Relationship between host searching and wind direction in *Ophraella communa* (Coleoptera: Chrysomelidae)

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Insects use visual, olfactory, and tactile sensory cues to detect potential oviposition sites and locations in the environment (Krugner et al. 2008; Obonyo et al. 2008). Chemoreception is essential to the recognition of host plants by some insect herbivores (Dethier 1982; Bernays & Chapman 1994; Ono & Yoshikawa 2004). Because the selection of a favorable oviposition site is critically important, adult host searching behaviors may be focused on a narrow range of plant species (Sarfraz et al. 2006). Previous studies showed that volatile substances from plants often play an important role in determining whether or not a plant is acceptable for oviposition or development (Ono & Yoshikawa 2004; Sarfraz et al. 2006). Winds at low to moderate speeds during periods with temperature inversions can carry an odor as an unbroken horizontal plume for long distances from the point of odor emission (Murlis 1986; Murlis & Jones 1981). Insects can navigate upwind within the plume and locate the source of the odor (Murlis et al. 1990).

Ophraella communa LeSage (Coleoptera: Chrysomelidae), native to North America (LeSage 1986), was discovered first in China in 2001 on the invasive weed, *Ambrosia artemisiifolia* L. (Asterales: Asteraceae) (Meng & Li 2005). Thus, *O. communa* is considered to be a fortuitous biological control agent of *A. artemisiifolia* in China (Zhou et al. 2009, 2014), and it feeds only on certain Asteraceae plants including *A. artemisiifolia* (Futuyma 1990). *Ophraella communa* adults do not attack sunflower plants (*Helianthus annuus* L.; Asteraceae), although both sunflower and *A. artemisiifolia* belong to the Compositae (Asteraceae) (Dernovici et al. 2006; Zhou et al. 2011), and only a fraction of *O. communa* immatures can survive on sunflower (Cao et al. 2011). *Ophraella communa* females tend to begin oviposition on the third day after mating, the ovipositional period lasts 40 to 60 d, and eggs can hatch within 4 to 6 d after oviposition (Zhou et al. 2010; Zheng et al. 2015). The length of a generation of the beetle (the mean time from the birth of the parents to the birth of their offspring) was shown to be 24 to 25 d (Zhou et al. 2010).

We conducted this study in 2010 in order to evaluate our hypothesis that in the field, *O. communa* recognizes *A. artemisiifolia* as a host primarily by olfactory chemoreception, and that *O. communa* can do so even when visual recognition of the host plants is blocked by dense plantings of sunflower, another Asteraceae species.

Seeds of common ragweed were sown in soil in an unheated greenhouse at the Institute of Plant Protection, Hunan Academy of Agricultural Sciences, Changsha, China (25.354947°N, 114.56111°E). The seedlings were watered every 4 d and fertilized with a solution of 13:7:15 (N:P:K) twice per mo. The ragweed seedlings were transplanted when they reached 15 cm in height. Also, sunflower seeds were germinated in seed plates in the same unheated greenhouse. The sunflower seedlings were watered every 4 d and were transplanted at the 2- to 4-leaf stage.

Ophraella communa pupae were collected in Miluo county (28.921289°N, 113.264269°E), Hunan Province, China, on 4 Jun 2010. The pupae then were stored in a transparent plastic box (19 cm × 12 cm × 6 cm) at 26 ± 1 °C, 70% ± 5% RH, and 14:10 h (L:D) photoperiod. Newly emerged males and females were raised separately on potted *A. artemisiifolia* plants in cages (40 cm × 40 cm × 60 cm) in the aforementioned insectary at a density of 20 adults per plant and 1 plant per cage. Two-d-old adult beetles were used for this study.

A field study was conducted in a suburb of Changsha City in Hunan Province in 2010. The site of the experiment was divided into 5 circular plots, and adjacent plots were separated by 3 m wide strips of fallow (cultivated but unplanted) ground. Each circular plot consisted of a central 4 m diam circle surrounded by four 1 m wide concentric bands (Fig. 1). Thirty common ragweed seedlings from the nursery were transplanted on 12 Apr 2010 into the central circle (r = 2 m), and

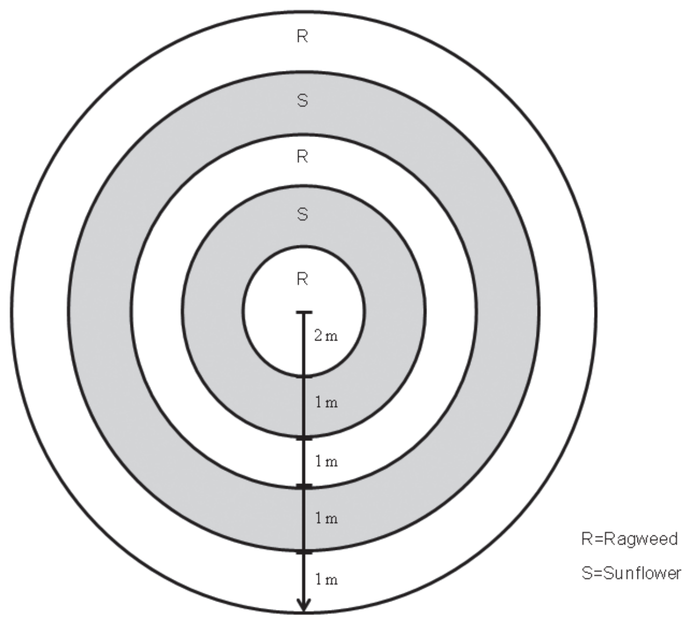

Fig. 1. Plot design to study the location of host plants by *Ophraella communa* adults in relation to wind direction. This diagram displays the planting pattern for 1 m wide concentric plots of the host, common ragweed, separated by 1 m wide concentric barriers of a non-host, sunflower.

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common ragweed seedlings and sunflower seedlings were transplanted into the alternate concentric bands as shown in Figure 1. In these concentric bands the between-row distance was 35 cm and the within-row distance between adjacent plants was 25 cm for both sunflower and common ragweed (Zhou et al. 2011).

Wind directions changed dramatically on different dates in 2010. Southwestern and southern winds prevailed from 5 to 10 Jul, with more southeastern, northwestern, and southwestern winds from 11 to 20 Jul, then southeastern, southern, and southwestern winds from 21 to 31 Jul. In addition, southeastern, southern, and southwestern winds were prevalent, but then were followed by more northwestern winds from 1 to 10 Aug. Southeastern, southern, and southwestern winds dominated wind directions from 11 to 15 Aug (Fig. 2). The meteorological data were obtained from Changsha Meteorological Bureau (Changsha City, Hunan Province, China).

Virgin *O. communa* adults were randomly selected from the aforementioned stock culture and randomly released on common ragweed plants in the central circle of each plot, at a rate of 50 males and 50 females per plot on 5 Jul 2010 (Zhou et al. 2011). Surveys were carried out by visual inspection of the plants on 19 Jul, 26 Jul, 2 Aug, and 10 Aug. During the first survey, 20 common ragweed plants (i.e., 10 plants per band) in each cardinal direction (i.e., north, south, east, or west) were randomly selected in each plot and labeled for the subsequent surveys (Zhou et al. 2011). The numbers of eggs and adults on each sampled common ragweed plant were recorded in each band of each plot at each survey.

Data were checked for normality and homoscedasticity, and if needed, were arcsine square-root or log-transformed before analysis by 1-way ANOVA (SAS Institute 2004). The least significant difference (LSD) test ($P < 0.05$) was used to compare the means of eggs or adults among directions for each date independently.

In general, the results showed that, in relation to the center of each plot, most eggs and adults were distributed to the south. The fractions of the eggs and adults that were distributed to the other cardinal directions varied somewhat from one survey to the next. Thus we found significant differences in the number of *O. communa* eggs ($F_{3,16} = 260.48$; $P < 0.0001$ on 16 Jul; $F_{3,16} = 197.17$; $P < 0.0001$ on 26 Jul; $F_{3,16} = 197.17$; $P < 0.0001$ on 2 Aug; $F_{3,16} = 7615.76$; $P < 0.0001$ on 10 Aug) and adults ($F_{3,16} = 128.00$; $P < 0.0001$ on 16 Jul; $F_{3,16} = 10.56$; $P = 0.0005$ on 26 Jul; $F_{3,16} = 82.67$; $P < 0.0001$ on 2 Aug; $F_{3,16} = 905.05$; $P < 0.0001$ on 10 Aug) among cardinal directions during our surveys in the 5 plots (Fig. 3).

The densities of *O. communa* adults and eggs were greatest on host plants situated in the direction from which the dominant wind blew, i.e., south. This clear result indicated that selection of oviposition sites by the females was determined primarily by olfaction. Thus, the beetles responded to chemicals emitted by the *A. artemisiifolia* host plants by flying upwind to their source, the host plants. The sunflower plants that served as a visual barrier did not prevent *O. communa* females from finding the *A. artemisiifolia* host plants.

Oviposition site selection by adult females is an important aspect of survival strategy, whereby suitable nutrition and habitat are provided to support the growth and development of their progeny (Jaenike 1978; Mayhew 2001; Liu et al. 2012). In general, insects use their sensory organs to detect potential oviposition sites and locations (Krugner et al. 2008; Obonyo et al. 2008), though some early studies suggested that selection of the oviposition substrate by some herbivorous insect species was influenced by leaf color (Loughrin et al. 1995; Held & Potter 2004; Khan et al. 2006). Thus, the oviposition site selection of some

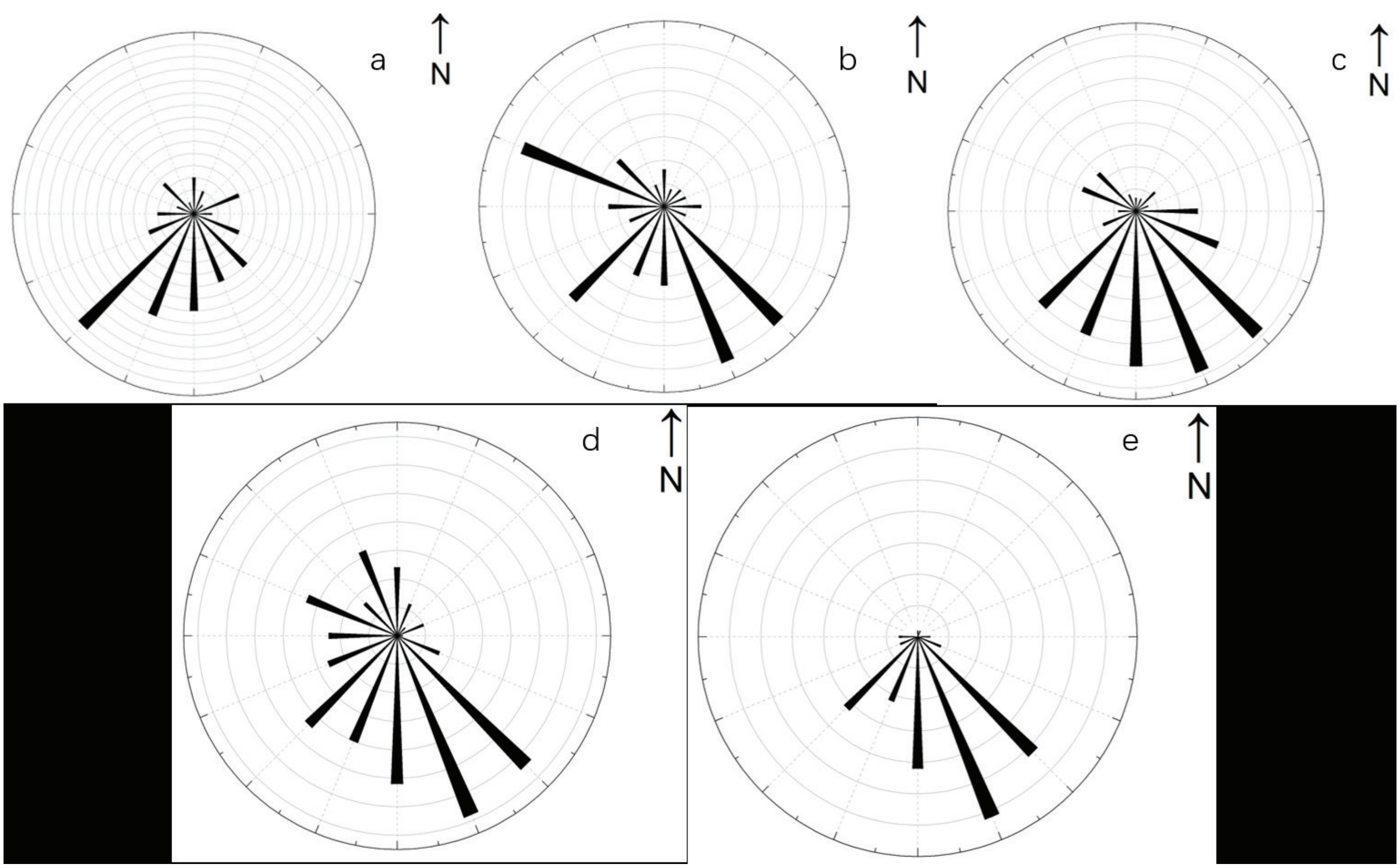

Fig. 2. Wind roses at different dates observed by Changsha Meteorological Observatory from 5 Jul to 15 Aug 2010. The letters a, b, c, d, and e in each small figure represented general wind roses on 5–10 Jul, 11–20 Jul, 21–31 Jul, 1–10 Aug, and 11–15 Aug 2010, respectively.

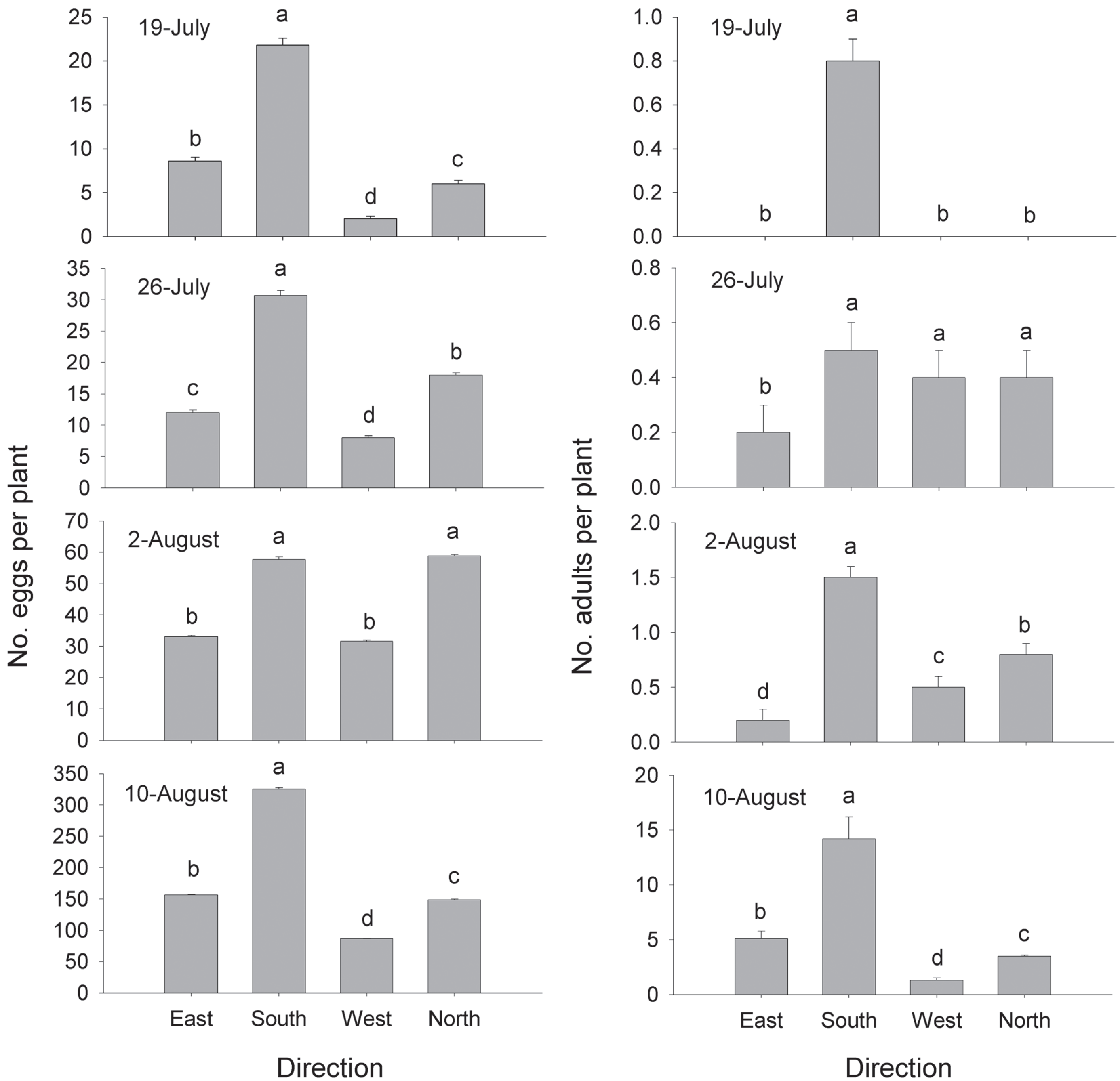

Fig. 3. Mean numbers (± SE) of *Ophraella communa* eggs and adults at various cardinal directions from the center of each plot on common ragweed plants in the concentric bands. Data represented by columns bearing the same letters were not significantly different (LSD, a = 0.05). The dominant direction of the wind during the period of the entire experiment was from the south.

insect species may correlate with the contents of a few pigments in the leaves of their host. However, our study suggested that oviposition preference of *O. communa* females is strongly dependent on the odors of its host plants. Therefore, *O. communa* females can find *A. artemisiifolia* plants that are upwind even when they cannot detect these host plants by visual stimuli.

As expected, we began to find some *O. communa* larvae when we conducted the first survey at 2 wk after the release of the adults, but we did not determine their densities, because these data were not needed to meet the objectives of our experiment. In addition, as mentioned above, the length of a generation of the beetle is 24 to 25 d. Thus, the eggs laid at the beginning of our experiment had developed into adults before the end of our experiment.

The densities of adults and eggs were higher than expected in the common ragweed in the northern sectors of a few plots, each located to the south of another plot (data not shown). Thus, it appears that some *O. communa* females that flew south from the more northern plot passed through 2 bands of sunflower and reached the common ragweed in the northern sector of the plot situated to the south.

We thank Ms. Min Li (Fujian Agricultural and Forestry University), Dr. Hong-Song Chen, and Ms. Wei Guo (Hunan Agricultural University), and Prof. Yuan-Hua Luo (Institute of Plant Protection, Hunan Academy of Agricultural Sciences, Changsha, China) for their help during the experiment. This work was supported by the National Natural Science Foundation for Excellent Young Scholars (No. 31322046) and the National Natural Science Foundation of China (No. 31171908).

Summary

The spread and oviposition of *Ophraella communa* LeSage (Coleoptera Chrysomelidae) adults on *Ambrosia artemisiifolia* L. (Asterales: Asteraceae) were affected by wind direction. The densities of adults and eggs were the highest on plants located in the direction from which the wind blew. Our results suggest that oviposition preference of *O. communa* adults may be more dependent on the odors emitted by host plants than on their color.

Key Words: odor; wind direction; oviposition preference

Sumario

La difusión y la oviposición de adultos de *Ophraella communa* LeSage (Coleoptera: Chrysomelidae) sobre *Ambrosia artemisiifolia* L. (Asterales: Asteraceae) dependían de la dirección del viento. La densidad de adultos y huevos fueron los más altos en las plantas situadas en la dirección desde la que soplaba el viento. Nuestros resultados sugieren que la preferencia de oviposición de los adultos de *O. communa* puede ser más dependiente de los olores emitidos por las plantas hospederas que de su color.

Palabras Clave: olor; dirección del viento; preferencia de oviposición

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