Effects of Ground Cover Plants on Providers of the Ecosystem Service of Pest Control in Paddy Field Levees

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Abstract

We evaluated the effects of ground cover plants on providers of the ecosystem service of pest control in paddy fields. Between May and September 2010, we investigated seasonal changes in the abundance of natural enemies such as wolf spiders and parasitoid wasps in 5 paddy levee vegetation types, specifically, 4 ground cover plants—*Eremochloa ophiuroides*, *Zoysia japonica*, *Phlox subulata*, and *Phyla canescens* and weedy vegetations—*Trifolium repens* and *Digitaria ciliaris*. The abundance of wolf spiders was similar among *Phyla canescens*, *Z. japonica*, and weedy vegetations during the observation periods, whereas it was extremely low in *E. ophiuroides*. The abundance of parasitoid wasps remained similar in all vegetation types. The results of this study showed that *P. canescens* and *Z. japonica* have no significant impact on the abundance of wolf spiders and parasitoid wasps when compared to that by weedy vegetation.

Keywords: ecosystem service, levee vegetation, parasitoid wasp, rice paddy field, wolf spider

I Introduction

Recently, farmland ecosystems have shown substantially degradation; therefore, ecologically sustainable agriculture needs to be developed [14)]. Farmland ecosystems provide valuable ecosystem services, such as pest control by natural enemies and crop pollination by pollinators, and help support sustainable agriculture [8,16)]. To maintain or enhance ecosystem services in farmlands, it is important to appropriately manage the habitats for the arthropods that provide such services [8,17,18,20)]. In upland fields in Europe and the United States, attempts have been made to enhance pest control and pollination by establishing strips of flowering plants that offer the service providers with nectar (as a food source) and shelter in the field margins [17,20,29)]. However, little is known about how to enhance arthropod-mediated ecosystem services in rice paddy fields. Paddy fields are surrounded by levees to retain water, and these levees could function as sources of natural enemies of pests, if they are planted with vegetation that provides resources such as nectar and shelter. Thus, ecosystem services in paddy fields could be enhanced.

In paddy field levees in Japan, several species of ground cover plants have recently been introduced to suppress weeds and prevent soil erosion. These species include *Eremochloa ophiuroides* (Munro) Hack. (Poaceae) [10,21,22)], *Zoysia japonica* Steud. (Poaceae) [3,4,21,28)], *Phlox subulata* L. (Polemoniaceae)

[11,12,21,28], and *Phyla canescens* (Kunth) Greene (Verbenaceae) [21,22]. By evaluating the efficiency in the functioning of these cover plants as sources of natural enemies of pests, we could better manage paddy levees to maintain or enhance the ecosystem service of pest control.

In previous studies, among these cover plants, *Phyla canescens* and *Phlox subulata* were shown to increase the population density of crickets that feed on weed seeds and, thus, contribute to weed suppression in the levees and interiors of paddy fields [5,6,7]. However, it is largely unknown whether the cover plants have a positive or negative impact on the natural enemies of insect pests. Natural enemies such as ground-dwelling wolf spiders [9,15,27] and parasitoid wasps [13,26,30] have the potential to regulate populations of rice insect pests. In this study, we evaluated the effects of ground cover plants on the abundance of wolf spiders and parasitoid wasps in paddy field levees.

Ⅱ Materials and methods

1 Study site

The experiments for assessing the ground cover plants were conducted in paddy fields in Gotemba City, Shizuoka Prefecture, Japan (35°19′N, 138°55′E, 505 m above sea level), in 2010. On parts of the levees of 3 paddy fields (field size: 1600–3700 m^2), *E. ophiuroides*, *Z. japonica*, *Phlox subulata*, and *Phyla canescens* were present before the experiments began. These cover plants were planted in the levees in 2008 as a local government initiative to demonstrate and promote the practical application of these plants, after which they were successfully established. All the plants are perennials and reproduce mainly by vegetative propagation. This study site was appropriate for evaluating the influence of cover plants on the natural enemies of pests in working paddy fields under the same environmental conditions. The numbers of natural enemies of pests were investigated monthly from May to September 2010 in the paddy levees with these cover plants and weedy vegetation (conventional management). Although it was impossible to replicate the cover plants in the working paddy fields, there are few sites similar to this in Japan and this investigation will be a valuable case study.

The lengths of the levees with *E. ophiuroides*, *Z. japonica*, *Phlox subulata*, *Phyla canescens*, and weedy vegetation were 95 m, 40 m, 30 m, 65 m, and 95 m, respectively, and the width of all the levees was 2 m. Each vegetation was continuous (not fragmented). Each levee was mowed using a weed cutter 1–2 times during the summer. Weeds on the levees with the cover plants were mowed over the cover plants to retain the cover plants intact, whereas the weeds on the levee with the weedy vegetation were mowed to the soil surface. No herbicides or insecticides were applied.

During the experimental period, the levees with *E. ophiuroides*, *Z. japonica*, *Phlox subulata*, and *Phyla canescens* were dominated by each cover plant (vegetation coverage of each cover plant > 70%) (Table 1). However, weeds emerged in these levees during some periods. The plant species that covered more than 25% of each levee are indicated in Table 1. The flowering periods of plants on the levees are indicated in Table 1.

Table 1 The plant species that covered more than 25% of the levees with each cover plant and with weedy vegetation. Bold type indicates the total vegetation coverage of all plant species in each levee. The plant species indicated in gray represent flowering.

	May	Jun.	Jul.	Aug.	Sep.
E. ophiuroides	*E. ophiuroides* (88%) **90%**	*E. ophiuroides* (88%) **101%**	*E. ophiuroides* (88%) **100%**	*E. ophiuroides* (88%) **93%**	*E. ophiuroides* (88%) **88%**
Z. japonica	*Z. japonica* (88%) **91%**	*Z. japonica* (73%) **101%**	*Z. japonica* (70%) *Glycine max* ssp. *soja* (30%) **120%**	*Z. japonica* (78%) **89%**	*Z. japonica* (83%) **106%**
P. subulata	*P. subulata* (88%) **104%**	*P. subulata* (88%) **91%**	*P. subulata* (88%) *Equisetum arvense* (31%) **126%**	*P. subulata* (83%) **99%**	*P. subulata* (83%) **100%**
P. canescens	*P. canescens* (75%) **100%**	*P. canescens* (88%) **91%**	*P. canescens* (88%) **94%**	*P. canescens* (88%) **94%**	*P. canescens* (88%) **95%**
Weedy vegetation	*Trifolium repens* (60%) **78%**	*Trifolium repens* (33%) **36%**	*Trifolium repens* (51%) *Digitaria ciliaris* (41%) **113%**	after mowing **0%**	*Digitaria ciliaris* (45%) **52%**

2 Investigation of natural enemies

The abundance of natural enemies of pests was investigated in the levees with each vegetation type from 11:00 to 12:00 on May 19, June 21, July 21, August 25, and September 21. Temperature and hours of sunlight from 11:00 to 12:00 in each experimental period were 16.3°C and 0.0 h, 21.6°C and 0.0 h, 29.9°C and 1.0 h, 28.1°C and 0.6 h, and 26.6°C and 1.0 h, respectively.

The abundance of wolf spiders was evaluated using 0.5 m^2 quadrats. Ten quadrats were set in the levees with each vegetation type, and the number of wolf spiders in each quadrat was counted. The abundance of parasitoid wasps was evaluated by sweep-netting (diameter, 36 cm), with 3 sets of 10 sweeps in each vegetation type. The captured parasitoid wasps were identified to family level because of the difficulty of identifying these wasps to species level.

3 Statistical analysis

The differences in the abundance of wolf spiders and parasitoid wasps among the vegetation types were tested using Tukey's honestly significant difference test for multiple comparisons using R [24]. The count data were log-transformed to achieve normality before the statistical analyses.

Ⅲ Results

The peak abundance of wolf spiders (Araneae: Lycosidae) was observed in June in each vegetation type, and many of these belonged to genus *Pardosa* (Fig. 1). In June, the abundance was not significantly different among *Z. japonica*, *Phyla canescens*, and weedy vegetation. In contrast, the abundance in *E. ophiuroides* was extremely low. In the other periods, the abundance was similar among all vegetation types, except for *E. ophiuroides*.

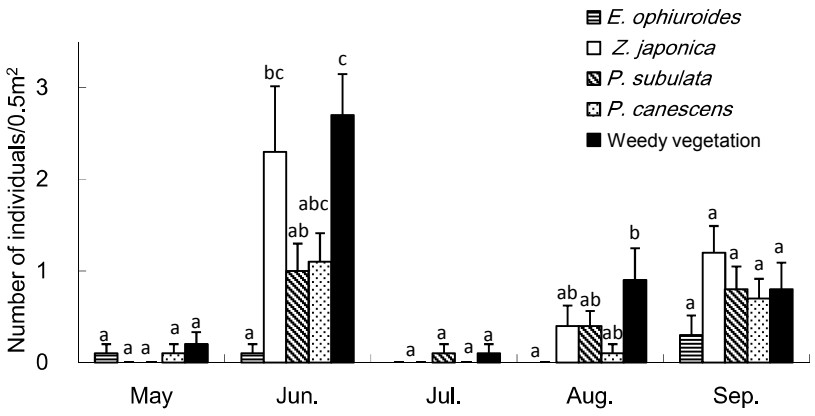

Fig. 1 Effect of vegetation type on the abundance of wolf spiders in each month. Data points represent the mean number of individuals per 0.5 m^2. Different letters indicate significant differences within each month at $P < 0.05$ on the basis of Tukey's honestly significant difference test. Vertical bars represent the standard errors of the means.

The parasitoid wasps only emerged in August and September and belonged to Braconidae, Scelionidae, Chalcidoidea, and Ceraphronoidea (Fig. 2). The abundance of parasitoid wasps was not significantly different between all vegetation types.

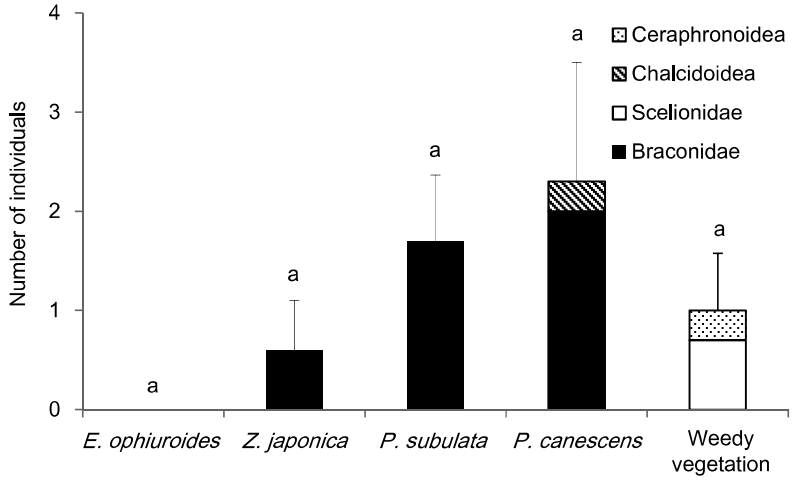

Fig. 2 Effect of vegetation type on the abundance of parasitoid wasps. The parasitoid wasps were only observed in August and September. Data points represent the sum of mean number of individuals per 10 sweeps in August and September.

Ⅳ Discussion

In this study, we evaluated the effects of ground cover plants on the abundance of wolf spiders and parasitoid wasps which were natural enemies of insect pests. The abundance of wolf spiders was similar among *Z. japonica*, *Phyla canescens*, and weedy vegetation in each period (Fig. 1). Thus, wolf spider density in levees with *Z. japonica* and *Phyla canescens* is not considered as largely reduced when compared to that in levees with weedy vegetation (conventional management). In contrast, because the abundance of wolf spiders in *E. ophiuroides* tended to be lower than that in the weedy vegetation, the levees with *E. ophiuroides* are not considered as suitable habitats for the wolf spiders. Although the reason for the low abundance of wolf spiders in *E. ophiuroides* is unknown, possible factors include habitat structure, presence of predators [25], and abundance and composition of prey [9,27]. It is necessary to investigate the effects of these factors on the abundance of wolf spiders in future studies. Although the weeds on the levee with the weedy vegetation were intensively mowed to the soil surface, the abundance of wolf spiders in weedy vegetation was similar to that in *Z. japonica* and *Phyla canescens*. When the mowing was conducted, the wolf spiders might temporarily escape from the levee with the weedy vegetation. However, after the mowing, the wolf spiders are considered to come back to the levee because of presence of plant residue and revegetation.

The abundance of parasitoid wasps was not significantly different between all vegetation types (Fig. 2). Thus, the abundance of parasitoid wasps in the levees with the cover plants are not considered as largely reduced when compared to that in levee with weedy vegetation. Species of Braconidae was observed in the levees with *Phyla canescens*, *P. subulata* and *Z. japonica*, and that of Chalcidoidea was observed in the levee with *Phyla canescens* (Fig. 2). These taxa are known to include parasitoids of

insect pests [1,13,23,26] and contribute to pest control. In previous studies, floral nectar is known to play an important role in the survival and reproductive success of parasitoid wasps [2,17,19,29]. Among these cover plants, *Phyla canescens*, which is a nectar-providing plant, flowered between June and September, and the parasitoid wasps might use the nectar from this plant. Although the abundance of parasitoid wasps was not significantly different between all vegetation types in this study, it is necessary to evaluate in detail the function of nectar-providing plants such as *Phyla canescens* in conserving the parasitoid wasps in paddy fields in future studies.

The ground cover plants provide various ecosystem services, including weed suppression, prevention of soil erosion, and esthetic value [3,4,10,11,12,21,22,28]. In particular, *Phyla canescens* and *Phlox subulata* are known to increase the population density of weed seed predators such as crickets, and enhance the ecosystem service of weed seed predation in the levees and interiors of paddy fields [5,6,7]. This study showed that *Phyla canescens* and *Z. japonica* have no significant impact on the abundance of both wolf spiders and parasitoid wasps, when compared with weedy vegetation. Therefore, the results of these studies suggest that *Phyla canescens* provides the various valuable ecosystem services including the weed seed predation without significant reduction of wolf spiders and parasitoid wasps, which are important natural enemies of insect pests. Therefore, planting *Phyla canescens* in the levees can contribute to maintaining or enhancing the ecosystem services in paddy fields.

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