Selection of indicator organisms for functional agrobiodiversity at the crop field level in Japan

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Abstract

Our aim was to select biotic indicators that can help to evaluate the effects of environment friendly farming techniques on the conservation and enhancement of agrobiodiversity at the crop field level. We compared the species richness and abundance of arthropods between environment-preserving fields and conventional ones and selected those arthropods that were abundant in environment-preserving fields as candidate indicator organisms. On the basis of preliminary surveys conducted in 2008 and 2009, ground-dwelling beetles and two types of spiders were selected as nationwide-common indicators, whereas parasitoid wasps, predatory lady beetles, predatory stinkbugs, hoverflies, staphylinid beetles, ants, and predatory mites were classified as regional-common indicators.

Key words: biodiversity, indicator organism, natural enemy

Introduction

In 2007, the Ministry of Agriculture, Forestry, and Fisheries of Japan drafted a strategy to maintain and enhance biodiversity, and a research project entitled “Selection of functional biodiversity indicators and development of assessment methods” was started in 2008. One of the objectives of the project is to select indicators that can be used to evaluate the effects of environment friendly farming techniques on the conservation and enhancement of agrobiodiversity. To promote sustainable agriculture, environment friendly or environment-preserving farming systems, in which decrease spraying frequency of pesticides and herbicides, or none at all, are used, have been developed and propagated in Japan and other countries. By definition, sustainable agriculture is compatible with the conservation of biodiversity. However, little is known about the actual effects of these farming techniques on biodiversity in agroecosystem.

The project consists of two research groups: one working to select indicator organisms and another that will develop simple assessment and prediction methods. The first group is divided into two subgroups: one that is analyzing indicator organisms at the landscape level and another working at the crop field level. The landscape-level group is mainly surveying paddy fields, whereas the crop field–level group is surveying fruit and vegetable fields and orchards.

The project will run for 5 years. In the 2 years to date, candidate indicator organisms have been selected. In the next 3 years, the research team will choose the best indicator organisms from among the candidates and will develop a manual for examining indicator organisms and using them to evaluate whether certain farm practices are maintaining biodiversity. In this paper, we outline the work of the crop field–level group and describe the candidate indicator organisms selected.

Crop Fields

To select indicator organisms—such as natural enemies of crop pests—that enhance the biodiversity of agroecosystem, surveys of arthropods were conducted in environment friendly and conventional fields. An environment-preserving field was defined as decrease spraying frequency of pesticides and herbicides, or none at all. On the basis of interviews with farmers, management of the fields, including application of germicides, fertilizers, and pesticides, were recorded.

Because the islands of Japan extend over a long distance in a north–south direction and are situated within various climatic zones, the country has a wide range of fauna and flora. To cover the breadth of Japan's fauna and flora, surveys were conducted in 27 crop fields in six regions (Fig. 1). The crops grown in the target fields and orchards were the major fruit and vegetable crops in Japan, including citrus (Shizuoka, Ehime, Fukuoka), apple (Aomori, Akita, Nagano), Japanese pear (Ibaraki [2 fields] and Saitama), peach (Fukushima and Okayama), tea (Shizuoka [2] and Kagoshima), cabbage (Iwate, Nagano, and Mie [2]), eggplant (Wakayama, Tokushima, and Miyazaki), green onion (Chiba, Shizuoka, and Nara), and soybean (Iwate, Miyagi, and Aichi). The surveys were conducted in the country's major production regions for each crop type.

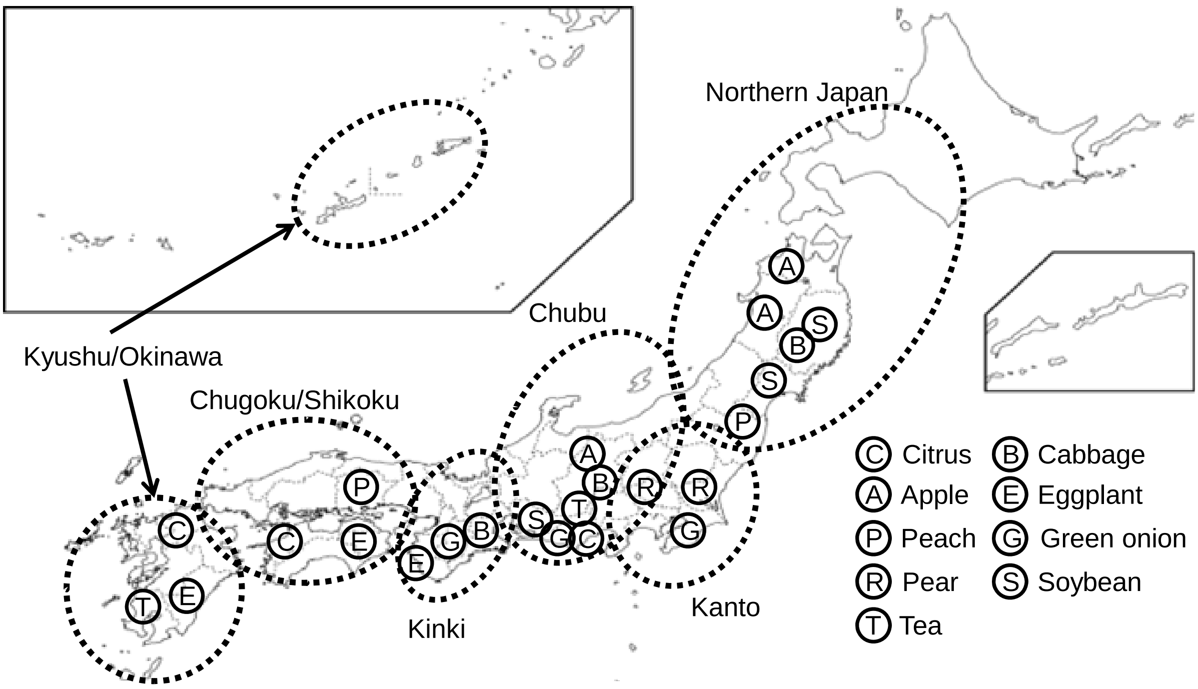

Fig. 1. Locations of the six study regions and the nine kinds of crop fields surveyed.

SELECTION OF CANDIDATE INDICATORS

Survey methods

In these surveys, we investigated those arthropods (i.e., insects, spiders, and mites) that have narrow home ranges, because the population levels of such organisms might be affected by pesticide spraying. Different methods were needed to survey the various organisms, but it was important to use a specific set of methods so that data from environment-preserving and conventional fields and from the six regions could be compared accurately. The following five survey methods were used: (1) using pitfall traps to collect arthropods wandering on the ground; (2) using yellow sticky traps to capture flying insects and wandering arthropods on plants; (3) sweeping vegetation within or surrounding the fields with a sweep net; (4) beating vegetation so that the arthropods fell into an insect net; and (5) visually observing and counting arthropods on the plants. From among these survey methods, members of the research group chose the several most appropriate for each crop type, and these were used consistently in surveys of the crop type across the six regions of Japan.

Selection of candidate indicators

Because the indicator organisms should reflect the effects of environment friendly farming techniques (such as Integrated Pest Management [IPM] and low levels of chemical application) on biodiversity in agroecosystem, the chosen indicators must be quantitatively measurable, beneficial for agricultural production (e.g., native natural enemies or organisms indirectly reflect the presence of organisms that are beneficial for agricultural production), and easily identified by instructors and farmers.

To select the candidate indicator organisms, abundance of organisms and the species richness were surveyed and analyzed in each crop field between 2008 and 2009. More than 2 million individuals (primarily arthropods, but also including frogs in paddy fields) were captured and identified in all the study regions in each year.

First, organisms that were significantly more abundant in the environment-preserving fields than in the conventional ones according to a statistical test were selected as candidates. In total, 231 organisms including several taxonomic levels from species to families met this criterion. Next, we considered the suitability of the candidates as indicator organisms—that is, whether each was beneficial for agriculture and representative of each habitat—on the basis of information from the literature. For practical purposes, several candidate indicator organisms were grouped at the appropriate higher taxonomic level. From these analyses, we selected two groups of indicators: nationwide-common indicators, which were more abundant in environment-preserving fields of all crop types in many of the surveyed regions, and regional-common indicators for each region (Fig. 2).

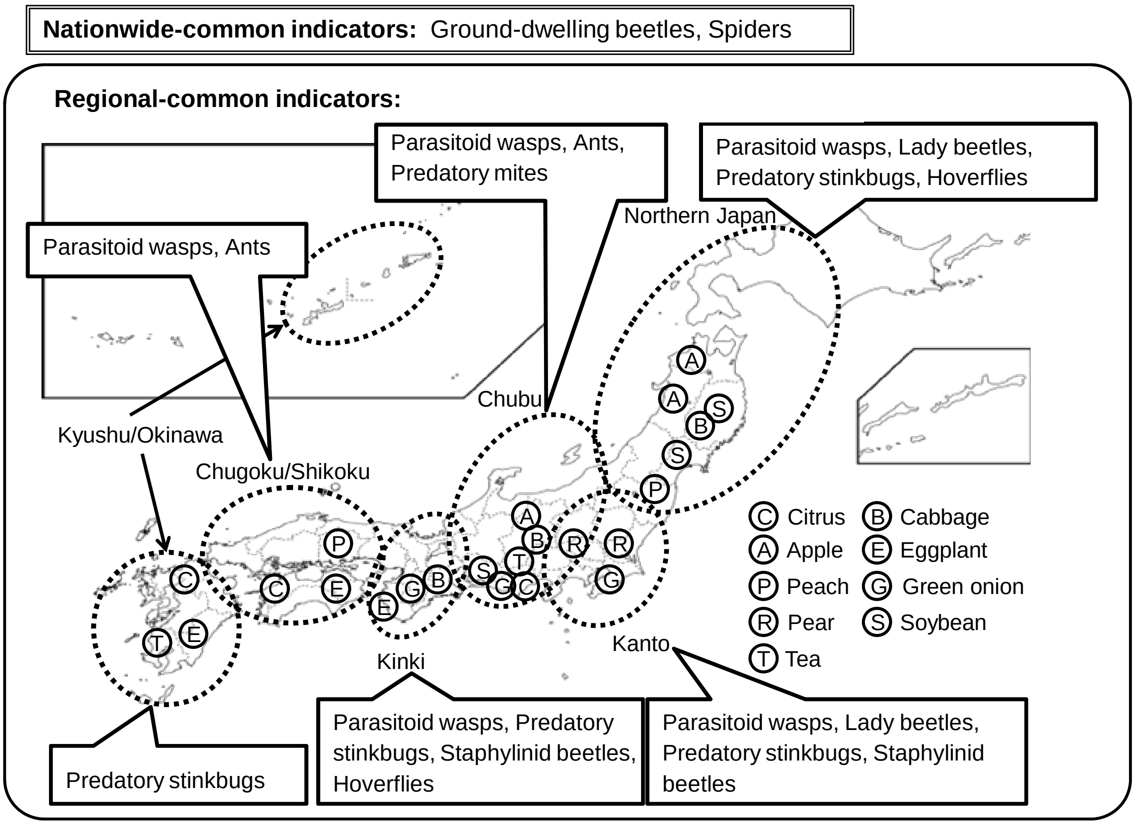

Fig. 2. Candidate indicators representing nationwide common organisms and regionally common organisms in crop fields

Ground-dwelling beetles and spiders were selected as nationwide-common indicators. The ground-dwelling beetles, which include carabids (Coleoptera, Carabidae) and carrion beetles (Coleoptera, Silphidae) were captured by pitfall traps. Two types of spider indicators were chosen: those that inhabit plants or construct their webs between plants and those that wander on the ground. The plant-inhabiting type consists of salticids (jumping spiders; Araneae, Salticidae), thomisids (crab spiders; Araneae, Thomisidae), and araneids (orb-weaver spiders; Araneae, Araneidae), which were surveyed by beating the plants or by visual observation. The wandering spiders were captured by pitfall traps; the most common group was lycosids (wolf spiders; Araneae, Lycosidae), although sheet weavers (Araneae, Linyphiidae) were also more abundant in environment-preserving fields than in conventional ones.

Various arthropods were selected as regional-common indicators: parasitoid wasps (northern Japan, Kanto, Chubu, Kinki, and Chugoku/Shikoku), lady beetles (northern Japan and Kanto), predatory stinkbugs (northern Japan, Kanto, Kinki, and Kyushu/Okinawa), hoverflies (northern Japan and Kinki), staphylinid beetles (Kanto and Kinki), ants (Chubu and Chugoku/Shikoku), and predatory mites (Chubu). Parasitoid wasps, which are natural enemies of crop pests such as aphids, scale insects, and whiteflies, were captured by yellow sticky traps. Lady beetles and hoverflies are well-known natural enemies of aphids, and they also were captured by yellow sticky traps. The indicator predatory stinkbugs belong to the genera *Piocoris* (Hemiptera, Lygaeidae) and *Orius* (Hemiptera, Anthocoridae), and they are natural enemies of spider mites, thrips, and whiteflies. The methods used to survey predatory stinkbugs depend on crop, for example, visually observation was used in eggplant fields to study *Piocoris*, and pitfall traps were used in green onion fields to study *Orius*. Predatory mites are also natural enemies of spider mites. Although predatory mites are too small (0.5 mm) to be seen on plants with the naked eyes, they can be collected by beating or washing plants. Ants and staphylinid beetles were captured by pitfall traps.

The most of indicators are generalist predators that are abundant in agricultural fields, suggesting that their populations would be affected by field management practices. Planting cover plants as habitat management in fields and/or field margins should have favorable effects on the indicator organisms, whereas spraying chemical pesticides would have detrimental effects, including direct toxic effects and the indirect effect of decreasing prey populations.

UTILIZATION OF INDICATORS

Now that the candidate indicator organisms have been chosen, our research group is confirming whether the selected candidates are suitable indicators. More crop fields in the six regions are being studied, and we are examining whether the candidates truly reflect the effects of environment friendly farming techniques. Also, we are working to develop simple and efficient techniques of surveying indicator organisms, as well as standard methods that will enable the indicators to be used to evaluate the environmental health of farms. At the end of the project, we will publish a manual that describes the methods of surveying, identifying, and evaluating the indicators.

The list of indicator organisms is being developed so that environment friendly agriculture will become more widespread in Japan. Here, we mention about some possible applications of the indicators to crop production based on IPM. The Ministry of Agriculture, Forestry, and Fisheries has developed IPM practice models for some crops (i.e., apples and citrus), and the indicators could be introduced to the IPM practice models in at least three ways.

First, the population level of indicators could be used to assess the environmental impact of IPM practices. When IPM practices are good for the environment, the populations of indicators should increase. Thus, famers could check the abundance of indicators in their fields and adjust their IPM practices accordingly.

Second, the indicators are natural enemies that control crop pests. The project manual will explain how to measure the indicator populations quantitatively, so that farmers themselves can monitor populations of natural enemies in their fields. When indicators are abundant, farmers can leave pest control to the natural enemies. When no indicators are found, farmers might choose to spray chemical pesticides.

Finally, the indicators could be incorporated into the Pest Forecasting Program, a national program of the Ministry of Agriculture, Forestry, and Fisheries, the aim of which is to control animals and plants injurious to plants in order to prevent their spread, and thereby ensure the safety and promotion of agricultural production. Prefectural organizations have been examining the seasonal occurrence of several serious crop pests, and these data are useful for efficient pest control. When data on the seasonal occurrences of the indicators are added to the Pest Forecasting Program, more information could be given to farmers for the efficient control of pests.