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Improved Traps for Monitoring *Riptortus pedestris* Thunberg (HEMIPTERA: ALYDIDAE) in Soybean Field

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ABSTRACT

The bean bug, *Riptortus pedestris*, is one of the most economically salient pests of leguminous crops in Korea. It damages crops by sucking pods and fruits. We evaluated various types of rocket traps, along with wing colors and combinations of landing boards of various colors, in soybean field in South Korea. We developed a modified rocket trap intended to enhance the capture efficacy of stink bugs in the field. We evaluated (1) rocket traps with black, green, yellow, and white color stimuli and (2) traps with a wing and landing board. Our results showed that black wings with a black landing board attracted significantly more *R. pedestris* than other traps. Use of this improved trap combination would therefore enhance the monitor and capture of *R. pedestris* in various agroecological landscapes. The potency of these traps with a specific color, combination of features, and modifications to monitor *R. pedestris* are accurately discussed. Continued improvement to traps to address the demands of pest evolution and subtleties of cropping seasons are required.

Key words: Hemipterans, wing and landing board, hue combination, monitoring, management

Introduction

In Korea and Japan, *Riptortus pedestris* is one of the most salient pests in several legumes, cereals, and fruit crops (Chung *et al.*, 1995; Leal *et al.*, 1995; Kim *et al.*, 1997; Kang *et al.*, 2003; Choi *et al.*, 2005; Lee *et al.*, 2007; Kim and Lim, 2012). Adult bugs and nymphs damage seeds and fruits by piercing and sucking (Chung *et al.*, 1995; Son *et al.*, 2000; Choi *et al.*, 2005), and they can reduce seed quality, germination potential, and yield (Todd and Turnipseed, 1974; Jensen and Newsom, 1972; McPherson *et al.*, 1979; Panizzi *et al.*, 1979; Brier, 1993).

Stink bugs have conventionally been managed with chemical insecticides (Nielsen *et al.*, 2008a; Leskey *et al.*, 2012a; Lee *et al.*, 2013). However, monitoring and managing *R. pedestris* is difficult for growers because of their high mobility, insecticide-avoidance behavior (Choi *et al*., 2005), and lack of reliable monitoring and decision-making tools; these cause growers to resort to frequent application of broad-spectrum insecticides (McPherson and McPherson, 2000; Wada *et al*., 2006; Leskey *et al*., 2012a, c; Pfeiffer *et al*., 2013). Frequent use of insecticides leads to negative consequences, such as decreased natural enemies, secondary pest outbreaks, and severely disrupted pest management programs (Leskey *et al*., 2012b, d). Underlying those facts, establishing and validating reliable monitoring tools for *R. pedestris* are critical. Early population detection can help to reduce the application of chemical insecticides and promote the use of alternative pest management tactics.

Various types of traps baited with species-specific pheromones are used in pest monitoring programs. Hue-based traps have been widely used for monitoring several insects both outdoors and in greenhouses (Matteson and Terry, 1992; Teulone *et al*., 1999; Blackmer *et al*., 2004, 2006; Demirel and Cranshaw, 2006), and their use has several advantages (Millar and Strickler, 1984). Although infestations of *R. pedestris* bugs and their distribution have been increasing in Korea, there is limited information on improved traps for use against them. Few studies have examined the effects of trap design on bugs captured (Prokopy *et al*., 1979; Villavaso, 2004). Recently, Bae *et al*. (2017) examined the effects of improved rocket traps and bait combinations for hemipterans; however, they did not examine combinations of wing color and landing boards for rocket traps. In this study, we compared traps with different combinations of wing color and landing board as well as traps of different colors and investigated the field responses of *R. pedestris*.

Materials and Methods

Rocket trap: standard design and our modifications

Commercially available rocket traps (Fig. 1) have four corrugated plastic fins at the base; each fin is 23-cm high and joined at the edges, such that they form four entryways for insects to crawl upward. A circular acrylic plate (17 cm in diameter) with a sliding lock is fitted on the top of the fins, 15 cm from the bottom. The upper portions of the fins join and taper to form a cone (18-cm high and 17 cm in diameter). The top of the acrylic cylinder on the top of the fins is covered by a white transparent circular acrylic lid (17 cm in diameter). This dome prevents insect escape and allows volatile olfactory attractants to move upward out of the entrapment chamber. At the top of the trap is a hook for easy hanging (Bae *et al*., 2017).

We modified this standard trap by adding a circular landing board to provide a wider space for the bugs to land and to prevent adults and nymphs dropping from the trap (Figs. 1 and 2). The landing board employed in this study was a single circular landing board (30 cm in diameter), matching the trap color, that was attached at the base of the corrugated plastic fins (Figs. 1 and 2).

Selection of traps for evaluation

To assess the effects of visual cues, four differently colored traps were deployed, named based on the color of Velcro attached to the fins: black wing (BlW), green wing (GW), yellow wing (YW), and white wing (WW) rocket traps. Four traps with both colored wings and landing board were also used: black wing and black landing board (BlW+BlL), green wing and green landing board (GW+GL), yellow wing and yellow landing board (YW+YL), and white wing and white landing board (WW+WL) (Fig. 2).

Comparison of trap efficacy

Our study was conducted in 2016 in soybean field of 2.5 ha in Miryang, Korea. All traps were baited with an aggregation pheromone of *R. pedestris* (75 μL/lure) [(E)-2-hexenyl (E)-2-hexenoate, (E)-2-hexenyl (Z)-3-hexenoate & myristyl isobutyrate] (Leal *et al*., 1995). The traps were hung on steel rods with brackets approximately 90 cm above the ground in the soybean field. The positions of the traps were randomly assigned, maintaining at least 10 m between traps, and each trap was randomly rotated from its original position in 10-day intervals. Traps were installed on August 5 in the soybean field. Bugs were collected every 5 days in labeled mesh bags. Bugs (nymphs and adult males and females) were monitored until the end of September, when the soybean plants are in podding stage

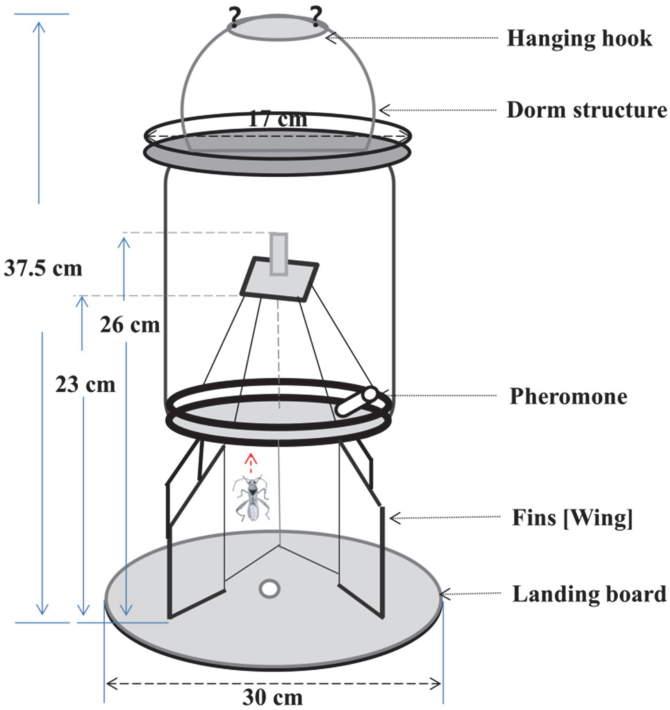

Fig. 1. Modified rocket trap with wing colors and landing boards along with dimensions baited with aggregation pheromone of *Riptortus pedestris* (Drawing: R. Maharjan)

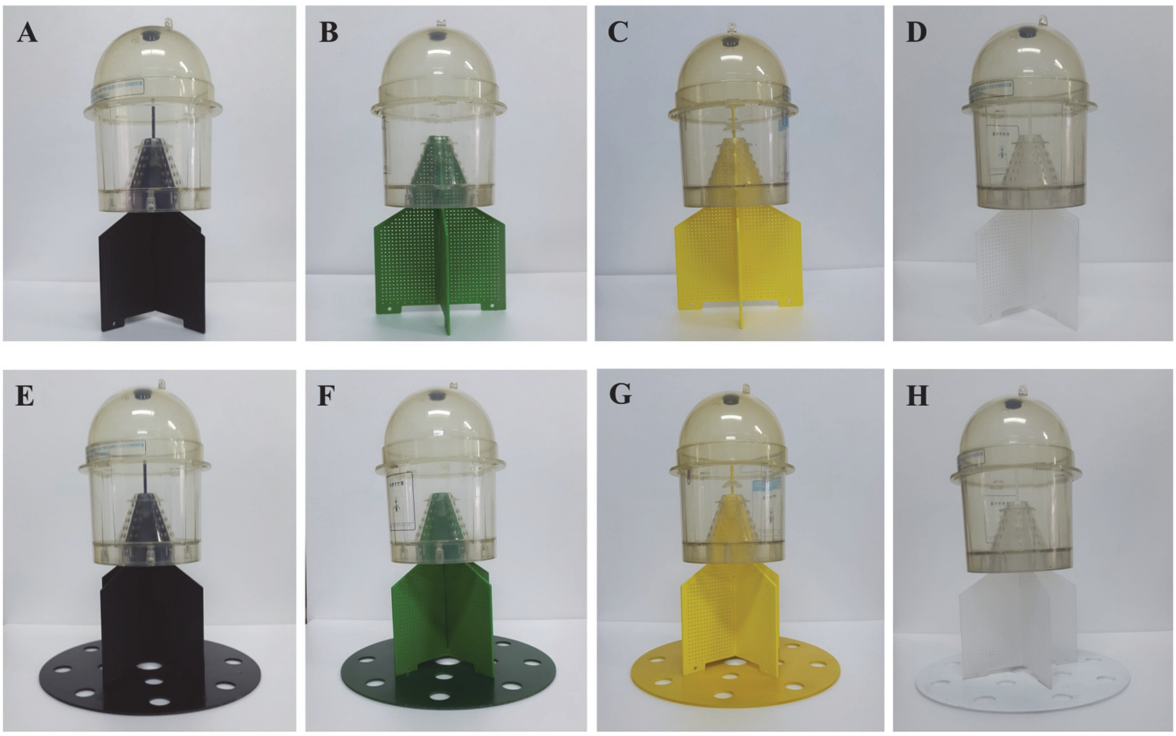

Fig. 2. Different types of rocket traps used in this study; A. black wing, B. green wing, C. yellow wing, D. white wing; and wing color and landing board combinations: E. black wing + black landing board, F. green wing + green landing board G. yellow wing + yellow landing board, and H. white wing + white landing board

Table 1. Mean (± SE) *Riptortus pedestris* in aggregation pheromone of *R. pedestris*-baited traps in soybean field

Trap		No. of stink bug captured / Trap			
Type	Wing and landing board combinations	Stages of *R. pedestris*			
		Female	Male	Nymph	Total
Rocket	BlW	27.42 ± 3.7b	18.73 ± 2.3b	0.73 ± 0.4a	46.88 ± 6.0b
	GW	25.55 ± 3.7b	18.52 ± 2.5b	0.67 ± 0.4a	44.73 ± 6.3b
	YW	23.15 ± 3.7b	15.94 ± 2.5b	0.48 ± 0.3ab	39.58 ± 6.2b
	WW	22.33 ± 3.3b	16.24 ± 2.0b	0.33 ± 0.2b	38.91 ± 5.1b
	BlW+BlL	34.55 ± 4.2a	25.85 ± 3.0a	0.61 ± 0.3ba	61.00 ± 6.9a
	GW+GL	28.45 ± 3.8ab	20.55 ± 2.3ab	0.55 ± 0.4ab	49.55 ± 6.1b
	YW+YL	27.52 ± 4.4b	18.55 ± 2.8b	0.67 ± 0.3a	46.73 ± 6.9ab
	WW+WL	27.67 ± 4.7b	17.18 ± 2.4b	0.39 ± 0.2b	45.24 ± 7.0b

Note: wing color: BlW: Black wing, GW: Green wing, YW: Yellow wing, WW: White wing; wing and landing board combinations: BlW+BlL: Black wing + black landing board, GW+GL: Green wing + green landing board, YW+YL: Yellow wing + yellow landing board, and WW+WL: White wing + white landing board

Means (5 days) in the same column followed by same letters are not significantly different (ANOVA, $p<.05$, Tukey's test).

and consider as the optimum time for monitoring and control bugs. Three of each trap were deployed.

Statistical analyses

Data on bug trap captures were square-root transformed as required to meet the assumptions of normality and homogeneity of variance. When data could not be normalized through this transformation, they were ranked and analyzed using ANOVA. Data for experiments were pooled for a seasonal total, and the effectiveness of each trap was evaluated through one-way ANOVA to determine whether trap catches comprised a single insect species. In case of trap catches with more than one species or sex, two-way ANOVA based on PROC GLM (SAS Institute, 2000) was used to determine the interaction between species and trap types.

Results

Comparison of trap efficacy

In the soybean field, traps baited with the aggregation pheromone of *R. pedestris* significantly influenced the seasonal catch of *R. pedestris* compared with control (F=19.02, df=26,768, $p<.0001$). The highest number of adults was captured in the traps with black wings and a black landing board (BlW+BlL) (Table 1). Trap type (F=2.20, df=8,768, p=.0323) and insect stage (F=206.96, df=2,768, $p<.0001$) significantly affected trap capture. However, no differences were found in the interactions between the trap type and insect stage (F=0.59, df=16,768, p=.8755) (Table 1). Based on mean captures, the black wing trap with black landing board was the most attractive combination to *R. pedestris* throughout the trapping period (Fig. 3).

Discussion

Traps must be efficient and accurately detect the pest population for pest management programs to be successful. Usually, traps are designed to target a single insect species based on responses to visual, gustatory, or olfactory stimuli (Russo *et al*., 2011). We aimed to develop a trap that would attract and kill as many individuals as possible of the major hemipteran bugs in leguminous crop fields in Korea. In pest management programs, several color-based traps have been used for monitoring insect species, such as stink bugs (Hogmire and Leskey, 2006); mirid *Lygus* bugs (Blackmer *et al*., 2008); the cicadellid, *Dalbulus maidis* (Delong and Wolcott) (Todd *et al*., 1990); and the thrips, *Frankliniella occidentalis* (Pergande) (Roditakis *et al*., 2001; Chen *et al*., 2004).

We tested variously colored modified traps (wing and landing board combinations) and found that more adult *R. pedestris* were

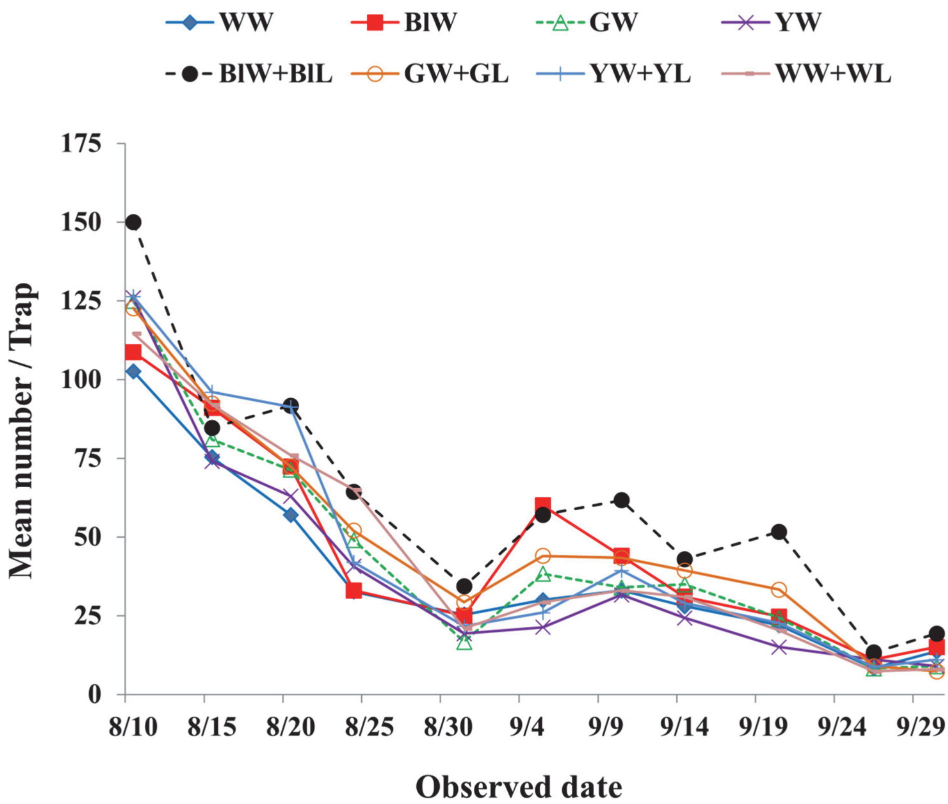

Fig. 3. Capture of *Riptortus pedestris* in various types of rocket trap baited with aggregation pheromone of *R. pedestris* in soybean field in 2016. BlW: Black wing, GW: Green wing, YW: Yellow wing, WW: White wing. Wing color and landing board combinations: BlW+BlL: Black wing + black landing board, GW+GL: Green wing + green landing board, YW+YL: Yellow wing + yellow landing board, and WW+WL: White wing + white landing board

captured in the black winged trap with a black landing board (Table 1), a finding similar to those of Leskey *et al*. (2012c) and Nielsen *et al.* (2013), who reported that black pyramid traps and black light traps, respectively, were effective for capturing the brown marmorated stink bug (*Halyomorpha halys*). The higher capture of *R. pedestris* in our black wing and landing board trap might also be caused by trunk-mimicking (Tedders and Wood, 1994). However, our results contrast those of Hogmire and Leskey (2006), who found higher captures of stink bugs in clean (no visual stimulus), green, and white pyramid traps than in black pyramids and only medium-level captures in yellow traps. This discrepancy might be caused by differences in geographical surroundings near the monitoring sites, host plants, or the designs of traps employed, because we used rocket traps and they used conventional pyramid traps.

From this study, a black color rocket trap with a landing board captured the highest number of *R. pedestris*, providing an efficient sampling method to monitor the spread and seasonal population dynamics of *R. pedestris*, in a wide range of legume field crops. However, the continuous modification and improvement of traps is required to respond to pest evolution and the subtleties of cropping seasons.

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改良型誘蟲器用以監測大豆田中點蜂緣蝽 (*Riptortus pedestris* Thunberg) (半翅目：蛛緣蝽科)

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摘　要

點蜂緣蝽 (*Riptortus pedestris* Thunberg) 是韓國豆科作物中最具經濟重要性的害蟲之一。牠經由吸食果莢與果實而為害作物。本研究主要希望能開發一種改良的火箭型誘蟲器，藉以提高田間誘捕蝽項的效率。我們在韓國南部的大豆田中，評估了不同組合的誘蟲器，包括翼片 (wing) 與著陸板 (landing board) 的顏色及有無，對誘蟲效果之影響，結果顯示具黑色翼片及黑色著陸板的誘蟲器誘到的點蜂緣蝽數量顯著地比其他組合誘蟲器為多；因此，使用這種改良型誘蟲器將可強化在各種農業生態系中對點蜂緣蝽的監測和誘捕。在本研究，我們已對這些具特定顏色與結構組合的誘蟲器對點蜂緣蝽的誘捕效力進行詳細的討論；然而，本誘蟲器仍需配合害蟲演化上的差異與作物耕作季節的不同而持續進行改良，以達最佳誘蟲效力。

關鍵詞：半翅目、翼片及著陸板、色調組合、監測、害蟲管理