Field Sampling Methods for Asiatic Garden Beetle (Coleoptera: Scarabaeidae) Adult Movement and Flight in the Great Lakes Region

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Source: Florida Entomologist, 106(2) : 117-121

Published By: Florida Entomological Society

URL: https://doi.org/10.1653/024.106.0208

Field sampling methods for Asiatic garden beetle (Coleoptera: Scarabaeidae) adult movement and flight in the Great Lakes region

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Abstract

The Asiatic garden beetle, *Maladera formosae* (Brenske) (Coleoptera: Scarabaeidae), was introduced into the US in 1921 and recently has become a significant early-season pest of field corn in Ohio, Indiana, and Michigan, USA. Adults emerge from the soil in mid-summer, feed, mate, and lay eggs in the crop soil. Although adult feeding causes no apparent damage in field crops, these beetles are responsible for laying eggs that hatch into the grubs that overwinter and feed on corn the following spring. The objective of this study was to evaluate sampling methods used for other annual white grub species for their efficacy with *M. formosae* adults in a corn-soybean production system. We performed 2 experiments to first evaluate pitfall traps and sticky cards for sampling beetle emergence, then evaluate antifreeze milkjug traps and blacklight traps for sampling beetle flight. Pitfall traps were effective at capturing beetles, but not sticky cards. Peak abundance was observed between 28 Jun and 5 Jul. Flying adults were predominately attracted to the blacklight trap and nearly 100 times more adults were trapped in the blacklight compared to the milkjug traps. Flying beetles were more attracted to milkjug traps containing propylene glycol antifreeze than water or ethylene glycol antifreeze. These findings may provide economical tools for monitoring adult flight movement and flight.

Key Words: *Maladera formosae*; scarab; pitfall trap; antifreeze milkjug trap; field crops

Resumen

El escarabajo asiático de jardín, *Maladera formosae* (Brenske) (Coleoptera: Scarabaeidae), se introdujo en los EE. UU. en 1921 y recientemente se ha convertido en una plaga importante de la época temprana del maíz en Ohio, Indiana, y Michigan, EE. UU. Los adultos emergen del suelo en el medio del verano, se alimentan, se aparean y ponen huevos en el suelo de cultivo. Aunque la alimentación de los adultos no causa daños aparentes en los cultivos de campo, estos escarabajos son responsables de poner huevos que se convierten en larvas que pasan el invierno y se alimentan del maíz en la primavera siguiente. El objetivo de este estudio fue evaluar la eficacia de los métodos de muestreo utilizados para otras especies anuales de gallina ciega sobre los adultos de *M. formosae* en un sistema de producción de maíz y soja. Realizamos dos experimentos para evaluar primero las trampas de caída y las tarjetas adhesivas para muestrear la emergencia de escarabajos, luego evaluar las trampas de leche anticongelante y las trampas de luz negra para muestrear el vuelo de los escarabajos. Las trampas de caída fueron efectivas para capturar escarabajos, pero no las tarjetas adhesivas. Se observó la abundancia máxima entre el 28 de junio y el 5 de julio. Los adultos voladores se sintieron atraídos predominantemente por la trampa de luz negra y casi 100 veces más adultos quedaron atrapados en la luz negra en comparación con las trampas de jarras de leche. Los escarabajos voladores fueron más atraídos por las trampas de jarras de leche que contenían anticongelante de propilenglicol que el agua o el anticongelante de etilenglicol. Estos hallazgos pueden proporcionar herramientas económicas para monitorear el vuelo y el movimiento de los adultos.

Palabras Clave: *Maladera formosae*; escarabajo; trampa de caída; trampa de jarra de leche anticongelante; cultivos de campo

The Asiatic garden beetle, *Maladera formosae* (Brenske) (syn. *M. castanea* [Arrow]) (Coleoptera: Scarabaeidae: Melolonthinae) was introduced from East Asia (Fabrizi et al. 2021) to North America in New Jersey in 1921 (Hallock 1929) and since has been reported in 24 states and 2 Canadian provinces (Eckman 2015). The larvae (soil-dwelling grubs) recently emerged as significant pests of field crops, particularly field corn, in northern Indiana (Krupke et al. 2007), southern Michigan (DiFonzo 2007), and northern Ohio (Turner 2013). An annual species, *M. formosae* overwinter as larvae in the soil and move toward the soil surface in spring to resume feeding which often coincides with corn planting in the Great Lakes region. Grubs feeding on roots cause plants to stunt, wilt, discolor, and ultimately die (Tashiro 1987). The grubs observed feeding on crops in spring hatched from eggs laid by the adults during the previous summer. Because of the typical annual corn/soybean rotation practiced in this part of the country, grubs damaging corn seedlings are often the result of adult oviposition in soybean.

Maladera formosae adults are present only in the summer mo in the Great Lakes region (Jun through Sep) and adult foliar feeding has not been observed causing economical damage in either field corn or soybean. The beetles are nocturnal and during the d they burrow under the soil surface near preferred host plants. On warm nights (temperature > 15.5 °C) adults emerge to feed and mate (Hallock 1936a).

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They are attracted to outdoor lights (Hallock 1936a; MacKellar 2011) and light traps (Hallock 1932, 1936b; Chong & Hinson 2015; Eckman 2015) and are reported to fly when nighttime temperatures approach and exceed 21.1 °C (Hallock 1936a). Though light traps are a common research tool, they are not practical for the typical farm manager to operate for pest monitoring in disparate field locations, in part because they are a technological investment, and also because they require electricity. Alternatively, *M. formosae* adults have been detected in antifreeze milkjug traps used to monitor for western bean cutworm moths (*Striacosta albicosta* Smith; Lepidoptera: Noctuidae) (DiFonzo 2011; MacKellar 2011), and pitfall traps used to assess arthropod communities in urban habitats (Perry et al. 2020). The antifreeze milkjug trap, in addition to commonly used trapping methods like sticky cards, have not been evaluated for adult *M. formosae* monitoring.

The objective of this study was to evaluate sampling methods for *M. formosae* adults in corn/soybean rotated fields. In this study we assessed 4 trapping methods: pitfall traps and sticky cards (2017) to monitor adult movement from the soil, and antifreeze milkjug traps and blacklight traps (2018) to monitor flying adults. We wished to determine if these low-tech and inexpensive tools were appropriate for monitoring *M. formosae* adults in either the research or management context.

Materials and Methods

EXPERIMENTAL LOCATIONS

Agricultural fields (Table 1) with a known history of *M. formosae* were sampled for adult beetles. Row spacing was 0.8 m for corn and 0.4 m for soybean, and fields were managed following standard practices for the region. No foliar insecticide applications were made during the study.

ADULT SAMPLING WITHIN FIELDS: PITFALL TRAP VS. STICKY CARD

In 2017, we compared pitfall traps (Fig. 1a) to sticky cards (Fig. 1b) to monitor adult movement from the soil in 2 sites; Fulton1 was planted to corn, and Fulton2 to soybean. These fields had a history of *M. formosae* infestation in high-sand areas. In each, a high-risk area was divided into an 8 × 5 grid of 40 plots, measuring 30 × 30 m. The total area was about 2 ha. A pitfall trap and a sticky card pair were placed in each plot, approximately 3 m apart in the same row, and checked each wk from 5 Jul to 26 Jul. Pitfall traps consisted of a 0.95 L white plastic deli container (11.4 cm W × 14.0 cm H) filled with water and a few drops of dish soap to break surface tension. These were placed in the ground with the lip of the container flush with the soil surface. Each wk, the contents of each pitfall trap were sieved into plastic bags and stored in 80% ethanol until sorting. We counted the number of *M. formosae* adults per trap in the lab. Yellow sticky cards (7.6 cm W × 12.7 cm L) (Olson Products, Inc., Medina, Ohio, USA) were placed about 1.2 m above the ground by securing each to the topmost hook of a plastic fence post hook with a zip tie. The beetles were counted each wk from each card, and cards were replaced as necessary.

ADULT SAMPLING AT THE FIELD EDGE: BLACKLIGHT VS. MILKJUG TRAP

In 2018, we evaluated the blacklight trap (Fig. 1c) and milkjug trap (Fig. 1d) at 2 sites (Table 1) to monitor adult flight. We placed 1 blacklight bucket trap (BioQuip Products, Inc., Rancho Domingo, California, USA) on a single field edge at each site. Each trap was powered daily from dusk until dawn using a solar timer with a 12V battery. We also evaluated 4 milkjug traps at each location to assess the milkjug trap with and without potential influence from the blacklight trap. One milkjug was placed 100 m away from the blacklight trap on the same field edge. The other 3 milkjugs were placed individually in the middle of each of the other field edges. Each milkjug trap consisted of a plastic 3.8 L milkjug with 2 large holes cut in the 2 sides opposite the handle to allow insects to enter the trap. Each milkjug was filled about 5.1 cm with Meijer RV Ethanol Anti-Freeze (propylene glycol, ethanol, and glycerin) (Meijer, Inc., Grand Rapids, Michigan, USA). This brand was used in western bean cutworm milkjug traps which attracted *M. formosae* in previous seasons (DiFonzo 2011; MacKellar 2011). The handles of the blacklight and milkjug traps were secured to 1.8 m tall t-posts at a height of 1.4 m using 2 zip ties. After 1 wk, the contents of each trap were emptied into individual Ziploc® bags (S. C. Johnson, Racine, Wisconsin, USA), and the number of adults were counted and sexed (Pekarcik et al. 2022). Traps were set up on 28 Jun and checked on 5 Jul to coincide with peak adult activity based on findings from Experiment 1. Trap contents were stored in a −20 °C freezer until they were processed.

In 2021, an experiment was set up at Fulton3 (Table 1) to compare adult attraction to milkjug traps containing water, Prestone Antifreeze+Coolant for All Vehicles (ethylene glycol, diethylene glycol, and proprietary inhibitors) (Prestone Products Corporation, Lake Forest, Illinois, USA), and Meijer RV Ethanol Anti-Freeze (propylene glycol, ethanol, and glycerin). Milkjugs were set up as previously described and arranged in a 3 × 4 grid using a randomized complete block design with 4 replicates per treatment. Each milkjug was placed about 30 m apart from neighboring milkjugs in an area of a soybean field with known grub infestation. The contents of each milkjug were collected every 7 d for 2 wk from 14 Jul to 28 Jul, and the number of *M. formosae* were counted and sexed (Pekarcik et al. 2022) in the laboratory.

STATISTICAL ANALYSIS

Pitfall Trap vs. Sticky Card

For each site, the average number of beetles sampled per plot across all sampling dates was analyzed for normality using PROC UNI-

Table 1. Field locations used to sample *Maladera formosae* adults in northern Ohio in 2017 and 2018. Sampling method abbreviations are as follows: BL = blacklight trap; MJ = milkjug trap; PT = pitfall trap; SC = sticky card.

Site name	Latitude, longitude	Nearest city	Year	Crop	Sampling methods
Fulton1	41.617739°N, 84.134506°W	Wauseon, Ohio	2017	Corn	SC, PT
			2018	Soybean	MJ, BL
Fulton2	41.639311°N, 84.177732°W	Wauseon, Ohio	2017	Soybean	SC, PT
Fulton3	41.623311°N, 84.091459°W	Wauseon, Ohio	2021	Soybean	MJ
Erie	41.357701°N, 82.517535°W	Huron, Ohio	2018	Corn	MJ, BL

Fig. 1. Sampling methods for *Maladera formosae* adults: within field – pitfall trap (a) and yellow sticky card (b); at field edge – blacklight trap (c), and antifreeze milkjug trap (d). Photo credit: Adrian Pekarcik, The Ohio State University, Wooster, Ohio, USA.

VARIATE (SAS 2013). Data for each site were non-normal ($P \leq 0.05$) and were fit to various distribution models using PROC GENMOD (SAS 2013) with a log-link function. The goodness-of-fit chi squared test indicated that the negative binomial distribution model would be appropriate for both Fulton1 ($\chi^2 = 162.6$; df = 156; $P = 0.3$) and Fulton2 ($\chi^2 = 138.7$; df = 156; $P = 0.8$) datasets.

We first compared the proportion of plots from which the pitfall trap and sticky cards sampled beetles in separate analyses for Fulton1 and Fulton2 using McNemar's test with PROC FREQ (SAS 2013). Each pitfall trap and sticky card pair per plot were treated as a matched pair for the analysis (Fagerland et al. 2013). We then compared the average number of adults trapped by either the sticky card or pitfall trap in separate analyses for Fulton1 and Fulton2 using a generalized linear mixed model with negative binomial distribution and log-link function in PROC GLIMMIX (SAS 2013). Sampling method was designated as a fixed effect, and sampling date as a random effect with subject designated as the sampling method nested within plot. Mean comparisons tests conducted using a simulated LS means at a $P \leq 0.05$ level. We used the adaptive Gaussian quadrature maximum likelihood estimation method to satisfy convergence criterion (Booth et al. 2003).

We performed additional analyses on the pitfall trap dataset to further scrutinize adult population densities over time. We used repeated measures analysis of variance to compare the number of beetles trapped (by only the pitfall traps) across all evaluation periods using PROC GLIMMIX (SAS 2013). We designated site, evaluation period, and site*evaluation period interaction as fixed effects and performed mean comparisons tests using a simulated LS means at a $P \leq 0.05$ level. The site ($F = 90.0$; df = 1, 312; $P < 0.0001$) and the site*date interaction ($F = 10.8$; df = 3, 312; $P < 0.0001$) were significant in the model for pitfall trap data, so the model was rerun in separate analyses by site with date as the only fixed effect.

Blacklight vs. Milkjug Trap

The total number of adults trapped per blacklight trap and antifreeze milkjug trap were compared in separate analyses for Erie and Fulton1 with Fisher's Exact test using PROC FREQ (SAS 2013).

The number of adults trapped in milkjugs at Fulton3 containing water, ethylene glycol antifreeze, or propylene glycol antifreeze were compared in separate analyses by sample wk with 1-way ANOVA using PROC MIXED (SAS 2013). Mean comparisons tests were conducted using Tukey-Kramer's post hoc test with LS means ≤ 0.05.

Results

ADULT SAMPLING WITHIN FIELDS: PITFALL TRAP VS. STICKY CARD

The number of beetles trapped by pitfall traps was much greater than by sticky cards at Fulton1 ($F = 48.2$; df = 1,315; $P < 0.0001$) and Fulton2 ($F = 19.3$; df = 1,315; $P < 0.0001$) (Table 2). Sticky cards captured virtually no *M. formosae*. There was just a single beetle in each of the 2 fields in 40 sample locations over a 4-wk period. At least 1 beetle was captured in 29 of 40 traps (72.5%) at Fulton2 and in all 40 traps (100%) at Fulton1, while the sticky card (2.5%) sampled a single beetle from a single plot at each site ($S = 26.1$; $P < 0.0001$). In contrast, the average number of beetles per trap over the 4-wk sample period was about 9 in Fulton1 and 1 in Fulton2; Fulton1 was a corn field rotated out of soybean.

The number of beetles significantly varied over time at Fulton1 ($F = 38.3$; df = 3,156; $P < 0.0001$; Fig. 2a), and Fulton2 ($F = 4.0$; df = 3,156; $P = 0.009$; Fig. 2b). Beetle densities were greatest from 28 Jun to 5 Jul, and from 5 Jul to 12 Jul at Fulton1 and Fulton2, respectively. In Fulton1, planted to corn, beetle catch was highest between 28 Jun and 5 Jul, averaging 23 beetles per pitfall. Catch dropped off significantly thereafter. In Fulton2, planted to soybean, catch was highest between 5 Jul and 12 Jul, a wk later than Fulton1. However, catch was a fraction of Fulton1, averaging only 2 beetles per pitfall on 12 Jul.

Table 2. Mean number of *Maladera formosae* adults captured by pitfall trap and on sticky card between 5 and 26 Jul in 2 high risk fields in northwest Ohio in 2017. Uppercase letters next to the reported means indicate significant differences at the $P \leq 0.05$ level from pairwise comparison analyses.

Trap	Fulton1	Fulton2
Sticky card	0.025 ± 0.006 B	0.025 ± 0.006 B
Pitfall trap	8.675 ± 1.427 A	0.894 ± 0.190 A

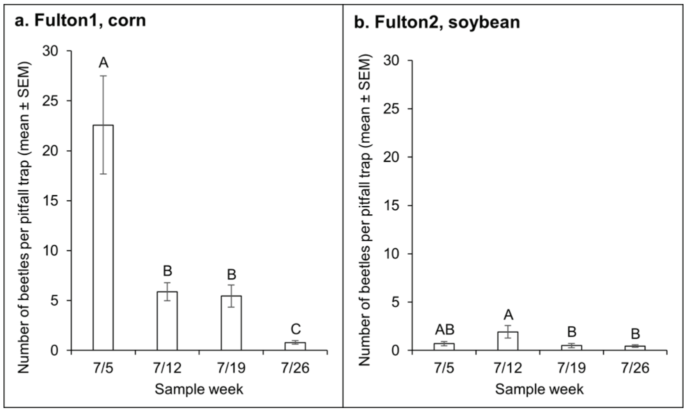

Fig. 2. Mean number of *Maladera formosae* adults captured in pitfall traps during individual evaluation periods at Fulton1 (a) and Fulton2 (b) sites, in northwest Ohio. Uppercase letter(s) above each bar indicates significant differences at the $P \leq 0.05$ level from pairwise comparison analyses. Traps were deployed on 28 Jun 2017, 1 wk prior to the sampling data indicated in each figure.

ADULT SAMPLING AT THE FIELD EDGE: BLACKLIGHT VS. MILKJUG TRAP

A total of 1,326 beetles were captured at field edges: 792 at Erie (corn) and 539 at Fulton1 (soybean). There was a significant difference in the number of beetles caught by trap type ($P < 0.0001$). The blacklight trap accounted for 97.6% of the total, or 1,299 beetles, including 773 at Erie and 526 at Fulton1. Only 32 beetles (2.4% of total) were caught in the milkjug traps. At Erie, the milkjugs opposite and near the blacklight trap captured 6 and 7 beetles, respectively. Milkjugs placed on the field edges to the left and right of the blacklight trap had 0 and 4 beetles, respectively. At Fulton1, the milkjug trap near the blacklight captured 8 beetles, but none on the opposite field edge. The other traps located along the left and right field edges from the blacklight trap had 1 and 4 beetles, respectively. All beetles were sexed in the lab; in the blacklight traps 98.5% of the beetles were male, and in the milkjug traps all (100%) were male.

There were significant differences in the number of adults trapped by milkjugs containing different liquids (Fig. 3). From 14 to 21 Jul, more adults were trapped in milkjugs with propylene glycol antifreeze than ethylene glycol antifreeze or water, which did not vary from another ($F = 9.56$; df = 2,9; $P = 0.006$; Fig. 3a). Similar trends were observed from 21 to 28 Jul ($F = 8.41$; df = 2,9; $P = 0.009$; Fig. 3b). Across both sampling periods, 95.6% of the 443 beetles trapped by all milkjugs were male.

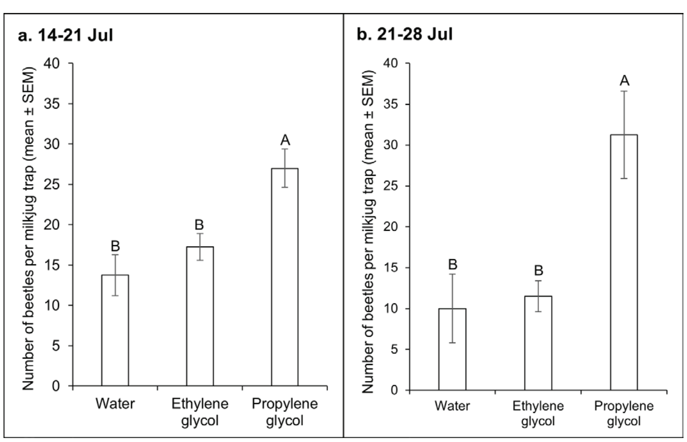

Fig. 3. Mean number of *Maladera formosae* adults captured in milkjug traps containing either water, ethylene glycol antifreeze, or propylene glycol antifreeze, from 14 to 21 Jul 2021 (a) and from 21 to 28 Jul 2021 (b) in soybean at the Fulton3 site near Wauseon, Ohio. Uppercase letter(s) above each bar indicates significant differences at the $P \leq 0.05$ level from pairwise comparison analyses.

Discussion

Adult oviposition is responsible for the distribution of the grubs which can become significant agronomic pests the following spring. It is important to identify useful sampling methods to monitor beetle abundance and distribution and predict future grub infestations for both research and management purposes. This study is the first to evaluate the sticky card and milkjug trap in field crops for adult localized movement within the field and aerial flight at the field edges. For research purposes it may be more informative to monitor localized adult movement within the field because beetles become active on the ground at a lower temperature (15 °C) than that at which actual flight occurs (21 °C) (Hallock 1936a). Activities like feeding, mating, and oviposition can occur below the temperature threshold of flight. Yellow sticky cards failed to capture adult beetles. Adults may be attracted to colors other than yellow that were not evaluated in this study, or are non-responsive to color since they are nocturnal (Meyer-Rochow and Gokan 1987).

Pitfall traps worked well in this study and allowed for relative comparisons of beetle numbers over time (sample wk) in different crops (corn and soybean). Although we did not have an absolute sampling method with which to make comparisons, *M. formosae* was the most abundant species trapped in this study. These findings are consistent with Perry et al. (2020) who identified *M. formosae* as the most abundant beetle species collected in pitfall traps in urban plots in Cleveland, Ohio, USA. Early pitfall catches likely reflect adult emergence out of the soil and may be useful in identifying peak emergence. It is also possible that adults captured in pitfall traps after peak activity are attracted to moisture for egg laying. Hallock (1936a) demonstrated that mated females seeking oviposition were attracted particularly to moist sites where eggs would not dry out. Further work is needed to better distinguish adult emergence (from pupa) from localized movement around the soil. Regardless, pitfall traps are an easy-to-implement monitoring tool for farmers and can be implemented with a plastic cup and water and checked as needed.

Blacklight traps captured large numbers of beetles near corn and soybean, several hundred within a wk, as previously reported in the literature (Hallock 1932, 1936b; Chong & Hinson 2015; Eckman 2015). Hallock caught about 300,000 beetles in a single light trap at a golf driving range in New Jersey, USA, in 1935 (Hallock 1936a). Although the blacklight provided information on timing and level of movement outside the field, it did not provide direction. Were beetles moving into or out of the field, or were they simply drawn to the light from afar? Nearly all the beetles (98.5%) at both sites over the 1-wk sampling period were male. This finding is consistent with Hallock (1936c) who reported that males emerged first in horticultural systems of New York, USA. However, beetles were sexed during this study only from a 1-wk period of light trapping. It is possible that females were present later in the summer and were missed due to the narrow sampling window.

The milkjug trap attracted beetles in this study, albeit far fewer than the blacklight trap. We determined that beetles were most attracted to milkjug traps containing propylene glycol antifreeze versus water or ethylene glycol antifreeze. The chemical composition of the antifreeze might be attractive. For example, 2,3-butanediol (i.e., dimethylene glycol) is an antifreeze agent (Soltys et al. 2001) that attracts other beetle species (Bengtsson et al. 2009). It is unknown why the beetles are attracted to the milkjug in general, although the moisture itself might be a factor. Adults are sensitive to soil moisture (Hallock 1930, 1933, 1936c) and are known to prefer moist environments (Hallock 1936a). Ultimately, this monitoring method may be a simple alternative for farmers because the traps are cheap and easy to make and do not require electricity as do blacklight traps. Furthermore, it has much less bycatch to sort (i.e., moths, midges, leafhoppers, and other night flying insects attracted to lights), and would allow for simultaneous monitoring of *S. albicosta* and *M. formosae*.

Here we have identified low-tech and inexpensive tools that can be used to monitor for *M. formosae* adult ground movement (pitfall traps) and flight (milkjug traps) in either a research or management context. Blacklight traps may have the greatest utility when large numbers of beetles need to be captured for research purposes. The distance from which milkjugs vs. blacklights attract beetles is a topic for future research. Though the techniques we examined do not illuminate the origin of captured beetles, they can provide both farmers and researchers information about the presence and relative abundance of this species at a given place and time.

Acknowledgments

We would like to acknowledge our anonymous collaborators who allowed this research to be conducted on their private farms. We extend thanks to Michael Gastier and Garth Ruff, Ohio State University extension educators from Erie and Henry counties, respectively, who identified and facilitated relationships with the collaborators for this study. We also would like to thank Ross Andre, Allyson Lombardo, Amberleigh Ray, Kathryn Suggs, and Megan Zerrer for their technical assistance with this study.

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