Effects of diverse surrounding ecosystems and pollinator species on crop pollination

Hisatomo Taki
Department of Forest Entomology
Forestry and Forest Products Research Institute
Matsunosato, Tsukuba, Ibaraki, 305-8687 Japan
E-mail: htaki@affrc.go.jp

Abstract

Animal crop pollination is an essential ecosystem service, much of which is provided by the managed European honeybee, as well as numerous wild species. This summary for the international seminar outlines our researches on common buckwheat pollination in Japan as a model agro-ecosystem. Furthermore, I have shown the importance of natural and semi-natural ecosystems surrounding crop fields, as well as diverse pollinator species, on sustainable crop pollination.

Keywords: ant, *Apis cerana*, *Apis mellifera*, bee, beetle, butterfly, *Fagopyrum esculentum*, fly, honeybee, landscape, non-honeybee

Introduction

Animal crop pollination is an essential ecosystem service, as approximately 75% of major crops worldwide require animal-mediated pollination (Klein et al. 2007). This service is provided by the managed European honeybee (*Apis mellifera*), as well as numerous wild species. (Richards 2001; Klein et al. 2007). Pollination by wild species has been negatively affected by human activity, including intense agriculture (Taki et al. 2007; Ricketts et al. 2008) frequently coupled with habitat loss and degradation (Kearns et al. 1998). Wild pollinators often nest and feed in natural and semi-natural habitats surrounding agricultural fields (Tscharntke et al. 2005).

Using Food and Agriculture Organization of the United Nations (FAO) statistics on temporal global trends in food production, Aizen et al. (2008) and Ghazoul and Koh (2009) showed that pollinator shortages do not affect crop yield on a global scale. However, agriculture has become more dependent on animal pollination because of a great increase in the land area used to cultivate pollinator-dependent crops. Consequently, the need for animal pollination services could increase greatly in the near future.

This summary for the international seminar “Enhancement of Functional Biodiversity Relevant to Sustainable Food Production in the Asia and Pacific Region” discusses our works on common buckwheat (*Fagopyrum esculentum*) pollination in Japan (Fig. 1) as a model agro-ecosystem. In particular, the studies investigated how diverse ecosystems and pollinator species near and around buckwheat fields affect crop pollination.

Model crop and agro-ecosystem

Buckwheat encompasses a variety of species in the plant family Polygonaceae. This family contains the Eurasian genus *Fagopyrum*, the North American genus *Eriogonum*, and the Northern Hemispheric genus *Fallopia*, all referred to as wild buckwheat. The cultivated common buckwheat (*Fagopyrum esculentum*) is the most economically important buckwheat species for world food production. Russia, China, and Ukraine produce the most common buckwheat, and total world production is about 2,500,000 tons (FAO 2009). However, many small landholders across Asia also grow common buckwheat. In 2007, Japan imported 71,000 tons of this crop, accounting for more than 70% of the total amount consumed in the country (MAFF 2008). Common buckwheat is important culturally in Japan, as flour made from this plant is used to make soba noodles, a type of thin noodle that is in high demand throughout the country. From 1986 to 2007, the land area planted with common buckwheat in Japan increased from about 19,600 ha to 46,100 ha (MAFF 2008).

Common buckwheat is a self-incompatible, distylous plant species with two unique flower morphs: pin and thrum (Fig. 2). Pin flowers have long styles that project beyond short stamens, whereas thrum flowers have long stamens that extend beyond short styles. These features indicate that this species depends highly on animal pollination (Campbell 1997). The flower morphs usually occur at a 1:1 ratio (Komaki 1982). Flowers are incomplete (lacking a corolla) but perfect (having both sex organs) and organized in racemes of cymes; however, each flower has only one ovule. A single plant produces multiple inflorescences over a 25- to 30-day period with each flower open and receptive for 1 day. Flowers produce nectar, secreted by glands at the base of the ovary. Numerous insect groups, including Hymenoptera, Diptera, Coleoptera, and Lepidoptera, visit common buckwheat flowers (Campbell 1997). Although wind pollination sometimes occurs over short distances (Adhikari & Campbell 1998), insects are the main pollinators.

In the studies, fields of the common buckwheat cultivar Hitachiakisoba, grown in Hitachiota, Ibaraki Prefecture, Japan, were used as model sites. In this prefecture, small local landholders grow common buckwheat in mountainous regions. The landscape of the study region is complex, consisting of both agricultural fields (e.g., paddies, orchards, and tea fields) and semi-natural and natural lands (e.g., grasslands, cedar plantations, and deciduous woodlands). Sowing is typically completed during the second week of August, and harvesting occurs in mid-October. No fertilizers, pesticides, or other agrochemicals were used in the common buckwheat fields.

Influence of field surroundings on pollinators and seed set

In Taki et al. (in press), the outcome of multiple spatial effects on common buckwheat pollination was examined, with a focus on pollinator abundance and pollination success. The study was conducted in an area where common buckwheat pollinators included a managed honeybee (*Apis* *mellifera*), a native honeybee (*Apis cerana*), and wild non-honeybee insects. Landscape factors had been expected to affect pollinator behavior, leading to interactions at different spatial scales. The correlation between different landscape factors at different spatial scales and pollinator abundance and pollination success was investigated.

The study found that the abundance of managed honeybees, native honeybees, and wild non-honeybee insects in fields was significantly correlated with the distance from managed hives, the area of forest cover within a several-kilometer radius, and the area of forest and grassland cover within a smaller radius, respectively (Fig. 3). However, only the latter two landscape factors showed significant positive correlations with seed set (Fig. 4). These findings suggest that considering field surroundings at different spatial scales associated with the characteristics of managed and wild pollinators could help to ensure crop yields.

Effects of diverse pollinator species on seed set

In Taki et al. (2009), the study investigated the effects of diverse pollinator species, especially non-honeybee insects, on the seed set of common buckwheat. The study focused on insects smaller than honeybees. While some small insects might not have sufficient body surface area to carry pollen between the two flower morphs, many land on, and consume pollen or nectar from, petals. Consequently, small insects may contribute to pollen transfer from the short anthers of pin flowers to the short styles of thrum flowers, resulting in sufficient seed set in thrum flowers.

The contribution of small insects to pollen transfer between the two flower morphs was tested. In distylous pollination systems, pollinator species are usually limited, although some distylous plants have diverse animal pollinators. In the study, the flowers were covered with wide-mesh bags to exclude honeybees and larger insects. The seed sets of bagged plants and untreated plants were compared for pin and thrum flower morphs.

The study found that the seed set of only bagged pin flowers was greatly reduced, and that small insects, including ants, bees, wasps, and flies, carried pin-morph pollen. These insects transferred pollen from the short anthers of pin flowers to the short styles of thrum flowers, leading to sufficient seed set in thrum flowers. These results indicate that even small, non-honeybee insects have the potential to maintain at least half of the yield of this mostly honeybee-dependent distylous crop.

Conclusion

These studies on common buckwheat crops in Japan show the importance of both natural and semi-natural ecosystems surrounding crop fields and diverse pollinator species on crop pollination sustainability.

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Figure captions

Fig. 1. Common buckwheat fields in a mountainous region in Hitachiota, Ibaraki, Japan.

Fig. 2. Common buckwheat pin-type (top) and thrum-type (bottom) flowers visited by an ant and an Asian honeybee, respectively. Pin flowers have long styles that project beyond the short stamens, whereas thrum flowers have long stamens that extend beyond the short styles.

Fig. 3. The relationship between natural or semi-natural areas surrounding farm fields and the abundance of common buckwheat pollinator insects (Asian honeybees and non-honeybee insects).

Fig. 4. The relationship between natural or semi-natural areas surrounding farm fields and seed set in common buckwheat.

Fig. 1

Fig. 2.

Fig. 3.

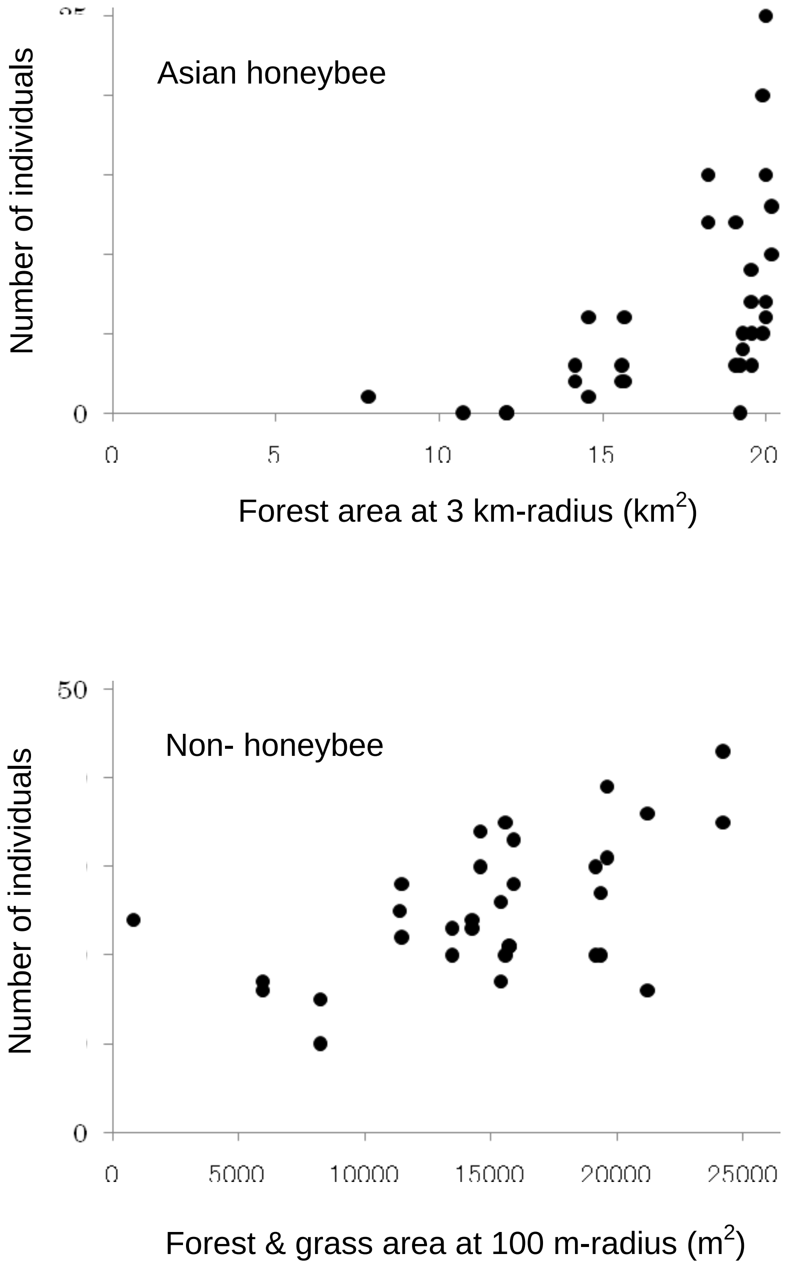
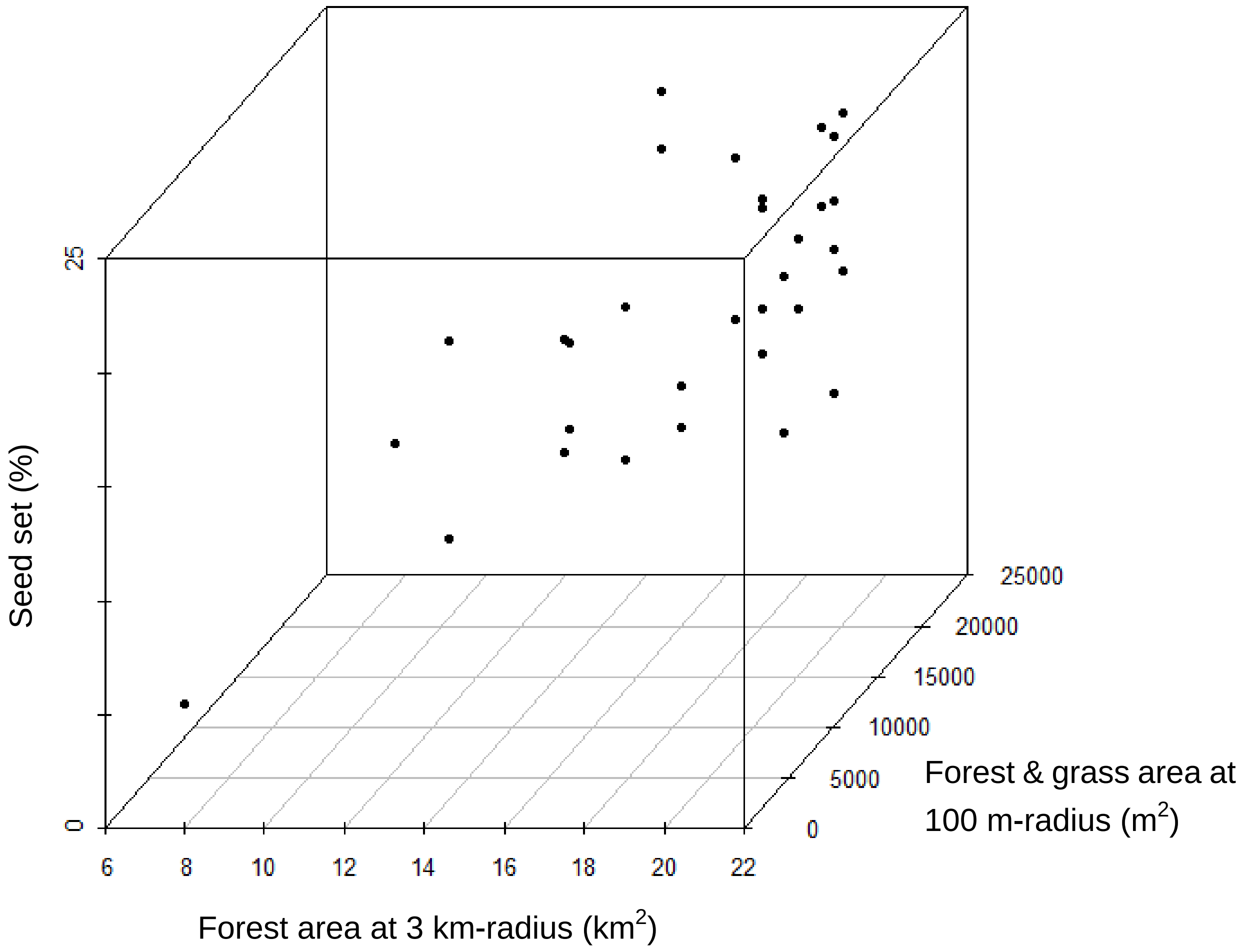

Asian honeybee
Number of individuals
0
0
5
10
15
20
Forest area at 3 km-radius (km2)
50
Non- honeybee
Number of individuals
0
0
5000
10000
15000
20000
25000
Forest & grass area at 100 m-radius (m2)

Fig. 4.


Seed set (%)
25
0
6
8
10
12
14
16
18
20
22
Forest area at 3 km-radius (km2)
25000
20000
15000
10000
5000
0
Forest & grass area at
100 m-radius (m2)