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Effect of soil moisture on *Plectris aliena* (Coleoptera: Scarabaeidae) oviposition

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Plectris aliena Chapin (Coleoptera: Scarabaeidae) is an invasive scarab pest in North Carolina that renders sweet potato roots unmarketable due to feeding by grubs. The adult beetles mate during May and Jun in North Carolina, at the time sweet potato is planted, and females lay eggs at varying depths in a mass or singly beneath the soil surface in grasslands and cultivated agricultural fields (Brill & Abney 2013). Soil moisture is an important factor influencing oviposition in several scarabs, including *Phyllophaga* species (Sweetman 1931; Gaylor & Frankie 1979), *Cyclocephala* species, *Ligyris subtropicus* Blatchley (Potter 1983; Cherry et al. 1990), *Popillia japonica* Newman, and *Macrodactylus subspinosus* F. (Régnière et al. 1979; Allsopp et al. 1992). Unfavorable soil moisture conditions may reduce the number of individuals that oviposit, thus lowering egg densities and subsequent larval populations in the field (Gaylor & Frankie 1979). Conversely, favorable soil moisture conditions may cause females to oviposit and optimize reproductive success (Ward & Rogers 2007). Improved knowledge of the relationship between *P. aliena* oviposition and soil moisture could be useful for understanding dynamics of the pest populations in agricultural fields. The objective of this study was to determine the effect of soil moisture on oviposition by *P. aliena*.

We conducted no-choice field and laboratory trials. In these experiments, individual female *P. aliena* beetles were placed in 1 of 3 soil moisture levels in closed cages. Adults of *P. aliena* were collected by hand above-ground during the evening mating period in Columbus County, North Carolina, from 27 May to 8 Jun 2011. All males and females were engaged in a mating flight behavior when collected (Brill & Abney 2013). After collecting, males and females were separated, and those used in laboratory studies were held individually in 59 mL plastic containers with loose field soil (obtained from the collection site) in a refrigerator at 2.5 °C for 24 to 48 h to prevent oviposition prior to initiation of experiments. Females were identified by the longer length of the lamellae in comparison with males (Brill & Abney 2013).

A moderately dark sandy loam soil (average of 63.6% sand, 28.4% silt, and 8.1% clay determined through laboratory testing at the Environmental and Agricultural Testing Service in the Department of Soil Science at North Carolina State University), obtained from the field where beetles were collected, was brought to the laboratory, mixed by hand, oven-dried (150 °F, i.e., 65.6 °C) and then brought to 2%, 11%, and 20% soil moisture (i.e., gravimetric water content by mass) and used for all experiments. These levels correspond to 7%, 39%, and 71%, respectively, of maximum water content by mass, or saturation (which was 28% for this soil). The field capacity of this soil was an average of 11% at -30 kPa, and the permanent wilting point was 3.7% at -1,500 kPa. Therefore, the 2%, 11%, and 20% moisture levels were considered “dry,” “normal,” and “wet,” respectively.

Cages were a 10 cm diameter × 15 cm deep PVC pipe, with a plastic disc glued to the bottom, and filled with soil to 13 cm. Cages in the laboratory were covered with saran wrap (S.C. Johnson & Son, Inc., Racine, Wisconsin). Cages in the field were covered with a mesh screen (1 × 1 mm) that was held in place with a metal clamp around the PVC pipe. Cages were then buried in the ground at the edge of the same field where females were collected. The top of the cage was flush with the ground. Cages were covered with 23 cm diameter plastic plates (Solo Cup Company, Lake Forest, Illinois) that were supported by bamboo stakes approximately 31 cm long to prevent rain from entering the cages. The bamboo stakes were pushed into the ground so that the plastic plate was suspended approximately 5 cm from the top of the cage. In all experiments, 1 female and up to 10 males were placed in each cage to ensure mating ($n = 25$ total field cages and $n = 44$ total laboratory cages).

Beetles remained in the cages in the field and laboratory for 7 to 10 d (laboratory cages at 24 °C under a 15:9 h L:D photoperiod), after which eggs and surviving females were recovered by sorting through the soil. Soil was removed from the cages and visually inspected for eggs by gently breaking apart the soil. Eggs were picked from the soil with a microspoon. The eggs are approximately 1.6 mm in diameter with a white-cream color, so the eggs were easily visible with the naked eye (Brill & Abney 2013). The following information was recorded for each experimental soil moisture level: 1) the number of eggs deposited per female, 2) the number of days between the time females were placed in cages until the cages were sorted for eggs, i.e., days to sorting, and 3) incidence of eclosion. All recovered eggs were immediately placed in 59 mL plastic containers (separate containers for eggs from each female) with 11% soil moisture and evaluated for presence of 1st instars after 12 to 19 d. Eclosion rate was calculated as the number of 1st instars divided by the original number of eggs laid × 100.

The effect of soil moisture on the number of eggs laid in cages by females was analyzed with square root transformed data using PROC GLM, SAS Version 9.2 (SAS 2008) with Tukey's multiple comparison test, conducted separately for field and laboratory experiments. An analysis by PROC GLIMMIX, SAS Version 9.2 (SAS 2008) with Tukey's multiple comparison test was used to determine whether egg deposition in dry (2%), normal (11%), or moist soils (20%) would affect egg eclosion once those eggs were placed into normal (11%) soil moisture. The effect of the days to sorting on the numbers of eggs laid was analyzed using PROC GLM, SAS Version 9.2 (SAS 2008). For the laboratory cages, the days to sorting were 7 ($n = 6$), 9 ($n = 14$), 10 ($n = 21$), and 11 ($n = 3$), and for the field cages, the days to sorting were 7 ($n = 10$), 8 ($n = 8$), and 10 ($n = 7$) across all soil moisture treatments.

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There was a significant effect of soil moisture on the mean number of eggs laid by *P. aliena* beetles in laboratory cages ($F = 9.23$; $df = 2,41$; $P = 0.0005$). In the laboratory, beetles laid up to an additional 20 eggs per cage in the higher soil moisture levels of 20% and 11% relative to the lowest soil moisture (2%) (Fig. 1). There was no effect of soil moisture on the mean number of eggs laid by *P. aliena* beetles in field cages ($F = 2.5$; $df = 2,22$; $P = 0.10$), most likely due to low egg recovery as a result of hot, dry field conditions accounting for up to 17% moisture loss in cages despite shade from rain shelters (as determined by gravimetric water content by mass at the end of the experiment). There was no effect of days to sorting on the number of eggs laid in either field ($F = 0.24$; $df = 2,22$; $P = 0.79$) or laboratory ($F = 1.54$; $df = 3,40$; $P = 0.22$) cages. The incidence of eclosion (in normal soil moisture of 11%) was not different between eggs laid originally in field or laboratory cages with soil moisture levels of 2%, 11%, or 20% ($F = 1.89$; $df = 2,19$; $P = 0.18$).

Reduced oviposition in very dry soil (0–5% soil moisture for sandy loam and sandy soils) was observed by Allsopp et al. (1992) and Gaylor & Frankie (1979) for *P. japonica* and *Phyllophaga crinita* Burmeister (Coleoptera: Scarabaeidae). Potter (1983) reported that oviposition by *Cyclocephala lurida* Bland (Coleoptera: Dynastidae) occurred only at soil moisture in the range of 12.5% to 25.5%. This result is similar to observations in the current study, in which oviposition was greatest at the higher soil moisture levels (11% and 20%). It is clear from these results that oviposition is inhibited at low soil moisture.

Egg deposition in dry, normal, or moist soil did not influence the eclosion rate once eggs were placed into normal (11%) soil moisture. Potter (1983) showed that *C. lurida* egg survival was dependent on available soil moisture. This study did not investigate the effect of prolonged exposure to low or high soil moisture on egg survival, but the results show that eggs laid in very dry and wet soil are capable of surviving to eclosion if soil moisture returns to approximately field capacity.

Brill et al. (2013) showed that more *P. aliena* grub damage to roots occurred in soils that were poorly drained (and thus held more moisture) compared with soils that were well drained. The findings in this study support the hypothesis that adequate soil moisture is important for egg deposition by *P. aliena* females. If *P. aliena* females laid eggs

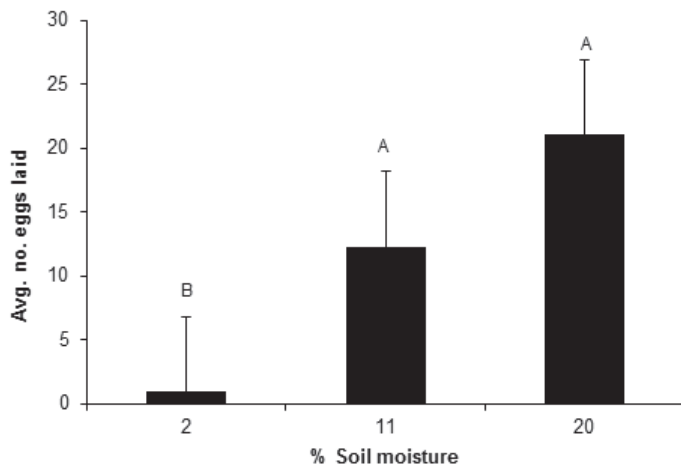


Fig. 1. Mean numbers of eggs laid by *Plectris aliena* in laboratory cages with soil moisture levels of 2%, 11%, and 20%. Means with the same letter are not significantly different from one another (Tukey's multiple comparison test, 5% level). Vertical bars are standard errors of the means.

where soil conditions were dry in the field, it is possible that eggs could hatch if a period of rainfall provided enough moisture after egg deposition. Populations of *P. aliena* are known to fluctuate from year to year (Brill & Abney 2013). This research indicates that soil moisture in the spring, when beetles are mating and laying eggs, can significantly affect oviposition and may be at least partially responsible for year-to-year changes in beetle abundance.

Summary

The effect of 3 soil moisture regimes (dry, normal, and wet) on oviposition was studied for the invasive soil pest *Plectris aliena* Chapin (Coleoptera: Scarabaeidae) in North Carolina agroecosystems. In laboratory cages, there was a significant increase of 20 more eggs deposited by females in wet soil compared with the dry soil (2% moisture) treatment. When the beetles were tested under field conditions, there were no significant differences in oviposition.

Key Words: invasive; soil pest; North Carolina

Sumario

Se estudió el efecto de 3 regímenes de humedad del suelo (seco, normal y húmedo) sobre la oviposición de la plaga invasora del suelo, *Plectris aliena* Chapin (Coleoptera: Scarabaeidae) en los agroecosistemas de Carolina del Norte. En las jaulas de laboratorio, hubo un aumento significativo de 20 o más huevos depositados por hembra en el suelo húmedo en comparación con el tratamiento del suelo seco (2% de humedad). Cuando los escarabajos fueron probados bajo condiciones de campo, no hubo diferencias significativas en la oviposición.

Palabras Clave: invasiva; plagas del suelo; Carolina del Norte

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