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Short Communication

Outbreak of an exotic flatid, *Metcalfa pruinosa* (Say) (Hemiptera: Flatidae), in the capital region of Korea

Yeyeun Kim [a], Minyoung Kim [a], Ki-Jeong Hong [b], Seunghwan Lee [a,*]

[a] *Entomology Program, Department of Agricultural Biotechnology, Research Institute for Agriculture and Life Science, Seoul National University, 599 Gwanak-ro, Gwanak-gu, Seoul, 151-921, Republic of Korea*
[b] *Pest Risk Assessment Division, National Plant Quarantine Service, 178 Anyang-ro, Manan-gu, Anyang-si, Gyeonggi-do, 430-015, Republic of Korea*

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ABSTRACT

The citrus flatid planthopper, *Metcalfa pruinosa* (Say, 1830) (Hemiptera: Flatidae), has a native distribution in eastern North America, It has recently invaded Italy in 1979 and has since spread to other European countries. In 2009, *Metcalfa pruinosa* was discovered in Seoul and the Gyeonggi Province, Republic of Korea. This is the first record in the eastern part of Palaearctic. One year after its discovery, in July 2010, we found significant populations and serious damage on many deciduous forest trees, ornamental trees, and agricultural crops in central regions of the Korean Peninsula. In this paper, we report the status of the outbreak and discuss the biology, morphological characters, distribution, host plants, and the importance of *M. pruinosa* as a potential insect pest in the Korean Peninsula.

Introduction

The family Flatidae is one of the largest groups of Fulgoroidea (Hemiptera: Auchenorrhyncha), with 918 species known worldwide (Nault and Rodriguez 1985). It is characterized among Fulgoroidea by the absence of a movable spur at the apex of the hind tibia and the presence of tubercles between the veins on the clavus of the forewing (Fletcher 1988). Only two species of Flatidae are known to be native to Korea: *Geisha distinctissima* (Walker 1858) and *Mimophantia maritima* Matsumura 1900.

The citrus flatid planthopper (CFP) originated in the Nearctic region, specifically in eastern North America, from Ontario to Florida, Mexico, and Cuba (Metcalf and Bruner 1948). In 1979, it was reported as an exotic insect pest in northern Italy (Zangheri and Donadini 1980). This was the first record of CFP out of its native distribution. Since then, it has been gradually spreading to neighboring countries: France (Della Giustina 1986), Slovenia (Sivic 1991), Great Britain (Malumphy et al. 1994), Croatia (Maceljski et al. 1995), Switzerland (Jermini et al. 1995), Spain (Pons et al. 2002), Czech Republic (Lauterer 2002), Austria (Kahrer and Moosbeckhofer 2003), Serbia and Montenegro (Hrncic 2003), Greece (Drosopoulos et al. 2004), Hungary (Orosz and Dèr 2004), Turkey (Karsavuran and Güçlü 2004), Bulgaria (Trenchev et al. 2006), Bosnia-Herzegovina (Gotlin et al. 2007), Romania (Preda and Skolka 2009), and Russia (Gnezdilov and Sugonyaev 2009).

CFP is not an economically important pest in its native region (Alma et al. 2005). However, as suggested by its common name, citrus can be damaged by this species (Dean and Bailey 1961). In Italy, the first place where it became established in Europe, the quality of grapes was reduced because of this insect. Dense CFP infestations caused stunting of shoots, reduced plant vitality, and wilting of herbaceous plants (Strauss 2010). According to Ciampolini et al. (1987), a loss of 30–40% of soybean was reported in Italy. Therefore, although CFP is generally not considered a threatening species in its native range, it becomes a hazardous pest under certain conditions, especially in the regions where it has recently invaded.

In 2009, CFP was discovered in Korea at several locations in the southern to central regions of the Korean Peninsula. It occurred discontinuously but in epidemic numbers. A wide range of host plants were observed with varying degrees of damage. Compared to the collections made in 2009, a significantly larger population of CFP was found in 2010. Here, we report on the sudden outbreak of CFP in Korea and include detailed biological, ecological, and distributional information. In addition, we compare its morphology and appearance with native Korean species of Flatidae.

Materials and methods

Adult and immature specimens were observed and collected from Mt. Umyeon in Seoul from 2009 to 2010, where serious damage was observed on host plants. They were stored both as dried specimens

* Corresponding author. Tel.: +82 2 880 4691; fax: +82 2 873 2319.
E-mail address: seung@snu.ac.kr (S. Lee).

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Fig. 1. Dorsal view of adult *Metcalfa pruinosa* (Say).

and as alcohol samples for morphological identification and molecular comparison. In order to identify the insects, dried specimens were pinned and compared with *M. pruinosa* specimens obtained from Delaware, USA. To survey the distribution, degree of damage and record the host plants in Korea, we investigated Mt. Umyeon, Mt. Gwanak, and the metropolitan landfill region in Incheon. The specimens observed are deposited in Seoul National University (SNU).

Systematic accounts

Metcalfa pruinosa (Say 1830)

Flata pruinosa Say 1830
Melormenis pruinosa Metcalf 1938
Ormenis pruinosa Melichar 1902

Diagnosis

(Figs. 1 and 2C) Length 7.0–8.5 mm. Head small, lateral margin arcuate; compound eye orange; two ocelli in lateral part of compound eye; antennae, first segment small and hard to detect, second segment swollen like a small roundish gall, third segment filamentous and short. Crown narrow and broad, posterior part covered by pronotum; pronotum large and protruding upward; forewing with waxy pruinescence except for sub-apical line, grayish color gradient from base to apex, dense venation throughout; membranous hind wing without wax, more bright gray than the front part; hind tibia simple with spine on external margin; leg slightly long.

Specimens examined

Korea: 8 adults and 2 nymphs, Mt. Umyeon, Yangjae-dong, Seocho-gu, Seoul, 13.viii.2009 (S. Kim, Y. Kim and S. Lee); 38 adults, Mt. Umyeon, Gwacheon-dong, Gwacheon-si, Gyeonggi-do, 26.vii.2010 (M. Kim, S. Lee, J. Lim and S. Shin); 25 adults and 10 nymphs, ditto, 29.vii.2010 (S. Kim, Y. Kim, S. Lee and J. Lim); 1 adult, National Academy of Agricultural Science (NAAS), Seodung-dong, Gwonseon-gu, Suwon-si, Gyeonggi-do, 26.viii.2010 (T. Han) (SNU).

Reference specimens from the United States: 2 nymphs, Newark, Delaware, 14.vi.2010 (K. Hoelmer); 46 nymphs, ditto, 17.vi.2010 (K. Hoelmer); 2 nymphs, ditto, 21.vi.2010 (K. Hoelmer); 59 nymphs, ditto, 25.vi.2010 (K. Hoelmer); 2 adults, ditto, 29.vi.2010 (K. Hoelmer); 25 adults, ditto, 30.vi.2010 (K. Hoelmer); 3 adults, ditto, 1.vii.2010 (K. Hoelmer).

Reference specimens from Europe: 50 adults, Antibes, France, 10.viii.2010. (J. C. Malausa).

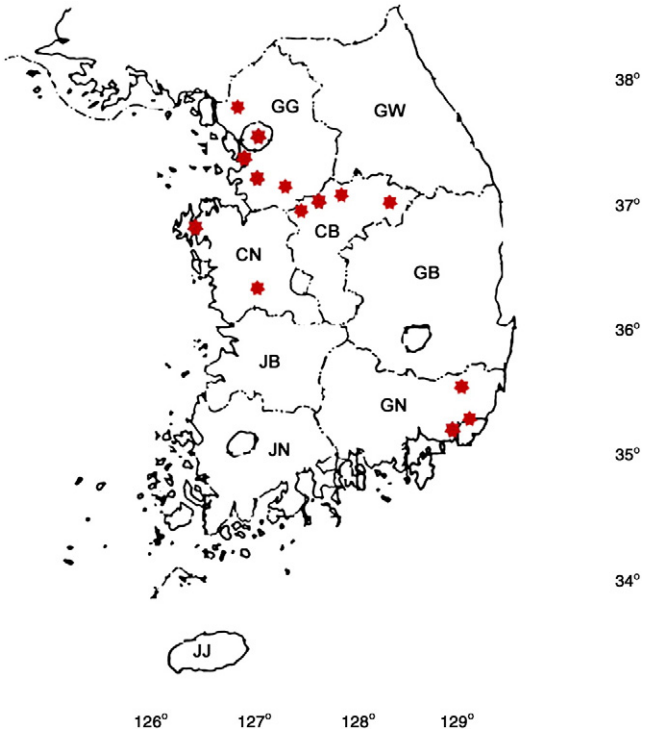

Fig. 3. Distribution of *Metcalfa pruinosa* (Say) in Korea.

Morphological comparison with other native flatid species in the Korean Peninsula

The native flatid species in Korea are *Geisha distinctissima* (Walker) (Fig. 2A) and *Mimophantia maritima* Matsumura (Fig. 2B). These two species are easily identified through their body color and size. *Geisha distinctissima* is light green and slightly reddish around the margin of wings and its size is 10.0–11.5 mm. On the other hand, *M. maritima* is straw-colored (pale brown) and about 6.0 mm long. The latter is found mainly on Poaceae weeds, while the former has a large and varied host range, mostly on woody plants, including apple, peach,

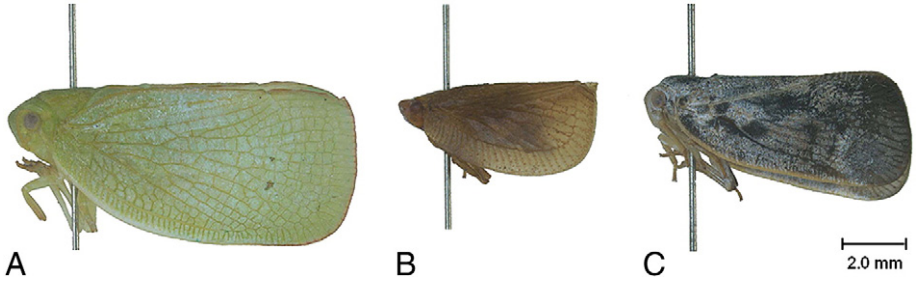

Fig. 2. Lateral views of the three species of Flatidae in Korea: (A) *Geisha distinctissima* (Walker); (B) *Mimophantia maritima* Matsumura; and (C) *Metcalfa pruinosa* (Say).

Table 1
Host plants and damage of *Metcalfa pruinosa* in Korea.

Host plants		Degree of density and/or damage observed	
Family name	Scientific name	Nymph and damage	Adult
Aceraceae	*Acer palmatum* Thunb.	+++	+++
Anacardiaceae	*Rhus chinensis* Mill.	++	+++
Anacardiaceae	*Toxicodendron vernicifluum* (Stokes) F.A. Barkley	++	++
Araceae	*Colocasia esculenta* (L.) Schott	++	
Araliaceae	*Eleutherococcus sessiliflorus* (Rupr. et Maxim.) S. Y. Hu	++	+
Asteraceae	*Ambrosia trifida* L.	++	+
Asteraceae	*Artemisia* sp.	++	
Asteraceae	*Circium setidens* (Dunn) Nakai	++	++
Asteraceae	*Cosmos bipinnatus* Cav.	++	++
Asteraceae	*Erigeron annuus* Pers.	++	
Asteraceae	*Helianthus annuus* L.		+++
Asteraceae	*Lactuca indica* L.	++	+
Balsaminaceae	*Impatiens textori* Miq.	++	++
Betulaceae	*Alnus japonica* (Thunb.) Steud.	++	++
Betulaceae	*Betula pendula* Roth	++	++
Bignoniaceae	*Campsis grandiflora* K. Schum.	++	+
Cannabaceae	*Humulus japonicus* Siebold et Zucc.	++	
Caprifoliaceae	*Weigela subsessilis* L.H. Bailey	++	++
Celastraceae	*Euonymus japonicus* Thunb.	+	+
Chenopodiaceae	*Chenopodium centrorubrum* (Makino) Nakai	++	
Convallariaceae	*Liriope platyphylla* F.T. Wang et Tang	++	
Cornaceae	*Cornus kousa* Buerger ex Miq.	+++	+++
Cornaceae	*Cornus officinalis* Siebold et Zucc.		+++
Cucurbitaceae	*Sicyos angulatus* L.	++	++
Dryopteridaceae	*Dryopteris crassirhizoma* Nakai	++	++
Ebenaceae	*Diospyros kaki* Thunb.	++	++
Ebenaceae	*Diospyros lotus* L.	+++	+++
Elaeagnaceae	*Elaeagnus glabra* Thunb.	+++	++
Elaeagnaceae	*Elaeagnus umbellata* Thunb.	++	++
Ericaceae	*Rhododendron indicum* (L.) Sweet	+++	++
Fabaceae	*Glycine soja* Siebold et Zucc.	++	
Fabaceae	*Lespedeza bicolor* Turcz.	+++	++
Fabaceae	*Pueraria lobata* (Willd.) Ohwi	++	++
Fabaceae	*Robinia pseudoacacia* L.	+++	+++
Fagaceae	*Castanea crenata* Siebold et Zucc.	+++	+++
Fagaceae	*Quercus acutissima* Carruth.	+++	++
Fagaceae	*Quercus dentata* Thunb.	+++	+++
Hostaceae	*Hosta longipes* L.H.Bailey	++	++
Hyacinthaceae	*Scilla scilloides* Druce	++	++
Lamiaceae	*Isodon japonicus* (Burm.f.) H. Hara	++	
Lauraceae	*Lindera obtusiloba* Blume	++	++
Liliaceae	*Lilium* sp.	++	++
Magnoliaceae	*Magnolia kobus* DC.	+++	+++
Malvaceae	*Hibiscus syriacus* L.	+++	+++
Moraceae	*Ficus carica* L.	+	++
Moraceae	*Morus alba* L.	+++	+++
Oleaceae	*Ligustrum obtusifolium* Siebold et Zucc.	++	++
Poaceae	*Setaria viridis* (L.) P. Beauv.	++	++
Poaceae	*Zea mays* L.	++	++
Pontederiaceae	*Monochoria plantaginea* Kunth	++	++
Rhamnaceae	*Rhamnus davurica* Pall.		+++
Rosaceae	*Malus pumila* Mill.	++	
Rosaceae	*Prunus armeniaca* L.	++	++
Rosaceae	*Prunus padus* L.	+++	++
Rosaceae	*Prunus serrulata* Lindl. f. *spontanea* (Maxim.) Chin S. Chang	+++	++
Rosaceae	*Prunus tomentosa* Thunb.	+++	++
Rosaceae	*Pyrus pyrifolia* Nakai	+++	+++
Rosaceae	*Rosa banksiae* (R.Br.)	++	+
Rosaceae	*Rosa multiflora* Thunb.	++	++
Rosaceae	*Rubus coreanus* Miq.	++	++
Rosaceae	*Rubus crataegifolius* Bunge	++	++
Rosaceae	*Sorbus alnifolia* (Siebold et Zucc.) K. Koch	+++	++
Rosaceae	*Sorbus commixta* Hedl.		+++
Rosaceae	*Spiraea simpliciflora* (Nakai) Hatus.	+++	++
Rosaceae	*Stephanandra incisa* Zabel	++	++
Salicaceae	*Salix* sp.	++	++
Simaroubaceae	*Ailanthus altissima* (Mill.) Swingle		+++
Smilacaceae	*Smilax china* L.	++	++
Solanaceae	*Lycium chinense* Mill.	+++	+++
Solanaceae	*Solanum melongena* L.	+	++
Sterculiaceae	*Firmiana simplex* W. Wight	++	++
Styracaceae	*Styrax japonicus* Siebold et Zucc.	+++	+++
Ulmaceae	*Zelkova serrata* Makino	++	+++
Urticaceae	*Urtica* sp.	+++	

+: less than 50 individuals on plant sample; ++: more than 50 individuals on plant sample, with associated white wax secretion; +++: more than 100 individuals nearly or completely covering the host plants with abundant wax exudate.

mulberry, cherry, and citrus. Flatids are usually distributed in tropical regions, and these two species are usually found in the southern part of Korea, including Yeosu city, Hong-do, Heuksan-do, Wan-do, and Jeju-do (Lee 1979).

Outbreak in central part of Korea from 2009 to 2010

In 2009, CFP was discovered concurrently at sites in Seoul and Suwon. It was especially abundant at Mt. Umyeon in Seoul, covering many plants with plentiful waxy exudates. At a nearby location, Mt. Gwanak in Seoul, CFP was also detected in 2010. Additional CFP populations were observed at greater distances from the capital in Gyeonggi-do (GG), Chungcheongbuk-do (CB), Chungcheongnam-do (CN), and Gyeongsangnam-do (GN). Fig. 3 shows that it has spread into Mt. Munhak, Mt. Seunghak and the metropolitan landfill in Incheon and Paju (GG), Yongin city (GG), Chungju city (CB) and Danyang (CB), Eumseong (CB), Jincheon county (CB), Taean county (CN) and Mt. Gyeryong in Gongju city (CN), and Changwon (GN), Kimhae (GN), Milyang city (GN).

Host plants observed in Korea

CFP is a polyphagous species that feeds on a wide range of host plants. The major forest host plants observed in Korea are *Robinia pseudoacacia* L., *Castanea crenata* Siebold et Zucc., *Styrax japonicus* Siebold et Zucc., *Diospyros lotus* L., and *Acer palmatum* Thunb.

According to our survey, woody trees are the primary hosts as CFP overwinter as eggs under the bark of twig. As their population grows, nymphs produce a tremendous volume of honeydew which drops onto the shrubs under the host trees. This honeydew promotes the formation of sooty mold. Many shrubs, and even some herbaceous plants, also serve as the intermediate hosts of CFP nymphs or adults. The major shrubs and herbaceous hosts observed in Korea are *Hibiscus syriacus* L., *Rhamnus davurica* Pall., *Lycium chinense* Mill., *Helianthus annuus* L., and *Urtica* sp. A total of 74 species in 41 families have been confirmed as CFP host plants in Korea (Table 1). More than 120 species in 50 families have been reported as CFP host plants in the United States (Wilson and Lucchi 2000) and 330 species in 78 families in Europe (Bagnoli and Lucchi 2000; Alma et al. 2005).

Table 2
Inspection records of the nursery stock imported from USA or European regions through 1996 to 2005 (documented by the National Plant Quarantine Service, Korea).

Year	Inspection frequency	Countries of export	Host plant
1996	8	USA, Italy, UK, France	*Malus pumila* Mill. *Vitis vinifera* L. *Rosa banksiae* Aiton *Citrus unshiu* (Swingle) Marcow.
1997	9	USA, Italy	*Malus pumila* Mill. *Prunus serrulata* var. *serrulata* f. *spontanea* (E. H. Wilson) C. S. Chang *Rhododendron schlippenbachii* Maxim. *Rosa banksiae* Aiton
1998	10	USA, Italy, UK, France	*Malus pumila* Mill. *Magnolia kobus* A. DC. *Hibiscus syriacus* L. *Rosa banksiae* Aiton *Malus pumila* Mill. *Acer palmatum* Thunb.
1999	11	USA, Canada	*Rosa banksiae* Aiton *Pyrus* sp. *Malus pumila* Mill. *Prunus persica* (L.) Batsch *Vitis vinifera* L. *Styrax japonicus* Siebold et Zucc. *Salix* sp.
2000	6	USA, Italy, France	*Toxicodendron vernicifluum* (Stokes) F. A. Barkl. *Malus pumila* Mill. *Robinia* sp. *Hibiscus syriacus* L. *Prunus persica* (L.) Batsch
2001	17	USA, Italy, UK, France	*Rosa banksiae* Aiton *Malus pumila* Mill. *Rhododendron schlippenbachii* Maxim. *Vitis vinifera* L. *Styrax japonicus* Siebold et Zucc. *Stewartia koreana* Nakai ex Rehder *Ulmus davidiana* Planch. *Salix* sp. *Morus alba* L. *Olea europaea* L.
2002	16	USA, France	*Rosa banksiae* Aiton *Pyrus* sp. *Prunus armeniaca* L. *Prunus persica* (L.) Batsch *Prunus domestica* L. *Rhododendron schlippenbachii* Maxim.
2003	21	USA, Italy, UK, France, Canada	*Hibiscus syriacus* L. *Rosa banksiae* Aiton *Pyrus* sp. *Spiraea prunifolia* Siebold et Zucc. *Euonymus* sp. *Rhododendron schlippenbachii* Maxim. *Clematis* sp. *Malus pumila* Mill. *Prunus persica* (L.) Batsch
2004	15	USA, Italy, UK, France	*Rosa banksiae* Aiton *Malus pumila* Mill. *Pyrus* sp. *Olea europaea* L. *Deutzia* sp.
2005	19	USA, France	*Rhododendron schlippenbachii* Maxim. *Rosa banksiae* Aiton *Clematis* sp. *Acer palmatum* Thunb.

Discussion

Invading route

Several papers discussed the potential invasion route of *M. pruinosa* into Europe. Ornamental nursery stock contaminated with CFP eggs is the most likely source of invasion (Lauterer 2002). In Europe, CFP was discovered first in Italy and has gradually been spreading to neighboring countries. It was discovered in Romania and Russia near the Black Sea in 2009 (Gnezdilov and Sugonyaev 2009; Preda and Skolka 2009). This report is the first record of CFP invasion into the Asian countries of the Palaearctic region. Two possible routes are suspected for CFP invasion into Korea: directly from North America, the place of origin, or from European countries that were invaded more recently. It is very likely that CFP arrived in Korea through the imports of horticultural nursery stock, considering the increase of the nursery imports in recent years (Table 2). To resolve this question, further research should be done to determine the pathway by which this invasive pest arrived in Korea.

Economic damage

CFP is one of the quarantine pests listed by National Plant Quarantine Service in Korea. Since CFP is gradually dispersing throughout Korea, it has the high potential as a key insect pest in agriculture. Nymphs and adults can cause serious nutritional damage by feeding directly on host plants (Fig. 4A) and can induce indirect damage by producing large amounts of waxy secretion (Figs. 4B and C) and honeydew which can induce sooty mold disease (Fig. 4D). As seen in Table 1, many forest trees can be the primary hosts of CFP, and fruit trees, cereals and some flowering plants (apple, apricot, pear, cherry, berry, chestnut, rose, sunflower, soybean, corn and eggplant etc.) are threatened by CFP. Deterioration of quality and yields of products are major concerns.

Biology

CFP biology is partly available by the reports from its native region. Eggs are deposited singly in a scattered distribution under the bark of twigs where they overwinter (Dean and Bailey 1961). Eggs hatch from March to the middle of May, depending on winter temperatures (Walden 1922). A whitish waxy powder is produced by nymphal stages, and the waxy secretion remains on leaves or stems. Sixty to 70 days after hatching, adults start emerging and continue feeding on the sap of the host plant. In late summer or early fall, eggs are laid on the overwintering hosts (Dean and Bailey 1961). In July and August, adult and immature stages are found together in large numbers. There is a possibility of a second generation produced by early adults of the first generation in Korea. However, only one generation has been reported in North America and Europe. The life cycle of CFP should be further studied, in particular the migration route of immatures and adults from primary overwintering sites, sap feeding sites, and oviposition sites.

CFP management

Chemical control is often not applicable for polyphagous pests because of side effects caused by widespread treatment against a broad range of plant hosts (Lauterer 2002). Nevertheless, successful control by 0.1% fenitrothion (Sumithion®) has been reported by Lauterer (2002). Pruning host plants has also been successful (Walden 1922). Biological control of CFP by the introduction of natural enemy, *Neodryinus typhlocybae* (Ashmead) (Hymenoptera: Dryinidae), from North America has been successful in Europe (Alma et al. 2005; Strauss 2010). *Neodryinus typhlocybae* attacks *M. pruinosa* nymphs and prevents it from emerging as an adult. Since its first introduction in Italy, *Neodryinus typhlocybae* has been released against *M. pruinosa* in northern, central, and southern Italy, southern France, Switzerland, Croatia, and Slovenia (Alma et al. 2005). *N. typhlocybae* was not found to attack non-target *Auchenorrhyncha* species in Austria where no native flatid species are found (Strauss 2009). Based on these results, the introduction of *N. typhlocybae* is highly recommended for Korea. However, the

Fig. 4. Symptoms of *Metcalfa pruinosa* (Say): (A) outbreak of gregarious adults on *Robinia pseudoacacia* L.; (B) wax covered stem; (C) nymphs and adults; (D) sooty mold of *Rosa multiflora* Thunb. by CFP honeydew, compared with healthy leaves of *Pueraria lobata* (Willd.) Ohwi.

introduction of the exotic natural enemy should be decided only after host range testing in Korea, especially with regard to the two native flatid species, *Geisha distinctissima* and *Mimophantia maritima*. A survey to document the existence of aboriginal natural enemies of these indigenous flatids and to study their effects on CFP is also recommended.

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