Potential of Unmanned Aerial Sampling for Monitoring Insect Populations in Rice Fields

Authors: Kim, Hong Geun, Park, Jong-Seok, and Lee, Doo-Hyung

Source: Florida Entomologist, 101(2) : 330-334

Published By: Florida Entomological Society

URL: https://doi.org/10.1653/024.101.0229

Potential of unmanned aerial sampling for monitoring insect populations in rice fields

Hong Geun Kim[1], *Jong-Seok Park*[2], *and Doo-Hyung Lee*[1,*]

Recently, remote-controlled unmanned aerial vehicles have gained popularity as a new platform to monitor and manage agricultural threat agents in various crop fields (Schmale III et al. 2008). Previous studies have demonstrated successful use of unmanned aerial vehicles to detect and control weeds and insect pests (Rasmussen et al. 2013; Shields & Testa 1999; Zhang & Kovacs 2012; Lopez-Granados 2010; Tan & Tan 2013; Tahir & Brooker 2009). For example, Park et al. (2017) developed unmanned aerial vehicles equipped with an aerial release system to disseminate a biological control agent, *Rhinoncomimus latipes* Korotyaev (Coleoptera: Curculionidae), to control an invasive weed, *Persicaria perfoliata* L. (Polygonaceae), in the United States. The aerial delivery system makes it possible to conduct spatial targeting and precision release of the biological control agents, overcoming challenges with the current visit-and-hand-release approach. Shields and Testa (1999) demonstrated the value of using a remotely piloted vehicle to study the role of weather fronts and changes in barometric pressure on fall migratory flight initiation of the potato leafhopper, *Empoasca fabae* Harris (Hemiptera: Cicadellidae). In addition, a recent civilian application for autonomous unmanned aerial vehicles allows aerobiological sampling up to 300 m above crop fields (Schmale III et al. 2008), and the release of new operational rules for unmanned aerial vehicles by the National Airspace System has opened up the possibility of large-scale deployment of unmanned systems for pest management (Park et al. 2017).

Despite progress in aerial sampling with unmanned aerial vehicles in the past decade, the use of unmanned aerial vehicles in agricultural fields or forests has been limited to a few countries including the United States, China, and Japan (Keller & Shields 2014; Ivošević et al. 2015; Xiongkui et al. 2017). Indeed, very few attempts have been made in other countries, including South Korea, to develop and apply unmanned aerial vehicles for aerial sampling in agricultural fields. Recently in South Korea, Ivošević et al. (2015) used unmanned aerial vehicles to acquire photographs and videos for monitoring birds as well as landscapes in areas that are difficult to access. In South Korea, unmanned aerial vehicles have promising potential for monitoring and management of insect pests, especially in rice fields. The acreages of vegetable and fruit fields in South Korea are fairly small and their distribution is fragmented, whereas rice fields are typically much larger, consisting of continuously neighboring plots on the flat cropping areas. For example, the agricultural area for rice paddy was reported to be 754,785 ha, but red pepper, a major vegetable crop, was only 28,329 ha in South Korea (KOSTAT 2017). Also, muddy pads of rice fields make it difficult for growers to actively scout their fields on a regular basis and to use monitoring tactics such as deployment of attractive traps in the fields. Moreover, agricultural communities in South Korea have become one of the most rapidly aging societies (Choi & Yoon 2012), and this socio-economic problem is a barrier to implement labor-intensive pest monitoring programs. Under the current circumstances, unmanned aerial vehicles could serve as a promising alternative to conventional monitoring methods by providing large-scale, fast, and accurate surveillance. Finally, the major pest complex of rice fields in South Korea consists of migratory planthoppers (e.g., brown planthopper (*Nilaparvata lugens* Stål), small brown planthopper (*Laodelphax striatellus* Fallén), and white-backed rice planthopper (*Sogatella furcifera* Horváth) (all Hemiptera: Delphacidae)) and moths (e.g., rice leaf roller (*Cnaphalocrocis medinalis* Guenée) (Lepidoptera: Crambidae) and rice armyworm (*Mythimna separata* Walker) (Lepidoptera: Noctuidae)), that emigrate from China in the spring. For this reason, unmanned aerial vehicles can be very useful for early detection of spring migratory flight of the pest complex at the west coast of the Korean Peninsula, or above rice fields. In fact, there have been monitoring programs to intercept the rice pests in the spring migratory flight, but the monitoring tool for aerial sampling was limited to stationary 10-m-high insect nets (1 m diam) at the border of rice fields in South Korea (RDA 2016).

In this study, we developed a rotary-wing unmanned aerial system (Fig. 1a) with 2 remote-controlled insect nets (28 × 32 cm [diam × length]) (Fig. 1b) that allows aerial sampling exclusively at designated altitudes. The unmanned aerial vehicle and insect net system were developed and assembled by Korea Aero Models Association, Seoul, South Korea. The main body (1.45 × 1.45 × 0.6 m [L × W × H], 7.1 Kg without battery) was made with a carbon fiber frame, carbon-30 (Artcopter, Paju, South Korea). It had 8 motors (MT3520 kv400, T-motor, Nanchang, China) with a flight controller (DJI A2, DJI, Shenzhen, China). With a separate remote controller, the insect nets were switched from the default position (facing downward) to the collecting position (facing the upwind direction) once the unmanned aerial vehicle reached its designated altitude. Then, the position of the net opening was reversed (facing downward) after the unmanned aerial vehicle had completed a 5 min sampling flight. The target altitudes for sampling were 5, 10, 50, and 100 m above the ground. We conducted a total of 21 sampling flights above a rice field (ca. 80 × 240 m) at Chungcheongnam-do, South Korea (36.3866°N, 126.5702°E) in Jun, Jul, and Aug 2017 to evaluate the potential of using the unmanned aerial vehicle to survey an aerial insect complex. All flights were manually operated by a remote pilot with an instructor's license, and who attempted to maintain a designated altitude with consistent flight speed. The flight altitude and speed were recorded using a GPS system on board (Garmin Edge

[1]Department of Life Sciences, Gachon University, Seongnam-si, 13120, South Korea; E-mail: hgkimkr@gmail.com (H. G. K.); dl343@gachon.ac.kr (D. H. L.)
[2]Department of Biology, Chungbuk National University, Cheongju-si, 28644, South Korea; E-mail: jpark16@chungbuk.ac.kr (J. S. P.)
*Corresponding author; E-mail: dl343@gachon.ac.kr

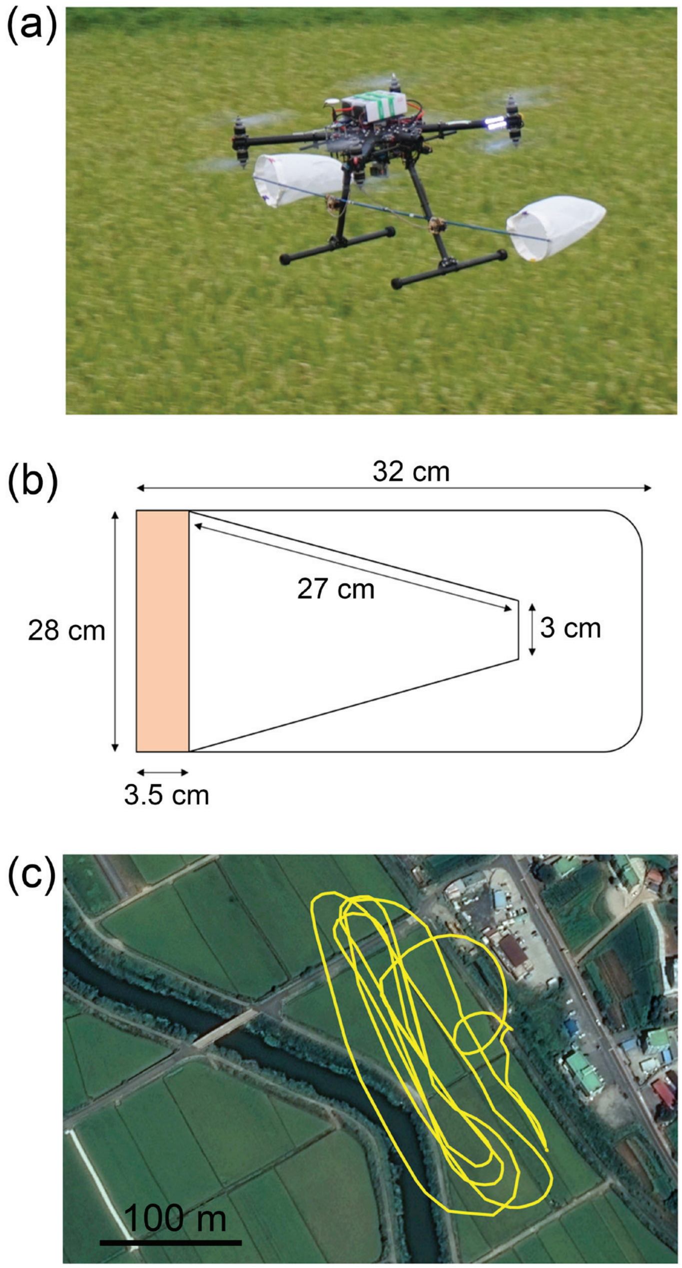

Fig. 1. Rotary-wing unmanned aerial vehicle equipped with remote-controlled insect net openings (a). Layout of double-layered insect net designed to prevent loss of insect samples during aerial sampling (b). Representative flight path of unmanned aerial vehicle for aerial sampling over rice field (c).

500, Garmin Ltd., Olathe, Kansas, USA). The data was not transmitted to the pilot in real time but retrieved after terminating the flight. The environmental conditions, flight information, and the results of aerial sampling are summarized in Table 1. Flight paths were typically in oval shapes to evenly cover the area of the rice field (Fig. 1c), and flight distances ranged from 1.06 to 2.45 km during the 5 min duration of the flight, depending on wind direction and speed during the sampling. In general, there was less than 10 m difference between the designated and actual flight altitudes (Table 1).

Among the 21 flights, 12 flights captured at least 1 arthropod yielding a total of 253 arthropods (251 insects and 2 spiders) in 6 orders and 22 families. (Hereafter, the 2 arachnid individuals were not included in data analysis.) A total of 235, 7, 6, and 3 insects were captured over 5-min flights at 5, 10, 50, and 100-m altitudes, respectively. The unusually high catch at 5 m sampling was due to the fact that 222 individuals were captured from 1 sampling event during a 5 m high flight on Aug 30. Among them, 205 individuals were Diptera, including Chironomidae and Phoridae. A recent survey in South Korea found 41 species of Chironomidae (Na et al. 2010), but only 2 chironomid midges, *Cricotopus oryzaphagos* Ree & Kim and *C. sylvestris* Swartz, have been reported to damage rice during the germination and young plant stages (Ree & Kim 1998). To our knowledge, there have been no reports of significant damage by Phoridae in rice fields in South Korea, whereas the phorid fly, *Megaselia* sp., is known to attack eumenid wasps near rice in Japan (Itino 1986). Hemiptera was the second-most abundant group, yielding 12 individuals, mostly in the family Aphididae. Yano et al. (1983) reviewed the biology and economic importance of rice aphids (Hemiptera: Aphididae) addressing 37 species and indicated that 3 species (*Aphis craccivora* Koch, *Myzus persicae* Sulzer, and *A. gossypii* Glover) (Hemiptera: Aphidae) are found sporadically on rice. Also, in our sample a specimen of Hemiptera was identified as a planthopper (Delphacidae). In South Korea, 3 migratory planthopper species (*N. lugens*, *L. striatellus*, and *S. furcifera*) are major rice pests, causing serious economic losses in rice fields (Son et al. 2014; Otuka et al. 2012). Among Hymenoptera, 3 individuals in the families Eulophidae, Aphelinidae, and Figitidae were collected. Eulophidae and Aphelinidae include beneficial parasitic wasps, and some species have been found in rice fields in South Korea and Iran (Bayegan et al. 2015; Kim et al. 2015). From the order Coleoptera, 4 individuals in families Ptiliidae and Staphylinidae were identified. Both families belong to Staphylinoidea, which are generally known as facultative predators or as scavengers, though only limited information is available for Ptiliidae. In addition, several members in Ptiliidae and Staphylinidae are facultative or obligatory fungal spore or pollen feeders (Betz et al. 2003). Lastly, 1 insect in the order Thysanoptera was captured, but damaged, making it impossible to identify to the family level. Thysanoptera are known as a serious pest complex in diverse crops and include rice thrips such as *Stenchaetothrips hifarmis* Bagnall (Thysanoptera: Thripidae) (Velusamy & Saxena 1991).

The results of this study indicate that aerial sampling using unmanned aerial vehicles can serve as an alternative to conventional sampling methods such as stationary 10-m-high insect nets in rice fields. Indeed, 21 aerial sampling flights captured a total of 251 insects in 22 families, most of which include major pest and beneficial species reported in rice fields in South Korea. Aerial sampling of insects over 10 m in height in South Korea rice fields was conducted for the first time in this study and revealed that both potential pests and beneficials were present in the air up to 100 m from the ground. It is noteworthy that the aerial sampling captured delphacids and thysanopterans, some of which are listed as major pests on rice in South Korea (RDA 2016). Although the pest complex was not monitored directly from rice in the current study, further study should address relationships between aerial samples and actual pest pressure on the crop. Then, given that the use of unmanned aerial vehicles is portable, this approach would provide a great predictive tool for early detection of the migratory planthopper complex emigrating from China to the west coast of the Korean Peninsula. Lastly, it is also noteworthy that 29 out of 251 insects were damaged during the aerial collecting making it difficult to identify them to the level of insect family.

This study was supported by a grant from the Agenda program (Project No. PJ01230702), Rural Development Administration, South Korea. We would like to thank Jongheon Lee at Korea Aero Models Association for excellent flight control.

Table 1. Environmental conditions, flight information, and results of aerial sampling using a rotary-wing unmanned aerial vehicle with remotely controlled insect nets.

Date	Flight number	Flight time	Temperature (°C)	Relative humidity (%)	Designated flight altitude (m)	Actual flight altitude (m) (Mean ± SE)	Flight distance (km)	No. of samples	Arthropod sample Order	Family	Remark
24 Jun 2017	1	5:58–6:05 PM	23.8	67	10	6.3 ± 1.6	1.30	1	Diptera	Ephydridae	
	2	6:18–6:25 PM	24.4	71	100	98.1 ± 0.7	1.36	0	-	-	
	3	6:36–6:43 PM	24.2	76	50	43.5 ± 2.8	1.40	1	Diptera	Ephydridae	
								1	Diptera	Unknown	Sample damaged
								1	Hemiptera	Delphacidae	
25 Jun 2017	4	8:26–8:33 AM	26.3	63	100	100.1 ± 1.9	2.38	1	Hemiptera	Aphididae	
	5	8:42–8:50 AM	25.9	65	50	62.7 ± 11.5	2.45	1	Diptera	Unknown	Sample damaged
								1	Hemiptera	Aphididae	
	6	9:01–9:07 AM	26.2	65	10	10.5 ± 1.5	1.44	4	Diptera	Unknown	Sample damaged
								1	Hymenoptera	Eulophidae	
	7	9:24–9:30 AM	28.1	65	5	3.4 ± 1.6	1.30	1	Diptera	Chironomidae sp.1	
								1	Diptera	Chloropidae	
								1	Diptera	Sciaridae	
								2	Diptera	Unknown	Sample damaged
27 Jul 2017	8	5:20–5:26 PM	31.5	63	50	56.2 ± 3.5	2.26	0	-	-	
	9	5:43–5:49 PM	31.6	66	10	13.4 ± 1.9	1.37	0	-	-	
	10	6:13–6:20 PM	31.6	66	100	98.5 ± 2.0	2.35	0	-	-	
28 Jul 2017	11	8:16–8:23 AM	30.4	67	50	35.5 ± 1.5	1.47	1	Araneae	-	
	12	8:39–8:46 AM	29.7	68	100	98.1 ± 0.8	2.05	0	-	-	
	13	8:58–9:05 AM	30.0	68	10	7.4 ± 0.8	1.29	0	-	-	
30 Aug 2017	14	5:11–5:17 PM	24.9	48	10	n/a*	n/a*	1	Diptera	Chironomidae sp.2	
	15	5:29–5:35 PM	25.2	51	50	37.1 ± 1.7	1.96	0	-	-	
	16	5:51–5:59 PM	23.6	54	100	96.4 ± 1.0	1.66	1	Hymenoptera	Eulophidae	
								1	Diptera	Unknown	Sample damaged
	17	6:09–6:16 PM	23.2	57	5	1.7 ± 0.7	1.50	2	Coleoptera	Ptiliidae	
								2	Coleoptera	Staphylinidae	
								1	Diptera	Asteiidae	
								13	Diptera	Ceratopogonidae	
								1	Diptera	Chironomidae sp.1	
								29	Diptera	Chironomidae sp.2	
								54	Diptera	Chironomidae sp.3	
								53	Diptera	Chironomidae sp.4	
								1	Diptera	Drosophilidae	
								2	Diptera	Phoridae sp.1	
								19	Diptera	Phoridae sp.2	
								17	Diptera	Phoridae sp.3	
								15	Diptera	Unknown	Sample damaged
								8	Hemiptera	Aphididae	
								1	Hymenoptera	Aphelinidae	

*n/a: flight information was not recorded due to technical problems with GPS system.

Table 1. Environmental conditions, flight information, and results of aerial sampling using a rotary-wing unmanned aerial vehicle with remotely controlled insect nets.

Date	Flight number	Flight time	Temperature (℃)	Relative humidity (%)	Designated flight altitude (m)	Actual flight altitude (m) (Mean ± SE)	Flight distance (km)	No. of vsamples	Arthropod sample Order	Family	Remark
								1	Hymenoptera	Eulophidae	
								1	Hymenoptera	Figitidae	
								2	Unknown	-	Sample damaged
31 Aug 2017	18	8:27–8:34 AM	22.4	69	10	9.1 ± 0.4	1.56	0	-	-	
	19	8:45–8:53 AM	22.9	70	50	36.1 ± 0.5	1.65	1	Araneae	-	
								1	Diptera	Chironomidae	
	20	9:15–9:23 AM	24.3	65	100	97.2 ± 1.1	1.64	0	-	-	
	21	9:50–9:57 AM	29.0	53	5	3.0 ± 0.8	1.06	3	Diptera	Chironomidae	
								3	Thysanoptera	Unknown	Sample damaged
								1	Hemiptera	-	
								1	Hemiptera	Aphididae	

*n/a: flight information was not recorded due to technical problems with GPS system.

Summary

Conventionally, sampling for insects has been limited to the ground level or low altitudes. Recent progress in unmanned aerial vehicles has made it more feasible to use this technique for aerial sampling of insect populations. In this study, we developed a rotary-wing unmanned aerial vehicle with remote-controlled insect net openings that allows serial sampling at designated altitudes. A total of 21 flights using the unmanned aerial vehicle system captured 251 insects in 6 orders and 22 families at 5, 10, 50, and 100 m above rice fields in South Korea. The results of this study demonstrate that the aerial sampling can collect diverse pest and beneficial insects above rice fields and demonstrate a promising alternative to conventional sampling methods.

Key Words: insect sampling; unmanned aerial vehicle; drone

Sumario

Convencionalmente, el muestreo de insectos se ha limitado al nivel del suelo o a bajas altitudes. El progreso reciente en vehículos aéreos no tripulados ha hecho que sea más factible utilizar esta técnica para el muestreo aéreo de poblaciones de insectos. En este estudio, desarrollamos un vehículo aéreo no tripulado de ala giratoria con aberturas de red de insectos controladas a distancia que permite el muestreo en serie a altitudes designadas. Un total de 21 vuelos que utilizan el sistema de vehículo aéreo no tripulado capturaron 251 insectos en 6 órdenes y 22 familias a 5, 10, 50 y 100 m sobre el campo de arroz en Corea del Sur. Los resultados de este estudio demuestran que el muestreo aéreo puede recolectar diversas plagas e insectos beneficiosos por encima del campo de arroz y demuestra una alternativa prometedora a los métodos de muestreo convencionales.

Palabras Clave: muestreo de insectos; vehículo aéreo no tripulado (VANT); dron; arroz; monitoreo

Reference Cited

Bayegan ZA, Lotfalizadeh H, Zargaran MR. 2015. Occurrence of eulophid wasps (Hymenoptera: Chalcidoidea, Eulophidae) in rice fields of eastern Guilan, Iran. Journal of Crop Protection 4: 199–205.

Betz O, Thayer MK, Newton AF. 2003. Comparative morphology and evolutionary pathways of the mouthparts in spore-feeding Staphylinoidea (Coleoptera). Acta Zoologica 84: 179–238.

Choi JH, Yoon HW. 2012. The changing spatial patterns of aging population in Korea. Journal of the Korean Geographical Society 47: 359–374.

Itino T. 1986. Comparison of life tables between the solitary eumenid wasp *Anterhynchium flavomarginatum* and the subsocial eumenid wasp *Orancistrocerus drewseni* to evaluate the adaptive significance of maternal care. Researches on Population Ecology 28: 185–199.

Ivošević B, Han YG, Cho Y, Kwon O. 2015. The use of conservation drones in ecology and wildlife research. Ecology and Environment 38: 113–188.

Keller MD, Shields EJ. 2014. Aerobiological sampling efficiency of media-containing Petri plates for use in lower atmosphere spore collection. Aerobiologia 30: 103–109.

Kim YJ, Lee JH, Back K, Kim CG. 2015. Arthropod diversity and community structure in fields of non-genetically modified (GM) and herbicide-tolerant GM Rice. Korean Journal of Applied Entomology 54: 335–343.

KOSTAT. 2017. Cultivated area of rice and pepper in 2017. http://kostat.go.kr/portal/eng/pressReleases/2/1/index.board?bmode=read&bSeq=&aSeq=363405&pageNo=1&rowNum=10&navCount=10&currPg=&sTarget=title&sTxt= (last assessed 27 Nov 2017).

Lopez-Granados F. 2010. Weed detection for site-specific weed management: mapping and real-time approaches. Weed Research 51: 1–11.

Na KB, Ree HI, Jung SW, Bae YJ. 2010. Chironomidae (Diptera) fauna of Seoul-Gyeonggi area in Korea. Entomological Research Bulletin 26: 59–67.

Otuka A, Zhou Y, Lee GS, Matsumura M, Zhu Y, Park HH, Liu Z, Sanada-Morimura S. 2012. Prediction of overseas migration of the small brown planthopper, *Laodelphax striatellus* (Hemiptera: Delphacidae) in East Asia. Applied Entomology and Zoology 47: 379–388.

Park YL, Gururajan S, Thistle H, Chandran R, Reardon R. 2017. Aerial release of *Rhinoncomimus latipes* (Coleoptera: Curculionidae) to control *Persicaria perfoliata* (Polygonaceae) using an unmanned aerial system. Pest Management Science 74: 141–148.

Rasmussen J, Nielsen J, Garcia-Ruiz F, Christensen S, Streibig JC. 2013. Potential uses of small unmanned aircraft system (UAS) in weed research. Weed Research 53: 242–248.

RDA. 2016. Handbook for Crop Pest Monitoring and Management. http://www.nongsaro.go.kr/portal/ps/psz/psza/contentMain.ps;jsessionid=K1xjtrkPpVuJoIL17mp05guXrPpeLZRd0pZhRnrUSInZswUA9QfdBfCOT59DNtN6.nongsaro-web_servlet_engine1?menuId=PS00200&pageIndex=2&pageSize=10&sKidofcomdtySeCode=&sYear=&sType=sCntntsSj&sText= (last assessed 27 Nov 2017).

Ree HI, Kim JY. 1998. A new species of the genus Cricotopus (Diptera: Chironomidae), a pest of rice in Seosan, Korea. Korean Journal of Biological Sciences 2: 309–313.

Schmale III DG, Dingus BR, Reinholtz C. 2008. Development and application of an autonomous unmanned aerial vehicle for precise aerobiological sampling above agricultural fields. Journal of Field Robotics 25: 133–147.

Shields EJ, Testa AM. 1999. Fall migratory flight initiation of the potato leafhopper, *Empoasca fabae* (Homoptera: Cicadellidae): observations in the lower atmosphere using remote piloted vehicles. Agricultural and Forest Meteorology 97: 17–30.

Son BI, Jung JK, Lee JH. 2014. Wing morphs and parasitism rates of the small brown planthopper, *Laodelphax striatellus* (Hemiptera: Delphacidae) in Korea. Korean Journal of Applied Entomology 53: 497–501.

Tahir N, Brooker G. 2009. Feasibility of UAV based optical tracker for tracking Australian plague locust. Australasian Conference on Robotics and Automation (ACRA 2009). Sydney, Australia. http://www.araa.asn.au/acra/acra2009/papers/pap140s1.pdf (last assessed 28 Feb 2018).

Tan LT, Tan KH. 2013. Alternative air vehicles for sterile insect technique aerial release. Journal of Applied Entomology 137: 126–141.

Velusamy R, Saxena RC. 1991. Genetic evaluation for resistance to rice thrips (Thysanoptera: Thripidae) in leafhopper- and planthopper-resistant rice varieties. Journal of Economic Entomology 84: 664–668.

Xiongkui H, Bonds J, Herbst A, Langenakens J. 2017. Recent development of unmanned aerial vehicle for plant protection in East Asia. International Journal of Agricultural and Biological Engineering 10: 18–30.

Yano K, Miyake T, Eastop VF. 1983. The biology and economic importance of rice aphids (Hemiptera: Aphididae): a review. Bulletin of Entomological Research 73: 539–566.

Zhang C, Kovacs JM. 2012. The application of small unmanned aerial systems for precision agriculture: a review. Precision Agriculture 13: 693–712.