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Pests of the Endangered Herb *Platycodon grandiflorus* in Central Japan

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ABSTRACT

Platycodon grandiflorus (Jacq.) A.DC. is a perennial herb in the Campanulaceae, whose wild populations in Japan are declining dramatically. As *Strongylocoris leucocephalus* (L.) (Hemiptera: Miridae) infests *Campanula* spp. in western Eurasia, and *Adenophora triphylla* (Thunb.) A.DC. var. *japonica* (Regel) H.Hara is a common pest in Japan, they may also be potential pests of *P. grandiflorus*. Field surveys, however, indicated that *S. leucocephalus* never infested *P. grandiflorus*, but that *Tetranychus kanzawai* Kishida (Acari: Tetranychidae) did. In addition, *S. leucocephalus* never fed on *P. grandiflorus* in the laboratory. Our results suggest that *T. kanzawai* is an important pest of *P. grandiflorus*, but that *S. leucocephalus* is not a potential pest of this endangered plant.

Key words: Adenophora triphylla var. *japonica*, Hemiptera, Miridae, Spider mite, *Strongylocoris leucocephalus*, *Tetranychus kanzawai.*

INTRODUCTION

Platycodon grandiflorus (Jacq.) A.DC. is a herbaceous flowering perennial plant that is native to East Asia (Satake, 1981). Their wild populations in Japan of this herb are declining dramatically due to overexploitation, vegetation succession, and grassland development (Japanese Ministry of the Environment, 2012).

Strongylocoris leucocephalus (Linnaeus) (Hemiptera: Miridae) is widely distributed across Eurasia, North Africa, and northern Japan (Kerzhner and Josifov, 1999; Yasunaga *et al.*, 2001; Konstantinov and Namyatova, 2009; Ghahari *et al.*, 2012). This plant bug infests *Campanula* spp. in western Eurasian (Göllner-Scheiding, 1972; Tatarnic and Cassis, 2012). In central Japan, they often feed on *Adenophora triphylla* (Thunb.) A.DC. var. *japonica* (Regel) H.Hara (Campanulaceae) but never consume *Campanula punctata* Lam. var. *hondoensis* (Kitam.) Ohwi (Takagi, 2014).

Strongylocoris leucocephalus and *A. triphylla* var. *japonica* are not distributed sympatrically, suggesting that the plant bug has expanded its geographic range by incorporating new hosts (Takagi, 2014). Accordingly, I hypothesized that *P. grandiflorus*, a Campanulaceae species that grows in central Japan, is a potential host plant of *S. leucocephalus* and that the plant bug deleteriously affects this endangered plant. The objectives of this study were to determine the pest species of *Platycodon*

grandiflorus (Jacq.) A.DC. and to determine whether *S. leucocephalus* was feeding on *P. grandiflorus* in central Japan.

MATERIALS AND METHODS

Study site

The study was conducted at the Sugadaira Montane Research Center (36°31'N, 138°21'E) at an altitude of approximately 1300 m on the Sugadaira highland, Ueda City, Nagano Prefecture, central Japan. Different types of vegetation are maintained along a successional gradient (i.e., grassland, Japanese red pine forest, red pine and broad-leaved mixed forest, and deciduous broad-leaved forest) at the research center. The dominant plant in the grassland is Japanese pampas grass *Miscanthus sinensis* Andersson, which is typical of mountainous areas in Japan, but *Artemisia indica* Willd. var. *maximowiczii* (Nakai) H.Hara, *Potentilla freyniana* Bornm., *Pteridium aquilinum* (L.) Kuhn, *Solidago virgaurea* L. subsp. *asiatica* (Nakai ex H.Hara) Kitam. ex H.Hara, *Sanguisorba officinalis* L., and *A. triphylla* var. *japonica* also occupy the grassland. All aboveground vegetation in the grassland was removed every autumn to prevent vegetative succession from grassland to forest.

Plant species

Three Campanulaceae species grow at the research center; *A. triphylla* var. *japonica* and *C. punctata* var. *hondoensis* are common, but *P. grandiflorus* is rare.

Adenophora triphylla var. *japonica* is a wild perennial herb distributed in Japan, Korea, and Sakhalin (Satake, 1981). It germinates or grows from its rootstocks in mid-May and then grows to 40-90 cm in height. The leaves are green, verticillate, and oblong. Flower stalks begin growing in mid-August and the flowers bloom from August to October with a campanulate corolla.

Campanula punctata var. *hondoensis* is a wild perennial herb. The plant is distributed in northern Japan (Okazaki 1993). It germinates or grows from its rootstocks in mid-May and then grows to 20-60 cm in height. The leaves are ovate and green. Flowers bloom from July to August.

Platycodon grandiflorus grows to 60 cm tall. The leaves are dark green verticillate and oblong. Flower buds swell like a balloon before fully opening, and blue flowers bloom in summer. The five petals are fused together into a bell shape at the base (Satake, 1981).

Plant bug

The plant bug *Strongylocoris leucocephalus* infests *Campanula* spp. in western Eurasia (Göllner-Scheiding, 1972; Tatarnic and Cassis, 2012), but they infest *A. triphylla* var. *japonica* and avoid the only *Campanula* species, *C. punctata* var. *hondoensis*, in the Sugadaira highland (Takagi, 2014). They emerge from mid-May through late August, and the leaves damaged by the plant bug are characteristic and easily identified.

Field survey

To determine whether *S. leucocephalus* feeds on *P. grandiflorus* in the field, fifty *P. grandiflorus* individuals were randomly observed on July 19, 2014, and the presence or absence of leaves damaged by *S. leucocephalus* was recorded.

Laboratory experiment

A feeding experiment was conducted to determine whether *S. leucocephalus* feeds on *P. grandiflorus* when experimentally deprived of its typical host plant in the laboratory. On July 14, 2014, 41 *S. leucocephalus* larvae and the stems of *A. triphylla* var. *japonica* and *P. grandiflorus* with apical and second leaves were collected in the grassland. Stems with leaves were placed in cotton batting containing water, and three larvae were placed in a transparent plastic container (W124 mm × D82 mm × H42 mm, UnixWare®; ASVEL Co., LTD., Yamatokohriyama, Japan) and kept at 15°C and under a 16-h photophase and 8-h scotophase. We used six replicates for each of the two plant species. Containers holding only two larvae in cotton batting and three larvae in cotton batting were used as controls. Plants and cotton battings were replaced on June 24, July 3, and July 12, 2014. The number of dead insects and their developmental stage (i.e., larva or adult) were recorded every day. Presence or absence of leaves damaged by *S. leucocephalus* was also recorded when the plants and cotton batting were replaced.

Analysis

Fisher's exact test was performed to compare the proportions of dead insects at larval and adult stages that fed on *A. triphylla* var. *japonica*, *P. grandiflorus*, or water.

A generalized linear model (GLM) with a Poisson distribution and log link was used to compare the length of the survival period among the three conditions. Means were compared using Tukey's HSD test. The analysis was performed by using R 2.14.1 and the multcomp package (Bretz *et al.*, 2010).

RESULTS AND DISCUSSION

No *P. grandiflorus* individuals were infested by *S. leucocephalus* in the grassland, indicating that the plant bug was not a pest of *P. grandiflorus*. Conversely, *Tetranychus kanzawai* Kishida (Acari: Tetranychidae) infested all 50 *P. grandiflorus* individuals in the field, suggesting that this spider mite was an important pest of the endangered plant.

Strongylocoris leucocephalus fed on *A. triphylla* var. *japonica* leaves but never fed on *P. grandiflorus* leaves in the laboratory, although eight individuals feeding on *A. triphylla* var. *japonica* or *P. grandiflorus* leaves successfully developed to adults. Conversely, no individuals feeding on only water developed to adults. The proportions of individuals that successfully developed into adults were not significantly different among foods (Fisher's exact test, $P = 0.253$). The survival period of individuals feeding on *P. grandiflorus* was significantly shorter than that of individuals feeding on *A. triphylla* var. *japonica*, although no significant difference was observed between the individuals feeding on *P. grandiflorus* and water (Fig. 1).

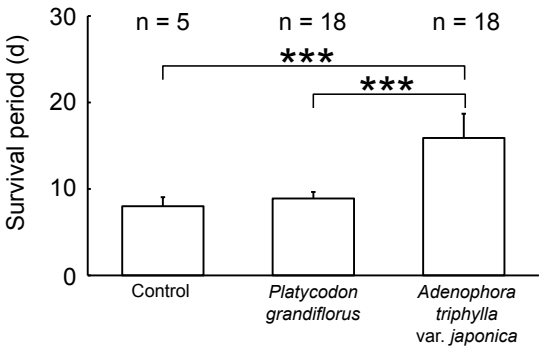

Fig. 1. Survival period of *Strongylocoris leucocephalus* feeding on *Adenophora triphylla* var. *japonica*, *Platycodon grandiflorus*, and water (control). Bars indicate the standard error (SE).

In the absence of host plants, oligophagous insect herbivores sometimes oviposit on plants of non host species (Zhou and Togashi, 2006; Ernst *et al.*, 2007; Azerefegne and Solbreck, 2010). Even monophagous insects oviposit on closely related nonhost plant species when experimentally deprived of host plants (Takagi and Togashi, 2013). *Strongylocoris leucocephalus* and *A. triphylla* var. *japonica* are not distributed sympatrically; the plant bug is widely distributed in Eurasia, North Africa, and northern Japan (Kerzhner and Josifov, 1999; Yasunaga *et al.*, 2001; Konstantinov and Namyatova, 2009; Ghahari *et al.*, 2012), but the host plant is distributed only in the eastern part of Eurasia and Japan (Satake, 1981). Given this variation in their distribution, Takagi (2014) suggested that the plant bug has expanded its geographic range from western to eastern Asia, or vice versa, by incorporating other Campanulaceae species as new hosts. Therefore, the plant bug was assumed to be a potential pest of *P. grandiflorus* in the Sugadaira highland, but our results indicate that only *T. kanzawai* is an important pest of this endangered plant.

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