Appl Entomol Zool (2011) 46:375–381
DOI 10.1007/s13355-011-0048-8

ORIGINAL RESEARCH PAPER

Risk to nontarget plants from *Ophraella communa* (Coleoptera: Chrysomelidae), a potential biological control agent of alien invasive weed *Ambrosia artemisiifolia* (Asteraceae) in China

Zhenjun Cao · Hongyuan Wang · Ling Meng · Baoping Li

Received: 22 November 2010 / Accepted: 21 April 2011 / Published online: 10 May 2011
© The Japanese Society of Applied Entomology and Zoology 2011

Abstract *Ophraella communa* LeSage is an oligophagous insect that shows promise for controlling the alien invasive weed *Ambrosia artemisiifolia* L. in China. This study was performed to evaluate the risk of *O. communa* on the basis of host-specificity testing of larval development under no-choice conditions and of oviposition preferences under choice conditions in greenhouses and in the open field. Under no-choice conditions, *O. communa* larvae experienced much higher mortality rates on the nontarget plants than on the target weed, but a small proportion of larvae completed development on the nontarget plants examined, including *Xanthium sibiricum* Patrin ex Widder, *Helianthus tuberosus* L., and *H. annuus* L. Multiple-choice tests indicated that *O. communa* showed a strong oviposition preference for the target weed over the nontarget plants and laid few eggs on the economically important *Helianthus* crops tested. In paired-choice trials, *O. communa* adults showed an obvious preference for the target weed over *X. sibiricum* but preferred *X. sibiricum* to *H. annuus*. The results suggest that *X. sibiricum* might be used as a lower-ranked host plant next to the target weed by *O. communa*, and that *Helianthus* crops would not be at risk of being used for oviposition in the field.

Keywords Host specificity · Biological weed control · Oviposition selection · Choice test · Open-field test

Z. Cao · H. Wang · L. Meng · B. Li (✉)
Department of Entomology, College of Plant Protection, Nanjing Agricultural University, Nanjing 210095, China
e-mail: lbp@njau.edu.cn

Introduction

Common ragweed (*Ambrosia artemisiifolia* L., Asteraceae) is native in North American and became naturalized in mainland China before 1935 (Wan et al. 1993). It flourishes as a pioneer species in disturbed habitats such as along river banks and motorways, in open lots, and in uncultivated crop fields (Wan and Wang 1990). Ragweed pollen is one of the primary causes of allergenic hay fever in China (Xia 1983; Zhang et al. 2007), Europe (Coutinot et al. 2008), and North America (Bagarozzi and Travis 1998; Ziska et al. 2003). Classical biological control of the common ragweed began in China in the 1980s. During that time, *Zygogramma suturalis* (Fabricius) (Coleoptera: Chrysomelidae) and *Epiblema strenuana* (Walker) (Lepidoptera: Tortricidae) were introduced and released into the field (Wan et al. 1993, 2005). Whereas *E. strenuana* has successfully become established and rapidly spread throughout all infested areas, the population of *Z. suturalis* was not sustained (Wan and Ding 1995). *E. strenuana* induces galls on the stem but is not able to effectively control the ragweed (Wan and Ding 2003). *Ophraella communa* LeSage (Coleoptera: Chrysomelidae), originating from the Nearctic region, was first reported in eastern China, where feeding by larvae and adults severely defoliate common ragweed (Meng and Li 2005), and was later considered as an effective biological agent to control ragweed in warm temperate areas where sunflower crops were rarely planted (Zhou et al. 2010). However, the major concern about using *O. communa* to control the common ragweed is the potential risk to nontarget plants.

O. communa is an oligophagous insect that feeds to some extent on some members of Ambrosiinae (Heliantheae, Asteraceae). LeSage (1986) originally reported only one host species, *A. artemisiifolia*, but it is now known to

feed upon other members of the subtribe Ambrosiinae, including *Parthenium hysterophorus* L., *Xanthium strumarium* L., and *A. psilostachys* DC (Palmer and Goeden 1991). *O. communa* was previously considered as a potential biological control agent for introduction into Australia to control the common ragweed (Palmer and Goeden 1991). In no-choice feeding tests under laboratory conditions, it could complete larval development by exclusively feeding on sunflower (*Helianthus annuus* L.), and was therefore rejected for introduction into Australia, even though it had never been recorded on sunflower under field conditions in North America (Hilgendorf and Goeden 1981). Later it was recorded feeding on *H. ciliaris* DC (Texas blueweed) (Futuyma 1990). Subsequent reports from Japan revealed occasional adult *O. communa* feeding in the field on *H. annuus* and *H. tuberosus* (Tokyo Metropolitan Plant Protection Office 1999; Emura 1999) as well as on *A. trifida* and *Xanthium* spp. (Yamazaki and Natuhara 2000). The no-choice test carried out in the laboratory found that nontarget *A. trifida* and *X. strumarium* could sustain larval development with the same survival rates as the target weed (Yamazaki and Natuhara 2000).

The observation of larval development completed on sunflower under no-choice confinement in the laboratory can be false positive if it does not attack sunflower in the field. Among the nontarget plants mentioned above on which occasional feeding was recorded, no *O. communa* eggs or larvae were located in the field on *Helianthus* spp. and *Xanthium* spp. (Palmer and Goeden 1991; Yamazaki and Natuhara 2000); only a few egg masses were found on *A. trifida* (Watanabe and Hirai 2004). As oviposition plays a central role in host selection, oviposition choice test constitutes an integral part of host specificity assessment in classical biological control practices. The test conducted in Canada showed that few or no eggs were laid on testing sunflower plants when the preferred host plants (*A. artemisiifolia*) were available, which led to the conclusion that native sunflower plants are not at risk of being attacked by adult *O. communa* (Dernovici et al. 2006). However, this conclusion, obtained from testing in the indigenous area, should be accepted with some caution: the risk of *O. communa* to native nontarget plants in recipient environments might be different due to genetic variation of tested plants and insects and in environmental conditions under which tests (field and semifield) were conducted. It is thus necessary to assess directly the risk of *O. communa* to native plants in recipient environments before it is used as a biological control of invasive common ragweed.

We carried out trials using laboratory, greenhouse, and outdoor cages and in the open field to evaluate host specificity of *O. communa*, with an emphasis on oviposition risk assessment of native sunflower crop cultivars and *X. sibiricum* of medicinal value.

Materials and methods

Insect and test-plant preparation

O. communa was collected from Jiangpu agricultural experiment farm of Nanjing Agricultural University, Nanjing (32.0°N and 118.7°E), and its colonies were maintained on potted *A. artemisiifolia* in outdoor gauze-covered cages (60 × 60 × 90 cm). The nontarget plants, selected for the trials, included *A. trifida*, *X. sibiricum*, *H. annuus* (Sandaohei), *H. annuus* (Liaofeng-F51), and *H. tuberosus*. These plants are the nearest relatives of the target weed *A. artemisiifolia* within the tribe Heliantheae of Asteraceae, which can be at highest risk of being attacked by *O. communa* according to their phylogenetic relationship to the target weed (Briese 2003). *A. trifida* is also an invasive weed as is its congeneric *A. artemisiifolia* but is limited in distribution to the northern parts of mainland China. *X. sibiricum,* a common plant all over China, can be used for its medicinal value in Chinese medicine (Li et al. 2005). The two cultivars of *H. annuus* are planted as important cash crops for oil and seeds in northern areas. *H. tuberosus* is an underexploited cash crop both for its value as food (Chi et al. 2009) and a resource for ethanol production (Nakamura et al. 1996). These plants were obtained from seeds grown in plastic pots (25 cm diameter × 20 cm high) in a greenhouse and used for the experiments when about 40 cm tall.

Nonchoice test of larval development using outdoor cages

This test evaluated development of *O. communa* larvae on the test plants in outdoor cages under a 16:8-h (L:D) photoperiod at 23–30°C. Forty neonate larvae were placed on a potted plant covered by a nylon gauze cage. The plant was examined daily for living larvae and their developing stage. Pupae were collected and weighed to an accuracy of 0.01 mg (Mittler XP-205DR, Switzerland). Each test plant was replicated ten times.

Multiple-choice oviposition test using greenhouse and outdoor cages

Two separate multiple-choice trials were established to evaluate *O. communa* preferences for oviposition among five nontarget plants in the presence of the target weed.

Experiment 1

This experiment was conducted in a greenhouse, gauze-covered cage (length × width × height = 60 cm × 60 cm × 90 cm) in the summer of 2008. Six potted plants each of the test-plant species were randomly arranged in a circle in

the cage. Newly emerged *O. communa* adults were grouped in a Petri dish for 48 h for mating and fed with the common ragweed leaves. Females from the grouping were treated as mated and then singly released into the cage. The plants were examined for eggs every 2 h until any eggs were found. The test was replicated 45 times.

Experiment 2

This experiment was done in a large outdoor walk-in cage (length × width × height = 3 m × 3 m × 2 m). Six potted plants of each of the five nontarget species and the target weed were placed with an equal distance of 0.5 m in a 6 × 6 Latin square design. A male and a female *O. communa* were introduced to each potted plant, with a total of 72 insects released in the cage. The plants were examined every other day for the presence of insects, and eggs and eggs were removed each time to avoid influence on follow-up oviposition. The observation was terminated 20 days after releasing insects. Three replicates were performed.

Multiple-choice test in the open field

This experiment was to evaluate *O. communa* adult preference between the test plants without the target weed in the immediate vicinity, which would provide more reliable measure of risk to nontarget plants. The plants were laid out as shown in Fig. 1 in the open field in the summer of 2008. A male and a female *O. communa* were placed on each pot plant in the center section, with a total of 60 insects released. The insects were marked before release with a red paint spot on an elytrum so as to be distinguished from others that occasionally immigrated into the plot. The plants were examined every other day for the presence of insects and eggs, and eggs were removed each time to avoid influence on follow-up oviposition. The observation was terminated 20 days after insect release. Testing was conducted under outdoor conditions at 25–30°C, 55–80% relative humidity (RH), and 14–10 h of light–dark of natural photoperiod.

Paired-choice test using outdoor cages

This experiment was conducted to evaluate *O. communa* host ranking for oviposition using paired-choice test. Three paired plant combinations were set up based on preferences performed in multiple-choice experiments, including *A. artemisiifolia* with *X. sibiricum, X. sibiricum* with *H. annuus* (Sandaohei), and *H. annuus* (Sandaohei) with *H. annuus* (Liaofeng-F51). The experiment was conducted in outdoor cages from July to August 2008 at a mean minimum and maximum temperature of 23°C and 30°C, respectively. Mated females treated as above were singly introduced into a gauze-covered cage (length × width × height = 60 cm × 60 cm × 90 cm) with one of the paired-plant combinations. The plants were examined for eggs every 2 h until eggs were located. For each of the paired-plant combinations, 40 replicates were exercised.

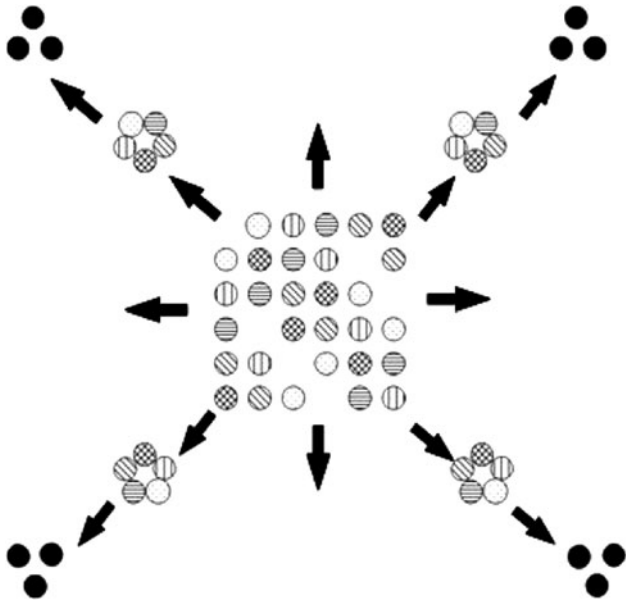

Fig. 1 Set design for the open-field test. The *solid circles* are common ragweed, and the *circles with different patterns* are nontarget plants (five species). The satellite nontarget plant groups were 2 m away from both the margin of the center potion and the satellite target-weed groups

Data analysis

Survival rates of neonate larvae in different stages in the no-choice trial were compared between the target weed and other separate test-plant species using a protected Kruskal–Wallis test performed on the ranks of percentage data, as they did not generally confirm to the assumptions of parametric tests. Frequencies of oviposition choices among test plants in the multiple-choice trial in the greenhouse trial were compared for an overall difference using the χ^2 test and for pair-wise differences using the Marascuilo procedure analogous to the Tukey test (Zar 2010). Frequencies of oviposition choices in paired-choice experiments were compared using the χ^2 test. Data analyses were carried out with R statistical software (R Development Core Team 2009).

Results

Nonchoice test of larval development

Survival of neonate larvae to each immature stage of *O. communa* was significantly lower on the nontarget

plants than on the target weed (protected Kruskal–Wallis test, $p < 0.05$) (Fig. 2). Among 40 neonate larvae from the start on each pot plant, <20% completed the first stadium on the nontarget plants, whereas 50.2% (± 6.4, SE) survived the same stage on the target weed; <6% survived to pupation on the nontarget plants, whereas 31.6% [±3.3, standard error (SE)] developed through to pupae on the target weed.

Multiple-choice oviposition test using greenhouse and outdoor cages

Experiment 1

In the greenhouse-cage trial, *O. communa* females exhibited a strong preference for the common ragweed over the nontarget plants on which to oviposit, with 28 choices among 45 options (replicates) for the target weed but less than seven choices for individual nontarget plants; *Helianthus* spp. were least preferred (Table 1).

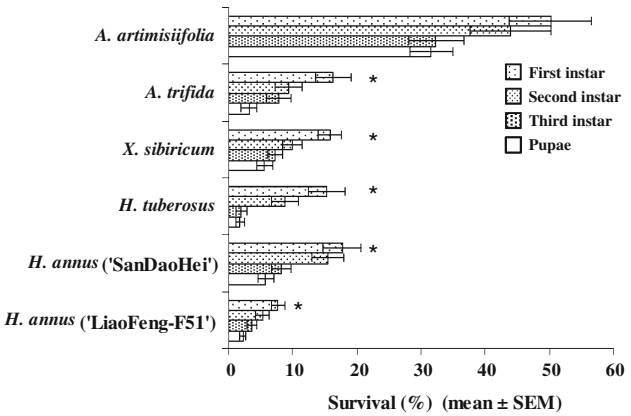

Fig. 2 Survival of neonate larvae to each immature stage on different test plant species under no-choice conditions. (*Asterisk* indicates a significant difference between *Ambrosia artemisiifolia* and each nontarget plant species in survival of neonate larvae to each stage by the protected Kruskal–Wallis test, $p < 0.05$)

Experiment 2

In the large outdoor walk-in cage test, *O. communa* adults, upon being released on each plant, immediately dispersed to the target weed from the nontarget plants. The number of insects increased to an average of 9.5 (±0.6, SE) per pot on the fourth day on the target weed and decreased to <1.0 on average on the nontarget plants (Fig. 3). Corresponding with the adult dispersal, many more eggs were laid on the target weed than on the nontarget plants (Fig. 4). Whereas an average of 5.2 (±0.6) eggs were laid on each pot plant per female on the common ragweed on the fourth day, only <1.0 eggs were deposited on nontarget plants at the same time. No eggs were deposited on *Helianthus* plants during the period of observation.

Multiple-choice oviposition test in the open field

After release on each nontarget pot plant in the center region (Fig. 1), *O. communa* adults rapidly moved to the target weeds located at a distance. The number of insects increased markedly to an average of 2.5 per pot plant on the sixth day on the target weed and decreased to <1.0 on average on *X. sibiricum*, *A. trifida*, and *H. tuberosus*, and to zero on *H. annuus*, from the fourth day onward (Fig. 5). Following movement of adults, eggs were laid predominantly on the target weed, whereas only a few seen on the nontarget plants. The number of eggs laid on the target weed increased significantly from the fourth day onward and peaked by 33.9 (±4.4, SE) on each pot plant per female on the 16th day after release, whereas many fewer eggs were oviposited on the nontarget plants (Fig. 6).

Paired-choice trials using outdoor cages

In paired-choice trials, female adults significantly preferred *A. artemisiifolia* on which to oviposit (28 choices in 45 trials) over *X. sibiricum* (12 choices) ($\chi^2 = 11.25$, $df = 1$, $p < 0.001$), *X. sibiricum* (35 choices) over *H. annuus* (Sandaohei) (5 choices) ($\chi^2 = 42.05$, $df = 1$, $p < 0.001$). But females did not show significant preferences between

Table 1 Frequency of oviposition choices of *Ophraella communa* among test plants ($n = 45$)

Test plants	No. oviposition choices	Prop. oviposition choices*	Standard error of mean proportion
Ambrosia artemisiifolia	28	0.622a	0.072
A. trifida	5	0.111b,c	0.047
Xanthium sibiricum	7	0.156b	0.054
Helianthus tuberosus	2	0.044c	0.031
H. annuus ('LiaoFeng-F51')	3	0.067c	0.037
H. annuus ('SanDaoHei')	0	0c	0

* Different small letters following values indicate significant differences between test plants using the Marascuilo procedure analogous to the Tukey test

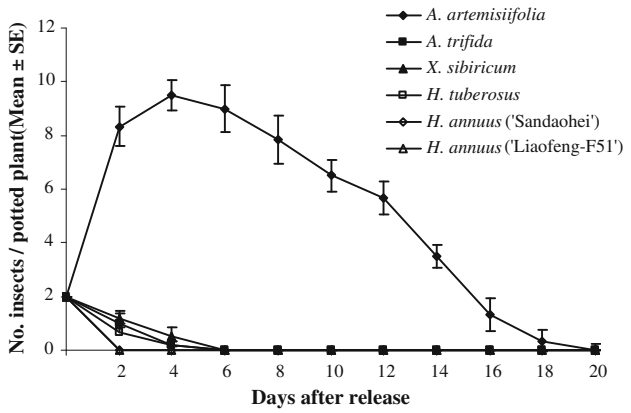

Fig. 3 Number of *Ophraella communa* adults on different days located on different test-plant species in a choice trial using outdoor walk-in cages

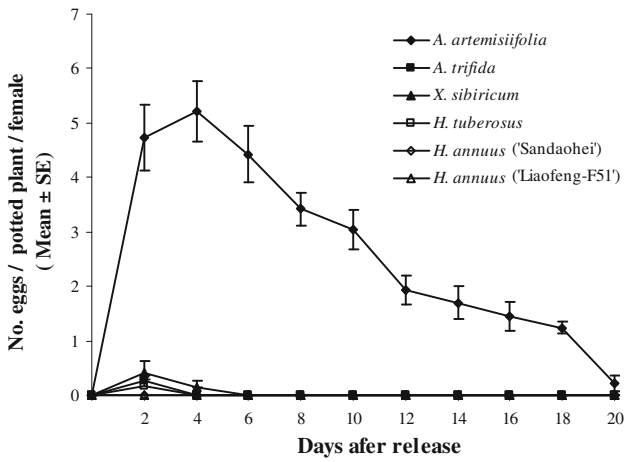

Fig. 4 Number of *Ophraella communa* eggs on different days laid on different test plant species in a choice trial using large walk-in cages

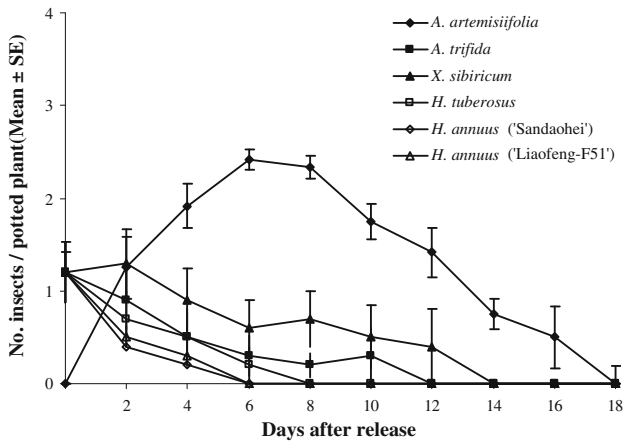

Fig. 5 Number of *Ophraella communa* adults on different days located on different test-plant species in a choice trial in the open field

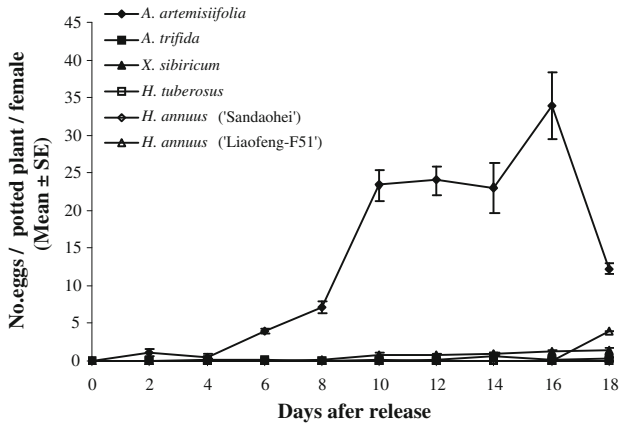

Fig. 6 Number of *Ophraella communa* eggs on different days laid on different test-plant species in a choice trial in the open field

two cultivars of *H. annuus* (Sandaohei and Liaofeng-F51) (23 vs 17 choices) ($\chi^2 = 1.25$, $df = 1$, $p = 0.26$).

Discussion

No-choice tests are designed to identify fundamental larval host ranges and range of plant species that can support complete development (Schaffner 2001). Under no-choice conditions, *O. communa* larvae experienced much higher mortality rates on the nontarget plants than on the target weed, but a small proportion of larvae can complete development on the nontarget plants examined. However, the tests conducted in Japan showed that *O. communa* performed similarly in larval survival both on the target weed and nontarget *A. trifida* and *X. strumarium* (Yamazaki and Natuhara 2000). The discrepancy may be explained by different constraints imposed by the two test designs. The testing in Japan was conducted in small vials in the laboratory, and insect larvae were fed with excised leaves. Developmental performances of the insects under such conditions can be impacted by the severe constraints from stringent spatial confinement and changes in nutrients of excised feeding leaves. The no-choice test in this study was exercised in outdoor cages, and larvae were placed in groups, as observed in the field, on pot plants. Such test design should, to a certain extent, relax the constraints inherent in those tests commonly made in the laboratory, as mentioned above, and therefore reduce false-positive results. Among the nontarget plants tested in this study, *X. sibiricum* and *H. tuberosus* are not known as food plants for completing *O. communa* larval development in North America (Palmer and Goeden 1991) and Japan (Yamazaki and Natuhara 2000). This addition of food plants may be a result of insect preadaptation, which can be explained by the concept of host substitution instead of host-range

expansion, according to Marohasy (1996). Our nonchoice test indicated that sunflower cultivars *H. annuus* (Sandaohei and Liaofeng-F51) can sustain *O. communa* larval development, but larval mortality was very high. Similar results were obtained in host-range testing conducted in the United States (Palmer and Goeden 1991).

In general, oviposition behavior seems more plastic than larval host range, with many extrinsic and intrinsic factors affecting the host choice made by an insect species (Bernays and Chapman 1994).The multiple-choice tests, conducted using greenhouse and outdoor cages with the presence of the target weed in the vicinity indicated that *O. communa* adults show a strong preference for the target weed over the nontarget test plants on which to lay eggs. The performance was also observed in the open-field experiment, where the target weed was placed some distance away from the nontarget plants. Though being highly specific in choosing plants for oviposition, *O. communa* adults did accept nontarget plants *A. trifida* and *X. sibiricum* for oviposition, especially when the preferable target weed was not available (Fig. 6). Though *A. trifida* has not been reported to be attacked in the field in China, it was occasionally found to have immature *O. communa* stages during the field survey undertaken in Japan (Yamazaki and Natuhara 2000). A trial was even made in Korea using *O. communa* to control *A. trifida* (Lee et al. 2007). It is thus assumed that *O. communa* may play a role in controlling invasive *A. trifida* in northern parts of China when dispersed to those areas.

Xanthium spp, a closely related group to the target weed, can be used by *O. communa* as host plants in North America (Hilgendorf and Goeden 1981; Goeden and Ricker 1985; Palmer and Goeden 1991) and Japan (Yamazaki and Natuhara 2000; Watanabe and Hirai 2004). Our paired-choice experiments showed a preference rank in oviposition, where *O. communa* adults strongly preferred to lay eggs on the target weed over *X. sibiricum*, and on *X. sibiricum* over *H. annuus*. All available evidence suggests that *Xanthium* plants should be ranked as hosts next to the target weed for *O. communa*. The potential risk of *O. communa* to *Xanthium* plants remained to be analyzed by considering both sides of the plants.

Under no-choice conditions, a slim fraction of larval cohorts can complete larval development on sunflowers, as observed in the experiments reported here as well as in earlier testing (Palmer and Goeden 1991). Therefore, sunflower can be included in the fundamental host range of larval development of *O. communa*. However, the fundamental host range may not be the same as the realized or ecological host range (Schaffner 2001). If sunflower is not selected for oviposition by *O. communa* adults, it would not be at risk of being attacked in the field. In oviposition preference experiments in this study, *O. communa* adults showed least preference for the economic *Helianthus* crops among test plants. Whereas few eggs were laid on *H. tuberosus*, almost no egg was oviposited on *H. annuus* (two sunflower cultivars) under multiple-choice conditions in field-cage and open-field trials. The negligible acceptance of *Helianthus* crops for oviposition may be explained by perception impedance. Experiments conduced in Japan show that extracts from *H. annuus* are much less a stimulant for feeding activity than those from other nontarget asteraceous plants (Tamura et al. 2004). The test designed to assess risks to sunflower carried out in Canada conclude that sunflower plants are at a negligible risk of being attacked by *O. communa* (Dernovici et al. 2006). With all available evidence, we argue that *O. communa* would not use sunflower as the host plant for oviposition and therefore pose no risk to it.

Acknowledgments We thank Fang Liu and Yuan He for help in the experiments. This study was supported by the National Basic Research and Development Program (2009CB119200), Natural Science Foundation of China (NSFC30470295), and National Science & Technology Pillar Program (2006BAD08A18). The experiments reported in this paper comply with the current laws of the People's Republic of China where they were conducted. All of the authors in this paper declare that they have no conflict of interest.

References

Bagarozzi D, Travis J (1998) Ragweed pollen proteolytic enzymes: possible roles in allergies and asthma. Photochemistry 47:593–598

Bernays EA, Chapman RF (1994) Host–plant selection by phytophagous insects. Chapman & Hall, New York

Briese DT (2003) The centrifugal phylogenetic method used to select plants for host-specificity testing of weed biological control agents: can and should it be modernized? In: Spafford-Jacob H, Briese DT (eds) Improving the selection, testing and evaluation of weed biological control agents. CRC Technol Ser No 7, pp 23–33

Chi J, Zheng Q, Long X et al (2009) Research on effect of *Helianthus tuberosus* L. Replanting on growth and soil bioactivity in Laizhou Bay. J Nat Res 24:1014–1021

Coutinot D, Starfinger U, McFadyen R et al (2008) Feasibility of biological control of common ragweed (*Ambrosia artemisiifolia*) a noxious and highly allergic weed in Europe. In: Julien MH, Sforza R, Bon MC, et al (eds) Proceedings of the XII international symposium on biological control of weeds, CAB International, Wallingford, pp 717–719

Dernovici SA, Teshler MP, Watson AK (2006) Is sunflower (*Helianthus annuus*) at risk to damage from *Ophraella communa*, a natural enemy of common ragweed (*Ambrosia artemisiifolia*)? Biocontrol Sci Technol 16:669–686

Emura K (1999) The ragweed beetle *Ophraella communa* LeSage (Coleoptera: Chrysomelidae) which injures harmful exotic plants. Plant Prot 53:138–141 (in Japanese with English summary)

Futuyma DJ (1990) Observations on the taxonomy and natural history of *Ophraella wilcox* (Coleoptera: Chrysomelidae), with a description of a new species. J N Y Entomol Soc 98:163–186

Goeden RD, Ricker RD (1985) The life history of *Ophraella notulata* (F.) on western ragweed, *Ambrosia psylostachya* De Candolle, in

southern California (Coleoptera: Chrysomelidae). Pan Pac Entomol 61:32–37
Hilgendorf JA, Goeden RD (1981) Phytophagous insects reported from cultivated and weedy varieties of the sunflower, *Helianthus annuus*, in north America. Bull Entomol Soc Am 27:102–108
Lee IY, Park JP, Oh SM et al (2007) Selection of insects for potential biological control of *Ambrosia trifida*. Korean J Weed Sci 27(4):309–317
LeSage L (1986) A taxonomic monograph of the nearctic galerucine genus *Ophraella* Wicox (Coleoptera: Chrysomelidae). Mem Entomol Soc Can 133:1–75
Li Q, Xiang W, Hao W (2005) The study and utilization of *Xanthium sibiricum*. Chin Agri Sci Bull 21:116–120 (in Chinese with English summary)
Marohasy J (1996) Host shifts in biological weed control: real problems, semantic difficulties or poor science? Int J Pest Manage 42:71–75
Meng L, Li B (2005) Advances on biology and host specificity of the newly introduced beetle, *Ophraella communa* LeSage (Coleoptera: Chrysomelidae), attacking *Ambrosia artemisiifolia* (Compositae) in continent of China. Chin J Bio Contr 21:65–69 (in Chinese with English summary)
Nakamura I, Ogata Y, Hamada S (1996) Ethanol production from Jerusalem artichoke tubers by *Aspergillus niger* and *Saccharomyces cervisiae*. J Ferment Bioeng 81:564–566
Palmer WA, Goeden RD (1991) The host range of *Ophraella communa* LeSage (Coleoptera: Chrysomelidae). Coleopts Bull 45:115–120
R Development Core Team (2009) R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL. [2009-5-31]. http://www.R-project.org
Schaffner URS (2001) Host range test of insects for biological control: how can it be better interpreted? Bioscience 51:951–959
Tamura Y et al (2004) Relationship between the host plant preference of the leaf beetle *Ophraella communa* LeSage (Coleoptera: Chrysomelidae) and distribution of feeding stimulants in Asteraceous plants. Jpn J Appl Entomol Zool 48:191–199 (in Japanese with English summary)
Tokyo Metropolitan Plant Protection Office (1999) Annual report. Pest Forecasting Spec 3:1–2 (in Japanese)
Wan FH, Ding JQ (1995) Biological control of *Ambrosia artemisiifolia* with introduced insect agents, *Zygogramma suturalis* and *Epiblema strenuana*, in China. In: Delfosse E, Scott RR (eds) Proceedings of 8th international symposium on biological control of weeds. Lincoln, NZ, DSIR/CSIRO, Melbourne, pp 193–200
Wan FH, Ding JQ (2003) Integrated control effects of *Epiblema strenuana* (Lepidoptera: Tortricidae) and *Ostrinia orientalis* (Lepidoptera: Pyralidae) against ragweed, *Ambrosia artemisiifolia* (Compositae). Acta Entomol Sin 46:473–478 (in Chinese with English summary)
Wan FH, Wang R (1990) Study on characteristics of biology and ecology of *Ambrosia artemisiifolia*. Chin J Weed 4:45–48 (in Chinese with English summary)
Wan FH, Guan GQ, Wang R (1993) Integrated management of ragweed, *Ambrosia artemisiifolia* (Compositae). Chinese Science and Technology Press, Beijing
Wan FH, Liu WX, Ma J et al (2005) *Ambrosia artemisiifolia* and *A. trifida*. In: Wan FH, Zheng XB, Guo JY (eds) Biology and management of invasive alien species in agriculture and forestry. Science Press, Beijing, pp 662–688
Watanabe M, Hirai Y (2004) Host-use pattern of the ragweed beetle *Ophraella communa* LeSage (Coleoptera: Chrysomelidae) for overwintering and reproduction in Tsukuba. Appl Entomol Zool 39:249–254
Xia FY (1983) Ragweed pollen allergy. Plant Quarantine 6:16–19 (in Chinese with English summary)
Yamazaki K, Natuhara Y (2000) Rapid population growth and food-plant exploitation in exotic leaf beetle, *Ophraella communa* LeSage (Coleoptera: Chrysomelidae), in western. Jpn J Appl Entomol Zool 35:215–223 (in Japanese with English summary)
Zar JH (2010) Biostatistical Analysis, 5th edn. Pearson Prentice Hall, NJ
Zhang W, Yao L, Liu GH (2007) Distribution of Ragweed pollen in Wuhan city and its relationship to airway responsiveness of allergic asthma patients. Cent China Med J 31:253–254 (in Chinese with English summary)
Zhou ZS, Guo JY, Wan FH et al (2010) Impacts of low temperature storage on survival and fecundity of *Ophraella communa* LeSage (Coleoptera: Chrysomelidae). Chin J Bio Contr 24:376–378 (in Chinese with English summary)
Ziska LH, Gerhard DE, Franz DA et al (2003) Cities as harbingers of climate change: common ragweed, urbanization, and public health. J Allergy Clin Immunol 111:290–295