Jul, reaching 11.2 ± 2.4 larvae per pepper plant. The second (12.6 ± 1.6 larvae per plant) and third (8.4 ± 1.9) peaks of larvae per plant occurred on 21 Aug and 25 Sep, respectively. A density of 2.8 ± 1.5 larvae per plant occurred on 31 Jul and again on 14 Sep (2.6 ± 1.1 larvae per plant). After the third peak, the population declined during early Oct and vanished at the end of Oct. The peaks in the number of A. eugenii larvae within fruits lagged 2 to 4 wk following an infestation peak (Fig. 2A), and an average of 1.12 larvae were found in an infested fruit.

INFERENCE OF PLANT DIRECTION, LAYER, AND SPACING ON THE INFESTATION LEVELS OF PEPPER WEEVIL IN THE OPEN FIELDS

The data are presented in Fig. 3. The number of infested fruits in the eastern side of pepper plant was markedly lower (2.0 ± 0.3 fruits per plant), while significant infestations occurred in the western (9.0 ± 0.7 fruits per plant) and central (9.5 ± 0.9 fruits per plant) parts (F3, 170 = 21.827; P < 0.001; Fig. 3A). The number of weevil larvae in eastern fruits (3.0 ± 0.7 larvae per plant) was significantly less than in central fruits (10.3 ± 1.1 larvae per plant) (F3, 157 = 12.85; P < 0.001; Fig. 3B).

Pepper weevils infested more fruits in the middle third of a plant (7.1 ± 0.8 fruits per plant), and in the bottom third of a plant (6.4 ± 0.8 fruits per plant) than in the top third of plants (4.5 ± 0.5 fruits per plant) (F3, 140 = 3.49; P = 0.034; Fig. 3C). There were more larvae in fruits in the bottom third of a plant (6.3 ± 0.6 weevils per plant) than in fruits in the middle third (4.9 ± 0.6 weevils per plant) or top of a plant (4.2 ± 0.5; F3, 130 = 3.938; P = 0.023; Fig. 3D). Pepper fruits (4.3 ± 0.6 fruits per plant) on plants at the distance of 40 cm between plants showed the lowest
weevil infestation \( (F_{4, 129} = 3.601; P = 0.008; \text{Fig. 3E}) \), leading to significantly fewer larvae in fruits \( (1.9 \pm 0.4 \text{ larvae per plant}) \) \( (F_{4, 129} = 10.162; P < 0.001; \text{Fig. 3F}) \).

Pepper fruits on the eastern side of plants had thicker walls \( (2.84 \pm 0.11 \text{ mm}) \) and were heavier in weight \( (9.15 \pm 0.23 \text{ g}) \), whereas fruits on the western side and the central plant fruits had thinner walls \( (\text{western, } 2.15 \pm 0.11 \text{ mm}; \text{central, } 2.22 \pm 0.13 \text{ mm}) \), and were lighter in weight \( (\text{western, } 7.11 \pm 0.34 \text{ g}; \text{central, } 7.08 \pm 0.32 \text{ g}) \) \( (\text{thickness, } F_{4, 45} = 5.349; P = 0.001; \text{Fig. 4A}); \text{weight, } F_{4, 45} = 7.295, P < 0.001; \text{Fig. 4B}) \). However, no significant differences were detected among various layers in fruit wall thickness \( (F_{2, 27} = 0.772; P = 0.472; \text{Fig. 4C}) \) and single fruit weight \( (F_{2, 27} = 0.09; P = 0.915; \text{Fig. 4D}) \). More thick-walled fruit \( (2.72 \pm 0.11 \text{ mm}; F_{4, 45} = 2.336; P = 0.047; \text{Fig. 4E}) \) and larger fruit \( (9.33 \pm 0.19 \text{ g}; F_{4, 45} = 9.47; P < 0.001; \text{Fig. 4F}) \) were produced in plants spaced 40 cm apart compared to other spacing intervals \( (20, 60, 80, \text{ and } 100 \text{ cm}) \). Overall, based on these results, both the fruit wall thickness \( (\text{Fig. 5A}) \) and fruit weight \( (\text{Fig. 5B}) \) were negatively correlated with the infestation level of pepper weevil.

**Discussion**

In North Florida, 3 generations of pepper weevil were recorded in our experiments. The second generation, occurring in Jul and Aug, triggered the highest infestation level and larval population, respectively, suggesting both times are most suitable for seasonal growth and development of the weevils. Wilson (1986) and Gordon and Armstrong (1990) also found that the pepper weevil population grew faster and higher during the summer months. In our study, the infestation level of *A. eugenii* and their larval population were close to zero at the end of Oct, indicating that pepper weevil failed to overwinter after harvest, although it has been suggested that in recent years weevils may have been overwintering in Georgia. Goff and Wilson (1937) indicated that pepper weevils cannot live through the winter where food and hiding places are not available. Based on the infestation and population dynamics, late Apr, late Jun, and early Aug are times associated with lower infestation, and those are potential periods to control *A. eugenii.*
Fig. 2. Infestation and larval density of pepper weevil in 2017. Vertical bars are standard errors of the means.
Overall, we found that jalapeño pepper plants with fruits on the eastern side of a plant with thicker walls and heavier fruits, and spacing of 40 cm between plants were attacked less often by pepper weevils. Conventional varieties of pepper, especially those cultivars with thin-walled mesocarp, are susceptible to *A. eugenii* infestation (Elmore et al. 1934). Pepper weevils prefer smaller, thin-walled fruits over high-
quality fruits (Toapanta et al. 2005). Thick-walled fruits also are attacked by pepper weevil, but there is often a switch in preference to younger, thinner-walled fruits (Patrock & Schuster 1992). Choosing pepper cultivars for stronger resistance or lower susceptibility to *A. eugenii* (Quinones & Favela 2002), excellent cultivation conditions, sufficient sunlight, and appropriate plant spacing can be effective strategies for controlling pepper weevil.

However, Seal and Martin (2016) suggested that larger fruits may result in more puncture marks and oviposition plugs than small fruits, due to the greater distances between sites of *A. eugenii* feeding and oviposition.

![Fig. 4. Fruit wall thickness and single weight in different jalapeño plant parts (means ± SE). Fruit wall thickness (A) and single weight (B) in 5 directions, fruit wall thickness (C) and single weight (D) in 3 layers, fruit wall thickness (E) and single weight (F) at 5 spacings. Different letters indicate significant differences among the treatments (means separated by Tukey’s HSD, \(P < 0.05\)).](https://bioone.org/journals/Florida-Entomologist)
Acknowledgments

Funding support for this study was provided in part by the USDA, NIFA, CPPM Program and IPIPE (Integrated Pest Information Platform for Extension and Education) USDA, AFRI Program. Also, Ph.D. exchange student funds were provided to the first author by the China Scholarship Council. We greatly appreciate the help of the late Philip A. Stansly (UF/IFAS Southwest Florida Research and Education Center) for the initial weevil colony from Immokalee, Florida, USA. The field and logistic support provided by the faculty and staff of the Center for Viticulture and Small Fruit Research, Florida A&M University, Tallahassee, Florida, USA, is greatly appreciated.

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