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Influences of the seminatural and natural matrix surrounding crop fields on aphid presence and aphid predator abundance within a complex landscape

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ABSTRACT

The biological control of pest insects in farmlands is an important ecosystem service provided by natural enemies, a tenet that is frequently supported by natural ecosystems; however, natural ecosystems can sometimes serve as a source of pests and can maintain them as an ecosystem disservice. We examined the effects of the surrounding seminatural and natural matrix on aphid presence and aphid predator abundance in buckwheat fields. We specifically aimed to detect whether the seminatural and natural matrix causes a trade-off between pest and natural enemy abundances. We established buckwheat study fields in a region of central Japan, the landscape of which is quite complex. Our results showed that aphid presence was not affected by either the abundance of ladybirds and lacewings or the area of the surrounding seminatural and natural matrix. We also found that the abundance of ladybirds, but not of lacewings, was significantly affected by the area of the seminatural and natural matrix. These findings suggest that in a complex landscape, as the area of seminatural and natural lands increases, some assemblages of natural enemies could also increase, but their biological control services would have little effect or would be compensated for by larger pest migration, leading to no net difference in pest damage.

1. Introduction

The biological control of pest insects in farmlands is a vital ecosystem service provided by natural enemies and this idea is frequently supported by natural ecosystems (Power, 2010). Non-crop lands often provide habitat and food resources for natural enemies of agricultural pests (Landis et al., 2000; Tscharntke et al., 2005). Several previous studies have reported greater diversity of natural enemies and more effective biological control services as the landscape structures surrounding agricultural fields become more complex, i.e., there is a larger area of non-crop lands (Thies and Tscharntke, 1999; Bianchi et al., 2006, 2008; Drapela et al., 2008; Boccaccio and Petacchi, 2009; Gardiner et al., 2009a). In fact, in many focal agricultural systems, the fields are usually surrounded by non-crop lands such as woodlands, grasslands, and residences. Therefore, to conduct agriculture with low pesticide inputs, native natural enemies that inhabit these surrounding habitats should be maintained and managed.

Conversely, natural ecosystems sometimes function as a source of pests and can maintain pest populations (Zhang et al., 2007). Non-crop lands may or may not serve as sources of agricultural pests (Hunter, 2002). For example, in a soybean system, fields surrounded by uncultivated grassy corridors exhibit higher pest densities and suffer from higher defoliation and lower yields (Kemp and Barrett, 1989). Incorporating a spatial scale broader than the agricultural field-patch scale is often important for the management of pests that partially inhabit non-crop ecosystems. To manage such pests, area-wide management is key and involves the systematic reduction of target pests to predetermined levels via the uniform application of mandatory pest mitigation measures over geographical areas clearly defined by biologically based criteria such as pest colonization and dispersal potential (Faust, 2008). Thus, the seminatural and natural matrix may cause increases in not only natural enemies but also pest abundances.

Many agricultural lands on mainland Japan have been established in rather complex landscapes. About 12% of the total land

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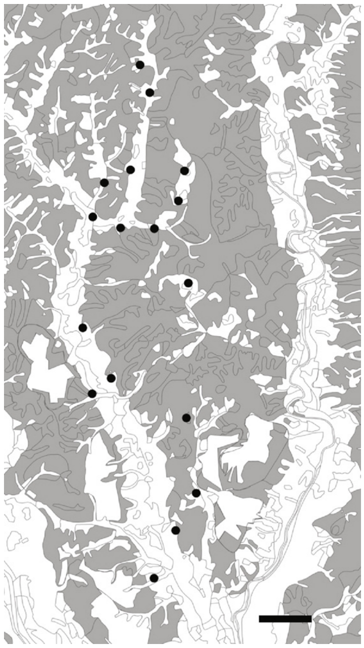

Fig. 1. Study sites in Hitachiota, Ibaraki Prefecture, central Japan. Gray areas indicate seminatural and natural land cover, and mostly conifer-planted and natural broad-leaved forest cover, and white areas indicate other land-cover types (agricultural fields, ponds, rivers, residences, and roads). Black dots represent study plots used for examinations of aphid presence and aphid predator collection. The black bar indicates 1-km scale.

cover is agricultural land, and farmers cultivate relatively small farms; approximately 82% of farmers own less than 2 ha (MAFF, 2009). Buckwheat (*Fagopyrum esculentum*) cultivation is one such cropping system. Various insect species, including the aphids *Aphis gossypii*, *Aulacorthum solani*, and *Macrosiphum euphorbiae*, are listed as pests of buckwheat (Japanese Society of Applied Entomology and Zoology, 2006). However, no insecticides for insect pests, excluding the noctuid moth *Spodoptera litura*, have been registered for buckwheat cultivation in Japan. These insect pests might be affected by the seminatural and natural matrix surrounding buckwheat fields within a complex landscape.

The purpose of the present study was to examine the effects of the seminatural and natural matrix on aphid presence and aphid predator abundance in buckwheat fields within a complex landscape. Specifically, we aimed to detect a trade-off caused by the seminatural and natural matrix between pest and natural enemy abundances. We established buckwheat study fields in a region of central Japan. We then investigated the proportion of plants with one pest aphid species in each of the buckwheat fields. The aphid species present was *A. gossypii*, which is extremely polyphagous and therefore has the potential to inhabit the surrounding matrix. Within the study fields, we also collected and counted aphid predators, i.e., ladybirds and lacewings.

2. Materials and methods

2.1. Study region and fields

Our study sites included fields of the cultivar Hitachiakisoba of buckwheat in Hitachiota, Ibaraki Prefecture, central Japan (36°30′–42°40′ N, 140°23′–140°31′ E) (Fig. 1). In this region, buckwheat is a distinctive crop grown by small local landholders for seed production in forest-dominated regions. The study was conducted at 17 individual field sites. The mean of the shortest distance between study sites was 787 m, ranging from 450 to 1402 m. The landscapes containing the buckwheat fields in the study region are rather complex, consisting of both agricultural fields such as paddies, orchards, and tea fields, and seminatural to natural lands such as grasslands, coniferous plantations, and broad-leaved woodlands. The area of the seminatural and natural matrix of the selected 17 buckwheat fields ranged from 25.9% to 79.9% (mean of 59.5%) within a 1000-m radius. The timing of sowing and harvesting of buckwheat is similar in all fields across the region. The sowing of each field is typically completed during the second week of August, and harvesting occurs in mid-October. Within-field effects were controlled, with no fertilizers, pesticides, or other agrochemicals used in the buckwheat fields studied (Taki et al., 2009).

2.2. Aphid presence and predators

In each field, we randomly selected 100 plants on 18 September and 100 plants on 6 October, 2008 for observation. On the second sampling date, we tried to avoid selecting plants that had already been checked on the first date. We selected plants at approximately 2–5 m from the southern edge of the field to standardize sampling among field sites. For individual selected plants, we carefully checked for the presence of the cotton aphid *A. gossypii*, which was the only aphid species found on the buckwheat plants in the study region, and counted the number of plants that harbored aphids. Results obtained from 100 plants on each day were combined.

For the collection of aphid predators, we used standard Townes-type Malaise traps (180 cm long, 120 cm wide, and 200 cm high; Golden Owl Publishers, Lexington Park, MD, USA). In each study buckwheat field, we set a Malaise trap at the edge of the field on the side where we had checked plants for aphid presence. Trapped ladybirds and lacewings were collected every 2 weeks from 25 August to 6 October, 2008, while buckwheat was planted in the field. Propylene glycol was used to preserve insects within the collection containers of the Malaise traps. All insects collected in each Malaise trap per site every 2 weeks were combined. The collected ladybirds and lacewings were identified, and we confirmed whether each species had been reported as a potential predator of the cotton aphid *A. gossypii* (Duelli, 2001; Nobunkyo, 2004).

2.3. Field matrix

The center of the area sampled for the proportion of plants with aphids in each of the common buckwheat fields was mapped using a global positioning system (GPS) device (eTrex Vista HCx; Garmin Ltd., Olathe, KS, USA) followed by geographic information system (GIS) analyses using ArcGIS 9.2 software (ESRI Inc., Redlands, CA, USA). We then measured the area of seminatural and natural lands, which were mostly natural broad-leaved and conifer-planted forests (Taki et al., 2011), surrounding the study sites at radii of 500, 1000, 1500, 2000, and 2500 m from the mapped points in the study fields. The area of seminatural and natural land was delineated from a 1:50,000 digital vegetation map, published by the Ministry of the Environment of Japan in 1999 (Taki et al., 2010). The vegetation map was updated with more recent large-scale deforestations through the interpretation of 2.5-m spatial resolution panchromatic SPOT 5 satellite imagery (SPOT Image, Toulouse, France) from 3 July, 2004, using ArcGIS 9.2 software. For more fine scales (i.e., radii of 100 and 200 m), we digitized the natural and seminatural land cover as well as other land-cover types, all of which were updated using actual field observations and interpretation of both ortho-rectified aerial photos taken on 8 June, 1991 and 2004 panchromatic SPOT 5 satellite imagery using the ArcGIS 9.2 software (Taki et al., 2010).

2.4. Data analysis

We began by using Mantel tests to check for significant spatial autocorrelation among study sites for the number of buckwheat plants with aphids and the abundance of collected ladybirds and