Kobe University Repository : Kernel

PDF issue: 2026-11-10

Substantial impact of seed-feeding fly on seed production of five endangered Japanese orchids

Suetsugu, Kenji
Fukushima, Shigeki
Sueyoshi, Masahiro

(Citation)
Ecology,99(12):2871-2873

(Issue Date)
2018-09-21

(Resource Type)
journal article

(Version)
Version of Record

(Rights)
© 2018 by the Ecological Society of America

(URL)
https://hdl.handle.net/20.500.14094/90005070

Ecology, 0(0), 2018, pp. 1–3
© 2018 by the Ecological Society of America

Substantial impact of seed-feeding fly on seed production of five endangered Japanese orchids

Owing to their excessive harvest for ornamentals, medicines, and foods, and the destruction of their natural habitats, many orchids are threatened globally (Hinsley et al. 2018). Consequently, supplemental artificial crossing has been recommended to restore the population of several endangered orchid species (Roberts 2003). However, even when pollination is successful, the resulting orchid seeds remain susceptible to herbivory by seed-feeding insects, which often destroy relatively large portions of their food supply (Janzen 1971). Nevertheless, the impact of seed predators on the reproductive ecology of rare orchid species is often overlooked (but see Kimura et al. 2009), especially when compared with the attention given to the impact of pollinators (Roberts 2003, Gale 2007).

While investigating their reproductive biology, we frequently observed the seed-feeding fly *Japanagromyza tokunagai* laying eggs in the ovaries of various Japanese orchids during or shortly after anthesis (Fig. 1). Less than 1 month from oviposition, the hatched larvae pupated within the fruit capsule. The fly can infest various orchids (Sasakawa and Matsumura 1998), whose flowering season differs significantly. Orchids are the only known hosts of *J. tokunagai*. Several fly generations per year are possible as the fly can exploit orchid species having different blooming periods.

Here, we investigated the effect of *J. tokunagai* on the seed production of five endangered orchid species in the Kanto Region of Japan (Ministry of the Environment, Government of Japan 2015; Table 1). The host plants belong to four genera and two subfamilies. Detailed information on pollination biology of the target species are listed in Table 1, Suetsugu and Fukushima (2014*a*, *b*), Suetsugu (2015) and Suetsugu et al. (2015). After cross pollinating the plants, we either (1) excluded the flies by completely bagging the plants with nylon netting (control treatment for non-infested capsules/seeds) or (2) left the plants unbagged, thereby allowing the flies to access the capsules (open treatment). Although the orchids appeared to abort most of the fly-infested capsules, all the infested fruits that were retained by the plants were dried and weighed (to the nearest 0.1 mg) to determine the degree of seed reduction. Preliminary observations revealed that seed predation, especially during the early fruiting stage, increased the proportion of seeds without embryos. We also determined the proportion of seeds with embryos by screening 100 randomly selected seeds from each capsule. The mass of the seeds with embryos was calculated for each capsule as the total seed mass per capsule × proportion of the seeds with embryos. Seed reduction was calculated as follows:

$$\text{Seed reduction} = (\text{FS}_{\text{open}}/\text{FS}_{\text{bagged}}) \times (\text{SW}_{\text{open}}/\text{SW}_{\text{bagged}})$$

where FS and SW represent the fruit set ratio at fruit maturity and the average mass of the seeds with embryos per capsule, respectively.

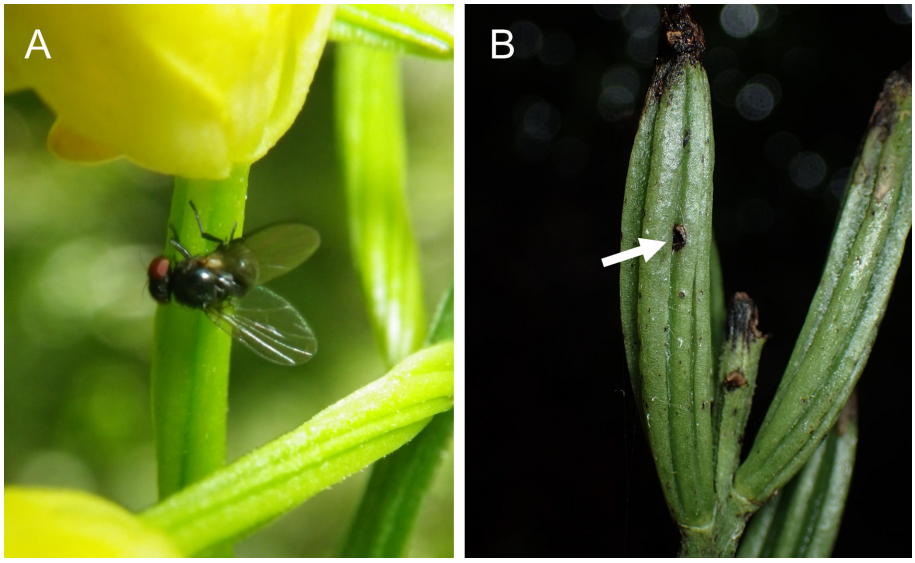

FIG. 1. (A) The agromyzid fly *Japanagromyza tokunagai* ovipositing in the ovary of one of its orchid hosts *Cephalanthera falcata*. (B) The fruit of *Cephalanthera falcata* with exit hole formed by newly emerged adult fly *J. tokunagai*. The hole is indicated by the arrow.

TABLE 1. Effects on fruit set, seed mass and seed reduction of five endangered Japanese orchids by the seed-feeding fly *Japanagromyza tokunagai.*

Species	Site		Open	Control	Year investigated	Breeding system	Conservation status
Epipactis helleborine var. *sayekiana*	Fujisawa City, Kanagawa Pref.	Fruit set (n/N)	3/20	15/20	2010	Autogamous	Vulnerable
		Total seed mass (mg)	0	8.3 ± 1.6			
		Seed mass with embryo (mg)	0	7.2 ± 1.4			
		Seed reduction (%)	100	–			
Cephalanthera falcata	Yokohama City, Kanagawa Pref.	Fruit set (n/N)	5/20	15/20	2014	Allogamous	Vulnerable
		Total seed mass (mg)	0.4 ± 0.8	21.7 ± 3.7			
		Seed mass with embryo (mg)	0.3 ± 0.6	19.8 ± 3.3			
		Seed reduction (%)	99.5	—			
Cypripedium japonicum	Sanbu City, Chiba Pref.	Fruit set (n/N)	4/10	10/10	2012	Allogamous	Vulnerable
		Total seed mass (mg)	20.3 ± 25.2	167.9 ± 15.8			
		Seed mass with embryo (mg)	14.7 ± 20.3	166.3 ± 15.8			
		Seed reduction (%)	96.5	—			
Cymbidium macrorhizon	Ichikawa City, Chiba Pref.	Fruit set (n/N)	3/20	13/20	2010	Autogamous	Vulnerable
		Total seed mass (mg)	1.3 ± 2.3	18.7 ± 3.2			
		Seed mass with embryo (mg)	0.6 ± 1.0	15.8 ± 3.6			
		Seed reduction (%)	99.2	—			
Cymbidium aberrans	Ichikawa City, Chiba Pref.	Fruit set (n/N)	2/20	12/20	2010	Autogamous	Endangered
		Total seed mass (mg)	0	17.4 ± 2.9			
		Seed mass with embryo (mg)	0	14.6 ± 3.2			
		Seed reduction (%)	100	—			

Notes: n/N, number of developed fruits/number of pollinated flowers; total seed mass and seed mass with embryo are indicated in mean ± SD. In spite of nylon netting, some seeds in 1–4 fruits of each species were consumed by the flies in control treatments. While these fruits were included in data on fruit set, they were excluded as the data on the seed mass.

We found that *J. tokunagai* heavily infested the fruit of all five orchid species, irrespective of their distinct phylogenetic positions, life histories (autotrophic or mycoheterotrophic), or breeding systems (allogamous or autogamous; Table 1). Seed reduction ranged from 96.5% to 100% (Table 1), indicating limited seed production. Therefore, seed predation can be a limiting factor for the alternation of generations in these orchids.

Paucity of seed recruitment has been shown to prevent the persistence of allogamous orchid populations that are subject to pollinator limitation (Tremblay et al. 2005). Seed quantity is generally overlooked as an impediment to seed recruitment, owing to the relatively high fruit set of such species (Gale 2007). The autogamous species included in the present study had low fruit set, with a considerable proportion of fruits being aborted, even though the plants were pollinated effectively. Further, the total seed mass and the proportion of seeds with embryos were significantly reduced by fly infestation, although the infested and non-infested capsules were similar in size and appearance (Fig. 1, Appendix S1: Fig. S1). These results suggest that the damage caused by seed-feeding flies, such as *J. tokunagai*, may be underestimated in many orchids. However, it should be noted that the presence of exit holes formed by newly emerged adult flies in what appear to be unaffected fruits could be used to recognize infestation by the flies (Fig. 1).

The results of the present study indicate that fly infestation can reduce seed production by more than 95% in all five orchidaceous species (Table 1). Considering that our data were obtained from unrelated orchid species at four different sites, *J. tokunagai* may substantially limit the reproductive success of these orchids.

However, it should be noted that the degree of damage from seed predators can vary, both temporally and spatially. For example, seed production frequently varies between years. Low attack rates by seed predators normally occur during a high seed production year (preceded by a low seed production year), during which insect populations grow. Predation threat is therefore high during the subsequent year (Janzen 1971). Our data are based on observations of each population for 1 year. Further research is needed to elucidate larger spatial and temporal effects of *J. tokunagai* on seed production in endangered orchid species in Japan.

In addition, it remains unclear why seed-feeding flies impact orchid seed production so severely. One possibility is that the population of seed-feeding flies might greatly expand due to disturbances, changes in land management practices, or climate change. For example, it is possible that the destruction and fragmentation of orchid populations reduces the population size of natural enemies, such as parasitoid wasps that might otherwise limit the population size of seed feeders. Therefore, it is worth investigating whether the degree of seed predation is impacted by habitat quality and availability.

Another possibility is that severe damage is related to the recent expansion in seed-feeding fly populations, which have reduced pressures imposed by their natural enemies due to their invasion into enemy-free areas. Interestingly, Onuki (2007) reported that *J. tokunagai* might have been introduced to Eastern Japan, including the Kanto region (the

location of our study sites), along with orchids collected from other areas for horticultural purposes.

Phylogeographic analyses can reveal patterns of dispersal within the novel ranges of invasive species (Estoup and Guillemaud 2010, Cristescu 2015, Hagenblad et al. 2015). Additionally, the intrapopulation and interpopulation phylogeographic patterns of pest species can provide insights into the human-facilitated dispersal of species and can help inform appropriate management strategies. Therefore, further investigations are necessary to reveal the population genetic structure of *J. tokunagai*.

Acknowledgments

The authors thank Kazuo Onuki and Yuki Ogura-Tsujita for the useful discussion. This work was financially supported by the JSPS KAKENHI (Grant Number 17H05016).

Literature Cited

Cristescu, M. E. 2015. Genetic reconstructions of invasion history. Molecular Ecology 24:2212–2225.

Estoup, A., and T. Guillemaud. 2010. Reconstructing routes of invasion using genetic data: why, how and so what? Molecular Ecology 19:4113–4130.

Gale, S. 2007. Autogamous seed set in a critically endangered orchid in Japan: pollination studies for the conservation of *Nervilia nipponica*. Plant Systematics and Evolution 268:59–73.

Hagenblad, J., et al. 2015. Low genetic diversity despite multiple introductions of the invasive plant species *Impatiens glandulifera* in Europe. BMC Genetics 16:103.

Hinsley, A., H. J. de Boer, M. F. Fay, S. W. Gale, L. M. Gardiner, R. S. Gunasekara, P. Kumar, S. Masters, D. Metusala, and D. L. Roberts. 2018. A review of the trade in orchids and its implications for conservation. Botanical Journal of the Linnean Society 186:435–455.

Janzen, D. H. 1971. Seed predation by animals. Annual Review of Ecology and Systematics 2:465–492.

Kimura, H., J. Yamazaki, Y. Adachi, M. Yokoo, and N. Ichikawa. 2009. Research on orchid fruits eaten by agromyzid flies. Proceedings of the Nagoya International Orchid Congress, Japan 2009:31–34.

Ministry of the Environment, Government of Japan. 2015. Red Data Book 2014 – Threatened wildlife of Japan. Vascular plants. GYOSEI Cooperation, Tokyo, Japan.

Onuki, K. 2007. An attempt to conserve the natural habitats of orchids in Inokashira Park. Orchid Sciences 16:21–29. [In Japanese].

Roberts, D. L. 2003. Pollination biology: the role of sexual reproduction in orchid conservation. Pages 113–136 *in* K. W. Dixon, S. P. Kell, R. L. Barrett and P. J. Cribb, editors. Orchid conservation. Natural History Publications, Sabah, Malaysia.

Sasakawa, M., and T. Matsumura. 1998. Agromyzidae (Diptera) in insect museum, National Institute of Agro-Environmental Sciences, with the description of seven new species. Bulletin of the National Institute of Agro-Environmental Sciences (Japan) 13:1–17.

Suetsugu, K. 2015. Autonomous self-pollination and insect visitors in partially and fully mycoheterotrophic species of *Cymbidium* (Orchidaceae). Journal of Plant Research 128:115–125.

Suetsugu, K., and S. Fukushima. 2014*a*. Bee pollination of the endangered orchid *Calanthe discolor* through a generalized food-deceptive system. Plant Systematics and Evolution 300:453–459.

Suetsugu, K., and S. Fukushima. 2014*b*. Pollination biology of the endangered orchid *Cypripedium japonicum* in a fragmented forest of Japan. Plant Species Biology 29:294–299.

Suetsugu, K., R. S. Naito, S. Fukushima, A. Kawakita, and M. Kato. 2015. Pollination system and the effect of inflorescence size on fruit set in the deceptive orchid *Cephalanthera falcata*. Journal of Plant Research 128:585–594.

Tremblay, R. L., J. D. Ackerman, J. K. Zimmerman, and R. N. Calvo. 2005. Variation in sexual reproduction in orchids and its evolutionary consequences: A spasmodic journey to diversification. Biological Journal of the Linnean Society 84:1–54.

Kenji Suetsugu,[1,4] Shigeki Fukushima[2], and Masahiro Sueyoshi[3]

Manuscript received 26 May 2018; revised 1 July 2018; accepted 10 July 2018. Corresponding Editor: John Pastor.

[1]Department of Biology, Graduate School of Science, Kobe University, 1-1 Rokkodai, Nada-ku, Kobe 657-8501 Japan.

[2]Chiba Prefectural Agriculture and Forestry Research Center, 1887-1, Haniya, Sanbu, Chiba 289-1223 Japan.

[3]Forest Zoology Group, Kyushu Research Center, Forestry and Forest Products Research Institute, 4–11–16 Kurokami, Kumamoto 860–0862 Japan.

[4] E-mail: kenji.suetsugu@gmail.com

Additional supporting information may be found in the online version of this article at http://onlinelibrary.wiley.com/doi/10.1002/ecy.2471/suppinfo