Scientific Notes

Evaluating effects of harmonic radar tag attachment on the survivorship and dispersal capacity of *Riptortus pedestris* (Hemiptera: Alydidae)

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The use of radar systems for entomological research offers new opportunities that allow continuous tracking of individual insects under natural field conditions. Since the 1980s, studies using harmonic radar techniques have generated direct measures of insect movement compared with conventional methods such as mark-release-recapture (Chapman et al. 2011). A unique feature of the harmonic radar systems is that the radar tag does not rely on battery power, allowing them to be lightweight. For example, the harmonic radar tag used for the brown marmorated stink bug (*Halyomorpha halys* [Stål]; Hemiptera: Pentatomidae) was 9 mm long and weighed approx. 3 mg (Lee et al. 2013, 2014). Indeed, harmonic radar systems have been used to study movements of a wide range of insects including the honey bee, forest tent caterpillar moth, Asian longhorned beetle, plum curculio, Colorado potato beetle, and large carabids (Chapman et al. 2011; Lee et al. 2014).

Riptortus pedestris (F.) (Hemiptera: Alydidae) is a polyphagous pest causing significant economic losses to soybean, especially in Korea and Japan (Kim et al. 2014). Both adults and nymphs feed on soybean pods causing crop damage over the season. Anecdotal evidence indicates that *R. pedestris* is highly mobile seeking suitable host plants and capable of avoiding chemical insecticides with its high flight activity. Therefore, it is crucial to understand the spatial and temporal distribution of *R. pedestris* populations in order to develop effective monitoring and management programs. Conventionally, traps baited with the aggregation pheromone of *R. pedestris* have been used to obtain indirect measures of the insect movement patterns in the field. However, no study has attempted to individually track *R. pedestris* in the field to study its dispersal capacity and behavior.

Harmonic radar systems require reliable radar tag attachment on target insects as a prerequisite to their use in the field. Moreover, radar tag attachment should not affect insect survivorship or mobility compared with untagged individuals. In the present study, we demonstrated procedures to securely attach harmonic radar tags on *R. pedestris* adults and examined any potential negative effects of the radar tag attachment on survivorship, walking capacity, and flight capacity of *R. pedestris*.

Adults of *R. pedestris* used in this study were collected using cylinder traps (15 cm diameter, 34 cm long) baited with the aggregation pheromone of *R. pedestris* (Greenagrotech Inc., Gyeongsangbuk-do, South Korea). Traps were deployed in a wooded area in Seongnam-si, Gyeonggi-do, South Korea (37.4503167°N, 127.1306639°E). Insects were collected every 3 d from the traps. Collected *R. pedestris* were brought immediately to the laboratory and held at 23 °C, 46% RH, and a photoperiod of 12:12 h L:D. Insects were maintained in meshed cages (60 × 60 × 60 cm) provided with bean plants (*Phaseolus vulgaris* L.; Fabales: Fabaceae), dried soybean, and dried peanuts. Harmonic radar tags were made following the methods described by Lee et al. (2013). The dipole radar tags were made of a small copper wire (9 mm long, 0.16 mm diameter), and the final weight of the radar tag was approx. 3.0 mg (Fig. 1).

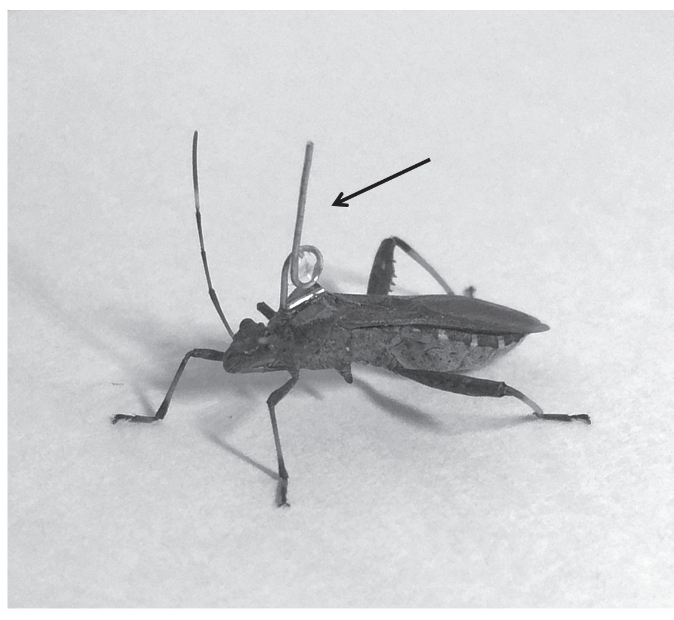

Fig. 1. Adult *Riptortus pedestris* with a dipole harmonic radar tag. The arrow indicates the radar tag attached on the pronotum.

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A laboratory experiment was conducted to determine whether sanding the pronotum of adult *R. pedestris* could significantly increase the adhesive bond strength of cyanoacrylate glue between the pronotum and the radar tag. Pronotal sanding was demonstrated previously as an effective way to remove cuticular waxes on the insect pronotum and thereby increase the quality of the glue bond between radar tag and insect (e.g., Lee et al. 2013). For sanded individuals, the pronotum was sanded lightly approx. 10 times with fine sandpaper (P600), and the droplet of cyanoacrylate glue (Loctite, Henkel Corporation, Rocky Hill, Connecticut, USA) was applied in the middle of the pronotum. Then, a radar tag was mounted carefully on the glued area and held for approx. 10 s to maintain the upright position of the tag on the insect (Fig. 1). For control, the radar tag was attached to the pronotum of *R. pedestris* without the pronotal sanding treatment. Test insects were placed individually into 100 mL plastic cups (6 cm diameter, 6 cm tall) and dropped 5 times from 2 m above the ground in the laboratory. After dropping the cup, we checked if the tag had remained attached to the pronotum.

The possible effects of radar tag attachment on the survivorship of *R. pedestris* were evaluated in the laboratory. Radar tags were attached to *R. pedestris* after the pronotal sanding as described above. The survivorship of radar-tagged *R. pedestris* was measured and compared with that of untagged individuals over 14 d. The insects were kept individually in 500 mL plastic cups (8 cm diameter, 15 cm tall) provided with dried soybean, dried peanut, and wet tissue at 21 ± 1 °C, 46 ± 10% RH, and a photoperiod of 12:12 h L:D.

The vertical mobility of *R. pedestris* was compared between untagged and radar-tagged individuals in the laboratory. Individuals were placed inside and at the base of a cylinder (5 cm diameter, 40 cm tall) made of metal mesh. If the insect climbed up 30 cm in the cylinder, then the cylinder was inverted. The total vertical distance climbed by *R. pedestris* for 10 min was recorded at 21 ± 1 °C and 46 ± 10% RH.

The possible impact of radar tag attachment on the flight behavior of *R. pedestris* was evaluated under field conditions by comparing untagged individuals with radar-tagged ones. The insects were tested individually in an open field to determine if they successfully took off and made sustained flight. Individuals were released at the center of a soccer field (37.4550722°N, 127.1351583°E) and given 3 min each to initiate flight. Time duration from release to take-off, flight direction, and the success or failure to make >30 m sustained flight were recorded.

In all tests, 30 individuals were tested for each treatment. The Fisher's exact test or chi-square test was used to compare proportional data sets (i.e., survivorship and success rates). The mean values were compared using the *t*-test and the data were log-transformed for normality if needed (SAS 9.3, SAS Institute, Cary, North Carolina, USA).

Results showed that there was no measurable statistical difference in the radar tag retention between unsanded (87%) and sanded (100%) *R. pedestris* in the dropping test (Fisher's exact test: $P = 0.1124$). Although statistical difference was not significant, the removal of cuticular waxes by sanding made it much easier for experimenters to hold and attach the radar tag in a proper position (Fig. 1). Furthermore, no adverse effect of the pronotal sanding was detected in previous studies (e.g., Lee et al. 2013) or in this study (see below). For this reason, we applied the pronotal sanding before attaching the radar tags in the following experiments.

Survivorship of radar-tagged *R. pedestris* (57%) was not significantly different from that of untagged individuals (60%) over 14 d ($\chi^2 = 0.069$, df = 1, $P = 0.7934$). Vertical walking capacity of *R. pedestris* was not affected by the radar tag attachment compared with untagged individuals. There was no significant difference in the distance climbed by *R. pedestris* for 10 min in the laboratory climbing test arena ($t = 0.58$, df = 58, $P = 0.5657$) (Fig. 2A). Likewise, there was no difference in the flight capacity and behavior of *R. pedestris* between untagged and radar-tagged treatments. No difference was found in the time duration from release to take-off ($t = 0.93$, df = 51, $P = 0.3563$) (Fig. 2B). The success rates of making >30 m sustained flight were 60 and 73% for untagged and radar-tagged individuals, respectively ($\chi^2 = 0.675$, df = 1, $P = 0.4113$). In the flight test, 3 untagged and 4 radar-tagged individuals did not take flight. In addition, the prevailing flight directions of *R. pedestris* were to the east from the release point in untagged and radar-tagged treatments (data not shown).

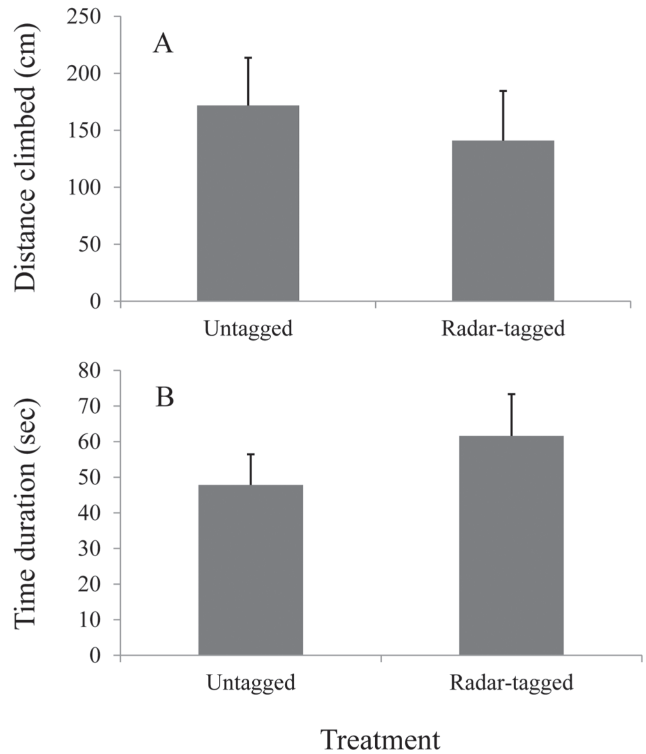

Fig. 2. Vertical distance (mean ± SE) climbed by *Riptortus pedestris* for 10 min in the laboratory climbing test arena ($n = 30$) (A). Time duration (mean ± SE) from release to take-off of *R. pedestris* under field conditions ($n = 27$ for untagged and 26 for tagged) (B).

Our results clearly support that the use of harmonic radar systems can be an effective method to track individual *R. pedestris* in the field without changing survivorship, walking mobility, or flight capacity. Lee et al. (2013) also reported no adverse effects of the same radar tagging on the survivorship and dispersal capacity of the larger pentatomid *H. halys*; in this species, the pronotal sanding substantially increased the adhesive strength of the same glue on the pronotum. The understanding of dispersal capacity and behavior will serve as baseline information to design and enhance monitoring and management tools for highly mobile heteropteran pests such as *R. pedestris*. Future studies using the radar systems should address the dispersal pattern of *R. pedestris* and its spatial–temporal dynamics in conjunction with the phenology of host plants at landscape levels.

I thank Minhyung Jung, Hongrae Jang, and Suji Kang for technical support. This research was funded by National Research Foundation of Korea (Grant #: NRF-2014R1A1A2056993).

Summary

We demonstrated procedures to securely attach harmonic radar tags on adult *Riptortus pedestris* (F.) (Hemiptera: Alydidae) and verified

that there were no detectable adverse effects of radar tag attachment on insect survivorship, or on walking or flight capacity. Thus, future studies should focus on individual-based tracking of *R. pedestris* to understand the dispersal capacity and pattern of this pest at landscape levels. These efforts will help us enhance monitoring and management tools for *R. pedestris*.

Key Words: soybean pest; harmonic radar technique; monitoring; flight dispersal

Sumario

Demostramos procedimientos para fijar con seguridad etiquetas radar armónicas en adultos de *Riptortus pedestris* (F.) (Hemiptera: Alydidae) y verificamos que no hubo efectos adversos detectables de las etiquetas de radar pegadas sobre la sobrevivencia de los insectos, o su capacidad de caminar o volar. Por lo tanto, los estudios futuros deben centrarse en el seguimiento de base individual de *R. pedestris* para entender la capacidad de dispersión y el patrón de esta plaga a nivel de campo. Estos esfuerzos nos ayudarán a mejorar las herramientas de seguimiento y manejo para *R. pedestris*.

Palabras Clave: plagas de soja; técnica de radar armónico; monitoreo; dispersión de vuelo

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