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SHORT COMMUNICATION

First report of seed dispersal by ants in *Dicentra peregrina* (Papaveraceae), an alpine plant in the Japanese Alps

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Abstract

Seed dispersal by ants, known as myrmecochory, is commonly observed among various plant taxa. The seeds of these plants have an elaiosome to attract ants. In Japan, myrmecochory has been well studied in several lowland plant species, but not in highland plant species that grow above the tree line. We investigated whether the seeds of *Dicentra peregrina*, known as the "queen of the alpine plants" in Japan, are carried by *Formica gagatoides* ants at 2510 m a.s.l. on Mt Norikura, Kita-Alps, Japan. We observed *F. gagatoides* workers picking up *D. peregrina* seeds by grasping the elaiosome and carrying the seeds into their nests. We inferred from the observed ant behavior and the seed morphology that *D. peregrina* is a myrmecochorous species.

Key words: elaiosome, Mt Norikura, myrmecochory, seed transport.

Seed dispersal by animals plays an important role in the life history, evolution and speciation of plants because it determines the movement of plant genes in space. Myrmecochory, seed dispersal by ants, is frequently encountered in terrestrial ecosystems, involving at least 11 000 plant species belonging to 334 genera (Berg 1975; Nakanishi 1988; Ohkawara *et al*. 1996). Myrmecochorous seeds have a lipid-rich appendage called an elaiosome that attracts ants. Typically, the ants carry the seeds to their nests as a food resource, eat the elaiosome, and then discard the uneaten parts of the seeds either within or outside of their nests. Thus, myrmecochory benefits plants by dispersing their seeds from the parent plant and reducing seedling competition (Howe & Smallwood 1982).

Studies of myrmecochory in Japan are scarce. A few myrmecochorous angiosperm genera (e.g. *Corydalis*, *Erythronium*, *Trillium* and *Viola*) have been identified in lowland temperate deciduous forest habitats (Higashi *et al*. 1989; Ohkawara & Higashi 1994; Ohkawara *et al*. 1996; Takahashi & Itino 2012). Some species in the genus *Dicentra* (Papaveraceae) are also known to be myrmecochorous (Berg 1969), and their seeds have an elaiosome that attracts various ant species (Kusmenoglu *et al*. 1989). Seeds of *D. peregrina* (Rudolph) Makino, 1908, which is known as the "queen of the alpine plants" in Japan, have a large elaiosome, which suggests that this species is also myrmecochorous (Chiba & Shimizu 2006; Fig. 1), but no direct field observations of *D. peregrina* seed dispersal by ants have been reported. We hypothesized that in *D. peregrina*, seed dispersal is mediated by an ant species whose habitat spatially overlaps that of *D. peregrina*, such as *Formica gagatoides* Ruzsky, 1904. In the Japanese Alps (central Honshu), *D. peregrina* and *F. gagatoides* are distributed at elevations above 2500 m a.s.l. (Kondoh 1976; Toyokuni 1988; Togai *et al*. 2012).

On 20 September 2013, we observed several nests of *F. gagatoides* within a circle of radius 200 m at 2510 m a.s.l. on Mt Norikura (36°08′36.6″N, 137°33′33.1″E), in the subalpine zone dominated by Japanese stone pine (*Pinus pumila*). In this study area, a few hundred *D. peregrina* individuals grow on gravelly soil around *P. pumila* bushes. The weather during the hours of the survey, 1030–1300 h Japan Standard Time, was seasonally warm, sunny and dry with no wind (temperature, 15°C; relative humidity, <10%; precipitation, 0 mm/h;

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wind velocity, <2.5 m/s; Mt Norikura (Fujimidake), the Environmental Monitoring Station, Institute of Mountain Science, Shinshu University).

We collected ten *D. peregrina* seeds (Fig. 1) from wilted flowers from each of three individual plants and identified two *F. gagatoides* nests (colony A and colony B, about 10 m apart) in the vicinity of these *D. peregrina* plants. We put five seeds near the entrance hole of each nest and observed the behavior of the ants for 1 hour. During this observation period, some workers took an interest in the seeds, and checked the seeds with their antennae. Then, they immediately picked up the seeds by grasping the elaiosome (Fig. 2) and carried the seeds into their nests. *Dicentra peregrina* seeds are thin and smooth, so it is likely that the workers could not easily grasp the seed except by the elaiosome.

Figure 1 Seed of *Dicentra peregrina* showing the elaiosome.

Figure 2 Worker of *Formica gagatoides* carrying a *Dicentra peregrina* seed.

We observed *F. gagatoides* workers carry five seeds into a nest (one seed was carried into colony A, and four were carried into colony B). This behavior suggests myrmecochory of *D. peregrina*.

We used Photo Measure software (Kenis Ltd, Osaka, Japan) and a binocular microscope (40× magnification) to measure the length and thickness of the seeds and elaiosomes of four of the collected samples. Measurements were made using images through the microscope. The seeds were black and disk-shaped, but with a re-entrant underside (length, 1.902 ± 0.047 mm; width, 0.967 ± 0.003 mm; mean ± SD; $n = 4$). The elaiosome, which was attached to the re-entrant part of the seed, was yellowish white, of indeterminate form and covered by sparse hairs (length, 0.521 ± 0.07 mm; width, 0.595 ± 0.085 mm; mean ± SD; $n = 4$). In overall shape, both the seed and elaiosome resemble those of some species of genus *Corydalis*, which belongs to the same family as *Dicentra* (Nakashishi 1994).

Some studies have suggested that the seeds of Japanese alpine herbs, including *D. peregrina*, which grow on gravelly soils, are dispersed mainly by the movement of gravel, water and wind (e.g. Masuzawa 1997; Ozeki & Otsuka 2008). Thus, it is possible that the ants play a subsidiary role in seed dispersal to such inorganic dispersal mechanisms.

In *Dicentra*, the elaiosome is generally a rich source of fatty acid (Kusmenoglu *et al.* 1989). Thus, the elaiosome of *D. peregrina* seeds may be very attractive to ants in the subalpine zone, where food resources are scarce. The ants probably consume the elaiosome in their nests, and discard uneaten parts of the seeds outside of their nests as garbage. Because *Formica* ants are food generalists, not specialist seed-eaters (e.g. Myrmecological Society of Japan 1991), they may not able to chew the seeds, which have a hard, smooth surface. In addition, only seeds discarded outside of the colony would germinate because seed germination in *D. peregrina* is known to be induced by light (e.g. Chiba & Shimizu 2006) and inhibited when the seeds are covered by soil, such as in an ant nest. Moreover, short-distance transport by *F. gagatoides* can be advantageous for the germination and growth of *D. peregrina*. Gorb and Gorb (2000) reported that *Formica* ants are not good at carrying small plant seeds (seed length <2 mm). Because *D. peregrina* seeds are less than 2 mm long, *F. gagatoides* workers would not likely carry them far enough to leave the area of gravelly soil on which *D. peregrina* individuals grow well.

We also considered whether any other ant species might contribute to the seed dispersal of *D. peregrina*, because the elaiosome should attract workers of many different ant species (Kusmenoglu *et al.* 1989). In the

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vicinity of our study site, we observed two additional ant species: *Leptothorax acervorum* Fabricius, 1793, and *Myrmica kurokii* Forel, 1907 (Ueda & Komatsu 2014). However, whereas *F. gagatoides* is distributed dominantly in the relatively open subalpine zone, *M. kurokii* is a forest dweller and *L. acervorum* is present in the subalpine zone only at low density. Thus, these other ant species probably seldom encounter seeds of *D. peregrina*. Therefore, we predict that even if these species are shown experimentally to have an interest in *D. peregrina* seeds, they will not actually carry the seeds.

Dicentra peregrina is listed as a threatened plant species in most Japanese prefectures in which it is found (e.g. Hokkaido Prefecture 2001; Niigata Prefecture 2001). Thus, further ecological and evolutionary studies of this species, especially from the viewpoint of its reproduction and seed dispersal, are needed.

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