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Biodiversity of Epigeic Spider Community in Pear Orchards Managed using Different Farming Methods*

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배 과원의 재배형태별 토양성 거미군집의 생물다양성

송장훈 · 서호진 · 임재성 · 최으뜸 · 김승태

This study was conducted to compare the community structure and biodiversity of epigeic spiders between pear fields cultivated by integrated pest management (IPM) and organic methods. This is the first study of this kind to be conducted in Korea. Eighty-four spider species from 22 families were identified among the collected 2,489 arthropods, with 754 individuals being sampled from IPM fields and 1,735 individuals from organic fields. Generally, Theridiidae, Linyphiidae, Lycosidae, Agelenidae, Gnaphosidae, and Salticidae were the dominant spider families in the pear orchard regardless of the farming methods, and species richness and abundance were higher in organic fields than in IPM fields. The dominant species were the wolf spiders (Lycosidae) and stone spiders (Gnaphosidae), and their cumulative abundance was 70.7% in IPM fields and 72.7% in organic fields. The community structure between organic and IPM fields was heterogeneous, with a 45% similarity level. Biodiversity, species richness, abundance, and species diversity index were higher in organic fields than in IPM fields, and significantly different between the farming methods. Seasonal fluctuations in biodiversity were similar in both IPM and organic fields. The species richness and species diversity index increased and the abundance decreased in the second half of the cultivation period. This study on

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the community structure and biodiversity of epigeic spiders, which form one of the most important predator groups, will provide principal ecological and faunistic information required to maintain the biodiversity of useful arthropods in agricultural ecosystems and help implement sustainable agriculture based on the active use of natural enemies.

Key words : *spider, biodiversity, community, pear orchard, IPM farming, organic farming*

Ⅰ. Introduction

The community of an agricultural ecosystem might vary with farming methods, contiguous environment, crop varieties and cropping patterns. Arthropods constitute the main terrestrial invertebrates in agricultural fields. Generally, arthropod community in agricultural fields consists mainly of insects and spiders. Recently, the agriculture management worldwide, including that in Korea, has shifted from conventional farming which use various agricultural pesticides and herbicides to environmentally friendly farming, or organic farming, which implements environmentally friendly substances for plant pest and disease control for to ensure food security and sustainable agriculture. Since the transition to environmentally friendly farming and organic farming, Integrated Pest Management (IPM) has been widely recommended. IPM is a broad-based approach that integrates practices for economic control of pests and aims to suppress pest populations below the economic injury level (EIL). IPM emphasizes the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms (Pedigo et al., 1986). Entomologists and ecologists have urged the adoption of IPM pest control since the 1970s (Knipling, 1972).

Despite the recent growth of organic agriculture, there has been a lack of research-based information pertaining to the mechanisms operating in organic farming systems (Zehnder et al., 2007). The study on the community structure and biodiversity of the living organisms in agricultural ecosystems provides very important information for the establishment of the pest control strategy in the sustainable agricultural system.

Spiders, which have a distinct ecological niche, play several important roles in ecosystems: 1) as a component of biodiversity, 2) by contributing to material circulation and energy transfer through preying on many animals in higher trophic levels in the food web, 3) as a natural enemy that feeds on many agricultural and forest insect pests, 4) as indicator species detecting environmental changes, such as global warming and environmental pollution, and 5) by providing physiologically active substances, such as poison and spider thread, which have been used in many research fields (Yoo et al., 2015; Kim et al., 2016).

Spiders are a ubiquitous and important predator group with high richness and abundance among invertebrates; they occur in many natural and in agricultural ecosystems (Specht and Dondale, 1960; Riechert and Lockley, 1984; Nyffeler and Benz, 1987; Sunderland, 1999). Effective use of natural predators in ecologically friendly agricultural systems such as organic farming is one of the important pest control strategies. Nevertheless, comparative studies on the community structure and biodiversity of agro-biological communities between different agricultural practices, such as organic farming, integrated pest management (IPM), and various other farming methods, have been very limited.

Therefore, this study was aimed to compare the community structure and biodiversity of epigeic spiders in fields managed by IPM farming and organic farming to provide fundamental information for efficient pest management using beneficial natural enemies like spiders which is one of the most important predator group in organic farming.

Ⅱ. Materials and Methods

1. Study sites

The study was conducted in three IPM and three organically managed pear orchards in Naju and Boseong areas in Jeollanam-do, Korea. The surveyed areas are detailed in Table 1.

Table 1. Cultivation information of areas managed by IPM and organic farming and surveyed for spider communities

Farming method	Areas surveyed	Fertilizers applied	Fungicides (times)	Insecticides (date)
IPM	Naju Godong-ri field #14	• Cow manure compost • Nitrogen fertilizer	• Lime-sulfur 1 • Pyrimethanil WP 2 • Difenoconazole WP 1 • Dithianon WP 3 • Mancozeb WP 1 • Iminoctadine Tris albesilate WP 3 • Fluxapyroxad SC1	• Paraffinic oil 1 • Flonicamid/sulfoxaflor WG + flubendiamide SC (May 11) • Abamectin EC (May 21) • Buprofezin/clothianidin SC + *Bacillus thuringiensis* WP (Jun 10) • Indoxacarb/teflubenzuron WP, *Bacillus thuringiensis* WP (Jun. 20) • Abamectin EC (Jun 25)

Farming method	Areas surveyed	Fertilizers applied	Fungicides (times)	Insecticides (date)
IPM				• Buprofezin/clothianidin SC + *Bacillus thuringiensis* WP (Jul1) • Flonicamid/sulfoxaflor WG + flubendiamide SC (Jul16) • Dinotefuran/methoxyfenozide WG (Jul 30) • Deltamethrin/thiodicarb SC (Aug 9) • Novaluron SC (Aug 19)
	Boseong Jangjwa-ri	• Compound fertilizer • Nitrogen Fertilizer	• Lime- sulfur 1 • Iminoctadine Tris albesilate WP 2 • Mancozeb WP 3 • Penthiopyrad SC 1 • Difenoconazle WP 2 • Kresoxim-methyl WG 2 • Difenoconazle/ dithianon WG 1	• Paraffinic oil 1 (Mar 1) • Acetamiprid WP (Apr 24) • Amitraz/bupropezin EC (May 2) • Abamectin EC (May 19) • Chlorpyrifos WP (May 29) • Spirotetramet SC (Jun 10) • Abamectin EC (Jun 16) • Thiacloprid SC (Jul 7) • Deltamethrin SC (Jul 17) • Dinotefuran/methoxyfenozide WG (Jul 28)
	Boseong Bonsan-ri	• Elk manure compost	• Lime- sulfur 1 • Captan WG 2 • Mancozeb WP 2 • Kresoxim-methyl WG 2 • Triflumizole WP 1 • Penthiopyrad SC 2 • Difenoconazle/ dithianon WG 1	• Paraffinic oil 1 (Mar 2) • Flonicamid WG (Apr 25) • Sulfoxaflor WG (May 10) • Abamectin EC (May 18) • Novaluron SC (May 29) • Thiacloprid SC (Jun 12) • Abamectin EC (Jun 26) • Spirotetramet SC (Jul 7) • Deltamethrin/thiodicarb SC (Jul 19) • Dinotefuran/methoxyfenozide WG (Jul 28) • Novaluron SC (Aug. 9)
Organic	Naju Godong-ri field #19	• Cow manure compost	• Lime sulfur 16 • Sulphur 4	• Pheromone (mating disruptor) • Paraffinic oil 4 • Matrine 4
	Boseong Yeongcheon-ri	• Chicken manure compost	• Lime sulfur 10 • Sulfur 1	• Paraffinic oil 2 • Pheromone (mating disruptor) • *Bacillus thuringiensis* WP 3
	Boseong Jangjwa-ri	• Without fertilizer	• Lime sulfur 5 • Sulfur 1 • Bordeaux mixture 4	• Paraffinic oil 2 • Pheromone (mating disruptor) • Dalmatian chrysanthemum 6

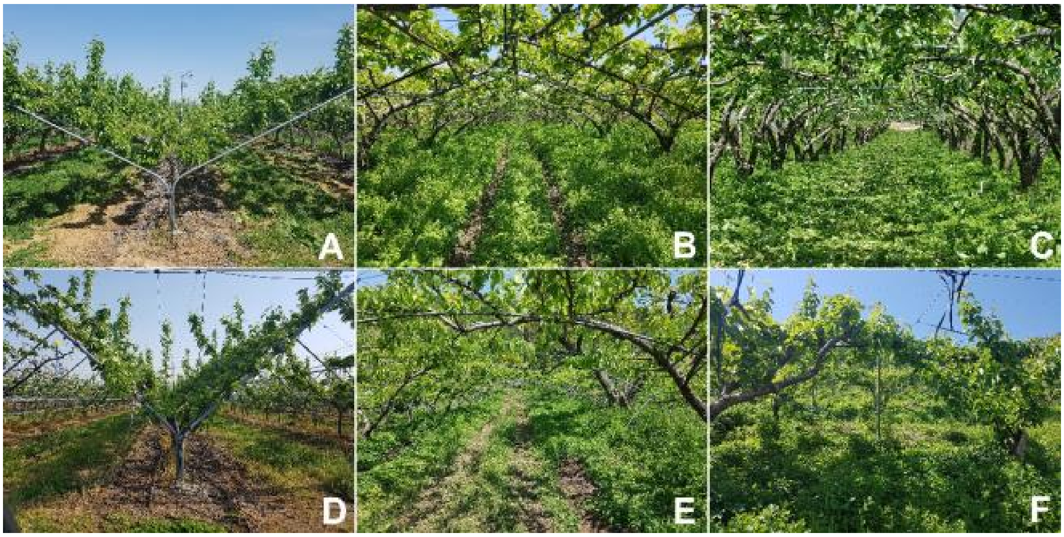

Fig. 1. Study areas of pear orchards managed by IPM (A. Naju Godong-ri field #14, B. Boseong Bongsan-ri, and C. Boseong Jangjwa-ri) and organic farming (D. Naju Godong-ri field #19, E. Boseong Yeongcheon-ri, and F. Boseong Jangjwa-ri) methods.

2. Sampling and identification of spiders

Epigeic spiders were collected at six different times (September, October, and November in 2016 and April, June, and August in 2017) during the pear growing season from the early development to harvest stage. The sampling consisted of 10 pitfall traps diagonally installed in each selected field. The pitfall trap consisted of a transparent plastic container, measuring 10.5 cm in diameter and 8 cm in height, with a plastic cover placed 3 cm onx top of the trap to prevent the inflow of rainwater and foreign matter. Each container was filled with ethyl-alcohol and ethylene-glycol at a ratio of 1:1, and 300 mL of preservative solution was added to prevent the decay of arthropods. The traps were exposed for 30 days. The sampled spiders were brought to the laboratory and identified to the species level under a dissecting microscope (Nikon SMZ 745T, Japan) by comparing their taxonomic characters including their epigyne and palpus. Domestic and scientific names follow the domestically recognized standard list (Yoo et al., 2015) and the World Spider Catalog (2019), respectively.

3. Biodiversity analysis

Species richness, abundance, and species biodiversity were analyzed using PRIMER v.6.0

computing software (Clarke and Gorley, 2006). In the biodiversity analysis, species richness means the number of species and abundance is the density of occurrence. Species diversity was calculated using the Shannon's diversity index (Shannon and Weaver 1949). The Shannon's index equation is as follows:

$$H' = -\sum_{i=1}^{s} P_i \ln(P_i)$$

Where, P_i is the relative abundance of ith species number and s is total number of species.

Statistical comparisons were conducted using SAS 9.1 (SAS Institute Inc., Cary, NC, USA, 2004).

Ⅲ. Results

Eighty-four species, representing 22 families, were identified from the collected 2,489 individuals; 754 individuals were trapped in the IPM fields and 1,735 individuals in the organic fields (Table 2). Overall, Theridiidae, Linyphiidae, Lycosidae, Agelenidae, Gnaphosidae, and Salticidae were the dominant spider families in pear orchards regardless of the farming methods. The species richness and abundance were higher in organic fields than in IPM fields, regardless of the farming methods (Figs. 2, 3). The occupancy rate of these six families was 91.5% and 79.0% in terms of species richness and their abundance was 91.4% and 91.5% in the IPM fields and in organic fields, respectively. Both species richness and abundance of the dominant families were higher in the organic fields than in the IPM fields. The most dominant species included the wolf spiders (Lycosidae) and stone spiders (Gnaphosidae); their abundance was 70.7% in the IPM fields and 72.7% in the organic fields. The abundance of all dominant spiders in the IPM fields was higher than that in the organic fields, and they included *Alopecosa moriutii*, *Arctosa kwangreungensis*, *Arctosa pungcheunensis*, *Piratula procurvus*, and *Arctosa ipsa* (Lycosidae); *Pisaura laura* (Pisauridae); *Drassodes serratidens* and *Gnaphosa kompirensis* (Gnaphosidae); *Ozyptila nongae* (Thomisidae); and *Anahita fauna* (Ctenidae) (Table 2, Fig. 3).

Table 2. List of epigeic spiders in pear orchards managed by IPM or organic farming (2016~2017)

Family	Scientific name	Farming method					
		IPM			Organic		
		Godong-ri #14	Bongsan-ri	Jangjwa-ri	Godong-ri #19	Yeong cheon-ri	Jangjwa-ri
Atypidae[1]	*Calommata signata*	1		1	8		
Leptonetidae[2]	*Leptoneta* sp.					1	
Mimetidae[3]	*Ero japonica*						1
Nesticidae[4]	*Nesticella mogera*	28	2	1	4		9
Theridiidae[5]	*Chrosiothes sudabides*						2
	Enoplognatha sp.	8					1
	Episinus nubilus					1	
	Paidiscura subpallens	2			12	5	
	Parasteatoda angulithorax			1			
	Steatoda cingulata		1		1	1	1
	Stemmops nipponicus				1	5	
Linyphiidae[6]	*Agyneta* sp.		1				
	Bathyphantes gracilis	1	1				
	Doenitzius pruvus					1	1
	Erigone edentata			3	6	7	
	Erigone prominens	2	4	2			3
	Gnathonarium dentatum		2				
	Hylyphantes graminicola	17			1		
	Neriene clathrata						4
	Neriene oidedicata					3	
	Nippononeta projecta				1	2	
	Nippononeta ungulata			2		7	1
	Saitonia pilosus						2
	Syedra oii	1					
	Ummeliata insecticeps				1		
Tetragnathidae[7]	*Pachygnatha tenera*					1	
	Pachygnatha clercki		3				
Lycosidae[8]	*Alopecosa moriutii*			2	71		
	Alopecosa virgata			1			
	Arctosa ipsa	11	127	77	26	4	1
	Arctosa kwangreungensis	5	54	76	18	226	13
	Arctosa pungcheunensis	7	48		39	3	
	Arctosa yasudai		6	4			18
	Lycosa coreana				13		6
	Lycosa sp.					9	

Family	Scientific name	Farming method					
		IPM			Organic		
		Godong-ri #14	Bongsan-ri	Jangjwa-ri	Godong-ri #19	Yeong cheon-ri	Jangjwa-ri
Lycosidae[8]	*Pardosa astrigera*	36	1	1	23	6	3
	Pardosa brevivulva						4
	Pardosa herbosa						1
	Pardosa laura	3	1	14	102	28	50
	Piratula procurvus	21	7	7	146	69	86
	Trochosa ruricola	1	4	3	40	1	
Pisauridae[9]	*Dolomedes sulfureus*		1				5
	Pisaura ancora		2			1	
	Pisaura lama			1		1	1
Oxyopidae[10]	*Oxyopes sertatus*			1		1	
Ctenidae[11]	*Anahitafauna*	3	2	8	23	52	22
Agelenidae[12]	*Agelena limbata*						1
	Alloclubionoides quadrativulvus	4	2	1		2	1
	Coelotes exitialis						1
	Draconarius coreanus		3	4		7	18
	Iwogumoa songminjae	1	1				1
	Pireneitega spinivulva	4					
Dictynidae[13]	*Cicurina japonica*	2	1		6	1	
Titanoecidae[14]	*Nurscia albofasciata*				1		
Miturgidae[15]	*Zora nemoralis*					1	
	Itatsina praticola		1	3			5
Phrurolithidae[16]	*Phrurolithus sinicus*					2	
Clubionidae[17]	*Clubiona kurilensis*	3		1			
Corinnidae[18]	*Castianeira shaxianensis*						1
Gnaphosidae[19]	*Cladothela parva*				3	6	2
	Drassodes serratidens		2	13	58	3	26
	Drassyllus coreanus		4	4		12	14
	Drassyllus yaginumai		5	4	1	6	2
	Gnaphosa kompirensis	7	21	9	63	11	14
	Micaria dives						1
	Zelotes davidi	2			3	9	2
Philodromidae[20]	*Philodromus* sp.		1				
Thomisidae[21]	*Ozyptila nongae*	6	2		107		
	Xysticus ephippiatus	2			5	11	27
	Xysticus hedini					1	
	Xysticus saganus	1	4	9	22	14	16
Salticidae[22]	*Asianellus festivus*						2
	Bristowia heterospinosa				1	2	
	Evarcha albaria				1	1	1
	Marpissa pulla						2

Family	Scientific name	Farming method					
		IPM			Organic		
		Godong-ri #14	Bongsan-ri	Jangjwa-ri	Godong-ri #19	Yeong cheon-ri	Jangjwa-ri
Salticidae[22]	*Myrmarachne formicaria*				1	6	
	Phintella bifurcilinea						13
	Phintella cavaleriei			1			3
	Plexippus setipes			1	1		
	Pseudeuophrys iwatensis		2				
	Sibianor pullus			1	2		1
	Siler cupreus			1			2
	Sitticus avocator	1					
	Synagelides agoriformis			1	2		1
Total		180	316	258	813	530	392

[1]Ground (purse) web builders, [4, 5, 13, 14]space web builders, [2, 6]wandering sheet weavers, [7]orb weavers, [8, 18, 19]ground runners, [9, 20, 21]ambushers, [3, 10, 22]stalkers, [11, 12]sheet web builders, [15, 16, 17]foliage runners.

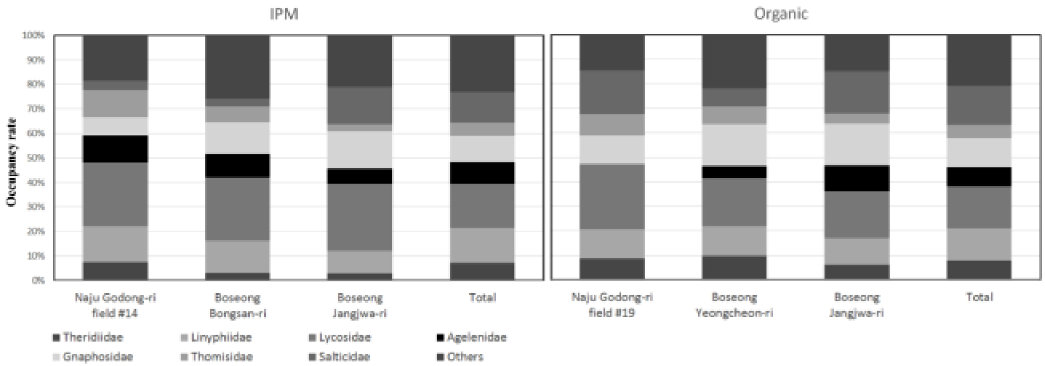

Fig. 2. Comparison of richness of epigeic spider species between pear orchards managed by IPM and organic farming.

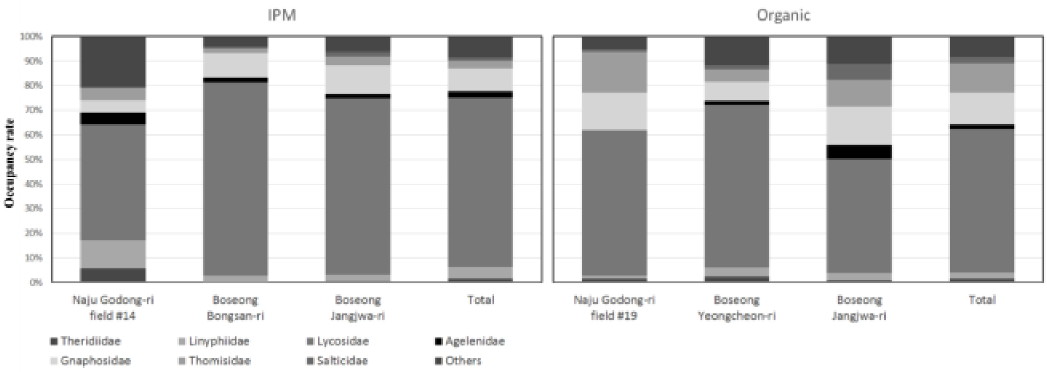

Fig. 3. Comparison of abundance of epigeic spiders between pear orchards managed by IPM and organic farming.

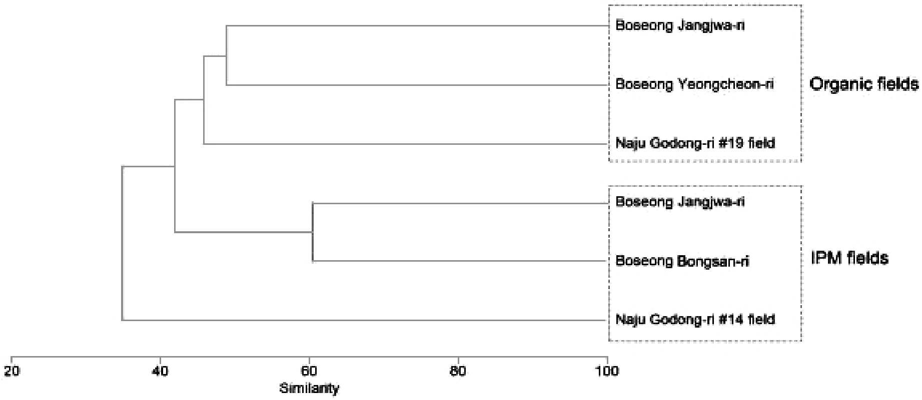

Fig. 4. Cluster analysis based on the epigeic spider community data between IPM and organically managed pear orchards.

The similarity of epigeic spider communities between the two farming methods analyzed using Bray–Curtis similarity coefficient matrix based on species composition and abundance was 45%, including heterogeneous community structure between organic fields and IPM fields (Fig. 4).

Biodiversity, species richness, abundance, and species diversity index were higher in the organic fields than in the IPM fields (Table 3) and biodiversity was significantly different between the farming methods, and the results were as follows: species richness (*t*-test; $t = 8.29$, d.f. = 58, $P < 0.001$), abundance ($t = 6.77$, d.f. = 58, $P < 0.001$), and species diversity index ($t = 5.75$, d.f. = 58, $P < 0.001$). Seasonal fluctuations in biodiversity were similar in both IPM and organic fields. The species richness and species diversity index increased and the abundance decreased in the second half of the cultivation period (Fig. 5).

Table 3. Comparison of the regional biodiversity of epigeic spiders between pear orchards managed by IPM and organic farming

Area	Farming method	Species richness (mean ± SE)	Abundance (mean ± SE)	Species diversity (mean ± SE)
Naju Godong-ri field #14	IPM	9.00±0.67	18.00±1.98	1.99±0.11
Boseong Bonsan-ri		9.50±0.72	31.60±3.62	1.68±0.05
Boseong Jangjwa-ri		9.20±0.98	25.80±2.91	1.76±0.08
Average		9.23±0.45	25.13±1.92	1.81±0.05
Naju Godong-ri field #19	Organic	16.30±0.67	81.00±6.41	2.41±0.05
Boseong Yeongcheon-ri		13.90±0.89	52.40±4.34	1.94±0.06
Boseong Jangjwa-ri		15.20±1.19	39.20±4.92	2.36±0.09
Average		15.13±0.55	57.53±4.38	2.24±0.05

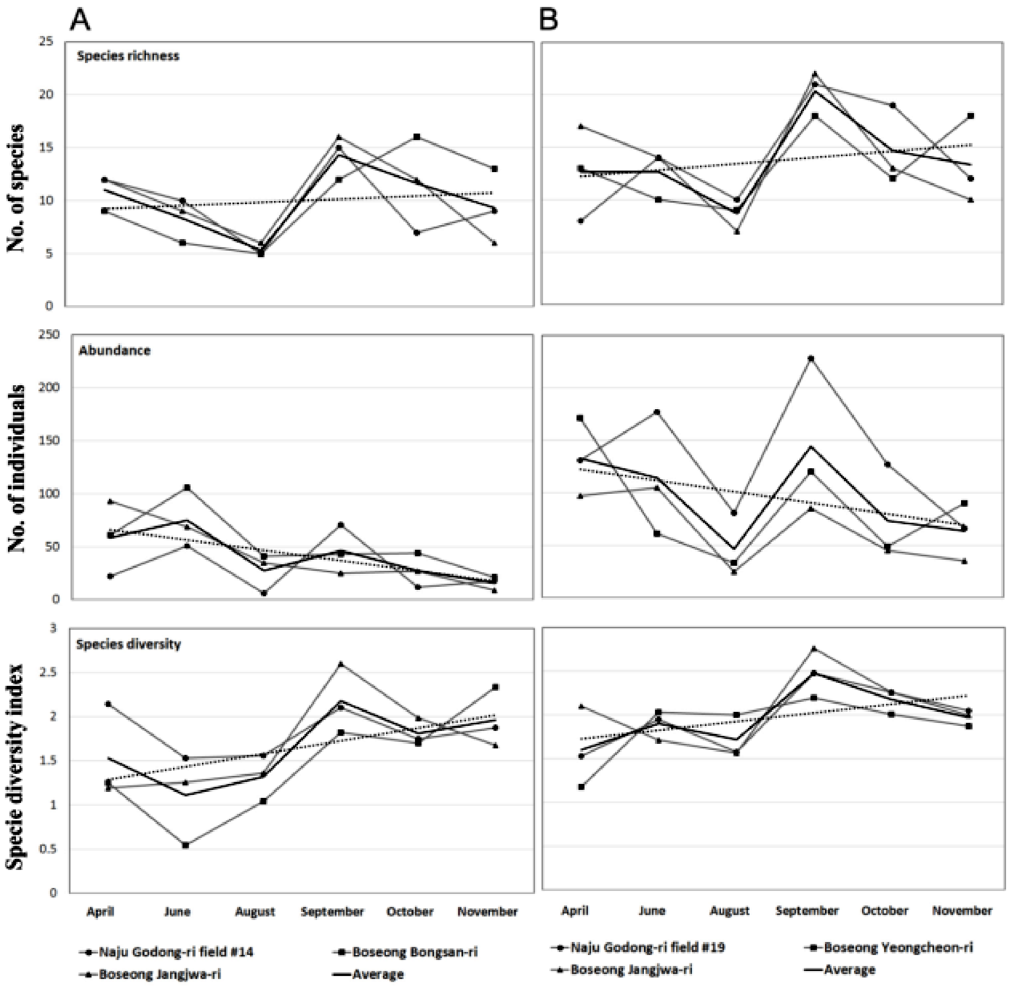

Fig. 5. Seasonal fluctuations in biodiversity of epigeic spiders between pear orchards managed by IPM (A) and organic (B) farming.

Ⅳ. Discussion

Until the late 1980s, biological conservation had been limited to undisturbed natural habitats. However, the general concerns of the biological conservation have been expanded to agricultural ecosystems to develop sustainable agriculture that will maintain agricultural biodiversity. Study on biodiversity associated with agricultural ecosystems is of significance to agroecologists and conservation biologists; the maintenance of biological diversity is essential for productive agriculture, and ecologically sustainable agriculture is in turn essential for maintaining biological diversity (Pimental et al., 1992). Research on spiders as natural enemies has been carried out in a variety of agricultural ecosystems, including rice fields, uplands, and orchards in Korea, but research in orchards has been mainly conducted in grape and citrus farms (Kim et al., 2016).

In the present study, we assessed the biodiversity of spider community in pear orchards managed by IPM and organic farming methods. The results revealed that the composition of dominant families and their species richness and abundance were higher in organic fields than in IPM fields (Table 2; Figs. 2, 3), and they showed a heterogeneous community structure between organic fields and IPM fields with a 45% similarity level (Fig. 4). The spiders *Syedra oii* (Linyphiidae), *Pireneitega spinivulva* (Agelenidae), and *Sitticus avocator* (Salticidae) found only in Naju Godong-ri #14 field seemed to have influenced the statistics of similarity analysis. This result shows that Naju Godong-ri #14 field was isolated from other fields. The overall biodiversity, species richness, abundance, and species diversity index were higher in the organic fields than in the IPM fields and were statistically different between the two farming methods (Table 3). Species richness and abundance of a predatory group, such as spiders, are known to be significantly higher than those of pest populations in organic fields where little or no pesticides are used (Hesler et al., 1993; Way and Heong, 1994; Wyss et al., 1995, Hole et. al., 2005; Fuller at. al., 2005). The seasonal fluctuations in biodiversity were similar in both IPM and organic fields, with species richness and species biodiversity index being the highest around September (Fig. 6). Therefore, biodiversity monitoring of epigeic spiders in pear orchards in Korea is recommended to be conducted in September, in addition to periodic surveys that may require a specific period. However, two peaks of abundance were observed in June and September. This was attributed to ground runners, categorized by ecologically functional groups, such as Lycosidae and Gnaphosidae, which has two generations per year (Table 2). Thus, more than two monitoring sessions per year are needed to determine the abundance of the spider community. The species richness and abundance decreased in both IPM and organic farming fields from April to August (Fig. 6). However, the degree of decrease was greater in the IPM fields than in the organic fields, which was attributed to the accumulation of various pesticides in the IPM fields from March to July. This suggests that the mortality of spiders increased and that IPM promoted the migration of spiders out of the area treated with various insecticides. These results are consistent with reports on the negative effects on spiders, one of the most important predator groups (Theiling and Croft, 1988; Clausen, 1990; Lee et al., 1993; Desneux et al., 2007). Especially, it has been reported that the epigeic spiders, the subject of the present study, are more vulnerable than the webbing spiders, which inhabit the air space (Specht and Dondale, 1960; Legner and Oatman, 1964; Bostanian et al., 1984). It has also been reported that the more active epigeic spider species is, the greater the damage is caused by pesticides (Bostanian et al., 1984). Therefore, when the density of naturally occurring spiders is negatively affected by environmental factors such as pesticides, more expenses can be incurred to control agricultural pests and therefore other control strategies should be implemented for pest control.

Various hypotheses have been proposed to maintain biodiversity by actively utilizing natural enemies in agricultural ecosystems. International standards and criteria related to the production of organic agricultural products and the criteria for production have been developed and implemented in some countries for efficient use of natural enemies in pest control (CONSLEG, 1991; USDA NOP, 2001; IFOAM, 2005). The importance of conservation and use of natural enemies for pest control in organic agriculture, as well as agricultural technical aspects such as location of fields, crop rotation, soil improvement, tillage, and resistant cultivars are some of the measures whose significance have been highlighted (Zehnder et al., 2007). In addition, Landis et al. (2000) emphasized the importance of conservation of natural enemies through habitat management in agricultural ecosystems. Wyss et al. (2005) proposed a conceptual model for the development of pest control program in organic agriculture and showed that proper vegetation management is needed to improve the effects of natural enemies.

This study on the community structure and biodiversity of epigeic spiders, therefore, is expected to provide important fundamental ecological and faunistic information for active use of natural enemies as a part of sustainable agriculture needed to maintain the biodiversity of useful arthropods in agricultural ecosystems.

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References

1. Bostanian, N. J., C. D. Dondale, M. R. Binns, and D. Pitre. 1984. Effects of pesticide on spiders (Araneae) in quebec apple orchards. Canadian Entomol. 116: 663-675.
2. Clarke, K. R. and R. N. Gorley. 2006. PRIMER v6: User manual/tutorial. PRIMER-E, Plymouth, UK.
3. Clausen, I. H. S. 1990. Design of research work based on a pilot study dealing with the effect of pesticides on spiders in a sugar-beet field. Acta Zool. Fennica 190: 69-74.
4. CONSLEG. 1991. European communities council regulation No. 2092/91

(http://europa.eu.int/eur-lex/en/consleg/pdf/1991/en 1991R2092 do 001.pdf).

5. Desneux, N., A. Decourtye, and J.-M. Delpuech. 2007. The Sublethal Effects of Pesticides on Beneficial Arthropods. Annu. Rev. Entomol. 52: 81-106.
6. Fuller, R. J, L. R. Norton, R. E. Feber, P. J. Johnson, D. E. Chamberlain, A. C. Joys, F. Mathews, R. C. Stuart, M. C. Townsend, W. J. Manley, M. S. Wolfe, D. W. Macdonald, and L. G. Firbank. 2005. Benefits of organic farming to biodiversity vary among taxa. Biol. Lett. 1: 431-434.
7. Hesler, L. S., A. A. Grigarick, M. J. Oraze, and A. T. Palrang. 1993. Arthropod fauna of conventional and organic rice fields in California. J. Econ. Entomol. 86: 149-58.
8. Hole, D. G., A. J. Perkins, J. D. Wilson, I. H. Alexander, P. V. Grice, and A. D. Evans. 2005. Does organic farming benefit biodiversity?. Biol. Conserv. 122: 113-130.
9. IFOAM. 2005. Norms for organic production and processing: IFOAM basic standards. Bonn, Germany: IFOAM. pp. 148.
10. Kim, S. T., S. Y. Lee, M. S. Im, and J. S. Yoo. 2016. Distribution of Korean spiders. National Institute of Biological Resources, Incheon. p. 1624.
11. Knipling, E. F. 1972. Entomology and the Management of Man’s Environment. Aus. J. Entomol. 11: 153-167.
12. Landis, D. A., S. D. Wratten, and G, M. Gurr. 2000. Habitat management to conserve natural enemies of arthropod pests in agriculture. Annu. Rev. Entomol. 45: 175-201.
13. Lee, H. P., J. P. Kim, and J. R. Jun. 1993. Utilization of insect natural enemies and spiders for the biological control in rice paddy field, community structure of insect pest and spiders, suppress effect on insect pest by natural enemies, and their over wintering habitats in rice paddy field. RDA J. Agri. Sci. (Agri. Inst. Coop.) 35: 261-274.
14. Legner, E. F. and E. R. Oatman. 1964. Spiders on apple in Wisconsin and their abundance in a natural and two artificial environments. Canadian Entomologist 96: 1202-1207.
15. Nyffeler, M. and G. Benz. 1987. Spiders in natural pest control: a review. J. Appl. Entomol. 103: 321-329.
16. Pedigo, L. P., S. H. Hutchins, and L. G. Higley. 1986. Economic Injury Levels in Theory and Practice. Ann. Rev. Entomol. 31: 341-368.
17. Pimental, D., U. Stachow, D. A. Takacs, H. W. Brubaker, A. R. Dumas, J. J. Meaney, J. A. S. O’Neil, D. E. Onsi, and D. B. Corzilius. 1992. Conserving biological diversity in agricultural/forestry systems. BioSci. 42: 354–362.
18. Riechert, S. E. and T. Lockley, 1984. Spiders as biological control agents. Ann. Rev. Entomol. 29: 299-320.

19. SAS Institute. 2004. SAS 9.1.2 Qualitication tools users guide. SAS Institute, Cary, NC.
20. Shannon, C. E. and W. Weaver. 1949. The mathematical theory of communication. University of Illinois Press, Illinois, USA.
21. Specht, H. B. and C. D. Dondale. 1960. Spider populations in New Jersey apple orchards. J. Econ. Ent. 53: 810-814.
22. Sunderland, K. 1999. Mechanisms underlying the effects of spiders on pest populations. J. Arachnol. 27: 308–316.
23. Theiling, K. M. and B. A. Croft. 1988. Pesticide side-effects on arthropod natural enemies: A database summary. Agri. Ecosys. Enviro. 21(3-4): 191-218.
24. USDA NOP. 2001. National Organic Program standards (http://www.ams.usda.gov/nop/indexNet.htm).
25. Way, M. J., and K. L. Heong. 1994. The role of biodiversity in the dynamics and management of insect pests of tropical irrigated rice-a review. Bull. Entomol. Res. 84: 567-587.
26. World Spider Catalog. 2019. World Spider Catalog. Version 20.0. Natural History Museum Bern, online at http://wsc.nmbe.ch, accessed on {20, April, 2019}. doi: 10.24436/2.
27. Wyss, E., U. Niggli, and W. Nentwig. 1995. The impact of spiders on aphid populations in a strip-managed apple orchard. J. Appl. Entomol. 119: 473-78.
28. Yoo, J. S., S. Y. Lee, M. S. Im, and S. T. Kim. 2015. Bibliographic checklist of Korean spiders (Arachnida: Araneae) ver. 2015. J. Spe. Res. 4 (Special Issue): 1-112.
29. Zehnder, G., M. G. M. Gurr, S. Kühne, M. R. Wade, S. D. Wratten, and E Wyss. 2007. Arthropod pest management in organic crops. Annu. Rev. Entomol. 52: 57-80.