Preservation of natural enemies as an indicator of agrobiodiversity in terms of planting ground cover in orchards

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Abstract

The research project “Development of management methods for preserving functional biodiversity in the perennial crop cultivations” has been conducted since 2009 to propose management methods for ground cover plants in orchards. In this paper, we have introduced the case of Japanese pear orchards as an example. The preservation of native natural enemies was compared using 2 cover plants, carpet grass and white clover. Both were effective in preserving natural enemies, especially parasitoid wasps and flower bugs. White clover seemed to be superior to carpet grass but additional studies are needed to confirm this preliminary finding.

Keywords: perennial crop, cover plant, natural enemy, Japanese pear orchard

The outline of the research project

Environmentally conservative agriculture systems are known to be friendly to the surrounding area; however, it is difficult to prove this scientifically. To resolve this problem, the Ministry of Agriculture, Forestry and Fisheries (MAFF) has funded a research project, “Selection of functional biodiversity indicators and development of assessment methods.” In this research project, some arthropods, such as ground beetles, predatory stinkbugs, ants, and spiders have been selected as indicators in various crops.

Many of these selected arthropods are known as native natural enemies observed in perennial crops, such as apples, Japanese pears, persimmons, peaches, satsuma mandarins, and tea. Since 2009, the research project “Development of management methods for preserving functional biodiversity in perennial crop cultivation” has been conducted using a grant-aid from the MAFF to develop practical methods to preserve the native natural enemies in the orchards. In this research project, the research institutes located in the chief producing district of the perennial crops mentioned above have initiated the following investigations from 2009 to 2011:

(1) Clarification of the population dynamics of the native natural enemies in orchards, where vegetation within the orchard and its surroundings are controlled.
(2) Evaluation of suppression effects on pest insects and productivity.
(3) Evaluation of preservation of biodiversity under the controlled vegetation.

The location of the chief producing regions and research targets in each crop are listed in Table 1. The aim of this research project is to propose management methods of ground cover and/or surrounding plants within or around orchards developed by these institutes to not only farmers, but also consumers. Furthermore, it is expected that many farmers would be able to introduce the environmental conservative agriculture systems relatively easily and that this agriculture system will become more common in Japan. In this paper, we introduce the case of the Japanese pear orchard as an example of this research project.

Cover plants and cover crops

Cover crops are plants that are cultivated on farmland during fallow periods or on the furrows, fallows, and ridges with main crops (Nakatani 2009). Cover plants are included in cover crops but are planted simultaneously with main crops. In this paper, we used cover plant as the word concerning our research projects, but we described cover plant or cover crop according to references.

Table 1. The location of chief producing regions and research targets in each crops organizing the research project, 'Development of management methods for preserving the functional biodiversity in the perennial crop cultivations'.

Crops	Chief producing region (Prefecture)	Ground cover plants or vegetation controlled	Indicator arthropods (Native natural enemies)	
Apple	Akita	*Trifolium repens*	Carabidae	Araneae
		Lotus corniculatus	Syrphinae	
		Cosmo sulphureus	Formicidae	
	Iwate	*Trifolium incarnatum*	Carabidae	Formicidae
		Vicia villosa	Araneae	Phytoseiidae
Japanese pear	Ibaraki	*Lippia canescens*	Carabidae	Formicidae
		Trifolium repens	Parasitoid wasps	Anthocoridae
			Syrphinae	Araneae
Persimon	Fukuoka	*Zinnia elegans*	Carabidae	Araneae
			Parasitoid wasps	
Peach	Fukushima	*Lippia nodiflora*	Carabidae	
		Mentha pulegium	Parasitoid wasps	
		Mentha piperita	Phytoseiidae	
		Mentha suaveolens		
Satsuma mandarin	Shizuoka	*Fetuca myuros*	Carabidae	Araneae
		Lippia canescens	Formicidae	
		Dichondra micranthan	Coccinellidae	
		Eremochola ophiuroides	Silphidae	
	Ehime	*Fetuca myuros*	Carabidae	
		Cynodon dactylon	Formicidae	
		Lippia canescens	Parasitoid wasps	
		Mentha suaveolens	Araneae	
Tea	Mie	*Tithonia rotundifolia*	Parasitoid wasps	Phytoseiidae
		hyssopus officinalis	Anthocoridae	
	Kagoshima	*Mentha suaveolens*	Formicidae	
		Natural weeds	Araneae	

Cover crops serve various functions in orchards as follows (Bugg and Waddington 1994):

(1) Reduction of soil erosion by wind and water.
(2) Facilitation of the availability of other nutrition, e.g., phosphorous and calcium, by adding or retaining soil nitrogen.
(3) Improving water infiltration and some case moisture retention by producing organic matter and by reducing soil compaction and crusting.

Furthermore, it has been revealed that cover crops also have an important function as a biological control agent against insect pests (Thompson and Hoffman 2009, Bugg and Waddington 1994, Altieri 1999).

Bugg and Waddington (1994) also proposed that cover crops may be selected or managed considering following points:

(1) Not harboring important pests.
(2) Diverting generalist pests.
(3) Confusing specialist pests visually or olfactorily, thus reducing their colonization in the orchard.
(4) Altering host-plant nutrition and thereby reducing pest success.
(5) Reducing dust and drought stress and thereby reducing spider mite outbreaks.
(6) Changing the microclimate and thereby reducing pest success.
(7) Consequently, cover crops increase the abundance or efficiency of natural enemies.

Recently in Japan cover crops have begun to be used in paddy fields practically (Iriyama and Tachibana 2009). However, few studies have reported the relationships between cover plants and the abundance of natural enemies in perennial crops such as fruit trees and tea trees. Therefore, the aim of this sub-topic is to clarify the seasonal prevalence of occurrences and preservation of native natural enemies on cover plants introduced into Japanese pear orchards, with the goal of using this data to select suitable cover plant species at the end of the research period.

Candidate cover plants

Two species of cover plants, *Lippia canescens* and *Trifolium repens* were used. However, *T. repens* did not grow well and therefore, was not examined in 2009.

(1) *Lippia canescens*
English name: Carpet grass
Family: Verbenaceae
Origin: Peru
Flowering period: June–October

(2) *Trifolium repens*
English name: White clover
Family: Leguminosae
Origin: Europe
Flowering period: April–August

Research site and a design of experiments

Field studies were conducted in newly planted Japanese pear orchards at the National Institute of Fruit Tree Science, located in Tsukuba-city, Japan (36.02°N, 140.0°E). The research orchard is 95 m from east to west and 15 m from south to north. Forty eight 3-year-old Japanese pear trees (var. KOUSUI) were planted in the orchard in 2008. This orchard was divided into 3 research plots:

(1) Carpet grass (CG): pots were planted under the pear trees in May 2008.
(2) White clover (WC): seeds were sown under the pear trees in March 2010.
(3) Sheet mulching (SM): Nonwoven fabric sheeting (Love sheet, Unitika. Ltd.) was mulched under the pear trees in May 2009.

No insecticide was applied during the research period, but germicides were sprayed according to the control schedule. Weeds were appropriately treated using herbicides outside of the research plots.

Survey of native natural enemies

Three methods were used to examine the abundance and seasonal prevalence of native natural enemies and insect pests, to compare their occurrence between the species of cover plants. The survey was conducted from May to November in 2009. For 2010, the survey began in April and the data from then until July were examined in this paper.

(1) Pitfall trap

Paper cups (205 ml in volume in 2009) and plastic cups (270 ml in volume in 2010) were used. Six traps were set in each research plot. Each trap contained a 20% solution of propylene glycol poured to a depth of 2 cm. Traps were set every 2 weeks and the captured arthropods were collected 24 h after setting. Traps were protected against rainwater with a roof, whenever rainfall was forecast. Collected specimens were transferred to 70% ethanol and identified in the laboratory.

The ground roaming bugs; ground beetles (Carabidae, Coleoptera), ants (Formicidae, Hymenoptera), crickets (Grylloidae, Orthopetera), pill bugs (Porcellionidae, Isopoda), spiders (Araneae), etc., were examined in both years (Table 2).

Table 2. Total numbers of captured arthropods in each cover plant plot by pitfall traps in 2009 and 2010.

Year (Research period)	Arthropods	cover plants		
		White colover	Carpet grass	Sheet mulching
2009 (May – October)	Carabidae			
	Adults	–	14	22
	Formicidae			
	Formica japonica	–	20 [a]	123 [b]
	Tetramorium tsushimae	–	635 [a]	293 [b]
	Gryllidae			
	Teleogrylus emma	–	21	21
	Loxoblemmus doeniti	–	2 [a]	15 [b]
	Araneae	–	28	37
	Isopoda	–	35	47
2010 (April – July)	Carabidae			
	Adults	30 [a]	5 [b]	10 [ab]
	Larvae	7 [ab]	25 [a]	1 [b]
	Formicidae			
	Formica japonica	14	14	5
	Tetramorium tsushimae	305	269	338
	Gryllidae			
	Teleogrylus emma	56 [a]	34 [ab]	14 [b]
	Araneae	122 [a]	116 [a]	55 [b]
	Isopoda	25	54	44

Different letters in the same line indicate a significant difference (Mann–Whitney's U–test in 2009 and Tukey's–test in 2010, $p<0.05$.) The data were analyzed stastically after log(x+0.5) transformation.

1) Carabidae

In 2009, eleven species of carabids were identified during the sampling period. The numbers of adult ground beetles captured were not significantly different between CG and SM. One larva was captured in CG. In 2010, nine species were identified during the sampling period. The number of adults in WC was greater than that in CG and SM. On the other hand, for larvae, numbers in WC and CG were larger than in SM, especially in CG.

2) Formicidae

The 2 most common species, *Formica japonica* and *Tetramorium tsushimae* represented 97% in 2009 and 80% in 2010. In 2009, both species indicated opposite results; fewer *F. japonica* were captured in CG than in SM, while more *T. tsushimae* were captured in CG than in SM. On the other hand, the numbers of captured individuals were not significantly different between research plots in 2010. This difference between 2009 and 2010 can be explained by the fact that the research of 2010 is incomplete; collection of data from August to November data is ongoing.

3) Grylloidae

In 2009, *Teleogrylus emma* and *Loxoblemmus doeniti* were captured. In *T. emma*, the numbers of captured individuals were not significantly different between CG and SM. A greater number of *L.*

doeniti, were captured in SM than in CG. In 2010, only *T. emma* was captured during the sampling period and their numbers in WC and CG were greater than in SM. The numbers of captured individuals were not significantly different between WC and CG.

4) Araneae

In 2009, the numbers of captured individuals were not significantly different between research plots. In 2010, their numbers in WC and CG were larger than in SM, but did not differ significantly between WC and CG.

5) Isopoda

Armadillidium vulgare was captured. In both years, the numbers of captured individuals were not significantly different between research plots.

(2) Yellow sticky trap

Yellow sticky sheets (Mushitori-kun, Idemitsu Kosan Co., Ltd.) were used as traps. Four traps were set in each research plot. In 2009, two traps were attached to a pole at 1.5 m and 0.5 m in height from ground level. Two poles were set in each plot. In 2010, one trap was attached to a pole at 0.5 m in height from ground level. Four poles were set in each plot. Traps were set every 2 weeks and collected after a week. Collected traps were stored at -20°C until they were identified. During 2009, the numbers of captured individuals tended to be larger in the lower traps throughout the research period; therefore, the comparisons between the research plots were conducted using the data of the lower traps.

Parasitoid wasps (Hymenoptera), flower bugs (Anthocoridae, Homoptera) ladybird beetles (Coccinellidae, Coleoptera), and spiders were observed in both years (Table 3).

1) Parasitoid wasps

Indicator candidate and relatively high numbers of individuals were captured from the following seven families in both years; Encyrtidae, Aphelinidae, Eulophidae, Aphidiidae, Ichneumonoidae, Platygastoidae, and Cynidoidae. In 2009, the numbers of captured individuals of Encyrtidae, Aphelinidae, Eulophidae, and Platygastoidae in CG were higher than in SM, but the numbers of the others were not significantly different between plots. In general, in 2010, the numbers of captured individuals increased in the order WC, CG, and SM except for Aphelinidae and Ichneumonoidae during the sampling period.

Table 3. Total numbers of captured arthropods on each cover plant plot by yellow sticky traps in 2009 and 2010.

Year (Research period)	Arthropods	cover plants		
		White colover	Carpet grass	Sheet mulching
2009 (May – October)	Encyrtidae	—	162.0 [a]	53.0 [b]
	Aphelinidae	—	375.0 [a]	164.0 [b]
	Eulophidae	—	53.0 [a]	18.0 [b]
	Aphidiidae	—	14.5	13.5
	Ichneumonoidae	—	8.0	2.0
	Platygastoidae	—	963.0 [a]	251.0 [b]
	Cynidoidae	—	43.0	20.0
	Anthocoridae	—	23.0 [a]	0.5 [b]
	Araneae	—	37.5	36.0
2010 (April – July)	Encyrtidae	43.3 [a]	21.0 [b]	8.5 [c]
	Aphelinidae	232.8 [a]	127.8 [b]	55.0 [c]
	Eulophidae	55.5 [a]	32.8 [b]	6.3 [c]
	Aphidiidae	9.5	6.8	4.8
	Ichneumonoidae	11.8 [a]	2.8 [b]	1.0 [b]
	Platygastoidae	375.3 [a]	373.8 [a]	65.8 [b]
	Cynidoidae	38.8 [a]	47.0 [a]	5.5 [b]
	Anthocoridae	22.8 [a]	3.8 [b]	0
	Coccinellidae			
	Harmonia axyridis	6.5	10.3	6.8
	Propylea japonica	3.5	1.8	1.0
	Scymnus posticalis	1.5	4.0	1.5
	Araneae	18.8 [a]	31.3 [b]	12.5 [c]

Different letters in the same line indicate a significant difference (Mann-Whitney's U-test in 2009 and Tukey's-test in 2010, $p<0.05$.)
The data were analyzed stastically after log(x+0.5) transformation.
Data of the traps attached on the lower posotion of the pole were used for analysis in 2009.

2) Anthocoridae

Most Anthocoridae captured were *Orius* sp. in both years. The numbers of captured individuals in CG were greater than those in SM in 2009 and increased in the order WC, CG, and SM during the sampling period in 2010.

3) Coccinellidae

Counting of this taxon was conducted in 2010 only. Relatively many individuals were captured in the following 3 species: *Harmonia axyridis*, *Propylea japonica*, and *Scymnus posticalis*. The numbers of captured individuals were not significantly different between research plots.

4) Araneae

In 2009, the numbers of captured individuals were not different between each research plot. In 2010, the numbers increased in the order CG, WC, and SM.

(3)Visual counting

Arthropods on 6 fixed trees in each research plot were investigated in both years. The following arthropods were observed: Aphids (Aphididae, Hemiptera), lace bugs (Tingidae, Hemiptera), Lepidopteran larvae, spider mites (tetranychidae, Acari), ants, hover flies (Syrphinae, Diptera), mantises (Mantidae, Mantodae), lacewings (Chrysopidae, Neuroptera), ladybird beetles, and spiders. The former 4 taxons of arthropods are agricultural pests and the others are native natural enemies. The taxons observed on the trees were not different between research plots in either year. However, the number of spiders was smaller in WC than in the other plots in 2010.

Conclusions

Cover crops are fundamental, sustainable tools used to manage soil fertility, soil quality, water, weeds (unwanted plants that limit crop production potential), pests (unwanted animals, usually insects, that limit crop production potential), diseases, and diversity and wildlife, in agroecosystems (Lu et al. 2000). In North America, undersowing a cover crop in apple orchards decreased infestation by codling moth, *Cydia pomonella*. This lower moth infection was correlated significantly with increased numbers of predators (spiders, Coccinellidae, Syrphidae, and Chrysopidae) present on trees with underlying cover crops (Altieri and Letourneau 1982).

In this study, the comparison of preservation of ground roaming arthropods under 2 types of cover plants was inconclusive. However, data from the yellow sticky traps in 2009 suggests that carpet grass was effective in preserving natural enemies within a crown, especially parasitoid wasps and flower bugs. This result suggests that these arthropods use carpet grass as an alternative source. The data of 2010 supported the carpet grass findings of 2009. On the other hand, white clover seems to be more efficient in promoting parasitoid wasps and flower bugs than carpet grass. To determine which cover plant is superior, more detailed studies must be done, because parasitoid wasps and flower bugs were also captured after August in the carpet grass plots in 2009. Further, while flowers of white clover decrease after August, carpet grass continues to bloom until October.

Orchards are semi-permanent systems and crop rotation does not apply in the short term, so particular situation affecting insects occur in these systems (Altieri and Letourneau 1982). Thus, cover plants are a worthwhile application in orchards to develop environment-friendly farming systems.

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