A journal of world insect systematics

INSECTA MUNDI

0850

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Date of issue: January 29, 2021

Center for Systematic Entomology, Inc., Gainesville, FL

Suh S-J, Choi D-S, Na S-M. 2021. Occurrence status of the fall armyworm (Lepidoptera: Noctuidae) in South Korea. Insecta Mundi 0850: 1–5.

Published on January 29, 2021 by
Center for Systematic Entomology, Inc.
P.O. Box 141874
Gainesville, FL 32614-1874 USA
http://centerforsystematicentomology.org/

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Printed copies (ISSN 0749-6737) annually deposited in libraries

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Electronic copies (Online ISSN 1942-1354) in PDF format

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Occurrence status of the fall armyworm (Lepidoptera: Noctuidae) in South Korea

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Abstract. To respond to the growing risk from *Spodoptera frugiperda* (J.E. Smith), the migratory fall armyworm (Lepidoptera: Noctuidae), the National Fall Armyworm Surveillance Program (NFASP) for early detection for this pest ran from April to November during 2019 and 2020. The fall armyworm surveillance program involved seasonal monitoring of the pest with pheromone traps placed in fields of cereal crops at high-risk locations. The trapping season ran from early spring to late autumn, with a total deployment of 396 traps. During the survey of 2019 to 2020, a total of 120 male adults of *S. frugiperda* were captured in these surveillance traps placed in South Korea. Eradication treatments using primary pesticide sprays were applied. Based on a subsequent monitoring and evaluation survey carried out simultaneously, the results indicated that the pest had been eradicated from these localities. Additionally, 20 non-target moth species were captured in the surveillance traps.

Key words. Invasive species, Migratory pest, *Spodoptera frugiperda*, surveillance.

ZooBank registration. urn:lsid:zoobank.org:pub:DBABC03A-9C81-490D-9A01-A8ECCB0E6C5E

Introduction

The genus *Spodoptera* Guenée (Lepidoptera: Noctuidae), known as armyworms, includes some of the most important pests of agricultural crops in the world. There are approximately 30 species that are distributed worldwide (Pogue 2002; Nagoshi et al. 2011). Of these, the following six species of *Spodoptera* have been documented as occurring in South Korea: *Spodoptera apertura* (Walker), *S. depravata* (Butler), *S. exigua* (Hübner), *S. litura* (Fabricius), *S. mauritia* (Boisduval) and *S. pecten* Guenée (Paek 2010).

The fall armyworm, *Spodoptera frugiperda* (J.E. Smith) native to the Americas, is a high-impact pest that feeds on a wide variety of host plants, causing significant economic losses in many food crops such as maize (*Zea mays* L.), rice (*Oryza sativa* L.), sorghum (*Sorghum bicolor* (L.) Moench) and sugarcane (*Saccharum officinarum* L.) (Harrison et al. 2019; CABI 2020). In early 2016, this species appeared on maize crops in West Africa for the first time and had not previously been recorded outside its native range. The fall armyworm has rapidly spread to Asia and invaded the whole of Southern China since January 2019. The maize-cropping area of Northeastern China, South Korea and Japan have also been estimated to be at a high risk (Wu et al. 2019).

In response to the growing risk from the migratory fall armyworm, the National Fall Armyworm Surveillance Program (NFASP) developed by the Rural Development Administration (RDA), South Korea was initiated during the 2019 to 2020 high-risk season for monitoring the fall armyworm that is now a significant pest in southern Asia, such as China and India (Wu et al. 2019; CABI 2020). The Animal and Plant Quarantine Service

(APQS) has worked together with the NFASP to improve the surveillance effort. The RDA recognizes that the major pathway for movement of the fall armyworm into South Korea is its capacity to fly long distances and its widespread occurrence in China, which is the key source for invasive species in the region. The RDA established the NFASP to provide an early warning of fall armyworm incursions, both to facilitate eradication and to keep South Korea free from this unwanted insect pest.

The purpose of this paper is to report information based on trapping data for the fall armyworm in South Korea during 2019 to 2020.

Materials and Methods

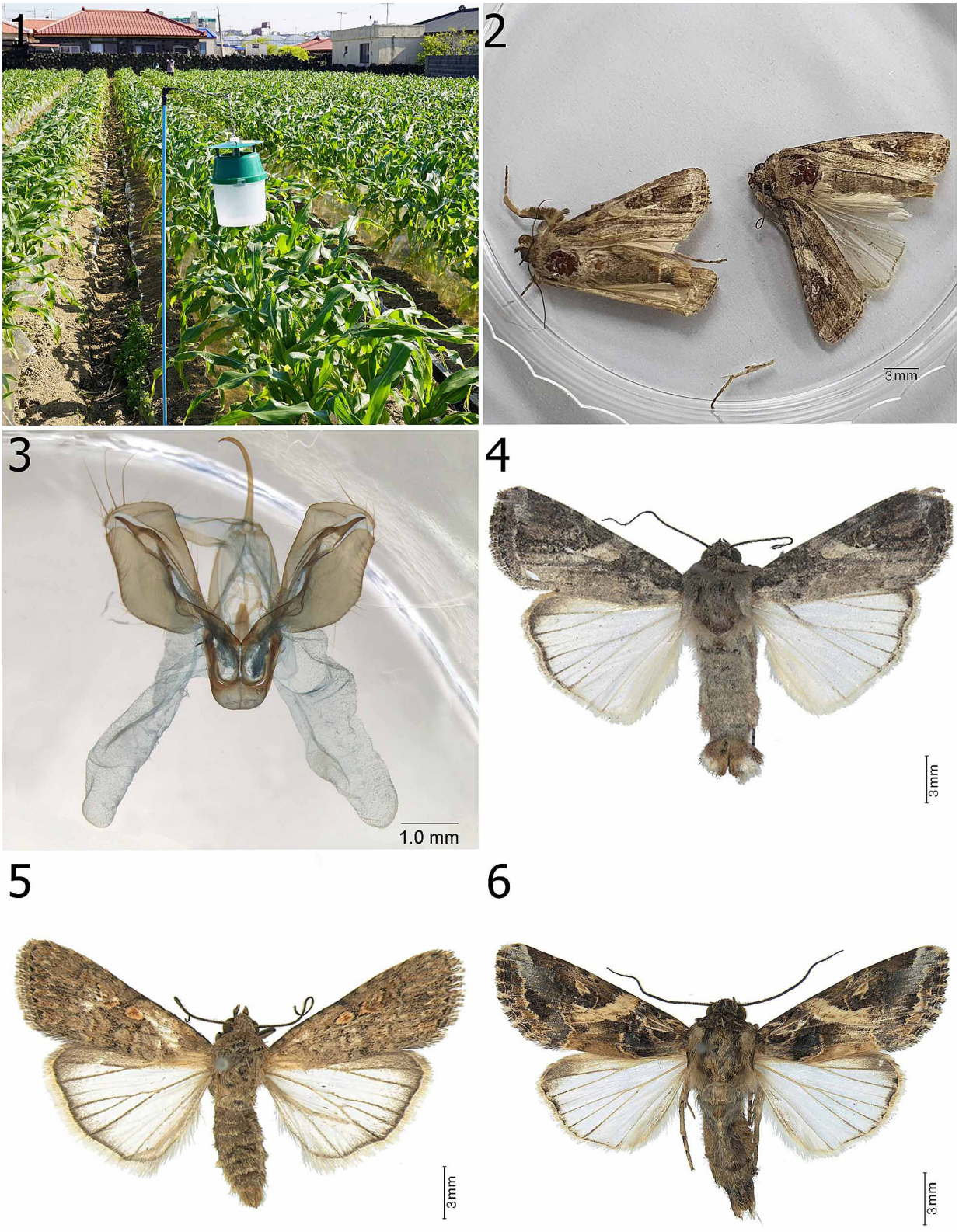
The program of seasonal monitoring for fall armyworm ran from May to October of 2019 and 2020 in most areas of South Korea (except for Jejudo and Jeollabukdo, where due to the warmer climate and high-risk sites, an extended trapping time was conducted from April to November). Approximately 396 funnel traps baited with a commercial pheromone lure (two component lure contained Z9-14:Ac and Z7-12:Ac/Greenagrotech, South Korea) were deployed on or near host crops at 249 different sites where maize crops have been cultivated in South Korea (Fig. 1). These were situated as close as possible to the coastal areas as it was thought that the pest would most likely arrive via the jet stream from the eastern part of China. Traps were placed on host plants (at 1.5 to 1.8 m from the ground) and the lures were replaced every four weeks. The traps were inspected every 10 working days. Suspect captured specimens were submitted to entomologists of the National Institute of Agricultural Science, RDA and Plant Quarantine Technology Center, APQS, South Korea for identification to the species level. The abdomens of some adult male specimens that were collected were removed, gently heated in 10% KOH, rinsed in water and stored in glycerin in microvials to examine genitalic characters (Fig. 2–3) to verify their species identity. Photographs were taken using an AxioCam MRc5 camera mounted on a ZEISS Axio Imager M2 Microscope and a Leica M165C microscope with a Spot Flex camera.

Results and Discussion

The trapping surveys ran from early spring to late autumn and these corresponded to the expected flight period for fall armyworm from China which is the key source of invasive species within the region. During the survey of 2019–2020, a total of 120 samples were collected from fall armyworm trap sites. The greatest number of captures occurred in May (67 samples) followed by October (22 samples) (Table 1). A delimiting survey was immediately implemented in areas where the pest had been collected in traps to determine the population distribution. According to the survey results, eradication treatments using primary pesticide sprays were applied. The results of a monitoring and evaluation survey carried out simultaneously indicate that the pest has been eradicated from

Table 1. Number of fall armyworm samples captured in traps in South Korea each month by region during 2019 to 2020. Abbreviations: GG, Gyeonggido; GW, Gangwondo; CN, Chungcheongnamdo, GN, Gyeongsangnamdo; JB, Jeollabukdo; JN, Jeollanamdo; JJ, Jejudo.

Period	Locality							Total
	GG	GW	CN	GN	JB	JN	JJ	
May			1	25		8	33	67
June				1	3	2	5	11
July		2	1	2		7	1	13
August					2			2
September	1				1			2
October	2				20			22
November					3			3
Total	**3**	**2**	**2**	**28**	**29**	**17**	**39**	**120**



Figures 1–6. Three species of *Spodoptera* moths. **1)** Funnel trap baited with pheromone for fall armyworm. **2–3)** *Spodoptera frugiperda* (J.E. Smith) male captured in surveillance traps and genitalia. **4)** *Spodoptera frugiperda* (J.E. Smith), male. **5)** *Spodoptera exigua* (Hübner), male. **6)** *Spodoptera litura* (Fabricius), male.

Table 2. List of non-target moths captured in the funnel traps baited with a pheromone lure for fall armyworm in South Korea.

Family	Species	Total # species
Noctuidae	*Acronicta pruinosa* (Guenée), *Amphipyra livida* (Denis and Schiffermüller), *Athetis lepigone* (Möschler), *Callopistria duplicans* Walker, *Conistra ardescens* (Butler), *Globia sparganii* (Esper), *Helicoverpa armigera* (Hübner), *Mamestra brassicae* (Linnaeus), *Mythimna compta* (Moore), *Mythimna loreyi* (Duponchel), *Mythimna separata* (Walker), *Peridroma saucia* (Hübner), *Senta flammea* (Curtis), *Spodoptera depravata* (Butler), *Spodoptera exigua* (Hübner), *Spodoptera litura* (Fabricius)	16
Erebidae	*Lymantria dispar* (Linnaeus), *Mosopia sordidum* (Butler), *Oraesia emarginata* (Fabricius)	3
Crambidae	*Goniorhynchus clausalis* Christoph	1

these localities. Samples collected in 2019 differed from those collected in 2020. In 2019, the first detection of fall armyworm in the trap was on July 17th and 10 samples were captured from traps (Suh 2020). Whereas the first detection of 2020 was on May 7th and 110 samples were captured from traps. These results could be due mainly to the migration of these moths from China. These differences should also be affected by the annual fluctuation of the density and the migration patterns of this pest in China, in relation to meteorological conditions, such as rainfall and wind. The Jejudo and Jeollabukdo provinces which are located closest to Northeastern China, are considered to be a likely point of entry for the introduction and establishment of emigrant populations of migratory insect pests from China into South Korea and were the provinces in which the most specimens of fall armyworm were collected from May to October in 2019 and 2020.

Although these pheromone traps attract the target moth, they also capture other non-target moths. Specimens of non-target moths (Lepidoptera) were mainly members of the family Noctuidae (80%); other moth families included Erebidae (15%) and Crambidae (5%) (Table 2). Moths of some species, such as *Spodoptera exigua* and *S. litura*, that were captured in the traps resemble the fall armyworm. The misidentification of the fall armyworm moth as being one of these species could lead to an erroneous application of quarantine measures (Fig. 4–6).

The fall armyworm is a migratory insect pest, in which the female adults migrate before oviposition (CABI 2020). It might be considered that the females that had arrived in South Korea started to lay eggs, bred in the summer and emerged in the autumn. This pest does not have a diapause phase and hence is only capable of overwintering in warmer climates (van Huis 1981; CABI 2020). Therefore, the fall armyworm can breed in the summer, but cannot survive over winter in the weather conditions of South Korea (Ma et al. 2019). Most of the fall armyworm (74%) were captured in the surveillance traps in spring and autumn. The percentage of detections regarded as significant has changed sharply over the two years. The likelihood that an invasive species will establish could be expected to increase with the number of individuals and the frequency of invasion.

Since the fall armyworm is an important migratory pest and very large numbers of this moth can arrive suddenly, it might constitute a severe threat to several important crops in the region, which provide a diverse source of host plants and favorable climatic conditions for reproduction in many areas (Goergen et al. 2016; Midega et al. 2018; Montezano et al. 2018). In addition, climate change has been predicted to alter the geographic range of many species, allowing the distribution of invasive species to expand (Perrings et al. 2005; Watson and Mifsud 2017). Therefore, early detection of invasive species in South Korea is critical for successful and effective of eradication programs.

Acknowledgments

We are grateful to Drs. Gregory A. Evans (USDA/APHIS/NIS, Washington, DC, USA) and Steven C. Passoa (USDA/APHIS/PPQ, Columbus, OH, USA) for reviewing the manuscript. Thanks also to the staff of APQS and RDA who collected materials for this study.

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Received December 28, 2020; accepted January 8, 2021.
Review editor Ryan St Laurent.