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Comparison of arthropod community between organic and conventional apple orchards

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ENTOMOLOGY PROGRAM

DEPARTMENT OF AGRICULTURAL BIOTECHNOLOGY

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Abstract

Comparison of arthropod community between organic and conventional apple orchards

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Apple is grown as a long-term perennial and plays an essential role in preserving agricultural biodiversity. Farming systems, organic and conventional, may have a different effect on arthropod communities. The present study surveyed arthropod communities by pitfall traps, yellow sticky traps, and leave sampling in organic and conventional apple orchards in four different areas.

A total of 319,943 arthropod individuals, except for spiders, were Acari, Collembola, and Insecta, identified as 255 species in 81 families belonging to 12 orders. The abundance of arthropods in organic orchards was significantly higher than that in conventional orchards by the farming system. Six orders (Acari, Collembola, Coleoptera, Diptera, Hemiptera, and Hymenoptera) were dominant in relative species richness and abundance. The six families, Ceratozetidae (Acari), Entomobryidae (Collembola), Carabidae and Staphylinidae (Coleoptera), Diapriidae, and Formicidae (Hymenoptera) were statistically different between the farming systems. Three dominant species, *Aleochara curtula* in Staphylinidae, *Nylanderia flavipe* in Formicidae, and Diapriidae sp.1 in Diapriidae showed statistical differences higher in an organic orchard. As a result of analyzing the similarity of arthropod community structure, it was generally clustered depending on the study area, regardless of the farming system. Arthropods were collected during the survey and categorized into five ecological guilds; Detritivores, Herbivores, Pollinators, Predators, and Parasitoids. All five guilds appeared regardless of the survey area and farming system. According to the farming system, the abundance of detritivores, herbivores, predators, and parasitoids was statistically significantly higher in organic orchards. As a result of analyzing the similarity of the arthropod guild structure, it was generally clustered into each farming system.

Overall, the species richness, abundance, and diversity index of arthropod communities were conspicuously higher in organic orchards than in conventional orchards. However, arthropod guild diversity was statistically higher in conventional orchards. In the seasonal fluctuations in the biodiversity of arthropod communities, the species richness and the abundance showed a mountain-shaped with one peak in the middle of the survey, while species diversity was observed in multiple peaks.

A total of 4,663 spiders were collected during the survey and identified as 94 species in 70 genera belonging to 21 families. The species richness and abundance of spiders in organic orchards were significantly higher than in conventional orchards. Five families (Thomisidae, Lycosidae, Linyphiidae, Gnaphosidae, and Nesticidae) were dominant in species richness and abundance regardless of the study area or farming system, and Lycosidae and Linyphiidae were very remarkable among the dominant families. Five dominant species, *Erigone prominens* in Linyphiidae, *Pardosa astrigera*, *Pardosa laura*, *Piratula procurvus*, and *Trochosa ruricola* in Lycosidae, showed statistical differences higher in an organic orchard. As a result of analyzing the similarity of the spider community structure, it was generally clustered into each farming system. Spiders were collected during the survey period and categorized into eight ecological guilds. Of the eight categorized spider guilds, four guilds, ground runners, space web builders, wandering sheet weavers, and wandering sheet web builders, were dominant guilds in apple orchards. Ground runners and wandering sheet weavers were statistically higher in organic orchards, whereas wandering sheet web builders were statistically higher in conventional orchards. As a result of analyzing the similarity of the spider guild structure, it was generally clustered into each farming system. Overall, the species richness, abundance, and diversity index of spider communities were conspicuously higher in organic orchards. However, guild richness and diversity were not different between farming systems. In the seasonal fluctuations in the biodiversity of spider communities, the species richness and the abundance showed a mountain-shaped curve with a peak in the middle of the survey, and in the case of species diversity, multiple peaks were observed. The seasonal fluctuations in the biodiversity of spider guilds were observed with similar results to that of spider communities. Regardless of the farming system, 27 species collected from all surveyed apple orchards were determined as the main arthropod species of Korean apple orchards, and their abundance was statistically high in the organic apple orchards.

Keywords: organic, conventional, apple orchard, arthropod, spider, guild

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I. Introduction

1. Definition of organic farming

In the midst of a sustainable agricultural crisis caused by the destruction of the ecosystem due to the side effects of farming practices and the decrease in biodiversity, humans began to reconsider the compatibility of continuous increase in production and biodiversity conservation (Ma and Joachim, 2006). Historically, among the various farming practices, organic farming is best known worldwide as the most effective means of offsetting the adverse effects of modern agriculture.

The basic definition of organic farming can be defined as an agricultural production system that preserves high levels of biodiversity and natural resources and produces agricultural products. The International Federation of Organic Movement (IFOAM), which establishes integrated standards for organic farming, stipulates that organic farming is a way to maintain genetic and agricultural diversity based on living ecosystems and circulation systems (IFOAM, 2005). Furthermore, organic farming can be classified by whether "natural" or "artificial" substances have been put in the agricultural ecosystem because there are strong regulations on the use of synthetic substances by law (Seufert et al., 2017). Through several studies, organic farming is reported to be better than conventional ones in terms of human health, diversity conservation in invertebrates, vertebrates, and plants, contributing to achieving sustainable agricultural goals (Magnusson et al., 2003; Benegtsson et al., 2005; Hole et al., 2005; Bouvier et al., 2011; Krauss et al., 2011).

2. Characteristics of the orchard ecosystem

Orchard is an agricultural ecosystem that produces high-quality products without a cultural rotation for years or even decades (Simon et al., 2010; Demestihas et al., 2017). The semi-permanent environment of orchards can enhance the stability and resilience of the ecosystem compared to annual crops (Brown and Welker, 1992; Kozar, 1992). Although the orchard ecosystem plays an essential role in preserving agricultural biodiversity, it is undeniable that more intensive and continuous cultivation management is required because of the long growing period of fruits before harvest. In addition, since fruits need high quality in the fresh market, it has no choice but to focus more on controlling pests that directly damage agricultural products and reduce their value.

The orchard has the characteristic of cultivating the same improved variety in a large area requiring more labor and control efforts to control pests. Thus spraying chemical pesticides can be considered the most efficient and convenient control means. However, more precise and safe alternatives are needed as concerns about over-use of agricultural inputs have been reported due to a negative impact on pollinators, organisms in the orchard as well as groundwater, subsoil, and air (Loewy et al., 2003; Cumming and Spiesman, 2006; Biddinger et al., 2013; Mottes et al., 2014).

Several studies have shown that extensive pesticide application negatively affects natural enemies and pollinators, which play an essential ecological role in pest control and fruit tree production (Geiger et al., 2010; Geiger et al., 2011; Biddinger et al., 2013). As the orchard ecosystem has a long cultivation period, pest appearance is also high, so natural pest management is essential. Conservation of natural enemies does not play a role as a direct pest control means, but it is closely related to minimizing crop damage and suppressing the occurrence of minor pests through potential pest control (Schellhorn et al., 2015). Another characteristic of orchard ecosystems is that they are designed as multi-strata types of understory and arboreal habitats. The orchard system with perennial multi-strata designs serves to inhabit several plants and provide a habitat to rich and diverse fauna of arthropods and wealthy resources to beneficial organisms (Simon et al., 2010; Cross et al., 2015).

Arthropods are representative biological groups that provide ecological functions within the agricultural ecosystem, and they coexist in the soil, grass, and canopy within the orchard ecosystem (Miliczky et al., 2000) and have a mutual interaction. The spatial and structural interaction also influence the complexity of the food chain and pest control, which is a critical factor in crop management.

Although the complex structural features of fruit trees are essential in maintaining various biodiversity, sometimes the probability of natural pest control is not higher than that of a simple agricultural ecosystem (Langellotto and Denno, 2004; Simon et al., 2007). Nevertheless, various biodiversity, including plants and arthropods in the orchard system, plays an essential role in enhancing the possibility of ecological pest control through direct or indirect effects (Demestihas et al., 2017).

3. Status of studies on pest control in Korean apple orchard

Apple is a fruit crop with a long cultivation history in Korea since the late 1880s. Although the domestic apple cultivation area has been steadily decreasing since its peak in the mid-1990s, it occupies the second-largest cultivation area among the domestic fruit crops as of 2020 (Fig. 1). Since strategies for producing high-quality fruits require much labor at each stage of apple tree growth, synthetic pesticides have been essential as an alternative to reducing apple farmers' work. The amount of pesticide used per unit area in the Korean apple orchard is known to be 22.1 kg/ha, higher than that of the United States of 20.1 kg/ha (Lim et al., 2003). Fortunately, insecticide spraying in apple orchards is gradually decreasing. However, it is still reported that an average of 10.5 times insecticides are sprayed annually, requiring efforts and management measures to reduce insecticide use (Lee et al., 2007). Efforts to strengthen the management of beneficial organisms will contribute to replacing the use of pesticides and enable sustainable agriculture by minimizing biodiversity losses simultaneously. In Korea, various studies have been conducted to improve intensive apple pest management, including ecological research on the predatory mites and integrated management of phytophagous mites using them, activity evaluation of lepidopteran pest with a sex pheromone, population dynamics of pest-natural enemies, and effective insecticide screening (Cho et al., 1996; Jung et al., 2001; Jung et al., 2003; Kim et al., 2003) In Korea, various studies have been conducted to improve intensive apple pest management, including ecological research on the predatory mites and integrated management of phytophagous mites using them, activity evaluation of lepidopteran pest with a sex pheromone, population dynamics of pest-natural enemies, and effective insecticide screening). However, although several studies have led to the development of integrated pest management in an apple orchard, research on arthropods' biodiversity in apple orchards is still rare. Kim et al (1995) reported that insect communities on ground-cover weeds in apple orchards could influence the occurrence of pests and natural enemies. Lee et al (1997) surveyed arthropod fauna in apple orchards during winter to find herbivores and decomposers, while natural enemies were rarely investigated. However, few studies have been conducted on the influence of arthropods in the apple orchard depending on farming practice for a more extended period. However, it has recently been reported that the weed management of apple orchards affects the abundance and diversity of spiders, beetles, and ground-dwelling arthropods (Kim and Jung, 2021).

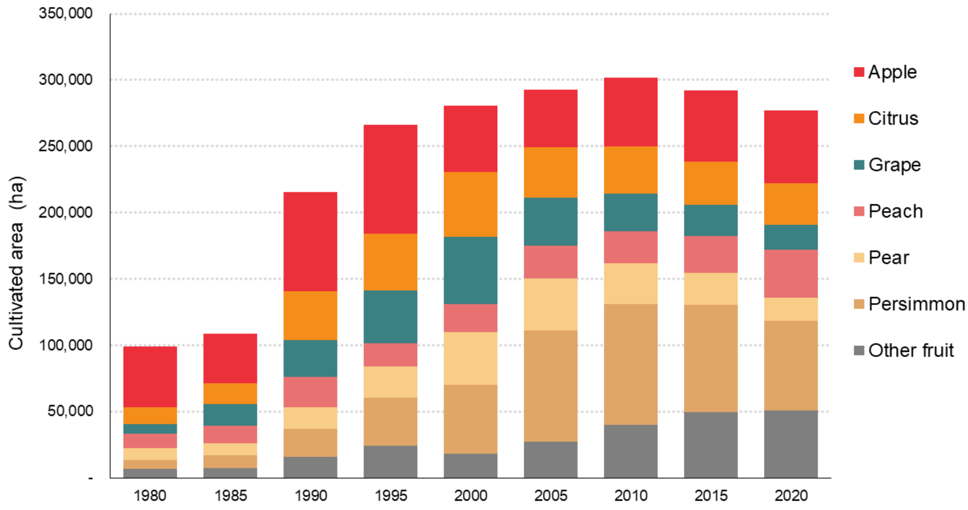

Fig. 1. Changes in the cultivated area by fruit species in Korea during 1980-2020 (Korean statistical information services, 2021).

4. Current status of organic apple cultivation

Rather than emphasizing productivity and cost efficiency, organic agriculture tends to increase its dependence on ecological processes through certification programs that limit the use of synthetic inputs (USDA, 2018). Unfortunately, these regulations limit crop protection agents that can quickly control pests that inevitably occur in crop production, making it challenging to produce quality crops. In particular, apples have been recognized as impossible to produce through organic farming due to the high-quality level required by consumers. Despite this negative perception, several fruit growers in the United States and European regions attempted to grow apples through organic farming in the 1970s (Evans, 2017; Wiggins and Nandwani, 2020). Although they had an enormous economic loss in the early stages of cultivation, they introduced new varieties through continuous research, and the organic apple sector spread as they received a price premium for organic cultivation. Since then, through continuous research on organic apples, the number of organic apple growers in the United States has increased to 728, and the organic apple grows area was 11,052 ha as of 2017 (USDA, 2018). Germany, France, Italy, and Poland are the representative producers of organic apples in Europe, and as a result of a 2017 survey, the number of organic apple growers and certified areas in these countries was 777 (6,092 ha) and 254 (6,742 ha), 1,283 (2,194 ha) and 3788 (5,400 ha), respectively (Zikeli et al., 2019).

Since organic production has become an inevitable trend for the sustainable development of the apple industry, numerous apple producers around the world are participating in organic production

Due to the heavy reliance on pesticides, organic apple production has been considered impossible in Korea. Farmers who want organic certified apple production have to choose low-pesticide certification instead due to the lack of eco-friendly certified control agents and organic cultivation information. Since some apple growers in Uiseong and Cheongsong were certified as pesticide-free and organic products in 2005, interest in organic apple cultivation has increased. The number of farms that grow apples with an organic certification shows a gradual increase trend: five farms in 2005, 53 in 2010, and 61 in 2014 (Song et al., 2013). The area of certified organic apples is shown in Fig. 2. It increased from 51 ha in 2015 to 82 ha as of 2020 but occupied a minimal share of 0.26% of the total apple cultivation area.

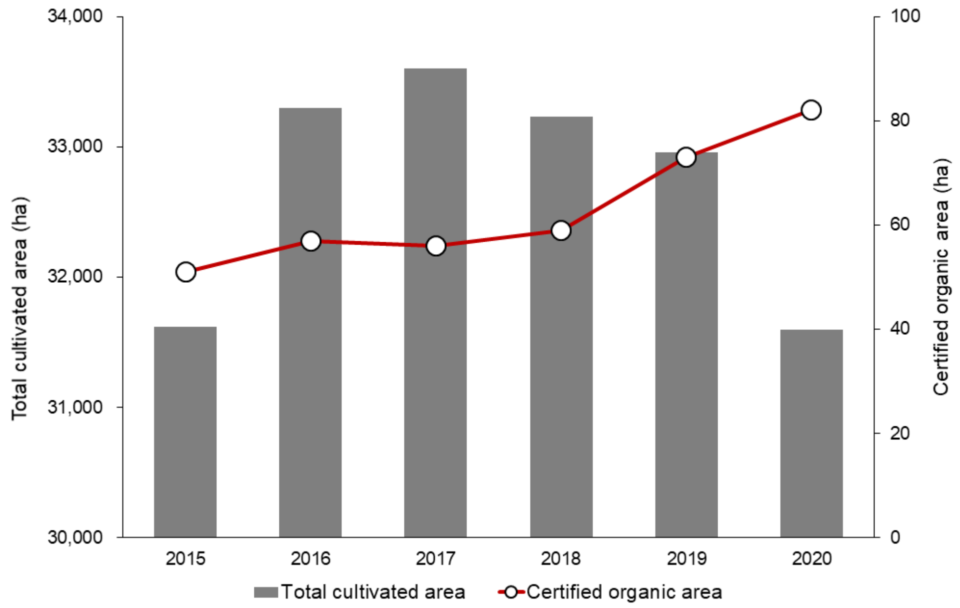

Fig. 2. Growth of the area of certified organic apples in Korea (Korean statistical information service, 2021; Environment-friendly agricultural products certification, 2021).

5. Arthropod community structure in apple orchards

The fruit tree canopy is semi-permanent, thus, providing relatively stable ecological habitats that support rich and diverse communities of arthropods. About a quarter of the arthropod fauna are pests, a quarter is natural enemies of pests, and the remaining half are benign to the trees, although they are essential parts of the arthropod food web (Milaire et al., 1974).

Research on the arthropod community in an agricultural ecosystem is essential for sustainable agriculture. A prerequisite to effective pest management is obtaining information on all species in the community (Brown and Welker, 1992). Orchards host a high abundance and diversity of natural enemies, such as spiders, predatory mites, earwigs, or lacewings (Solomone et al., 2000; Porcel et al., 2016). The insects in Carabidae, Staphylinidae, and Spiders are generalist predators in agricultural ecosystems (Mathews et al., 2004). Several studies (Chang, 1996; Losey and Denno, 1998, Riechert and Lawrence, 1997) reported that these predators control major pests on agricultural farms. Especially in apple orchards, there were reports that these predators suppressed the outbreak of significant pests such as aphids, lepidopteran larvae, pupae, and so on (Allen and Hagley, 1990; Hagley and Allen, 1988; Urbaneja et al., 2006). Carabid beetles are relatively well known taxonomically and ecologically (Kanpp and Řezáč, 2015). They seem to be suitable bioindicators for apple orchards, and their large body size allows them to be easily found in the field (Funayama, 2011). Carabids are potentially important natural pest-control agents and can be crucial for sustainable agricultural systems by preventing insect pest outbreaks (Kromp, 1999).

The farming system could directly affect the populations of these predators. It is generally known that cover plants, composts, and animal manures positively affect the density of these predators (Badejo et al., 1995; Culliney and Pimentel, 1985; Larsen et al., 1996; Litsinger and Ruhendi, 1984; Riechert and Bishop, 1990), and chemical pesticides negatively affect their density due to their high sensitivity to these chemicals (Everts et al., 1989). Moreover, the farming system could indirectly affect the populations of these predators by affecting the composition or densities of their prey. Thus, the intensive use of chemicals in agricultural farms generally reduces biodiversity and negatively affects the community structures of these predators (Kleijn et al., 2009; Rusch et al., 2014).

6. Ecological guild structure in apple orchards

Regarding the supply of fruits, apples are produced in 96 countries, with 86 million tons in 2018, recording the second-largest fruit crop in the world (FAOSTAT, 2020). In many countries where apples are grown, studies have been conducted on the interactions between organisms and agricultural practices such as birds, insects, spiders, and plants in apple orchards (Altieri and Schmidt, 1984; Wyss, 1995; Bogya and Markó, 1999a; Bouvier et al., 2011; Gontijo et al., 2013).

Various studies to minimize the side effects caused by the use of pesticides on the orchard ecosystem have also been conducted. For example, conservation of natural enemies and pest mating disruption techniques can be an ecological alternative to reduce dependence on chemical pesticides and preserve biodiversity in fruit orchards (van de Meer et al., 2020).

In particular, ecological studies of predators and parasites of significant pests in the apple orchard and studies on the effects of farming practice on these beneficial arthropods are dominated. For example, in Hungary, a major apple-producing country in Europe, beneficial arthropods such as spiders, carabids, rove beetles, and phytoseiid mites have been reported to inhabit apple orchards (Bogya et al., 2000; Balog et al., 2003; Kutasi et al., 2004; Szabó et al., 2014). Also, in China, the natural enemies of major lepidopteran pests in Chrysopidae, Coccinellidae, Encyrtidae, Eulophidae, Anthocoridae, Trichogrammatid, Reduviidae, Carabidae, and Ichneumonidae have been reported. China is the world’s largest apple production country, accounting for more than 30% of the world's total apple production (Wu and Pan, 2021). In New Zealand, the use of pesticides against codling moth disruption does not affect the invertebrate communities of the apple orchard, but it affects herbivores, omnivores, detritivores, fungivores, parasitoids, or predators, depending on the farming management (Malone et al., 2017).

Increasing fruit production while preserving biodiversity is challenging for sustainable agriculture. Apple orchard, highly dependent on intensive management, needs alternative management to preserve biodiversity and increase production. Organic farming has become an inevitable trend in solving these compatibility issues (Granatstein et al., 2013). Although organic farming prohibits the input of synthetic pesticides and fertilizers, management practices by growers can still affect biodiversity (Marliac et al., 2016).

Organic management has been reported to affect apple orchard organisms positively. For instance, it increases the natural enemies' abundance and diversity, the functional and taxonomic diversity of beetles (Mickaël et al., 2015), and the structural and functional diversity of epigeal spiders (Mazzia et al., 2015).

The insects in Carabidae and Staphylinidae and spiders were one of the generalist predators in agricultural ecosystems (Sunderland et al., 1986; Mathews et al., 2004). Several studies (Chang, 1996; Losey and Denno, 1998, Riechert and Lawrence, 1997) reported that these predators control major pests on agricultural farms. In apple orchards, these predators suppressed the outbreak of major pests such as aphids, lepidopteran larvae, pupae, and so on (Allen and Hagley, 1990; Hagley and Allen, 1988; Urbaneja et al., 2006).

The farming system could directly affect the populations of these predators. It is generally known that cover plants, composts, and animal manures positively affect the density of these predators (Badejo et al., 1995; Culliney and Pimentel, 1985; Larsen et al., 1996; Litsinger and Ruhendi, 1984; Riechert and Bishop, 1990), but chemical pesticides negatively affect their density due to their high sensitivity to these chemicals (Everts et al., 1989). Moreover, the farming system could indirectly affect the populations of these predators by affecting the composition or densities of their prey. Thus, the intensive use of chemicals in agricultural farms generally reduces biodiversity and negatively affects the community structures of these predators (Kleijn et al., 2009; Rusch et al., 2014).

Spider is one of the most famous biological indicators to evaluate the quality of habitats and the effects on environments by contaminant sources (Bonte et al., 2004). In agricultural ecosystems, diverse species of spiders are present and have a pivotal role in controlling pests (Bogya et al., 2000; Nyffeler and Sunderland, 2003). The advantages of spiders as a biological indicator are that they are found in diverse environmental conditions and are relatively easy to sample (Wise, 1995). Thus, spiders are popularly used to evaluate ecological status as a biological indicator (Marc et al., 1999).

Spiders are generally sensitive to chemical pesticides (Santos et al., 2007; Markó et al., 2009). In particular, the spider that lives in an ecosystem where chemical pesticides are intensively applied is inevitably exposed to them. These chemicals would directly affect the populations of spiders (Santos et al., 2007; Markó et al., 2009) and indirectly affect them by decreasing their prey's density and changing compositions (Sauphanor et al., 2012). The spider species on tree crowns are heavily influenced by the indirect effects of their prey (Pekar, 2012), and the impact of the spiders on the soil surface can be direct (Everts et al., 1989).

The insects of Staphylinidae are generalist predators, mainly feeding small insects, spiders, and nematodes (Bohac, 1999; Balog et al., 2009). It is already known that these insects suppress the outbreak of agricultural pests and are easily affected by their surrounding environment and soil conditions (Balog et al., 2009; Cividanes et al., 2010). In addition to these characteristics, the high activities of this insect make them the biological indicator (Bohac, 1999; Perner and Malt, 2002; Shah et al., 2003). However, the insects of Staphylinidae are not popularly used as the biological indicator due to limited information related to their community according to environmental conditions (Hole et al., 2005).

Carabidae is a free-living generalist predator inhabiting various agricultural areas, including orchards (Gallandt et al., 2005; Menalled et al., 2007). An ecological function of Carabidae to inhibit the occurrence of significant pests of fruit trees has been reported (Riddick and Mills, 1994), and in North America, 15 carabids has been reported as a predator of the main pests of codling moth 5^{th} instar larvae (Riddick and Mills, 1994; Hagley and Allen, 1988). In addition, carabid is recognized as a good indicator of ecological changes in agricultural environments because of its high sensitivity to environmental disturbance (Irmler, 2003).

7. Biodiversity of arthropod communities and guilds in apple orchards

The agricultural ecosystem can be defined as an ecosystem in which humans replace ecological functions to produce food, fibers, fuels, and other products within a community of plants and animals interacting with the physical and chemical environments (Caprio et al., 2015). However, even if this ecosystem is artificially affected by humans, it still has to rely on ecological services provided by the natural ecosystem, such as pollination, biological pest control, soil structure, fertility maintenance, nutritional circulation, and hydrological services (Power, 2010).

Since most of these ecological services are biological, biodiversity conservation is essential even in managed agricultural ecosystems (Altieri, 1994). Agricultural biodiversity consists of the diversity of species such as pollinators, pests, predators, parasites, and other organisms that interact with and relate to the agricultural ecosystem in which crops are grown (Qualset et al., 1995). In addition, biodiversity within the agricultural ecosystem also includes a wide range of plant and animal genetic resources on which agriculture depends.

Agricultural management through the input of chemical pesticides has steadily increased agricultural production. These systems were defined as conventional farming and became a set of principles for application to the agricultural production process. Conventional farming is focused on creating an optimal environment for the mass cultivation of single target crops by eliminating weeds and pests (Omer et al., 2007). Application of agricultural practices such as tillage, drainage, intercropping, rotation, and pesticides increased agricultural yields but caused negative effects on a wide range of ecosystem services, including moisture, nutrient cycling, water quality, soil retention, carbon sequestration, and biodiversity conservation (McLaughlin and Mineau, 1995; Tilman et al., 2002; Demestihas et al., 2017).

The most prominent threat to agricultural biodiversity is the simplification of landscape structure with the diminution of non-crop habitats (Benton et al., 2003). However, it is more critical that the use of chemicals, including insecticides, fungicides, and herbicides, is another crucial cause of the rapid decline in non-target or important ecological species (Dudley and Alexander, 2017). Many researchers have continuously reported that habitat destruction and intensive farming practice that apply excessive chemical input negatively affect the agricultural biodiversity responsible for ecosystem services (Hooper et al., 2005; Geiger et al., 2010; Tsiafouli et al., 2015; Chagnon et al., 2015). In addition, increasing the use of synthetic materials can destroy the ecosystem due to at least high toxicity within the sprayed area and reduced species diversity near the sprayed area (McLaughlin and Mineau, 1995; Shorette, 2012). In particular, organisms with lower trophic levels, which are resources for those with higher trophic levels, appear to be vulnerable to ecosystem disturbance, and both diversity and abundance are known to decrease within the disturbed environments (Kruess and Tscharntke, 1994).

8. Purpose of this present study

Conventional farming uses synthesized chemical pesticides or fertilizers, but it is recently changing to low-input farming that minimizes their use. Organic farming relies on crop rotation, green manure, composting, and biological control to maintain soil productivity and control pests on arable land. Despite the recent growth of organic agriculture, there has been a lack of research-based information to help understand the mechanisms operating in organic farming systems (Geoff et al., 2007). Geoff et al. (2007) also emphasized the importance of natural enemies and other aspects such as field location, crop rotation, soil improvement, tillage, and resistant varieties to control pests in organic agriculture.

In Korea, organic apple cultivation is increasing along with the development in organic farming practices, but comparative studies on arthropod communities between organic and conventional apple orchards are very insufficient.

The purpose of this study is (1) to understand the general differences in arthropod community structure between organic and conventional apple orchards, (2) to compare the difference in the ecological guild structure of arthropods, and (3) finally, to know the functional group structure and biodiversity of arthropods depending on the farming system in the area where apples are typically grown in Korea. These results are expected to provide important ecological information for sustainable apple cultivation while maintaining beneficial arthropod biodiversity in the orchard ecosystems.

Ⅱ. Materials and Methods

1. Orchards selection

The survey was conducted by selecting organic and conventional orchards for each location in four representative apple production areas in Korea (Danyang in Chungcheongbuk-do in 2012, Muju in Jellabuk-do in 2013, Cheongsong and Uiseong in Gyeongsangbuk-do in 2014). Since few farmers produce apples commercially using organic practices in Korea, we identified them through Environment-Friendly Agricultural Products Certification website (https://www.enviagro.go.kr) and technical advisors in each region. Based on this information, the organic apple orchards with a cultivation area of 0.4 ha or more and organic certification for at least five years were finally selected (Table 1). The conventional orchards were chosen within the same area as organic orchards (Table 1, Fig. 3-4). The average sizes of the investigated organic and conventional apple orchards were 0.81 and 0.63 ha, respectively. In orchard size, there was no statistical difference (t [6] = 0.77, P = 0.470) (Table 1).

Table 1. Description of study sites in relation to geographical information

Farming system	Study year	Location	Latitude	Longitude	Altitude (m)	Variety	Cultivated area (ha)
Organic	2012	Danyang	36º 57' 11.2"	128º 24' 28.3"	392	Fuji	0.56
	2013	Muju	35º 51' 46.9"	127º 41' 70.3"	494	Hongro	0.34
	2014	Uiseong	36º 21' 21.0"	128º 52' 90.4"	403	Fuji	1.15
	2014	Cheongsong	36º 17' 38.6"	129º 00' 30.5"	232	Fuji, Siano sweet	1.17
Conventional	2012	Danyang	36º 54' 36.4"	128º 25' 108"	556	Fuji	0.81
	2013	Muju	35º 51' 43.1"	127º 40' 57.8"	481	Fuji	0.48
	2014	Uiseong	36º 21' 36.0"	128º 50' 46.5"	264	Fuji	0.53
	2014	Cheongsong	36º 16' 18.5"	129º 30' 40.6"	357	Fuji	0.71

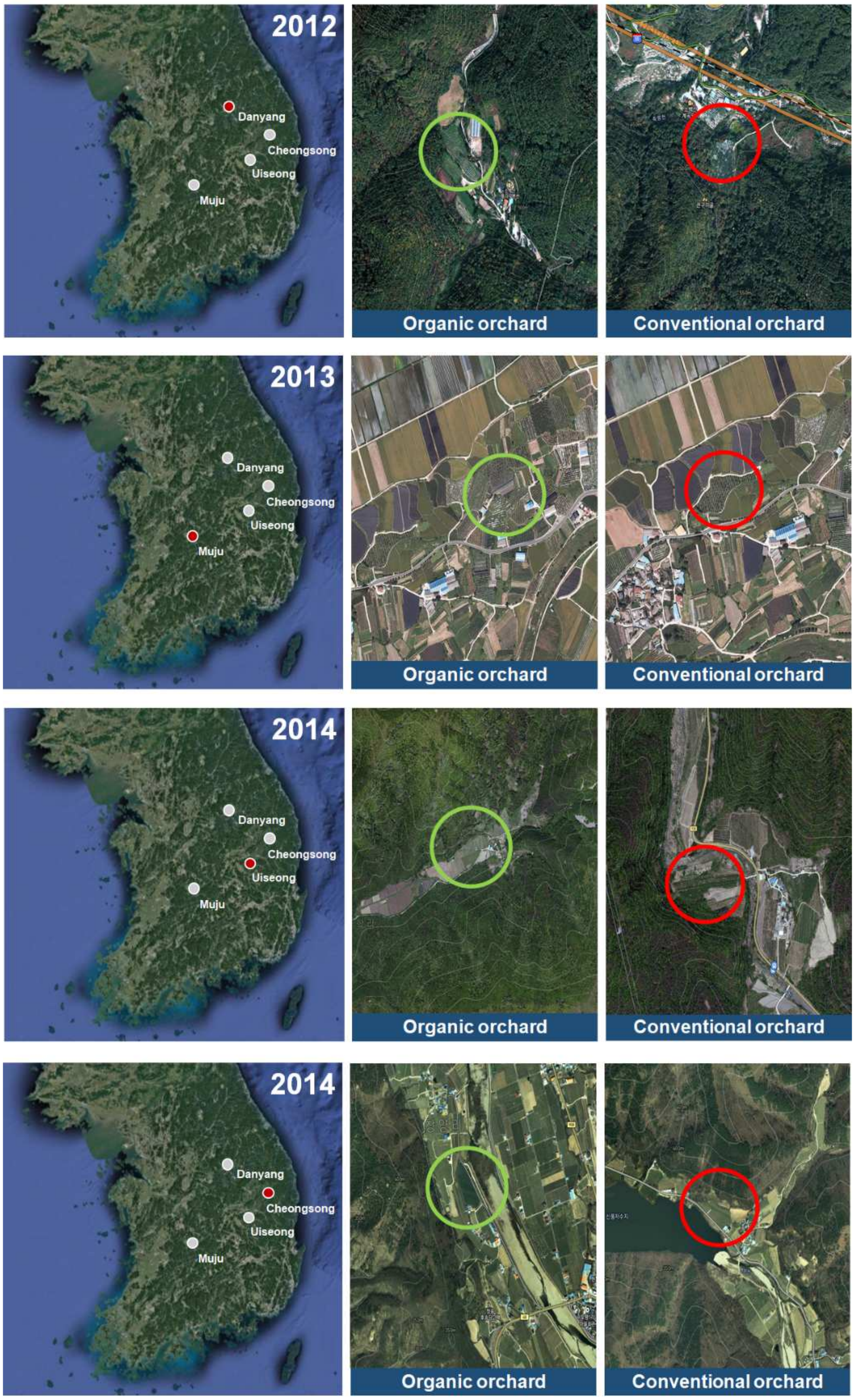

Fig. 3. The satellite photograph of surveyed organic and conventional apple orchards.

Fig. 4. The photos of surveyed organic and conventional apple orchards.

2. Farming practice information

Farming practice information such as treatment frequency and method for pest and weed control and soil management used at each commercial apple orchard was obtained through a recorded treatment calendar and interviewing farm owners when visited for investigation (Table 2). Regardless of farming practices, the main pests in all apple orchards were aphids (e.g., *Aphis spiraecola*, *Myzus persicae*, and *Ovatus malisuctus*), larvae of Lepidoptera (e.g., *Adoxophyes orana*, *Archips breviplicanus*, *Carposina sasakii*, *Grapholita molesta*, *Lyonetia prunifoliella*, and *Phyllonorycter ringoniella*), and stink bugs (e.g., *Halyomorpha halys*, *Plautia stali*, and *Riptortus pedestris*). However, mites (e.g., *Panonychus ulmi* and *Tetranychus urticae*) had mainly damaged only conventional orchards, which might be related to acaricide resistance or the absence of natural enemies. All organic orchards in this experiment used lime bordeaux mixture, lime sulfur mixture, machine oil, and plant extract oil to control apple diseases and pests. As another pest control agent in organic sites, aggregation pheromone traps and mating disruption were also used for controlling *R. pedestris* and lepidopteran males (*A. orana*, *A. breviplicanus*, *C. sasakii*, and *G. molesta*), respectively. There were no statistical (t [6] = 0.15, P = 0.888) differences in the average frequency (mean±SE) of pest control measure in both organic (10.00±1.47) and conventional (9.75±0.85) orchards. All the surveyed farms were mowed in late spring to prevent nutrient competition between apple trees and weeds. However, conventional orchards also got chemical herbicides with mowing. Unlike other farms, two apple orchards (organic and conventional) in Muju got non-woven mulching mats on surface tree roots.

In soil management, conventional orchards were treated with only synthetic fertilizers, while organic orchards got various fertilizers such as organic fertilizers, fermented cattle manures, and microbial fertilizers.

Table 2. Orchard management information of organic and conventional apple orchards in this study

Farming system	Location	Pest management frequency (times/year)[1]	Weed management frequency (times/year)[2]	Soil management frequency (times/year)[3]
Organic	Danyang	PO (10)	MW (2)	OF (2)
	Muju	LB (5), LS (3), MO (1), PO (4)	MW (3)	FM (1), OF(1)
	Cheongsong	LS+MO (1), PO (1), LS (8)	MW (5)	OF (1)
	Uiseong	LB (2), PO (4)	MW (3)	OF (1), MF (1)
Conventional	Danyang	SP (9)	MW (1), HC (2)	SF (1)
	Muju	SP (12)	MW (2), HC (4)	FM (1), SF(1)
	Cheongsong	SP (8)	MW (3), HC (2)	SF (1)
	Uiseong	SP (10)	MW (2), HC (3)	SF (2)

[1] LB (Lime bordeaux mixture); LS (Lime sulfur mixture); MO (Machine oil); PO (Plant extract oil); SP (Synthetic pesticide)

[2] HC (Herbicide); MW (Mowing)

[3] FM (Fermented cattle manure); MF (Microbial fertilizer); OF (Organic fertilizer), SF (Synthetic fertilizer)

3. Above-ground sampling

In order to investigate the arthropods of the apple tree canopy, various collection methods such as beading, branch clipping, and sweeping were required (Basset et al., 1996), but due to the cultivation conditions of apple orchards, it was impossible. Therefore, yellow sticky traps and apple leaves were investigated for sampling arthropods above-ground in the apple orchard (Fig. 5). The edge effect was minimized by installing a 9.0 × 13.0 cm (width × height) yellow sticky trap inside the apple orchard. The five yellow sticky traps were installed at the height of 1.8 m of apple trees designated diagonally, and the distance between them was at least 15 m to minimize their influence. The replaced yellow sticky trap was covered with a transparent wrap (12.0 × 15.0 cm) to protect the collected arthropods, minimizing damage. Traps were replaced every other week from the 2nd week of April to the 4th week of October.

The apple leaf survey was conducted by randomly sampling five leaves from trees with yellow sticky traps, and the sample leaves were stored in a paper bag (10.5 × 20.5 cm).

The transparent wrap and a paper bag containing the sampled traps were placed into zip-lock bags (Ziploc, 26.8 × 27.3 cm, Thai, Griptech Co., Ltd.; Bangkok, Thai) and stored in an ice box and brought to the laboratory of Seoul National University.

4. Ground sampling

Pitfall traps were used to sample arthropods on the surface of the apple orchards. Five pitfall traps were installed from the middle lows along a diagonal across except for the marginal areas of each orchard to exclude edge effects. Each pitfall trap was placed approximately 1.2 m far away from the apple tree trunk for a sampling of arthropods. The distance between traps was roughly 15 m. The traps consisted of plastic bottles (11.0 × 8.0 cm, diameter × height) and the lids with six holes of 2.5 cm diameter perforated opening to prevent amphibians from entering (Fig. 5). Each trap was filled with 300 ml of a mixture (1:1) of 99.5 % ethylene glycol and 94.0 % ethyl alcohol and was protected from rainfall with plastic dishes (18 cm diameter). The traps of each area were replaced biweekly during apple crop season, from the 2nd week of April to the 4th week of October. Collected arthropod samples were kept in 94.0% ethyl alcohol for identification.

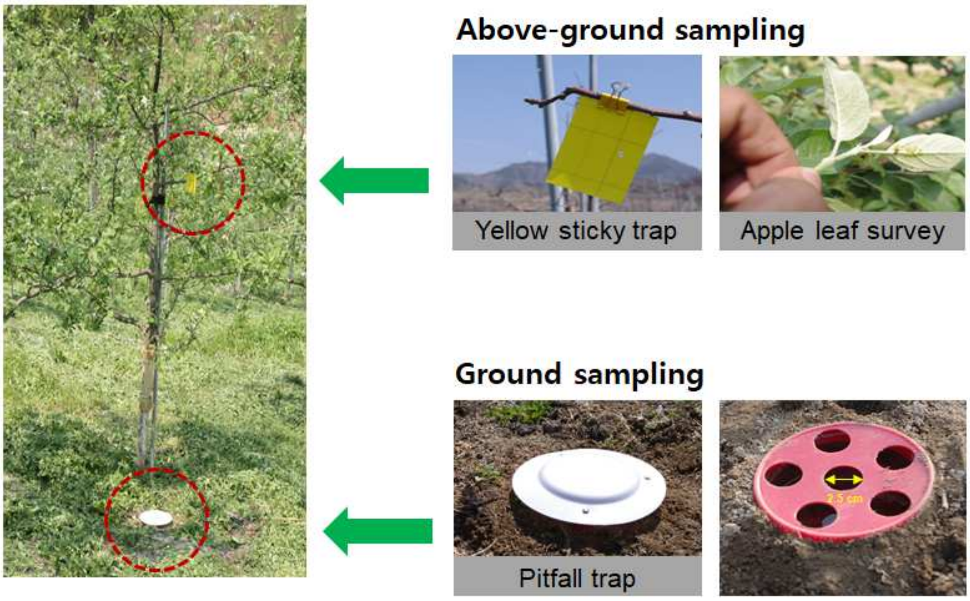

Fig. 5. The sampling methods of arthropods in apple orchards.

5. Taxonomical identification

The collected arthropods were sorted taxonomically at the orders or families level. In addition, using the illustrative guide for Korean insects (Park et al., 2012), it was reclassified to a species level possible through morphological characters under an anatomical microscope. Finally, the classified samples were re-identified by the following specialist, and the population was counted based on the species identified for each taxonomical group (Spider, Prof. Seung Tae Kim in Konkook University; Acari, Prof. Won-Gu Lee in Jeonbuk National University; Collembola, Prof. Kyung-Hwa Park in Jeonbuk National University; Coleoptera, Dr. Sang Wook Park in □esearch Institute of Forest Insects Diversity; Staphylinidae, Prof. Kee-Jeong Ahn in Chungnam National University; Diptera, Prof. Ho-Yeon Han in Yonsei University; Aphidae; Prof. HyoJoong Kim in Kunsan University; Hymenoptera, prof. Jong-Ok Lim in Wonkwang University; Formicidae, Prof. Dong Pyeo Lyu in Sangji University; Orthoptera: Dr. Tae-Woo Kim in National Institute of Biological Resources).

6. Guilds identification

6-1. Arthropod (Acari, Collembola, and Insecta) guilds

Classification of arthropod guild was performed through literature and internet search (John et al., 1976; Milton et al., 1979; Martin et al., 1980; Simon et al., 1982; Kiman et al., 1985; Donald et al., 1988; IAN, 1988; □alph et al., 1990; Hendrichs et al., 1994; John et al., 1998; Peter et al., 1999; Morandin et al., 2001; Wallin et al., 2002; Manzari et al., 2002; Lisbeth et al., 2003; Lemos et al., 2003; Ellen et al., 2004; Mark et al., 2004; Michael et al., 2004; Emilio and Gennaro, 2005; Emilio and John, 2005; Jensen et al., 2006; Ozlem et al., 2007; José et al., 2008; Donald et al., 2009; Howlett et al., 2011; Moraesa et al., 2012; Dennis et al., 2013; Ozan et al., 2014; Echegaray et al., 2015; Michael et al., 2015; Venkatesh et al., 2015; Duncan et al., 2016; Hannah et al., 2019; Imran et al., 2019; Maria et al., 2020; Ikponmwosa et al., 2020; Hosna et al., 2021; Slagle et al., 2022)

[Reference internet sites]
https://projects.ncsu.edu/cals/course/ent425/library/compendium/diptera.html
https://www.britannica.com/animal/hymenopteran
https://www.britannica.com/animal/beetle

6-2. Spider guilds

Classification of spider guild generally followed Uetz (1992). However, some families of spiders collected in the present study were not included in Uetz's guild classification. So, the guilds of these families were categorized by citing criteria used to construct a new spider guild classification by Uetz (1992).

7. Data analysis

7-1. Comparison of species or guild richness and abundance,

A paired *t*-test was performed to compare the species (or guild) richness and abundance of dominant orders, families, and species between organic and conventional orchards. The data were tested for normality using the Shapiro-Wilk test. All statistical analyses were performed using SAS statistical software ver. 9.4 (SAS Institute, Cary, NC, USA, 2013).

7-2. Comparison of the community and guild structure

A similarity analysis based on species composition was performed to compare the community structure of spiders between organic and conventional orchards. Data prepared for analysis were transformed to square root to avoid bias between the number of species and individuals. Then cluster analysis was performed based on the Bray-Curtis similarity index (Bray and Curtis, 1957). The SIMPROF test was conducted to confirm the statistically significant difference between clustered groups. Finally, a scatter plot was created by NMDS (Nonmetric multidimensional scaling) based on the number of organic and conventional orchards species in each study area. Cluster analysis, SIMPROF test, and NMDS analysis were performed using PRIMER 7 ver. 7.0.21 (Clarke and Gorely, 2015), a biological community analysis program.

7-3. Comparison of the biodiversity indices

Fisher's alpha diversity index (Fisher et al., 1943) was chosen to estimate arthropod and spider diversity. This index is widely used as a diversity index to compare communities varying in a number of individuals (Simons et al., 2014; Salman et al., 2019; Heneberg and Bogusch, 2020) and assumes the abundance of species following the log series distribution. This index is defined as :

$$S = \alpha \ln (1 + n / \alpha)$$

Where S is the number of taxa, n is the number of individuals, and α is the total number of individuals.

The analysis of the biodiversity of arthropods, spiders, and their guilds between organic and conventional orchards was performed using PRIMER 7 ver. 7.0.21 (Clarke and Gorely, 2015), a biological community analysis program.

A paired *t*-test was performed to compare the diversity indices between organic and conventional orchards. In addition, the data were tested for normality using the Shapiro-Wilk test. All statistical analyses were performed using SAS statistical software ver. 9.4 (SAS Institute, Cary, NC, USA, 2013).

III. Results

Section i. Comparison of arthropod community structure between organic and conventional apple orchards

1. Arthropods (Acari, Collembola, and Insecta) communities

1.1. Comparison of relative richness and abundance

A total of 319,943 arthropod individuals, except spiders, were identified as mites, springtails, and insects. They were identified as 255 species in 81 families belonging to 12 orders. Species with less than ten individuals collected during the entire survey period were 65 species, which was 25.5% of the total (*Appendix* 1, Table 3).

The species constituting the arthropod community differed depending on the study area. Regionally, the species richness of the spiders was the lowest in Muju area with 99 species and the highest in Uiseong area with 164 species. According to the farming system, 224 species were identified in organic orchards, and 184 species were identified in conventional orchards, suggesting that species richness in organic orchards was higher than in conventional orchards. Species richness in organic orchards was the highest in Uiseong area but the lowest in Muju area. In conventional orchards, Uiseong area was high, and Muju area was low. By farming system, the collected arthropods in organic orchards were 213,510 individuals, significantly higher than 106,433 individuals in conventional orchards. The abundance of organic orchards was high in Danyang area but low in Cheongsong area. In conventional orchards, Cheongsong area was high, and Muju area was low (Table 3).

Table 3. Summary of the arthropod community in the apple orchard in study areas

Study area	Farming system[a]	Community structure			
		No. of orders	No. of families	No. of species	No. of individuals
Danyang	OF	9	53	116	68,394
	CF	10	48	95	27,488
	Total	**10**	**58**	**137**	**95,882**
Muju	OF	8	38	93	62,642
	CF	8	35	72	21,574
	Total	**8**	**41**	**99**	**84,216**
Uiseong	OF	10	54	146	45,506
	CF	8	44	104	28,859
	Total	**10**	**59**	**164**	**74,365**
Cheongsong	OF	10	46	119	28,512
	CF	10	41	100	36,968
	Total	**10**	**53**	**140**	**65,480**
Total	OF	12	75	224	213,510
	CF	10	65	184	106,433
	Total	**12**	**81**	**255**	**319,943**

[a]OF, organic farming; CF, conventional farming

Six orders (Acari, Collembola, Coleoptera, Diptera, Hemiptera, and Hymenoptera) were dominant in relative species richness and abundance regardless of the study area or farming system. As a result of analyzing the relative species richness and abundance of these six species, there was no statistical difference between organic and conventional orchards, except for Coleoptera and Acari, respectively (Table 4-5; Fig. 6-7).

The families with the highest relative species richness and abundance in each order are as follows; Creatozetidae, Opiidae, Digamasellidae, and Tetranychidae in Acari (7.2% species richness and 8.4% abundance of the total in organic orchard; 7.2% species richness and 12.6% abundance of the total in conventional orchard) (Fig. 8-9), Entomobrydae, Isotomidae, and Kaitiannidae in Collembola (5.9% species richness and 56.3% abundance in organic orchard; 4.1% species richness and 15.1% abundance in conventional orchard) (Fig. 10-11), Carabidae, Staphylinidae, and Scolytidae in Coleoptera (36.9% species richness and 5.5% abundance in organic orchard; 28.8% species richness and 1.4% abundance in conventional orchard) (Fig. 12-14), Phoridae, Drosophilidae, Muscidae and Sicaridae in Diptera (16.7% species richness and 17.8% abundance in organic orchard; 14.4% species richness and 15.6% abundance in conventional orchard) (Fig. 14-15), Aphididae and Cicadellidae in Hemiptera (3.6% species richness and 1.2% abundance in organic orchard; 4.1% species richness and 0.7% abundance in conventional orchard) (Fig. 16-17), and Chalcidoidea, Diapriidae, Formicidae in Hymenoptera (23.4% species richness and 5.2% abundance in organic orchard; 19.8% species richness and 1.9% abundance in conventional orchard) (Fig. 18-19).

As a result of analyzing the relative species richness in dominant families, Muscidae (Diptera) showed a statistically higher in organic orchards only. The relative abundance in the dominant families was statistically higher in Ceratozetidae (Acari) in conventional orchards, while Staphylinidae (Coleoptera) and Muscidae were statistically higher in organic (Table. 6-7). There was a difference in occupancy of the relative species richness and abundance by study area. However, most of these relative occupancies statistically do not differ between organic and conventional orchards.

Table 4. Comparison of relative species richness of dominant arthropod orders in apple orchards

Farming system[a]	OF	CF	Paired *t*-test		
Orders	(mean ± SE)	(mean ± SE)	*df*	*t*	*P*
Acari	12.66±1.63	13.31±1.88	3	1.17	0.328
Collembola	8.15±1.22	7.76±0.42	3	0.17	0.873
Coleoptera	14.90±2.11	12.30±1.50	3	4.27	**0.024**
Diptera	25.51±1.92	26.19±2.60	3	0.23	0.835
Hemiptera	7.63±1.31	9.50±1.16	3	1.22	0.309
Hymenoptera	23.93±1.98	22.81±1.04	3	0.58	0.601

[a]OF, organic farming; CF, conventional farming

Table 5. Comparison of relative abundance of dominant arthropod orders in apple orchards

Farming system[a]	OF	CF	Paired *t*-test		
Orders	(mean ± SE)	(mean ± SE)	*df*	*t*	*P*
Acari	25.64±13.18	9.32±11.11	3	3.84	**0.031**
Collembola	29.76±23.30	51.25±28.48	3	1.64	0.199
Coleoptera	2.85±1.21	6.16±6.51	3	1.29	0.287
Diptera	31.16±9.19	20.89±15.41	3	1.74	0.180
Hemiptera	1.50±0.40	1.23±0.64	3	1.62	0.204
Hymenoptera	3.82±1.49	6.03±4.34	3	1.54	0.221

[a]OF, organic farming; CF, conventional farming

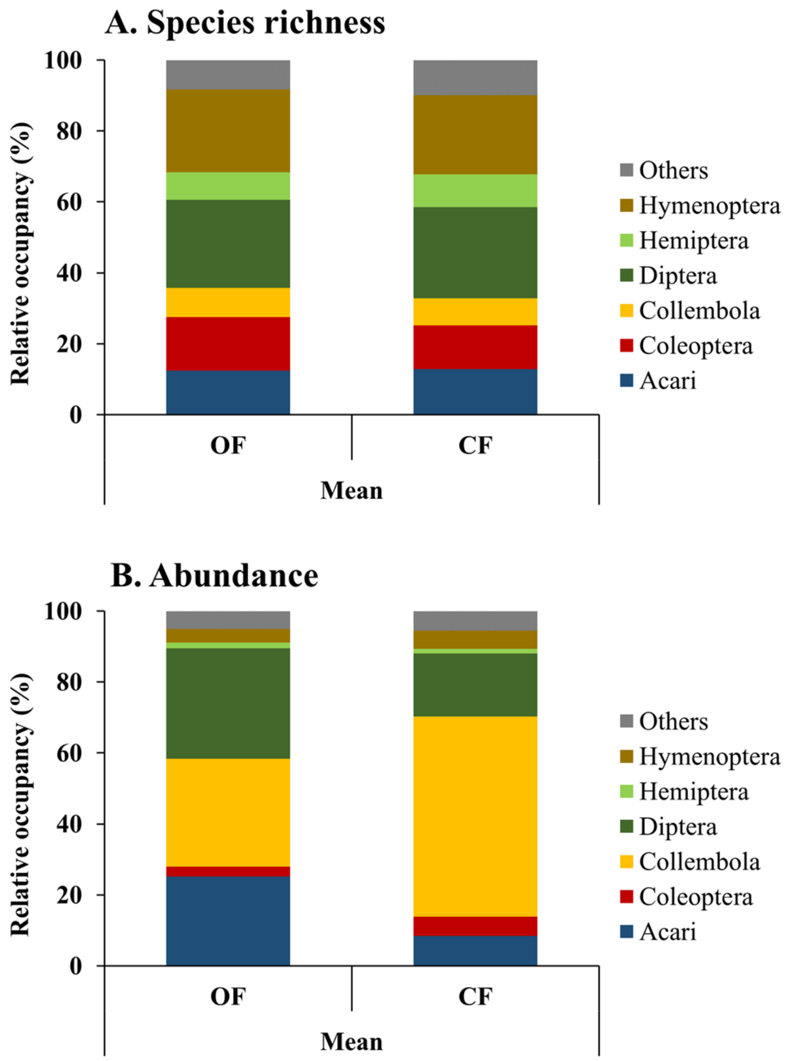

Fig. 6. The average relative species richness and abundance of dominant arthropod orders in the apple orchards (OF, organic farming; CF, conventional farming).

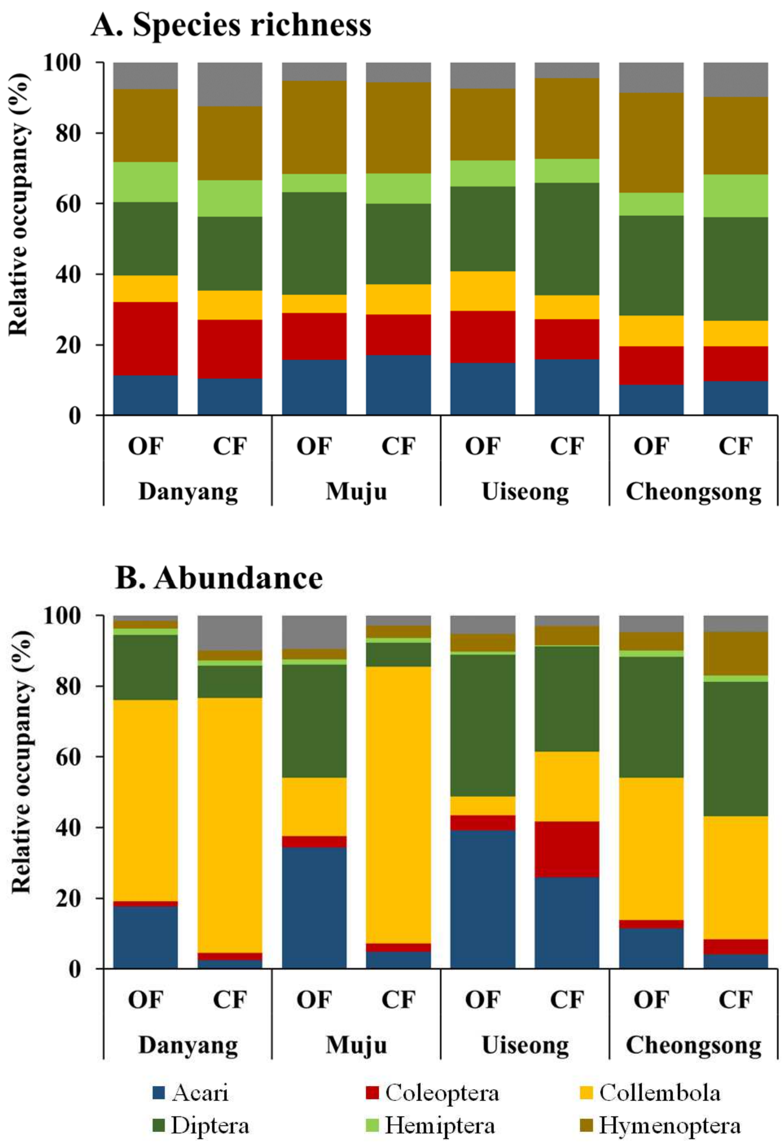

Fig. 7. The relative species richness and abundance of dominant arthropod orders sampled from apple orchards by study areas (OF, organic farming; CF, conventional farming).

Table 6. Comparison of relative species richness of dominant arthropod families in apple orchards

Order	Dominant family	Farming system[a]		Paired *t*-test		
		OF (mean±SE)	CF (mean±SE)	*df*	*t*	*P*
Acari	Ceratozetidae	18.39±5.16	25.24±11.91	3	2.03	0.135
	Digamasellidae	23.18±11.19	23.45±6.07	3	0.24	0.826
	Oppiidae	11.93±3.61	14.52±5.45	3	2.55	0.084
	Tetranychidae	22.20±10.49	14.52±5.45	3	2.62	0.079
Collembola	Entomobryidae	36.88±16.50	47.50±18.93	3	0.96	0.409
	Isotomidae	25.63±11.25	26.25±9.46	3	0.14	0.895
	Katiannidae	12.50±16.67	11.25±13.15	3	0.52	0.638
Coleoptera	Carabidae	30.08±8.08	35.60±9.25	3	1.11	0.349
	Staphylinidae	29.29±8.67	23.45±3.46	3	1.54	0.221
	Scolytidae	10.43±3.61	14.56±5.21	3	2.02	0.136
Diptera	Phoridae	11.91±1.86	16.85±3.52	3	2.98	0.059
	Drosophilidae	15.65±2.23	14.25±3.84	3	1.59	0.209
	Muscidae	13.65±5.02	10.44±5.59	3	3.26	0.047
	Sciaridae	9.27±2.72	11.54±2.21	3	2.27	0.108
Hemiptera	Aphididae	48.81±15.61	44.17±13.16	3	0.66	0.059
	Cicadellidae	13.99±10.40	13.33±9.03	3	0.25	0.108
Hymenoptera	Formicidae	17.57±1.71	19.94±2.20	3	1.66	0.195
	Chalcidoidea	13.85±1.91	18.36±7.94	3	1.00	0.390
	Diapriidae	13.89±2.18	11.16±4.33	3	1.92	0.150

[a]OF, organic farming; CF, conventional farming

Table 7. Comparison of relative abundance of dominant arthropod families in apple orchards

Order	Dominant family	Farming system[a]		Paired *t*-test		
		OF (mean ± SE)	CF (mean ± SE)	*df*	*t*	*P*
Acari	Ceratozetidae	27.56±8.08	47.34±13.86	3	3.79	**0.032**
	Digamasellidae	24.74±9.95	8.56±5.12	3	1.78	0.174
	Oppiidae	26.95±24.32	25.98±20.86	3	1.33	0.276
	Tetranychidae	9.24±9.06	8.85±1.04	3	0.00	0.997
Collembola	Entomobryidae	66.75±19.52	82.91±17.20	3	0.92	0.426
	Isotomidae	23.08±22.15	15.29±18.66	3	0.43	0.698
	Katiannidae	7.23±13.22	0.29±0.54	3	1.00	0.391
Coleoptera	Carabidae	43.85±28.58	41.18±27.95	3	0.08	0.938
	Staphylinidae	21.73±10.10	10.25±9.06	3	4.33	**0.023**
	Scolytidae	13.59±12.52	37.14±24.77	3	2.86	0.065
Diptera	Phoridae	3.78±1.40	2.37±1.76	3	1.82	0.167
	Drosophilidae	26.57±24.12	23.09±10.26	3	0.03	0.974
	Muscidae	7.86±4.65	5.15±3.12	3	3.92	**0.030**
	Sciaridae	27.51±9.35	37.48±17.77	3	0.83	0.466
Hemiptera	Aphididae	86.02±9.29	93.12±4.60	3	2.23	0.112
	Cicadellidae	9.83±9.37	4.78±4.17	3	1.56	0.217
Hymenoptera	Formicidae	54.05±33.54	46.34±28.51	3	1.18	0.324
	Chalcidoidea	7.57±2.87	20.12±13.63	3	2.16	0.119
	Diapriidae	6.71±4.60	7.67±2.24	3	0.89	0.437

[a]OF, organic farming; CF, conventional farming

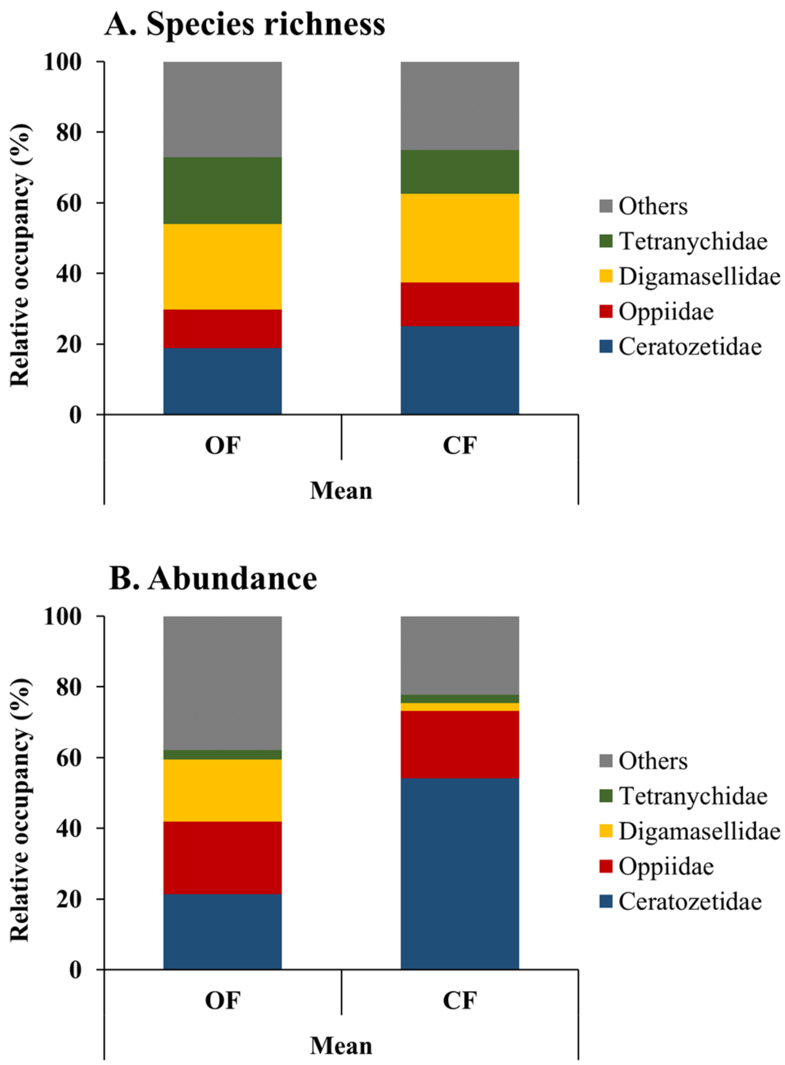

Fig. 8. The average relative species richness and abundance of dominant families belonging to Acari in the apple orchards (OF, organic farming; CF, conventional farming).

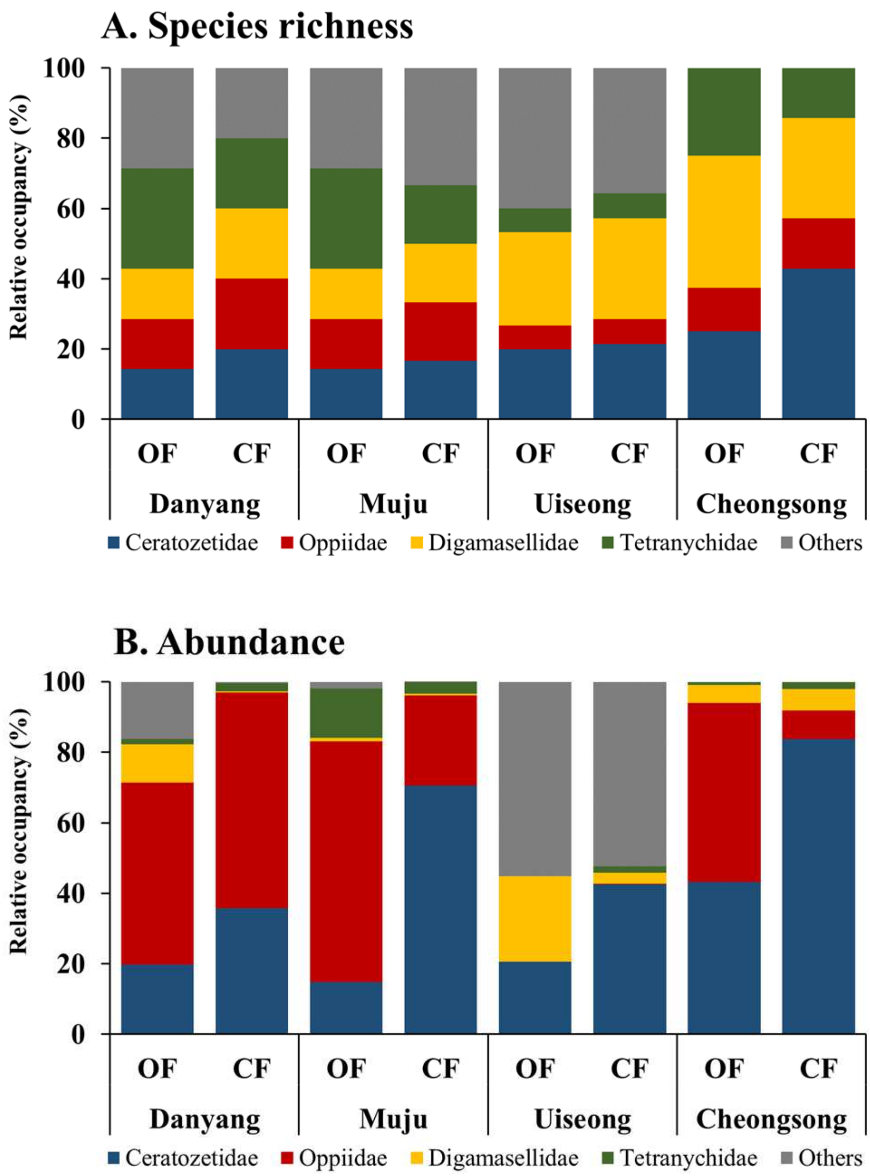

Fig. 9. The relative species richness and abundance of dominant families belonging to Acari in apple orchards by study areas (OF, organic farming; CF, conventional farming).

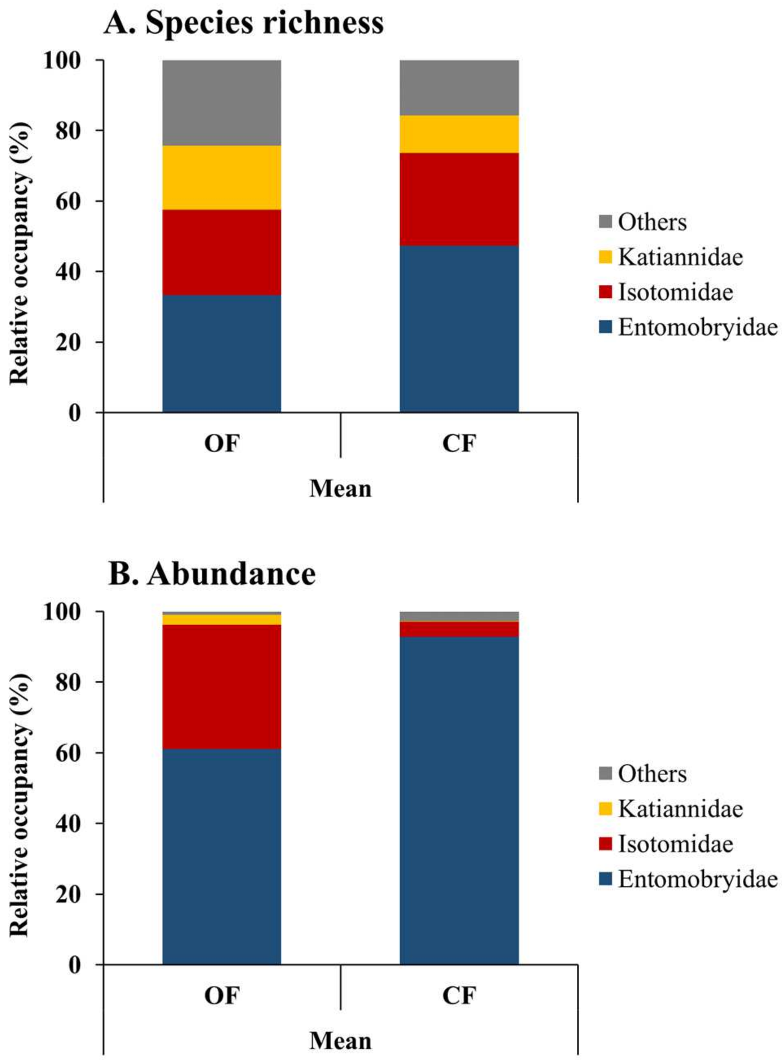

Fig. 10. The average relative species richness and abundance of dominant families belonging to Collembola in the apple orchards (OF, organic farming; CF, conventional farming).

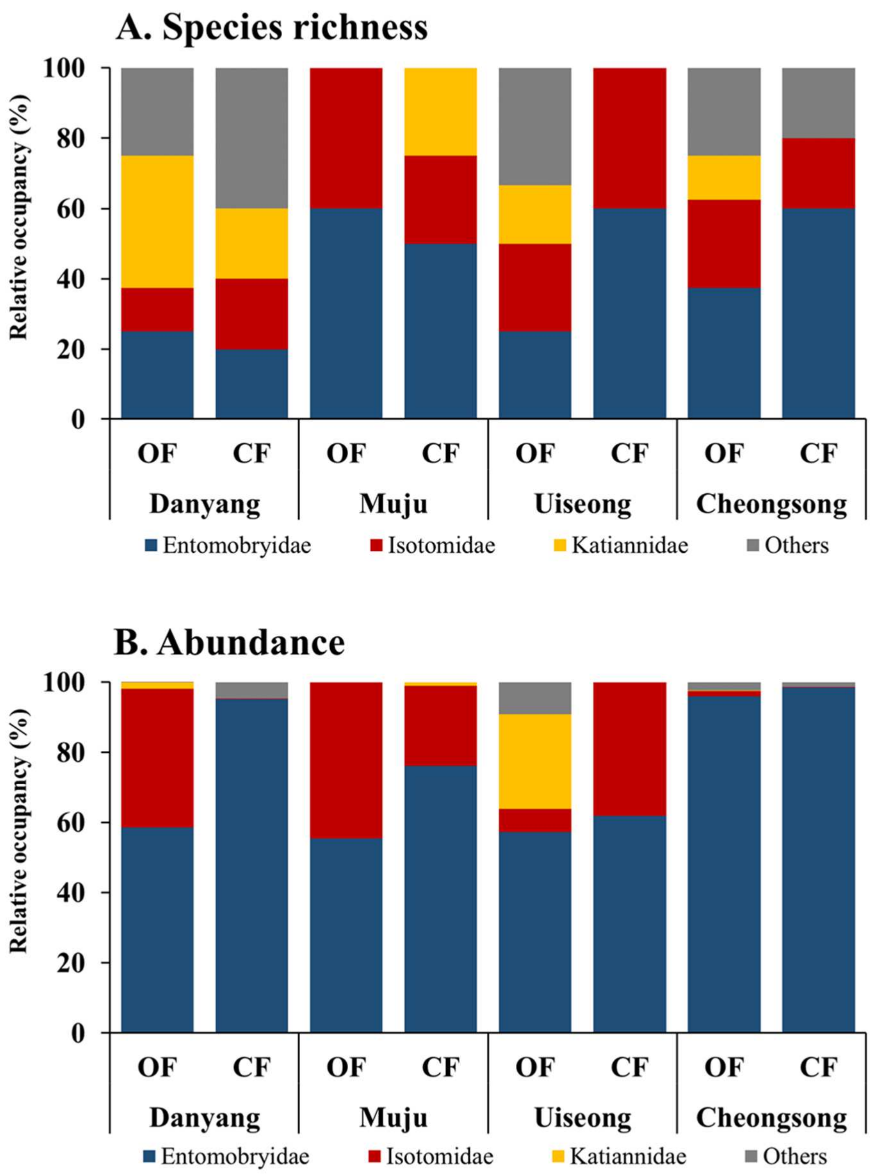

Fig. 11. The relative species richness and abundance of dominant families belonging to Collembola in apple orchards by study areas (OF, organic farming; CF, conventional farming).

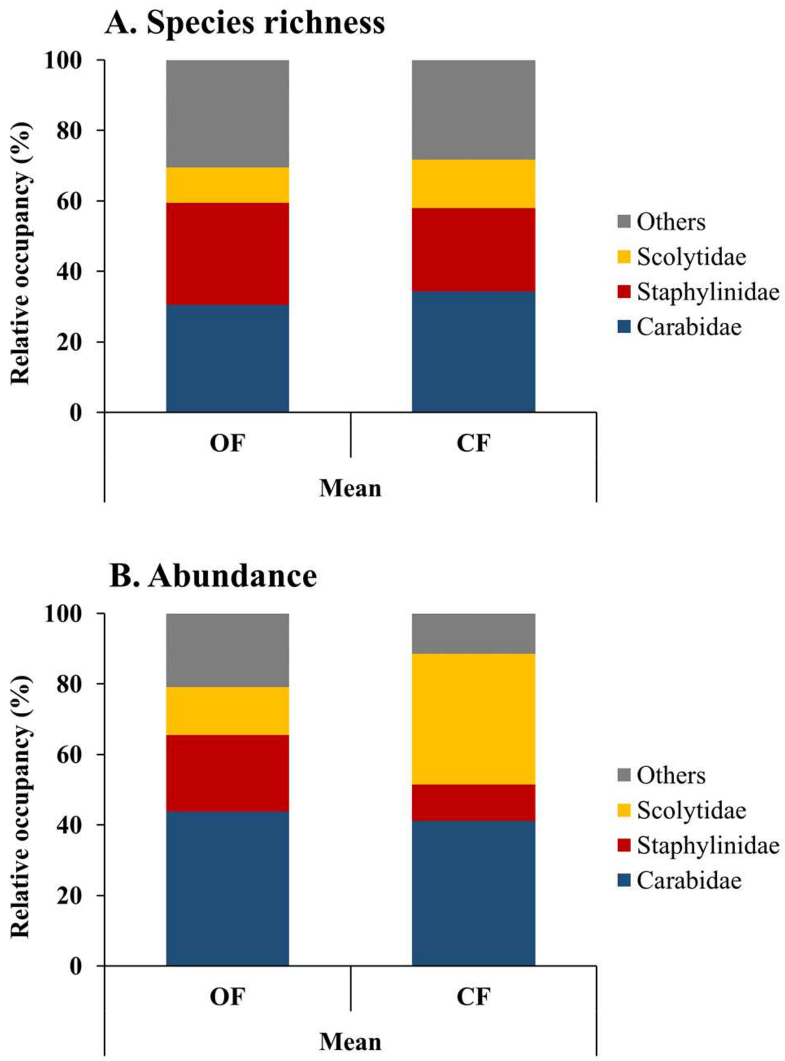

Fig. 12. The average relative species richness and abundance of dominant families belonging to Coleoptera in the apple orchards (OF, organic farming; CF, conventional farming).

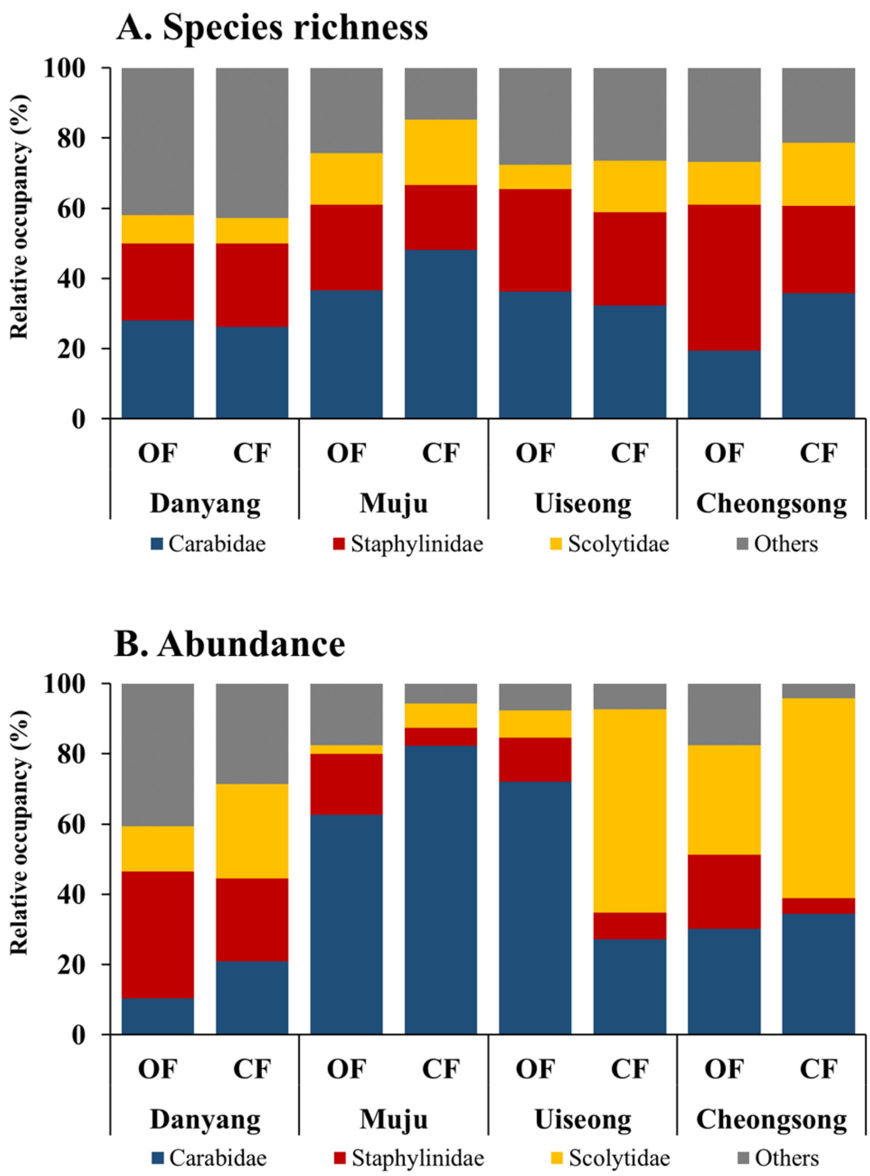

Fig. 13. The relative species richness and abundance of dominant families belonging to Coleoptera in apple orchards by study areas (OF, organic farming; CF, conventional farming).

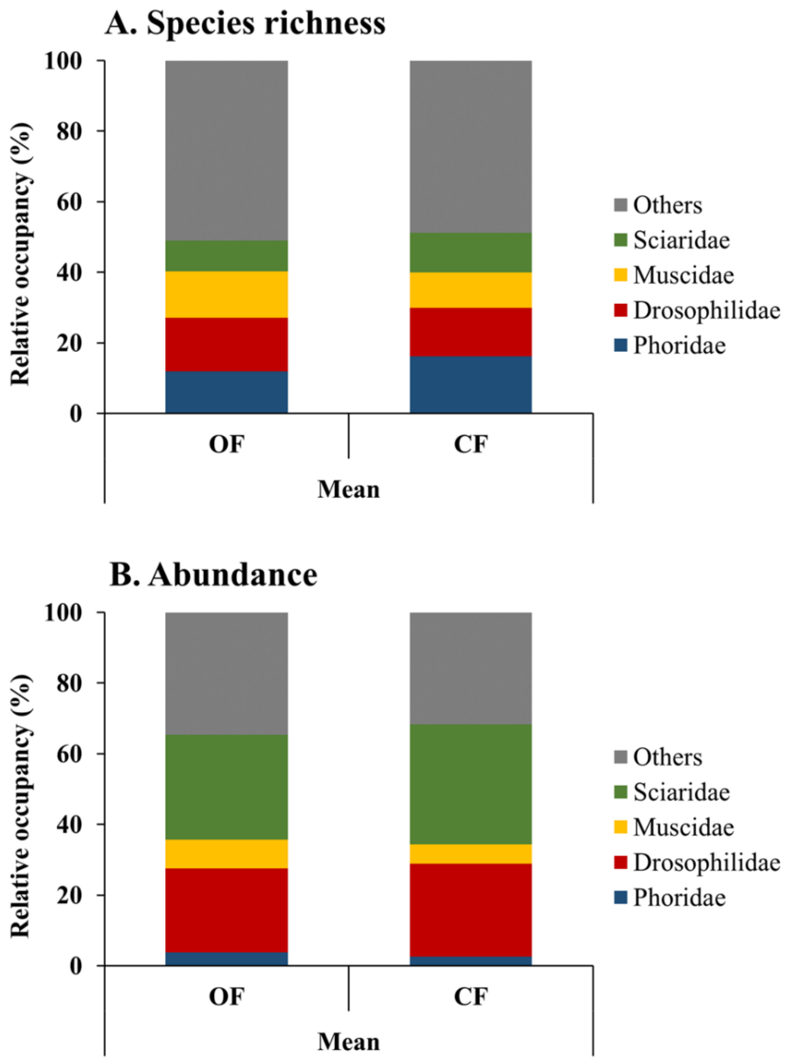

Fig. 14. The average relative species richness and abundance of dominant families belonging to Diptera in the apple orchards (OF, organic farming; CF, conventional farming).

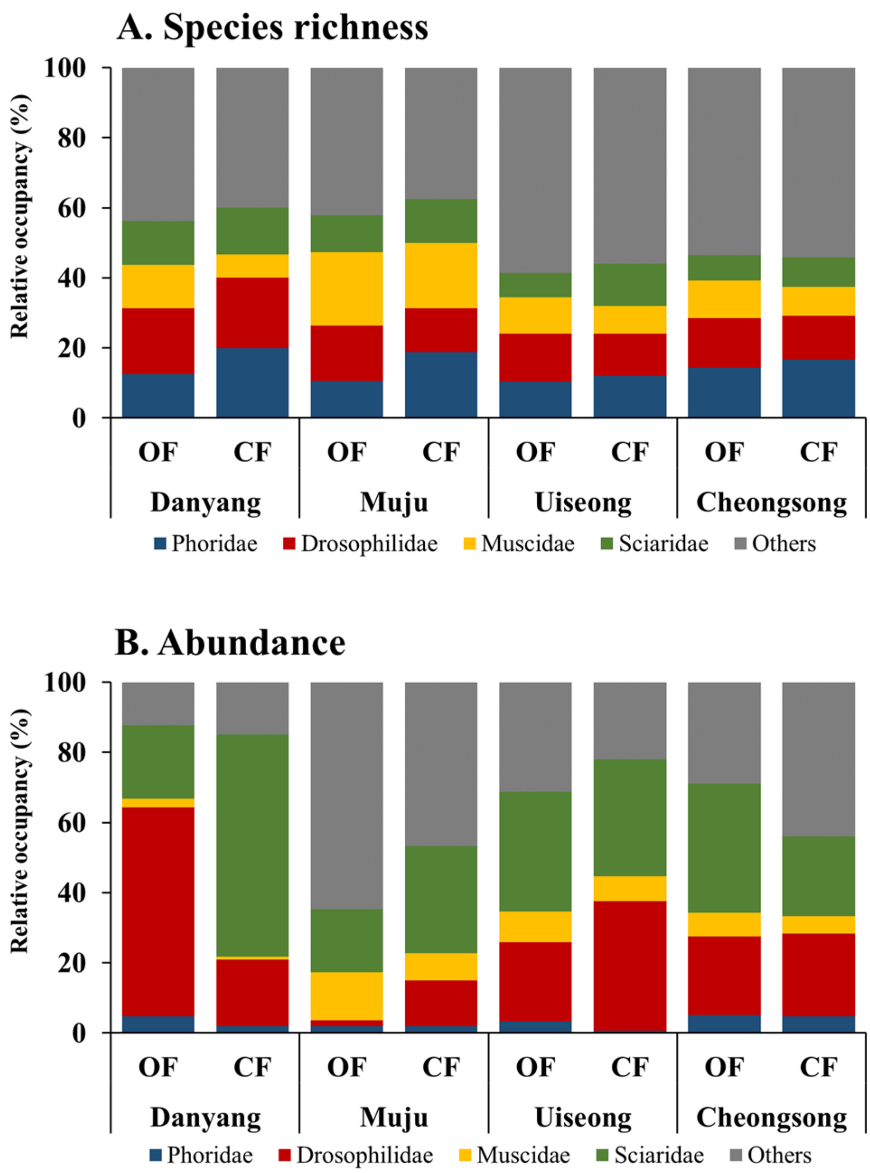

Fig. 15. The relative species richness and abundance of dominant families belonging to Diptera in apple orchards by study areas (OF, organic farming; CF, conventional farming).

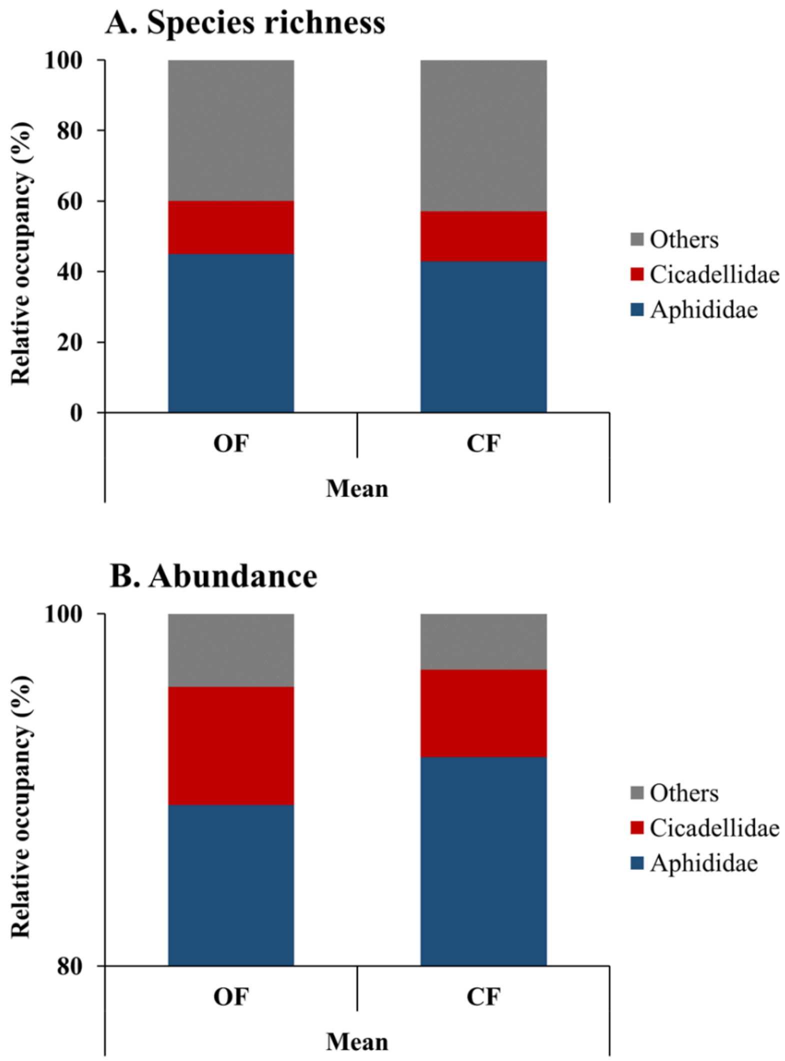

Fig. 16. The average relative species richness and abundance of dominant families belonging to Hemiptera in the apple orchards (OF, organic farming; CF, conventional farming).

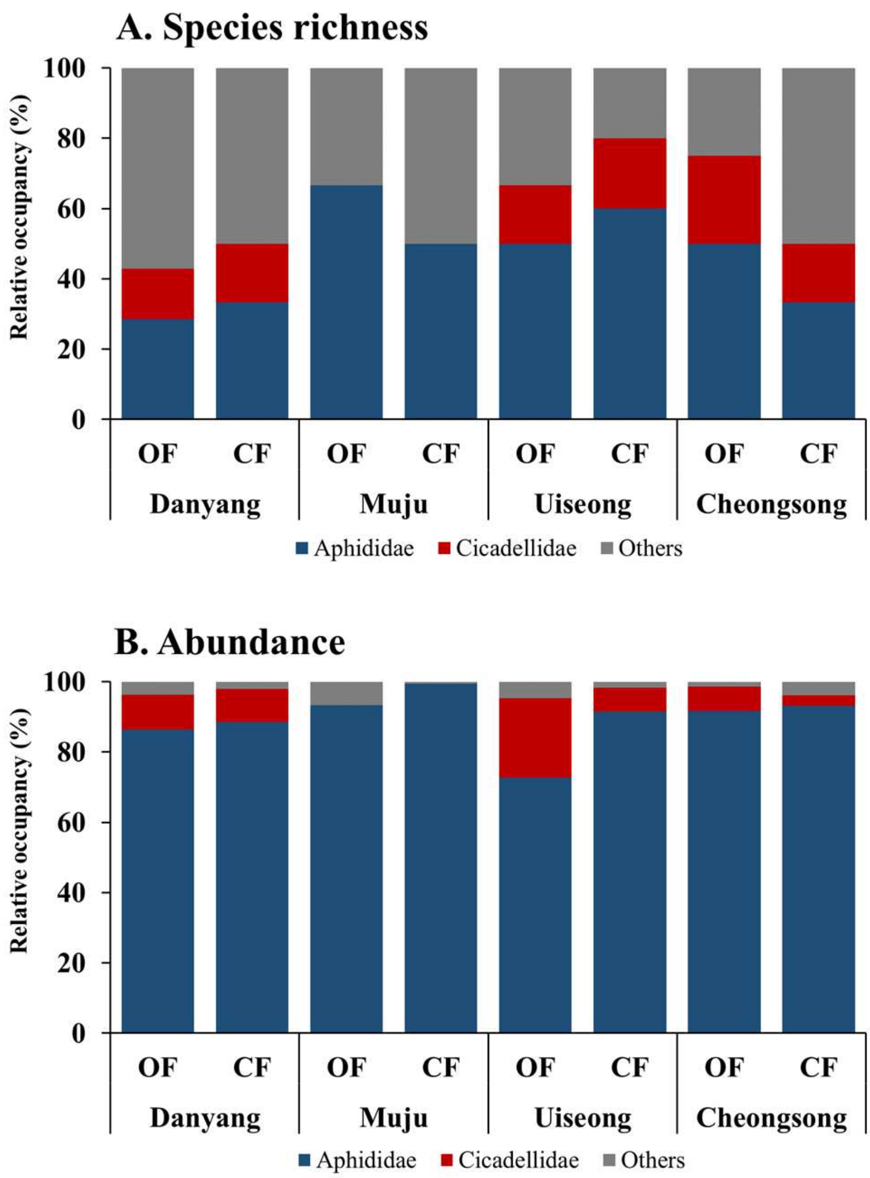

Fig. 17. The relative species richness and abundance of dominant families belonging to Hemiptera in apple orchards by study areas (OF, organic farming; CF, conventional farming).

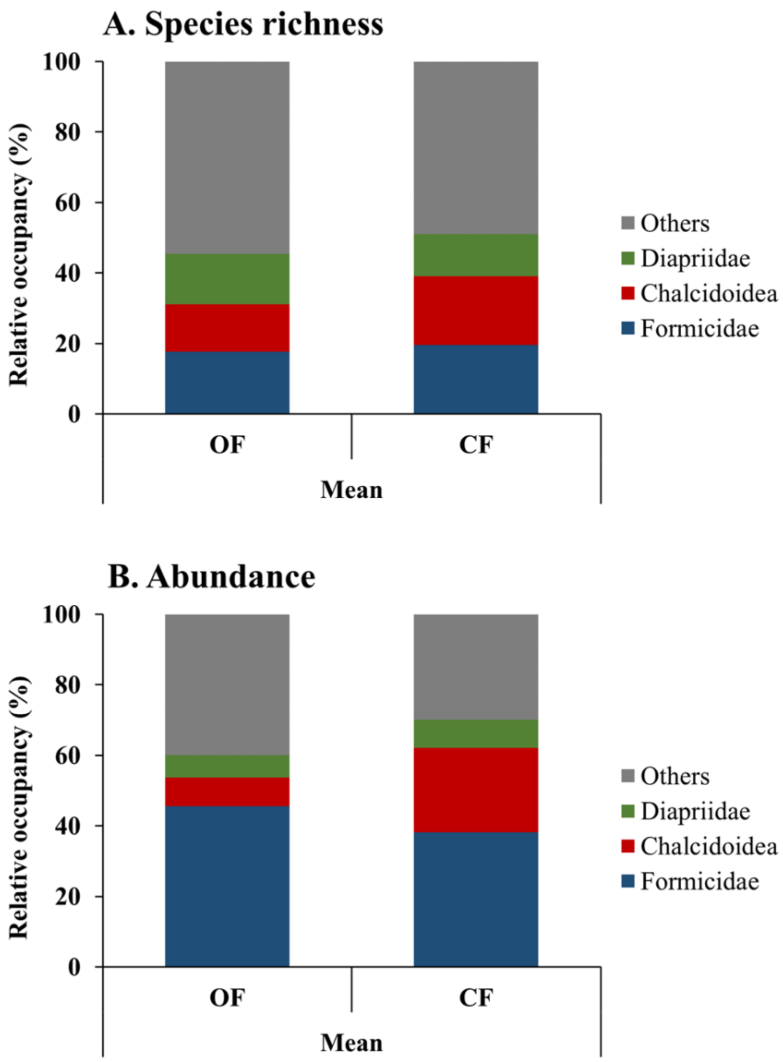

Fig. 18. The average relative species richness and abundance of dominant families belonging to Hymenoptera in the apple orchards (OF, organic farming; CF, conventional farming).

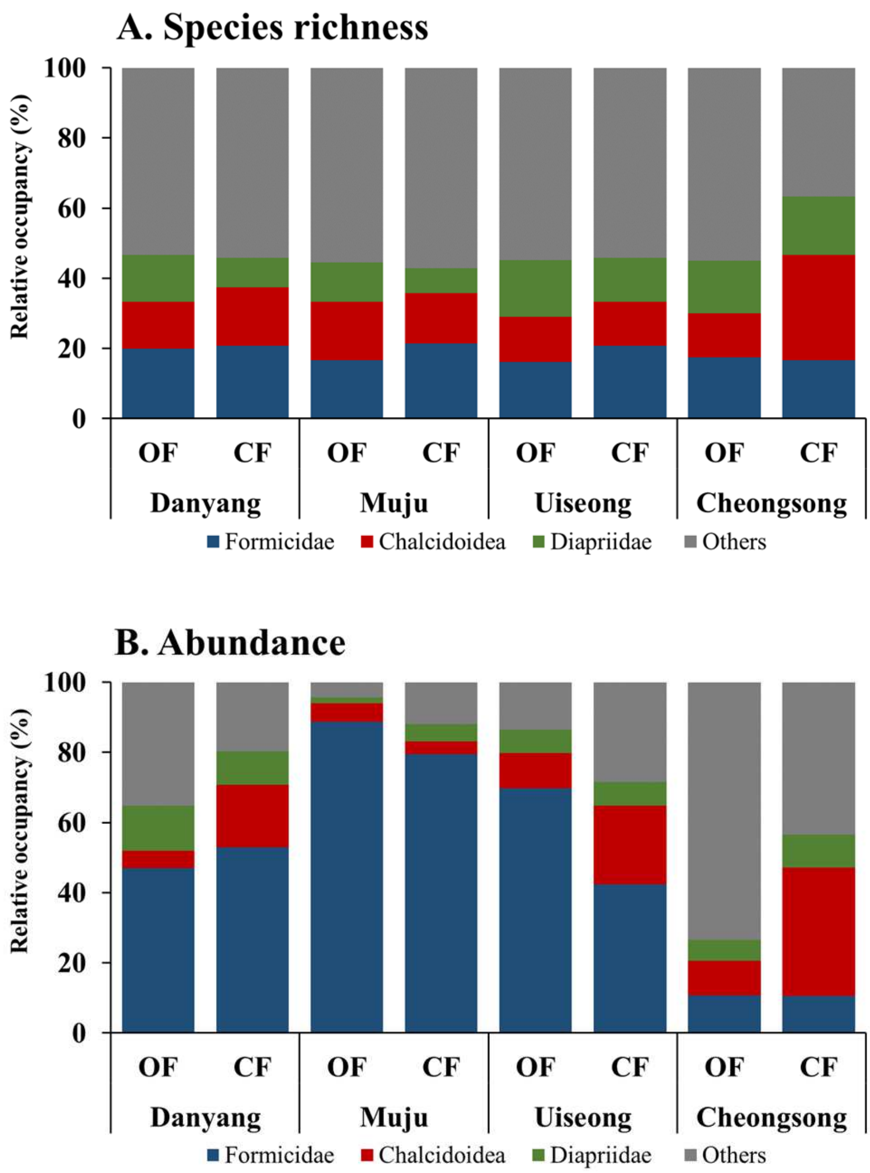

Fig. 19. The relative species richness and abundance of dominant families belonging to Hymenoptera in apple orchards by study areas (OF, organic farming; CF, conventional farming).

1.2. Comparison of dominant orders, families, and species

As a result of comparing organic orchards with conventional orchards for the abundance of dominant orders, there were statistical differences between farming systems in the three orders. Collembola (t [19] = 6.11, $P < 0.001$), Coleoptera (t [19] = 10.16, $P < 0.001$), and Hymenoptera (t [19] = 9.07, $P < 0.001$) showed higher abundance in organic orchards (Fig. 20-22).

Among the orders, the abundance of eight families, Ceratozetidae and Oppiidae (Acari), Entomobryidae (Collembola), Carabidae, Scolytidae, and Staphylinidae (Coleoptera), Drosophilidae, Muscidae, and Sciaridae (Diptera), Aphididae (Hemiptera), and Chalcidoidea, Diapriidae, and Formicidae (Hymenoptera) was very high, accounting for 62.9% of the total (*Appendix* 1-3).

Of the 13 dominant families, the abundance of Ceratozetidae was high in conventional orchards, while all other statistically significant families were significantly higher in organic orchards (Table 8-10).

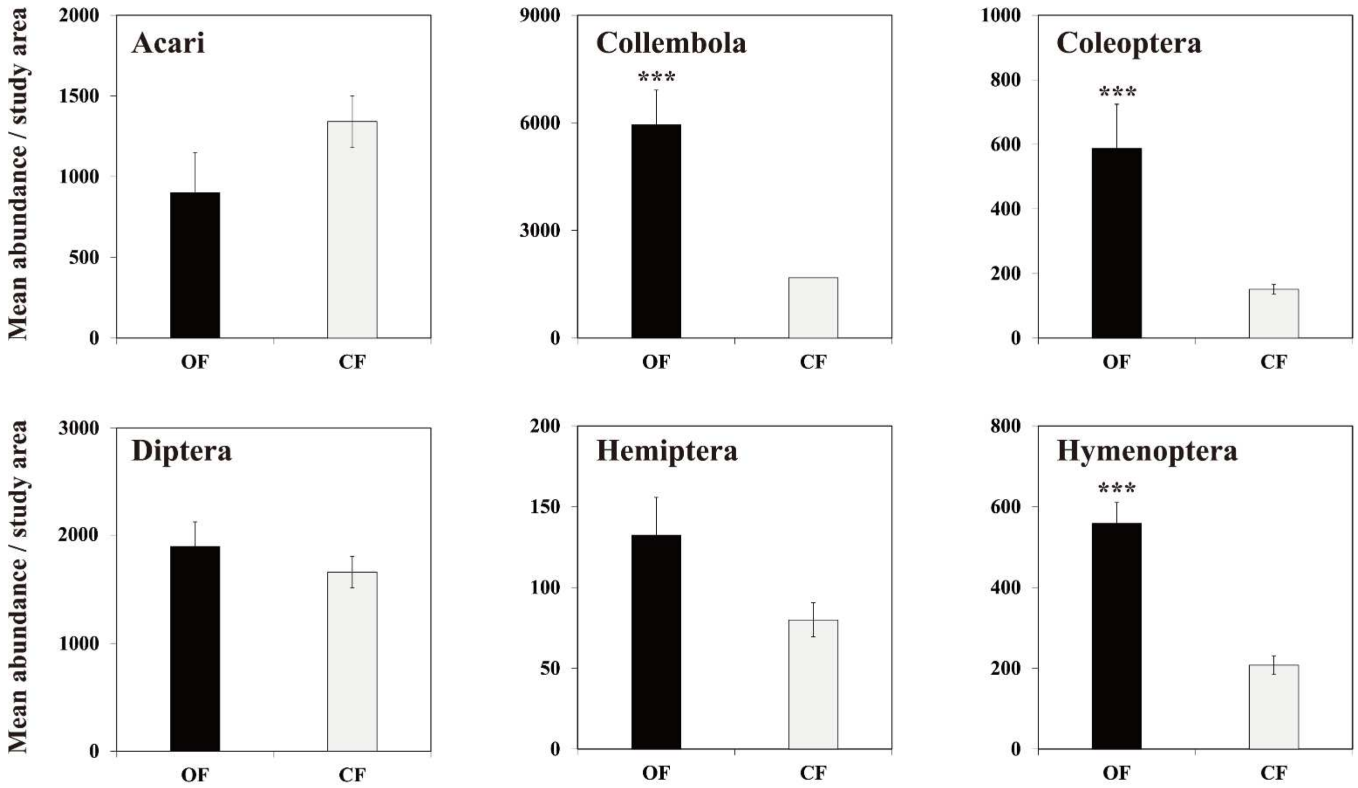

Fig. 20. Comparison of the average abundance (mean±SE) of dominant arthropod orders in surveyed apple orchards (OF, organic farming; CF, conventional farming) (Paired *t*-test; * 0.01 < P < 0.05, ** 0.001 < P < 0.01, *** P < 0.001)

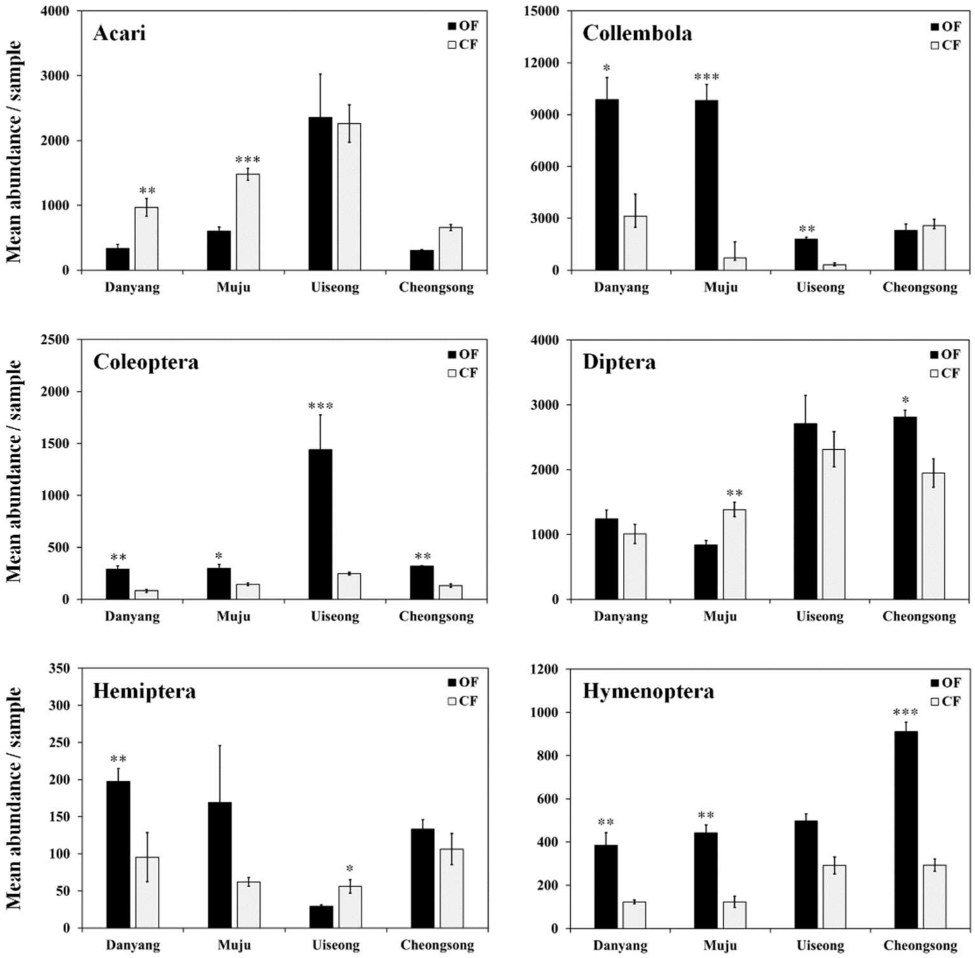

Fig. 21. Comparison of the abundance (mean±SE) of dominant arthropod orders in apple orchards (OF, organic farming; CF, conventional farming) (Paired *t*-test, * $0.01 < P < 0.05$, ** $0.001 < P < 0.01$, *** $P < 0.001$).

Table 8. Comparison of the average abundance of dominant arthropod families in surveyed apple orchards

Order	Dominant family	Farming system[a]		Paired *t*-test		
		OF (mean±SE)	CF (mean±SE)	*df*	*t*	*P*
Acari	Ceratozetidae	4.90±0.18	6.46±0.12	19	8.63	**< 0.001**
Collembola	Entomobryidae	3676.60±543.62	1495.75±315.34	19	5.35	**< 0.001**
Coleoptera	Carabidae	372.55±119.76	66.25±9.50	19	5.80	**< 0.001**
	Staphylinidae	122.10±16.02	14.85±3.13	19	12.70	**< 0.001**
Diptera	Drosophilidae	502.35±102.35	395.90±64.45	19	2.08	0.052
	Muscidae	101.35±17.25	136.20±18.83	19	2.77	**0.012**
	Sciaridae	646.65±65.00	492.25±69.39	19	2.28	**0.034**
Hymenoptera	Diapriidae	35.60±5.04	16.30±2.41	19	9.40	**<0.001**
	Formicidae	254.40±30.71	79.40±11.88	19	4.24	**<0.001**

[a]OF, organic farming; CF, conventional farming

Table 9. Comparison of the abundance of dominant families of Acari, Collembola, and Coleoptera in apple orchards

Order	Dominant family	Study area	Farming system[a]		Paired *t*-test		
			OF (mean±SE)	CF (mean±SE)	*df*	*t*	*P*
Acari	Ceratozetidae	Danyang	4.18±0.13	5.81±0.14	4	11.13	**<0.001**
		Muju	4.49±0.07	6.94±0.07	4	21.17	**<0.001**
		Uiseong	6.12±0.17	6.77±0.22	4	1.75	0.155
		Cheongsong	4.82±0.17	6.31±0.05	4	7.74	**0.002**
Collembola	Entomobryidae	Danyang	10.60±5.09	24.00±7.08	4	2.18	0.095
		Muju	65.40±6.62	188.40±24.61	4	18.73	**<0.001**
		Uiseong	191.60±21.33	200.80±28.15	4	6.30	**0.003**
		Cheongsong	137.80±19.47	131.60±20.29	4	0.65	0.551
Coleoptera	Carabidae	Danyang	44.40±3.17	22.20±2.69	4	4.09	**0.015**
		Muju	218.60±24.43	121.60±10.53	4	3.08	**0.037**
		Uiseong	1110.20±294.30	72.40±15.34	4	24.25	**<0.001**
		Cheongsong	117.00±8.20	47.40±6.62	4	5.74	**0.005**
	Staphylinidae	Danyang	152.80±26.49	25.20±10.29	4	5.71	**0.005**
		Muju	60.60±18.23	7.60±1.75	4	3.57	**0.023**
		Uiseong	193.60±30.64	20.40±2.99	4	23.66	**<0.001**
		Cheongsong	81.40±5.68	6.20±1.59	4	9.88	**<0.001**

[a]OF, organic farming; CF, conventional farming

Table 10. Comparison of the abundance of dominant families of Diptera and Hymenoptera in apple orchards

Order	Dominant family	Study area	Farming system[a]		Paired *t*-test		
			OF (mean±SE)	CF (mean±SE)	*df*	*t*	*P*
Diptera	Drosophilidae	Danyang	234.20±18.67	600.80±122.03	4	3.53	**0.024**
		Muju	108.40±9.12	22.40±4.34	4	7.18	**0.002**
		Uiseong	1003.00±260.32	524.00±69.65	4	3.60	**0.023**
		Cheongsong	663.80±69.92	436.40±96.32	4	1.57	0.191
	Muscidae	Danyang	10.60±5.09	24.00±7.08	4	1.80	0.146
		Muju	65.40±6.62	188.40±24.61	4	6.07	**0.004**
		Uiseong	191.60±21.33	200.80±28.15	4	0.32	0.762
		Cheongsong	137.80±19.47	131.60±20.29	4	0.28	0.796
	Sciaridae	Danyang	786.00±99.16	211.40±38.62	4	6.97	**0.002**
		Muju	256.80±56.82	250.20±49.46	4	0.04	0.968
		Uiseong	905.40±75.81	792.20±120.73	4	1.64	0.177
		Cheongsong	638.40±43.07	715.20±60.62	4	1.55	0.197
Hymenoptera	Diapriidae	Danyang	49.20±8.87	11.80±4.36	4	4.85	**0.008**
		Muju	7.20±1.46	6.00±1.14	4	0.35	0.743
		Uiseong	32.60±2.42	20.00±3.51	4	3.48	**0.025**
		Cheongsong	53.40±8.19	27.40±3.44	4	4.45	**0.011**
	Formicidae	Danyang	181.00±22.00	65.00±13.24	4	4.09	**0.015**
		Muju	393.00±36.57	98.00±23.77	4	4.93	**0.008**
		Uiseong	346.00±40.22	123.60±26.96	4	3.58	**0.023**
		Cheongsong	97.60±9.35	31.00±1.97	4	7.52	**0.002**

[a]OF, organic farming; CF, conventional farming

Among the dominant families, six species, *Oppiella nova* (Oudemans, 1902) (Oppiidae), *Homidia mediaseta* Lee and Lee, 1981 (Entomobryidae), *Anisodactylus punctatipennis* Gebier, 1833 (Carabidae), *Aleochara curtula* (Goeze, 1777) (Staphylinidae), *Nylanderia flavipes* (Smith, 1874) (Formicidae), and Diapriidae sp. 1 (Diapriidae), dominated the arthropod community in apple orchards. Three dominant species, *A. curtula* (t [19] = 13.31, $P < 0.001$), *N. flavipes* (t [19] = 2.78, $P < 0.05$), and Diapriidae sp. 1 (t [19] = 3.80, $P < 0.01$) showed statistical differences between organic and conventional orchards (Figs. 22-23).

1.3. Comparison of seasonal fluctuation of dominant orders, families, and species

Seasonal fluctuations of six dominant orders showed serrated curves with one or two peaks, as shown in Fig. 24. Acari appeared with one peak in the 4th week of August in organic orchards and two peaks in the 4th week of July and the 2nd week of September in conventional orchards. Collembola appeared with two peaks in the 4th week of July and the 2nd week of September in organic orchards and one peak in the 4th week of August in conventional orchards.

Coleoptera appeared with one peak in the 4th week of August in organic orchards, but the abundance was low in conventional orchards so that no clear trend could be identified during the entire period of the survey (Fig. 24-25). Diptera appeared with two peaks in the 2nd week of July and 4th week of September in organic orchards and two peaks in the 4th week of July and the 4th week of August in conventional orchards. Hemiptera appeared with one peak in the 4th week of April in organic orchards and one peak in the 4th week of June in conventional orchards. Finally, Hymenoptera appeared with two peaks in the 4th week of July and the 4th week of September in organic orchards and one peak in the 4th week of July in conventional orchards (Fig. 24-26).

Overall, toward the latter half of the survey, the occurrence of Acari, Collembola, Coleoptera, and Diptera was increasing while Hemiptera and Hymenoptera decreased regardless of the farming system.

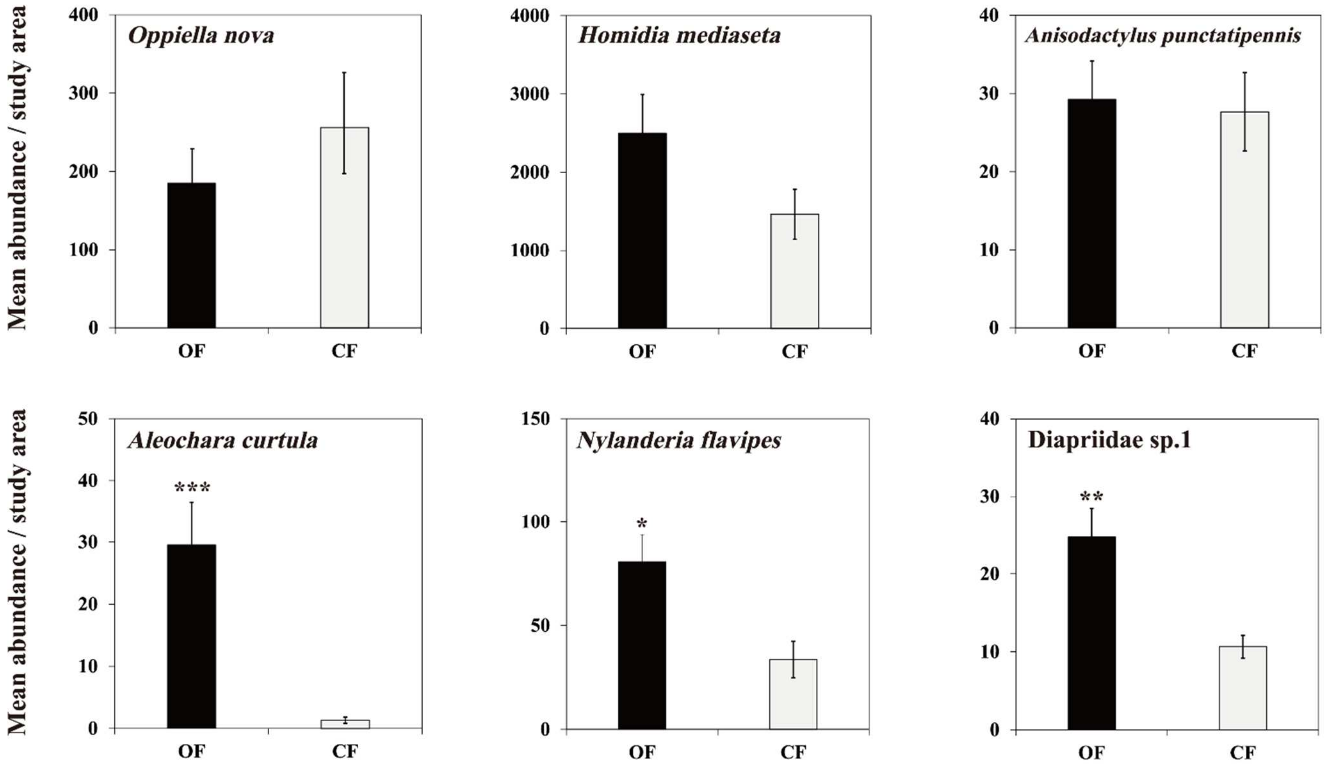

Fig. 22. Comparison of the average abundance (mean±SE) of dominant species in apple orchards (OF, organic farming; CF, conventional farming) (Paired *t*-test, * $0.01 < P < 0.05$, ** $0.001 < P < 0.01$, *** $P < 0.001$).

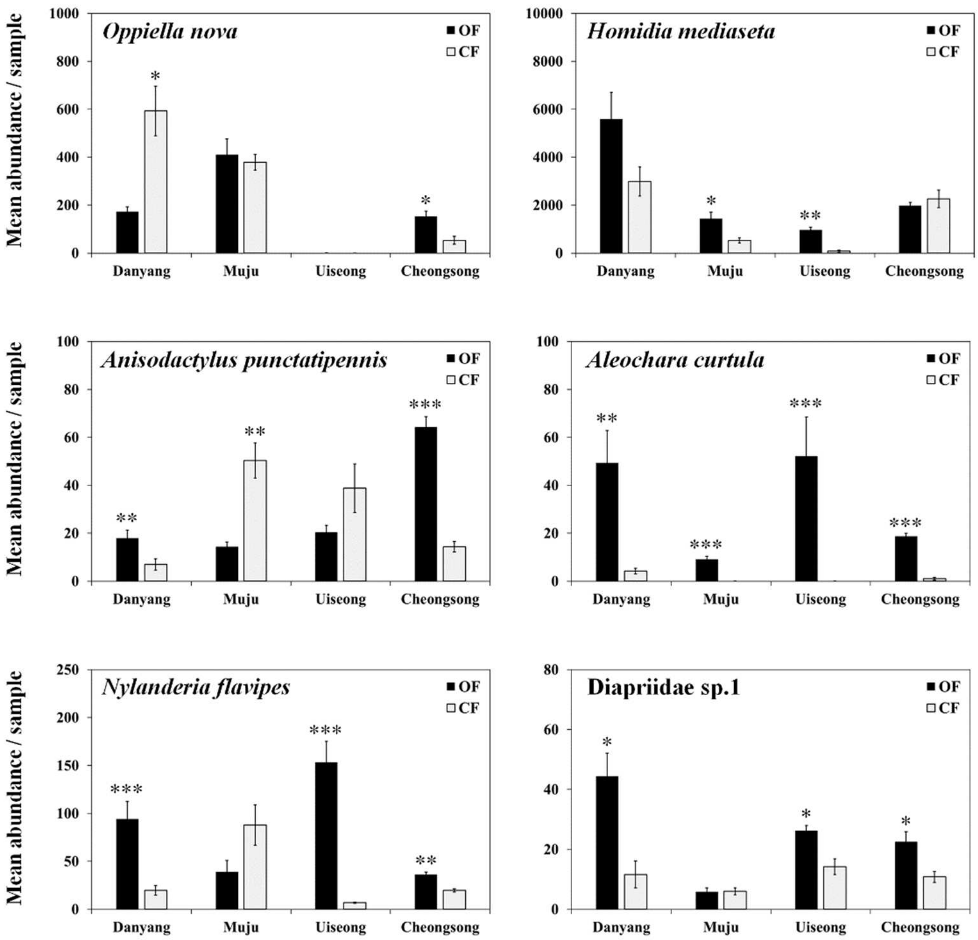

Fig. 23. Comparison of the abundance (mean±SE) of dominant species in apple orchards (OF, organic farming; CF, conventional farming) (Paired *t*-test, * 0.01 < *P* < 0.05, ** 0.001 < *P* < 0.01, *** *P* < 0.001).

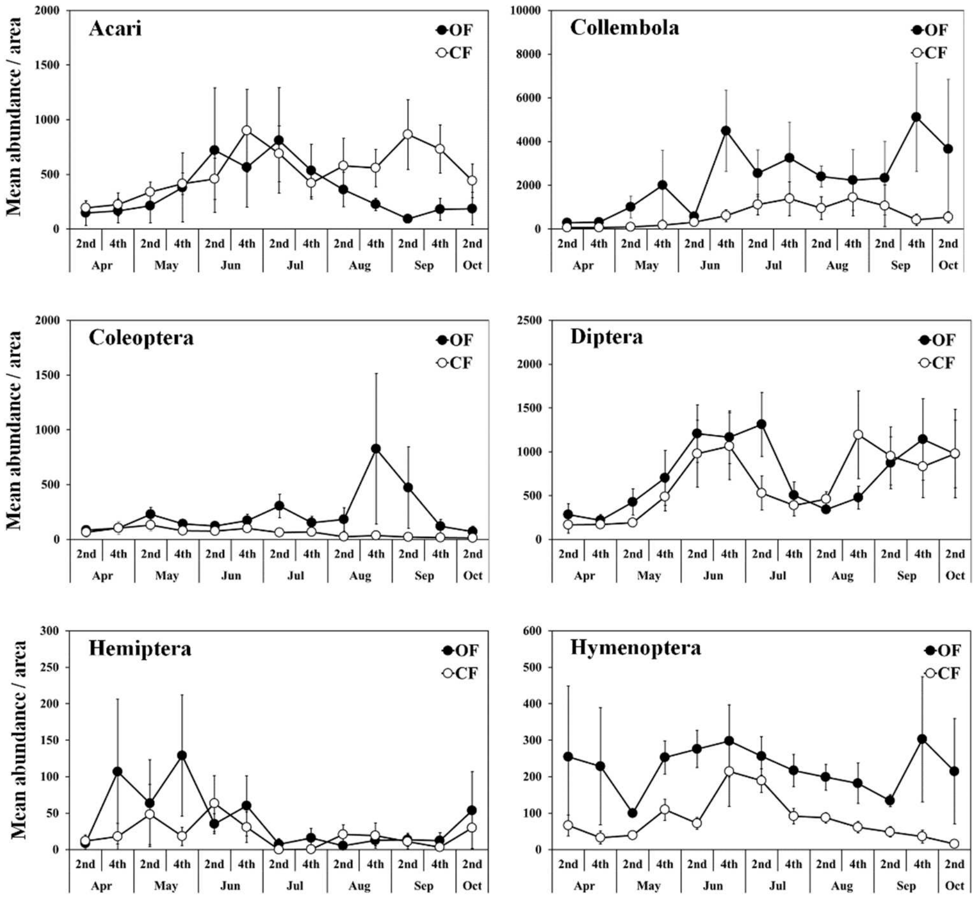

Fig. 24. Comparison of the average seasonality of dominant orders in apple orchards (DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong).

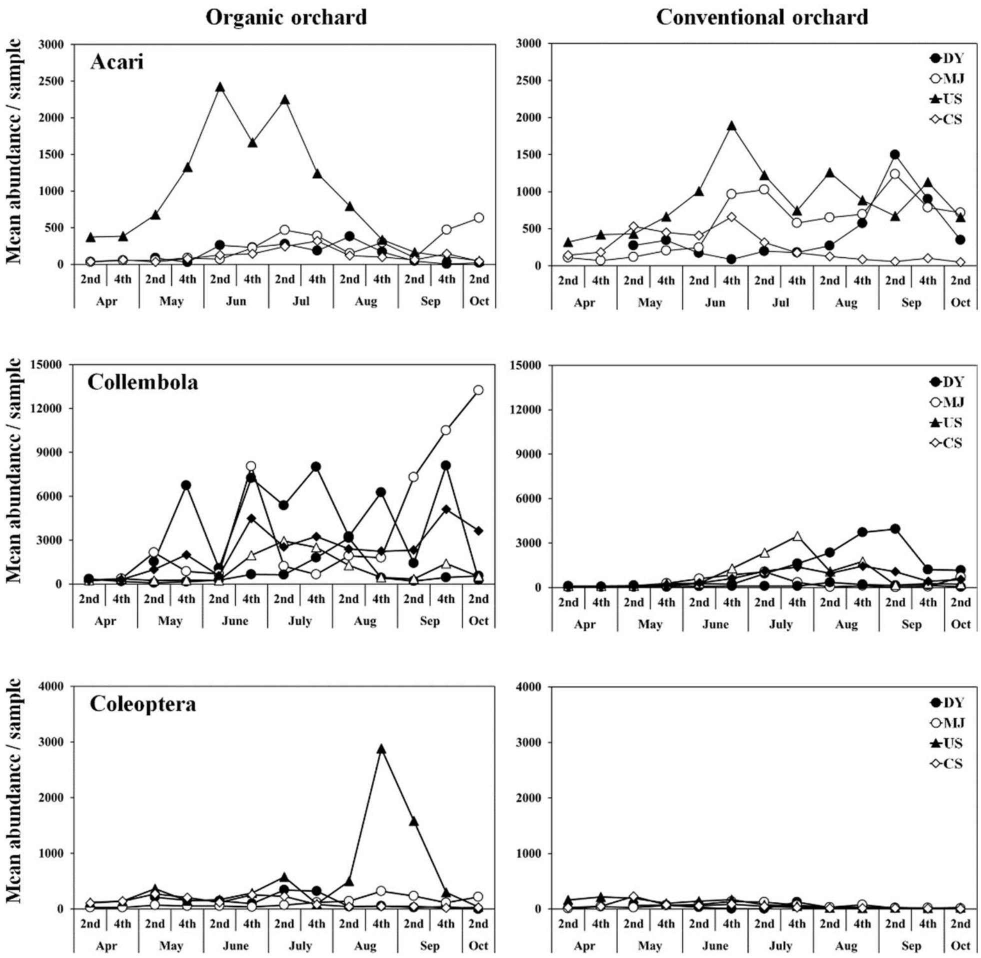

Fig. 25. Seasonality of dominant orders (Acari, Collembola, and Coleoptera) arthropod in apple orchards (DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong).

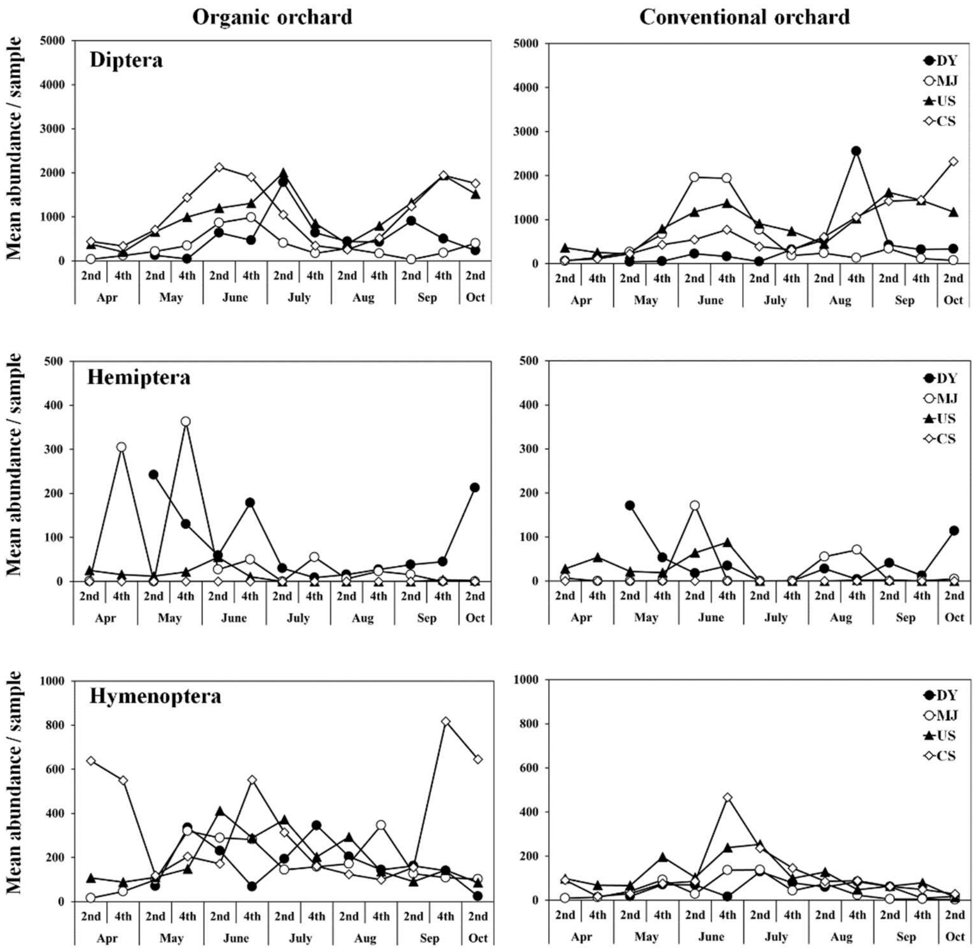

Fig. 26. Seasonality of dominant orders (Diptera, Hemiptera, and Hymenoptera) arthropod in apple orchards (DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong).

The seasonal fluctuations of three dominant species, *A. curtula*, *N. flavipes*, and Diapriidae sp. 1, which had statistically significant differences between farming methods in the apple orchard, are shown in Fig. 27. In organic orchards, *A. curtula* appeared with three peaks in the 2nd week of June, 2nd week of July, and 4th week of August, but the abundance was low in conventional orchards so that no clear trend could be identified during the entire process period of the survey.

In organic and conventional orchards, *N. flavipes* appeared with one peak in the 2nd week of July. Diapriidae sp. 1 appeared with two peaks in the 2nd week of July and the 2nd week of August in organic orchards, but the abundance was low in conventional orchards so that no clear trend could be identified during the entire period of the survey (Fig. 27). In general, the occurrence of these three species showed little change with a slightly decreasing trend during the survey period (Fig. 28).

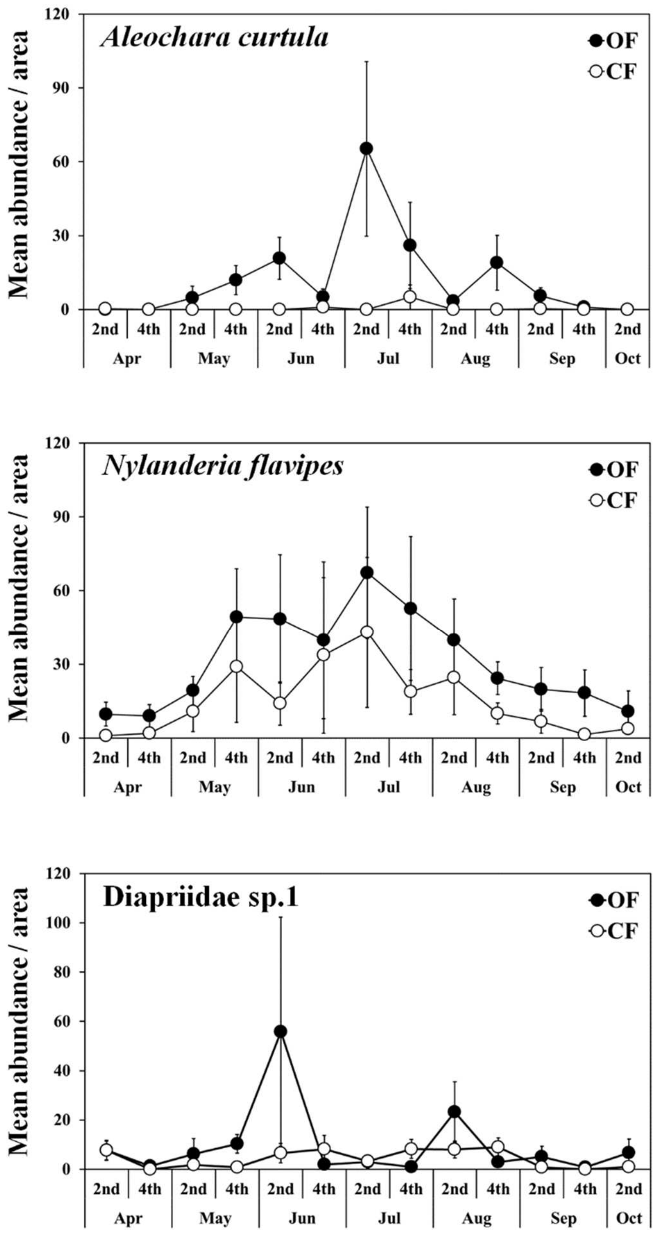

Fig. 27. Comparison of the average seasonality of dominant species in apple orchards (DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong).

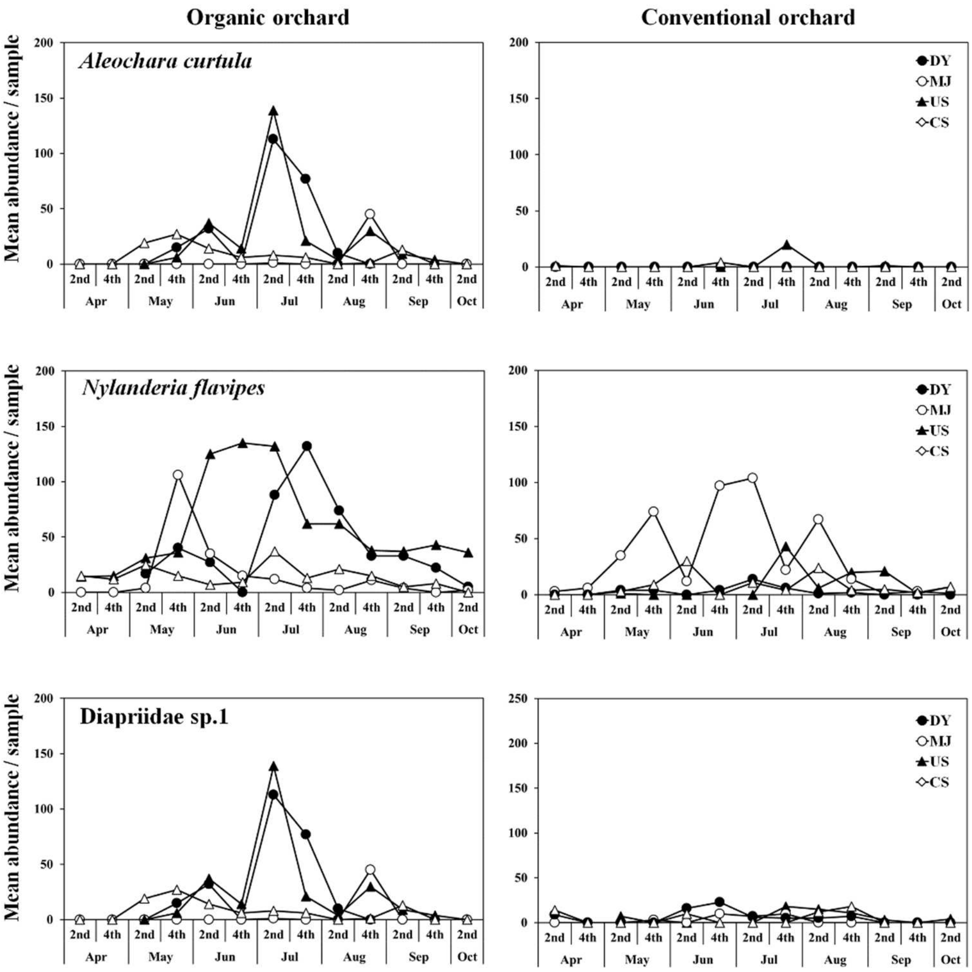

Fig. 28. Seasonality of dominant species in apple orchards by study area (DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong).

1.4. Comparison of community structure

As a result of comparing the similarity of the community structure between study areas based on the species richness and abundance of arthropods (Acari, Collembola, and Insecta), the arthropod community structure between the study areas were found to be similar at the level of 48.76% and divided into two regions Uiseong and Cheongsong areas, and Danyang and Muju areas, but no statistical significance was found (SIMPROF test, P = 0.085) (Fig. 29).

From the result of Bray-Curtis similarity analysis, the similarity of the arthropod community structure between Danyang and Muju areas showed a statistically different similarity by farming systems at 62.97% level (SIMPROF test, P = 0.001) (Fig. 30). However, there was no difference between organic and conventional orchards in the other two areas. The result of NMDS analysis, the arthropod community structure varies depending on the study area and the farming system, but it was not differentiated by farming method (Fig. 31).

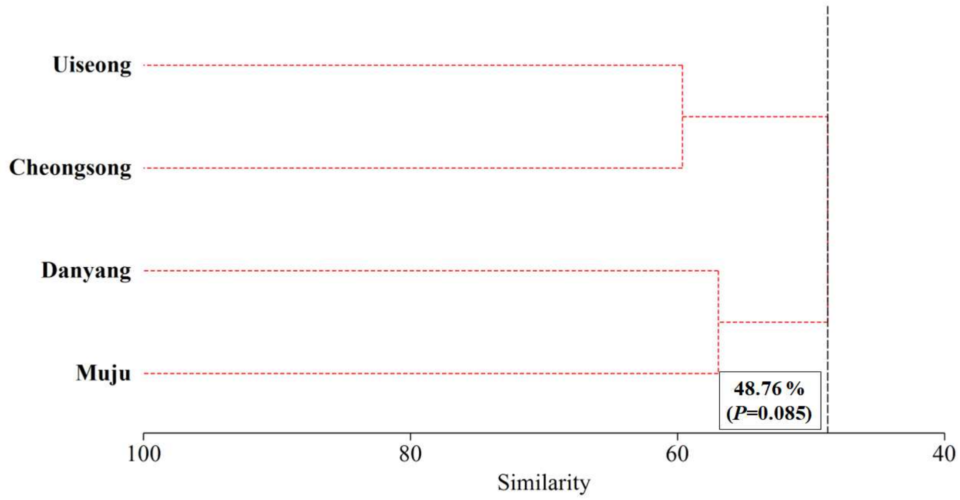

Fig. 29. Cluster analysis based on Bray-Curtis similarity index of arthropod community in study areas (Broken lines indicate the same group by SIMPROF test).

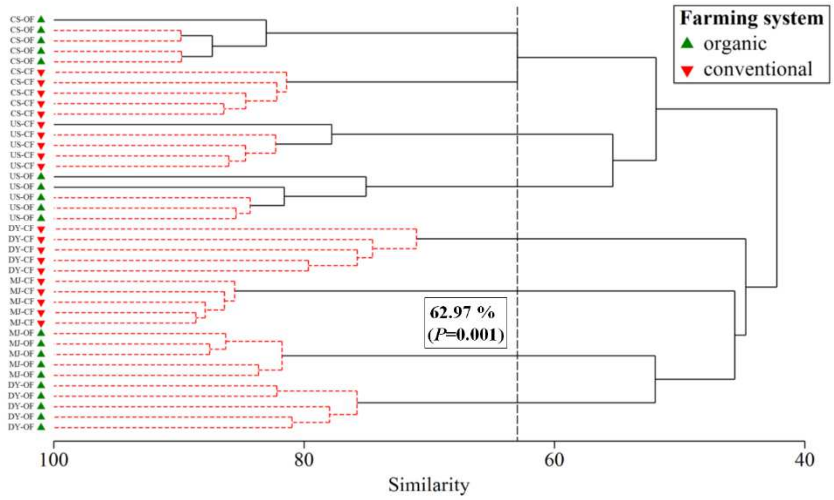

Fig. 30. Cluster analysis based on Bray-Curtis similarity index of arthropod community from organic and conventional orchards within study (Broken lines indicate the same group by SIMP□OF test; Each point represents a sampling trap in an individual orchard sampled).

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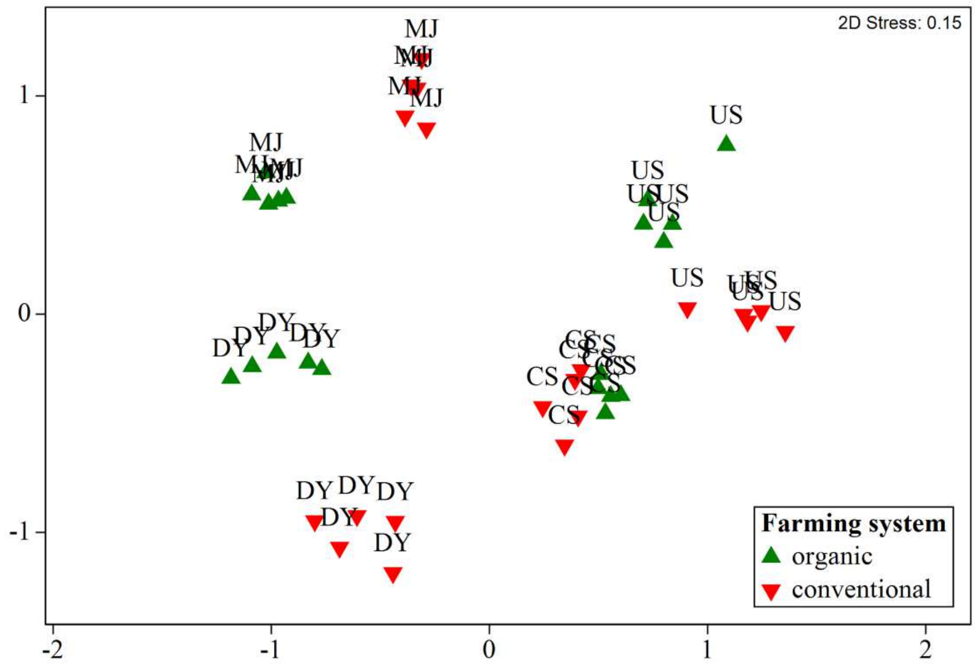


Fig. 31. Non-metric multi-dimensional scaling (NMDS) plot of the similarities in arthropod community by the farming system in apple orchards (Broken lines indicate the same group by SIMP□OF test; Each point represents a sampling trap in an individual orchard sampled).

2. Spider communities

2.1. Comparison of relative richness and abundance

A total of 4,663 spiders were collected during the survey and identified as 94 species in 70 genera belonging to 21 families (Table 11). Most of the collected spiders were ground dwellers, and only three individuals of spiders were collected from the above-ground throughout the study period. Of the 94 spider species collected, 60 species were represented by <10 individuals. These species represented 63.2% of the species richness and 2.7% of the abundance (*Appendix* 4).

The species constituting the spider community were somewhat different depending on the study area. Regionally, the species richness of the spiders was the lowest in Danyang area with 39 species and the highest in Muju area with 53 species. According to the farming system, 72 species were identified in organic orchards, and 65 species were identified in conventional orchards, suggesting that species richness in organic orchards was higher than in conventional orchards. Species richness in organic orchards was high in Uiseong areas. In conventional orchards, Uiseong areas were high, and Cheongsong area was low. By farming system, the collected spiders in organic orchards were 3,194 individuals, significantly higher than 1,469 individuals in conventional orchards. The abundance of organic orchards was high in Uiseong area but low in Danyang area. In conventional orchards, Uiseong area was high, and Cheongsong area was low (Table 12-13).

Table 11. Summary of the spider community in the apple orchard in study areas

Study area	Farming system[a]	Community structure		
		No. of families	No. of species	No. of individuals
Danyang	OF	13	35	533
	CF	13	22	286
	Total	**15**	**39**	**819**
Muju	OF	14	35	757
	CF	15	34	248
	Total	**17**	**53**	**1,005**
Uiseong	OF	15	36	1,177
	CF	16	27	652
	Total	**18**	**45**	**1,829**
Cheongsong	OF	16	35	727
	CF	14	28	283
	Total	**19**	**46**	**1,010**
Total	OF	21	72	3,194
	CF	21	65	1,469
	Total	**21**	**94**	**4,663**

[a]OF, organic farming; CF, conventional farming

Five families (Thomisidae, Lycosidae, Linyphiidae, Gnaphosidae, and Nesticidae) were dominant in relative species richness and abundance regardless of the study area or farming system, representing 50.5% and 85.8% of the total, respectively. The species richness of these five families was 55.8% and 89.8% in organic and conventional orchards, respectively, and that abundance was 60.6% and 77.9% in organic and conventional orchards, respectively. As a result of analyzing the relative species richness and abundance of these five families, there was no statistical difference between organic and conventional orchards, except for Lycosidae in relative species richness (Table 12-13, Fig. 32-33).

Table 12. Comparison of relative species richness of spiders in apple orchards

Farming system[a]	OF	CF	Paired *t*-test		
Families	(mean ± SE)	(mean ± SE)	*df*	*t*	*P*
Lycosidae	19.12±3.42	16.04±1.60	3	3.38	**0.043**
Linyphiidae	17.87±5.63	12.89±7.30	3	1.15	0.333
Gnaphosidae	10.37±6.12	11.03±2.93	3	0.31	0.773
Thomisidae	8.82±0.84	7.59±2.94	3	0.71	0.530
Nesticidae	2.73±0.18	4.30±1.79	3	1.74	0.181

[a]OF, organic farming; CF, conventional farming

Table 13. Comparison of relative abundance of spiders in apple orchards

Farming system[a]	OF	CF	Paired *t*-test		
Orders	(mean±SE)	(mean±SE)	*df*	*t*	*P*
Lycosidae	40.24±18.20	53.10±26.44	19	0.73	0.517
Linyphiidae	42.44±30.65	11.88±6.87	19	1.72	0.184
Gnaphosidae	2.66±3.28	8.01±9.18	19	1.83	0.164
Thomisidae	2.50±2.14	3.04±2.49	19	0.21	0.848
Nesticidae	2.29±2.55	3.53±4.14	19	0.45	0.684

[a]OF, organic farming; CF, conventional farming

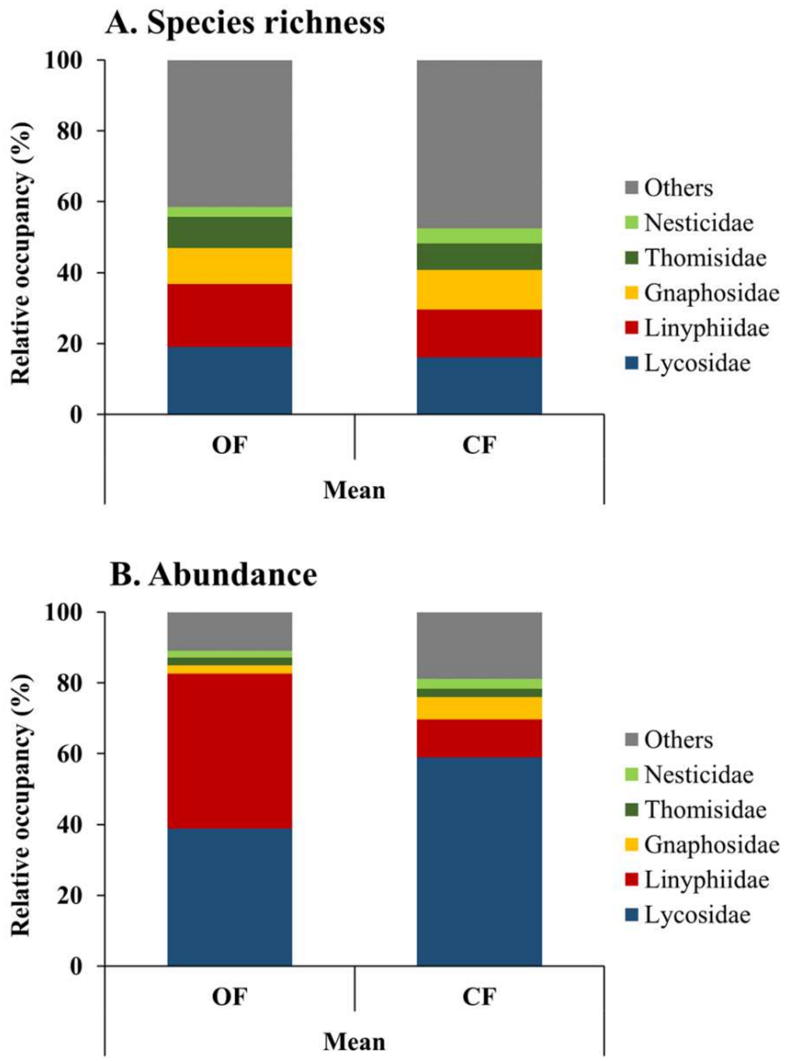


Fig. 32. The average relative species richness and abundance of dominant spider families in the apple orchards (OF, organic farming; CF, conventional farming).

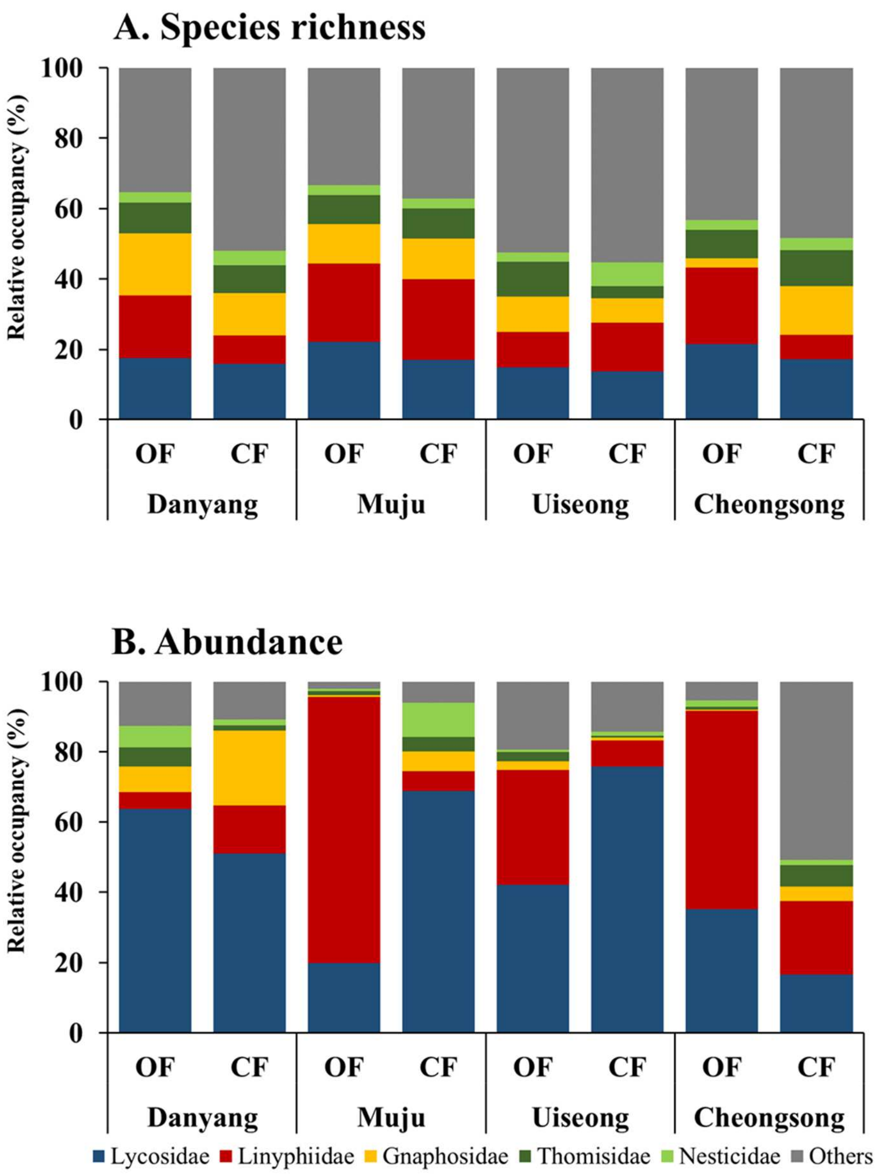


Fig. 33. The relative species richness and abundance of dominant spider families sampled from apple orchards by study areas (OF, organic farming; CF, conventional farming).

2.2. Comparison of dominant orders, families, and species

Among them, the abundance of Linyphiidae and Lycosidae was remarkable, accounting for 77.8% of the total. Linyphiidae accounted for 43.5% and 10.6% in organic and conventional orchards, respectively, and there was a statistically significant difference (Paired *t*-test; t [19] = 5.88, $P < 0.001$). Lycosidae accounted for 38.7% and 57.7% in organic and conventional orchards, respectively. There was a statistical difference between the farming systems (Paired *t*-test; t [19] = 2.64, $P < 0.05$) (*Appendix* 1, Fig. 34). Linyphiidae showed statistically high abundance in organic orchards in all study areas except Danyang, but Lycosidae did not show a distinct tendency between the farming systems (Fig. 35).

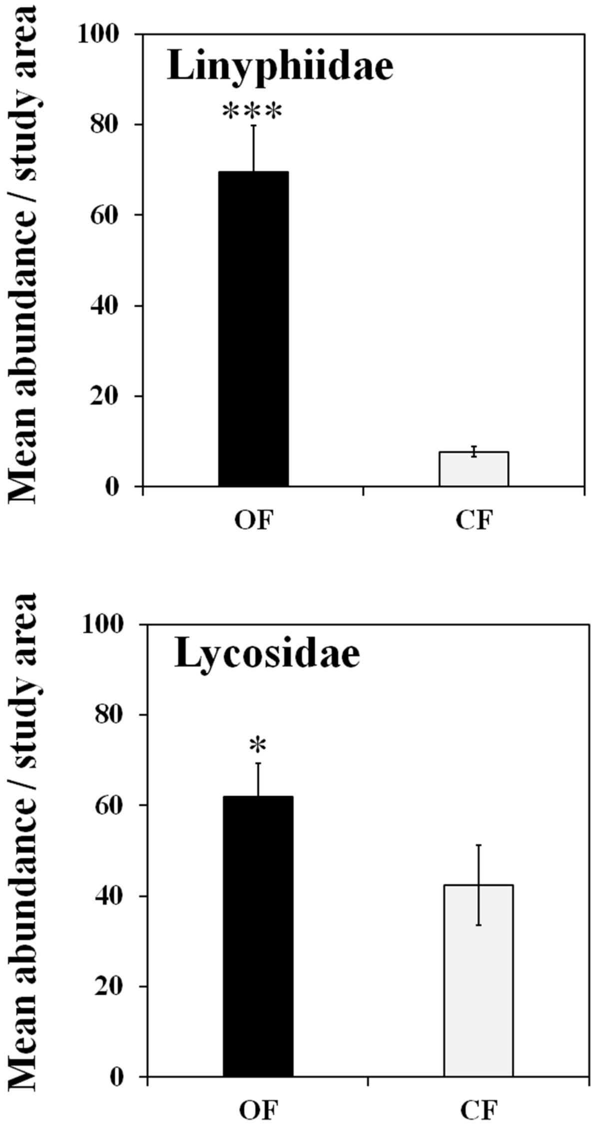


Fig. 34. Comparison of the average abundance (mean±SE) of dominant spider families in apple orchards (OF, organic farming; CF, conventional farming) (Paired *t*-test, * 0.01 < P < 0.05, ** 0.001 < P < 0.01, *** P < 0.001).

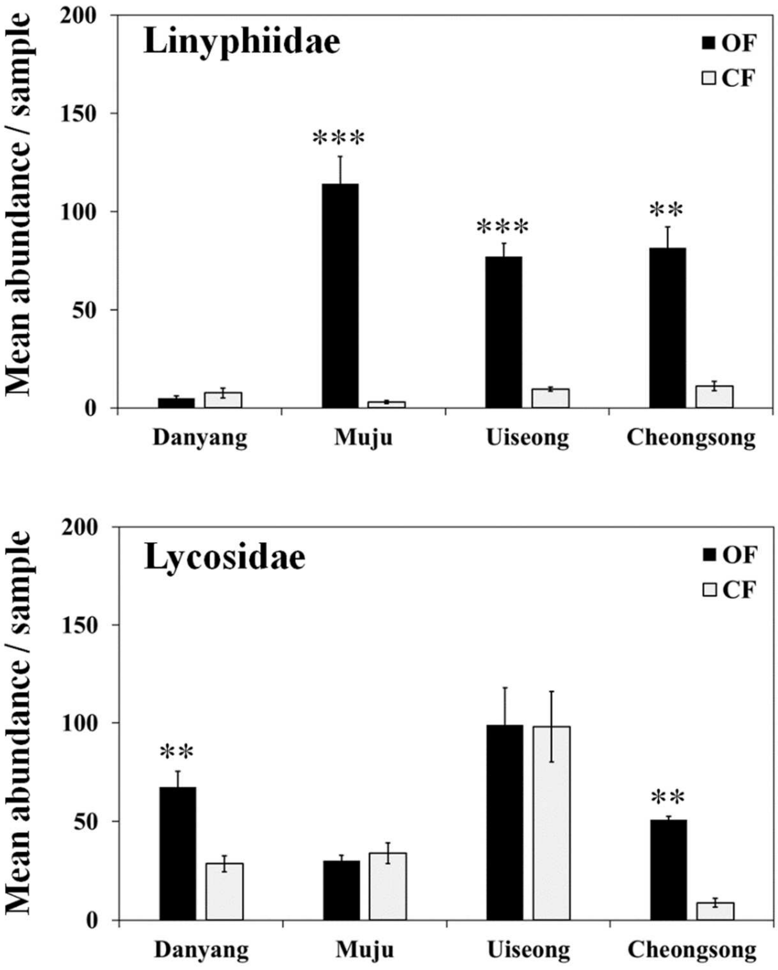


Fig. 35. Comparison of the abundance (mean±SE) of dominant spider families in apple orchards by study areas (OF, organic farming; CF, conventional farming) (Paired *t*-test, * 0.01 < P < 0.05, ** 0.001 < P < 0.01, *** P < 0.001).

Six species belonging to Linyphiidae and Lycosidae dominated the spider community in apple orchards. The six dominant spider species, ranging from 2.8 to 20.3% of the total abundance, were *Collinsia inerrans* (O. Pickard-Cambridge, 1885) and *Erigone prominens* (Bösenberg and Strand, 1906) in Linyphiidae, *Pardosa astrigera* L. Koch, 1878, *Pardosa laura* Karsch, 1879, *Piratula procurvus* (Bösenberg and Strand, 1906), and *Trochosa ruricola* (De Geer, 1778) in Lycosidae. The most abundant species was *Pi. procurvus* (20.3% of the total individuals), followed by *E. prominens* (13.2% of the total individuals). By farming, the abundance of *E. prominens* (19.1% of the total number of individuals) was the highest in organic orchards, followed by *Pi. procurvus* (17.4% of the total number of individuals) and that of *Pi. procurvus* (26.6% of the total number of individuals) was the highest in conventional orchards, followed by *T. ruricola* (2.5% of the total number of individuals) (*Appendix* 1). The two dominant species of the Linyphiidae, *C. inerrans,* were no statistically different between organic and conventional orchards (t [19] = 1.88, P = 0.077), while *E. prominens* were statistically different (t [19] = 5.22, P < 0.001) (Fig. 36). *E. prominens* showed statistically high abundance in organic orchards in all study areas except Uiseong (Fig. 37). The four dominant species the Lycosidae, *P. astrigera, P. laura, Pi.procurvus, and T. ruricola,* were statistically different in both farming systems (t [19] = 4.78, P < 0.001; t [19] = 4.40, P < 0.001; t [19] = 3.78, P < 0.01; t [19] = 5.00, P < 0.001, respectively) (Fig. 38). In all organic orchards in the study area, these four dominant species of Lycosidae also showed a higher abundance than in conventional orchards (Fig. 39).

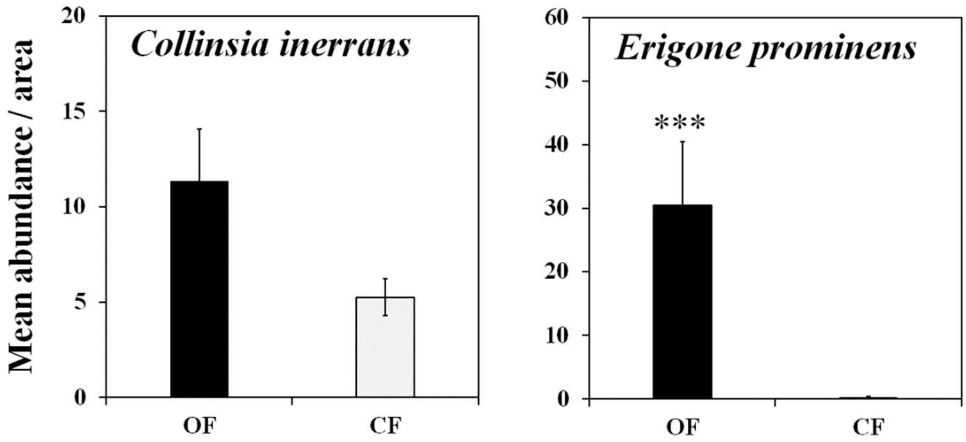


Fig. 36. Comparison of the abundance (mean±SE) of dominant species belonging to Linyphiidae in apple orchards (OF, organic farming; CF, conventional farming) (Paired *t*-test, * 0.01 < P < 0.05, ** 0.001 < P < 0.01, *** P < 0.001).

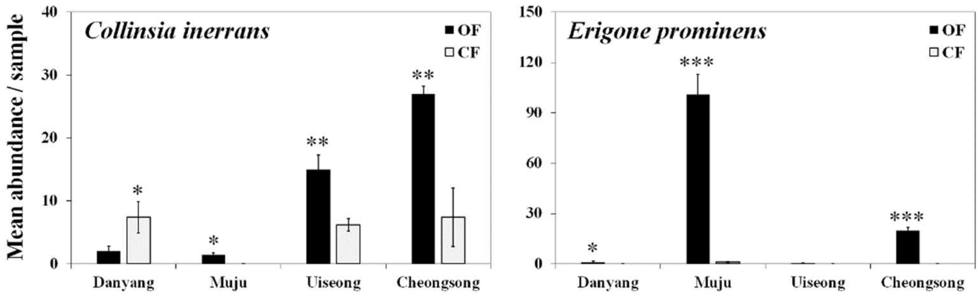


Fig. 37. Comparison of the abundance (mean±SE) of dominant species belonging to Lycosidae in apple orchards (OF, organic farming; CF, conventional farming) (Paired t-test, * $0.01 < P < 0.05$, ** $0.001 < P < 0.01$, *** $P < 0.001$).

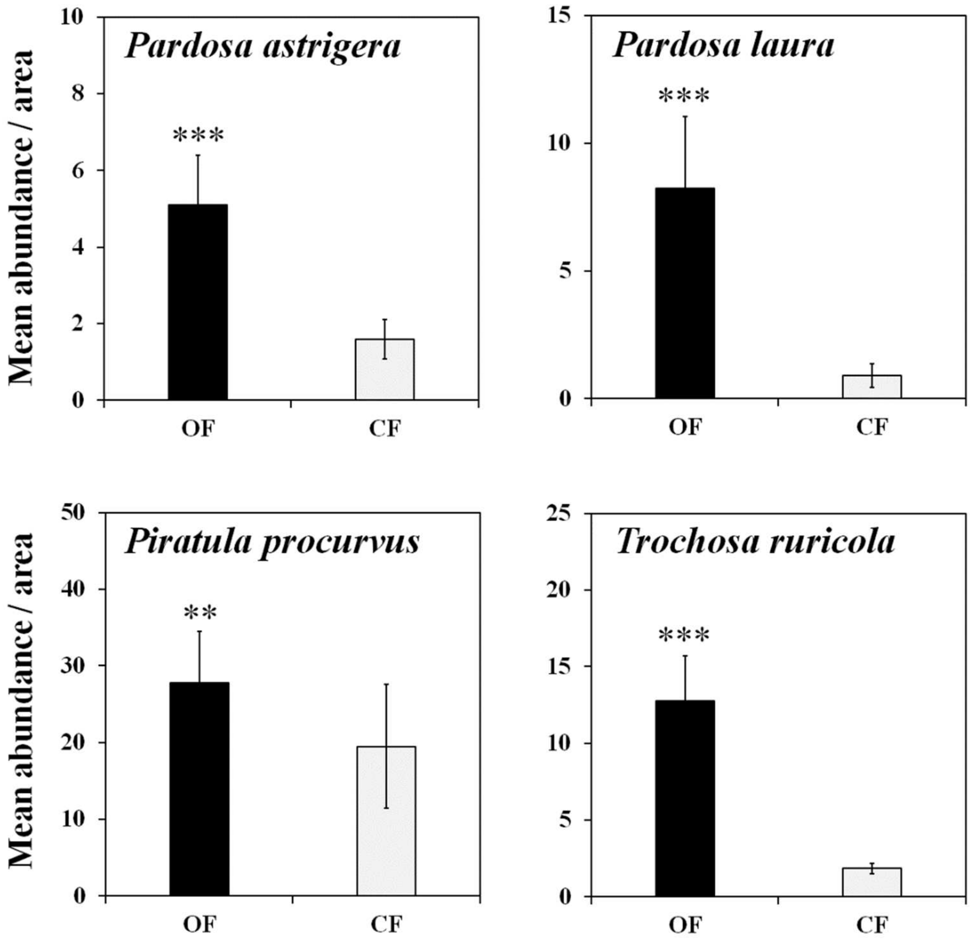


Fig. 38. Comparison of the abundance (mean±SE) of dominant species belonging to Lycosidae in apple orchards (OF, organic farming; CF, conventional farming) (Paired *t*-test, *0.01 < P < 0.05, ** 0.001 < P < 0.01, *** P < 0.001).

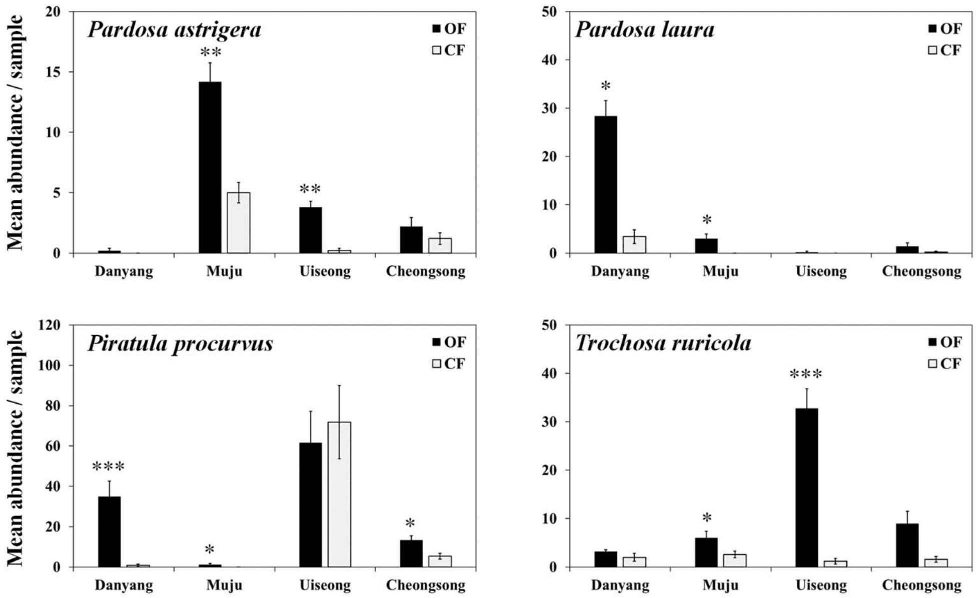


Fig. 39. Comparison of the abundance (mean±SE) of dominant species belonging to Lycosidae in apple orchards by study areas (OF, organic farming; CF, conventional farming) (Paired *t*-test, * $0.01 < P < 0.05$, ** $0.001 < P < 0.01$, *** $P < 0.001$).

2.4. Comparison of seasonal fluctuation of dominant orders, families, and species

The seasonal fluctuations of dominant families, Linyphiidae and Lycosidae, were observed in organic and conventional orchards. The occurrence peak of Linyphiidae appeared in the 2nd week of July in organic and conventional orchards. In organic orchards, abundance slightly decreased toward the latter half of the survey but increased somewhat in conventional orchards. The occurrence peak of Lycosidae appeared in the 4th week of June and 2nd week of July in organic orchards and the 2nd week of July in conventional orchards. Abundance slightly decreased toward the latter half of the survey in organic and conventional orchards (Fig. 40-41).

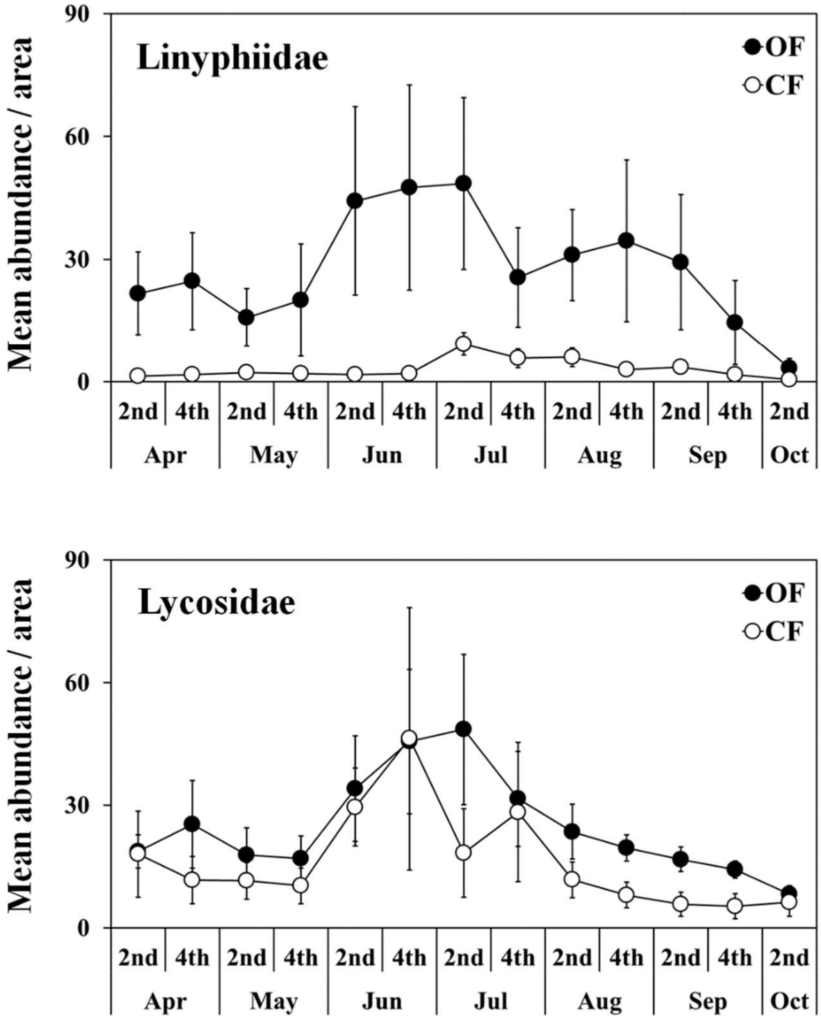


Fig. 40. Comparison of the average seasonality of dominant families in organic and conventional apple orchards (DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong).

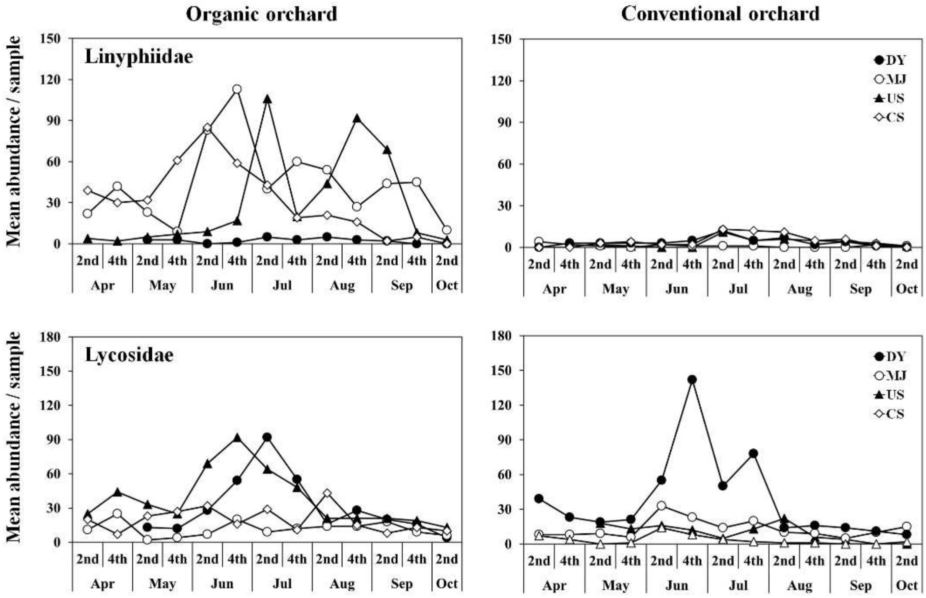


Fig. 41. Seasonality of dominant families in organic and conventional apple orchards by study area (DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong).

C. inerrans appeared with two peaks in the 2nd week of July and 4th week of August in organic and conventional orchards. *E. prominens* appeared with one peak in organic orchards in the 4th week of June, while conventional orchards did not show a clear trend due to low abundance (Fig. 42). The abundance patterns of *C. inerrans* and *E. prominens* by study area were different, but the abundance was higher in the same region than in conventional organic farming. Although the abundance of *C. inerrans* and *E. prominens* by study area differed, the abundance of two species in organic orchards was higher than in conventional ones (Fig. 43).

P. astrigera belonging to Lycosidae appeared with four peaks in the 4th week of April, 4th week of June, 4th week of July, and 2nd week of September in organic orchards. On the other hand, conventional orchards had no peak due to a continuous decrease from the 2nd week of April (Fig. 44). *P. lauta* belonging to lycosidae appeared with one peak in organic orchards in the 4th week of June but no in conventional ones (Fig. 44). *Pi. procurvus* showed similar patterns in organic and conventional farming, and the abundance peaks were surveyed in 2nd week of July, and 2nd week of June, respectively (Fig. 45). *T. ruricola* appeared with two peaks in the 2nd week of May and 2nd week of August, but in conventional orchards, a clear trend could not be identified (Fig 45). Although the pattern of abundance occurrence was different for each region, all four dominants in Lycosidae showed high abundance in organic apple sources except for *Pi. procurvus* in Uiseong (Fig. 46).

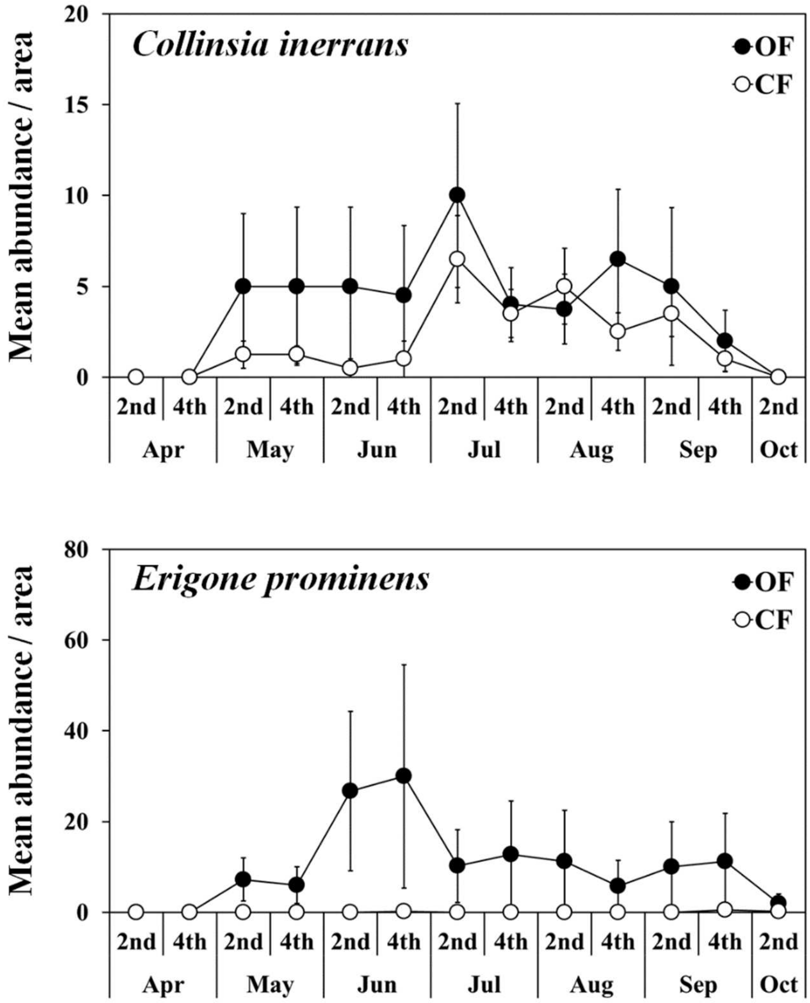


Fig. 42. Comparison of the average seasonality of dominant species belonging to Linyphiidae in organic and conventional apple orchards (DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong).

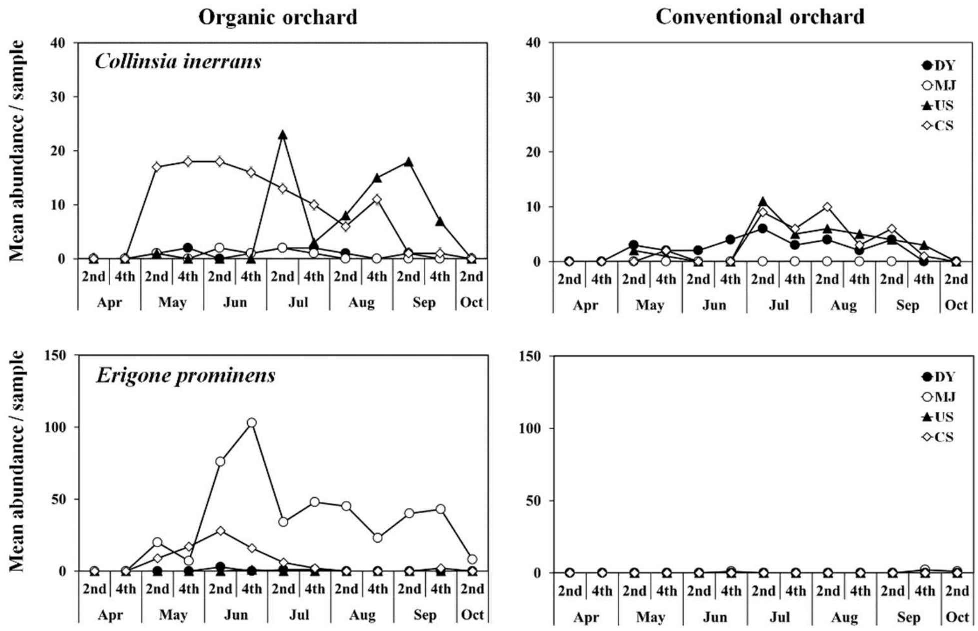
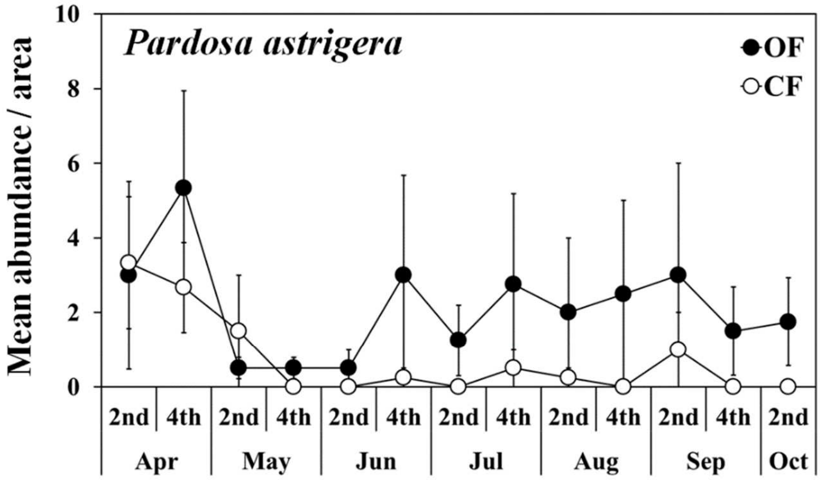


Fig. 43. Seasonality of dominant species belonging to Linyphiidae in organic and conventional apple orchards (DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong).



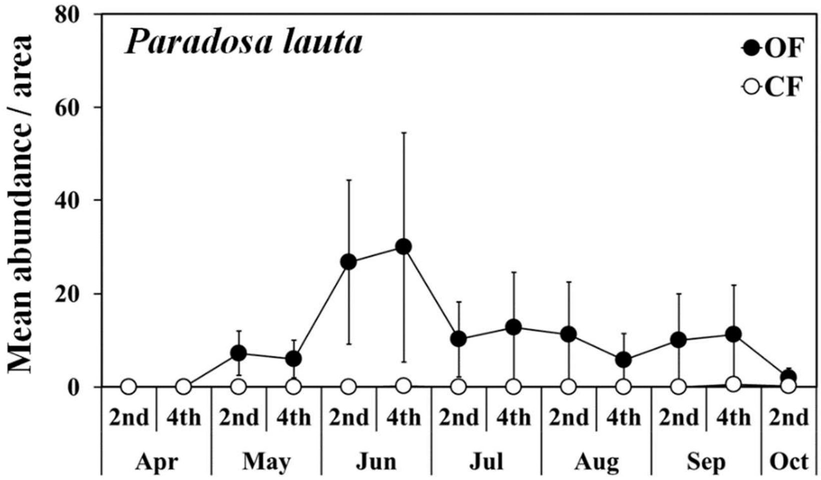


Fig. 44. Comparison of the average seasonality of dominant species belonging to Lycosidae in organic and conventional apple orchards (DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong).

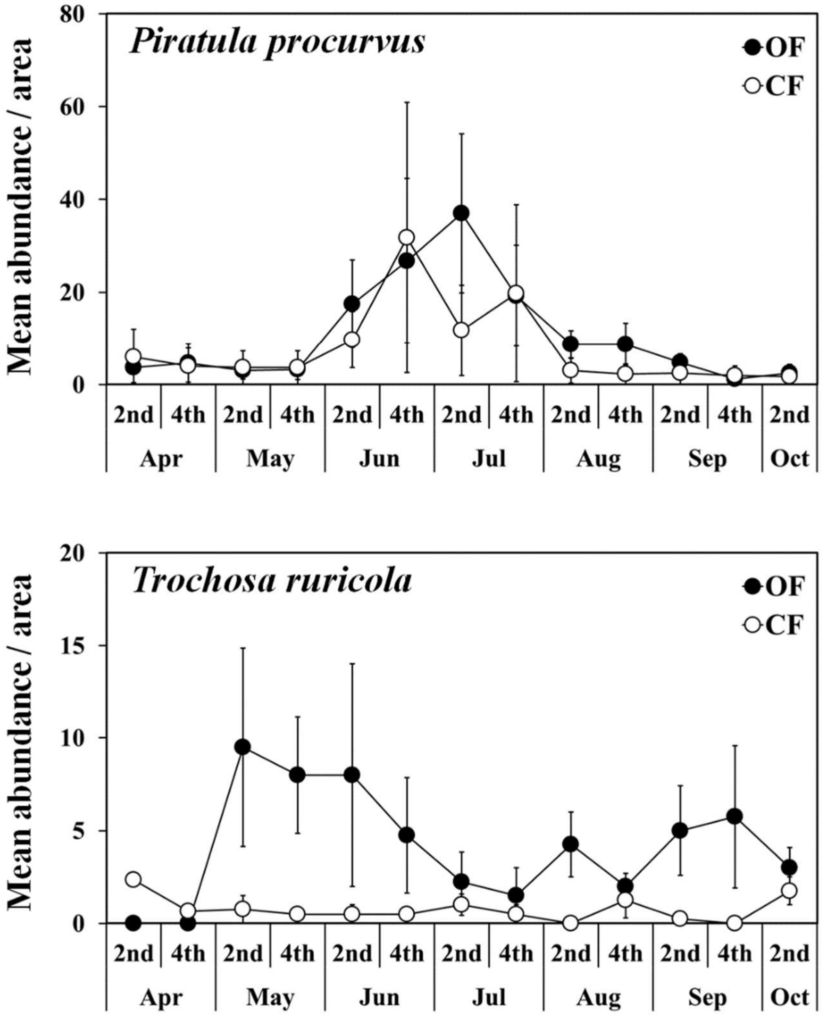


Fig. 45. Comparison of the average seasonality of dominant species belonging to Lycosidae in organic and conventional apple orchards (DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong).

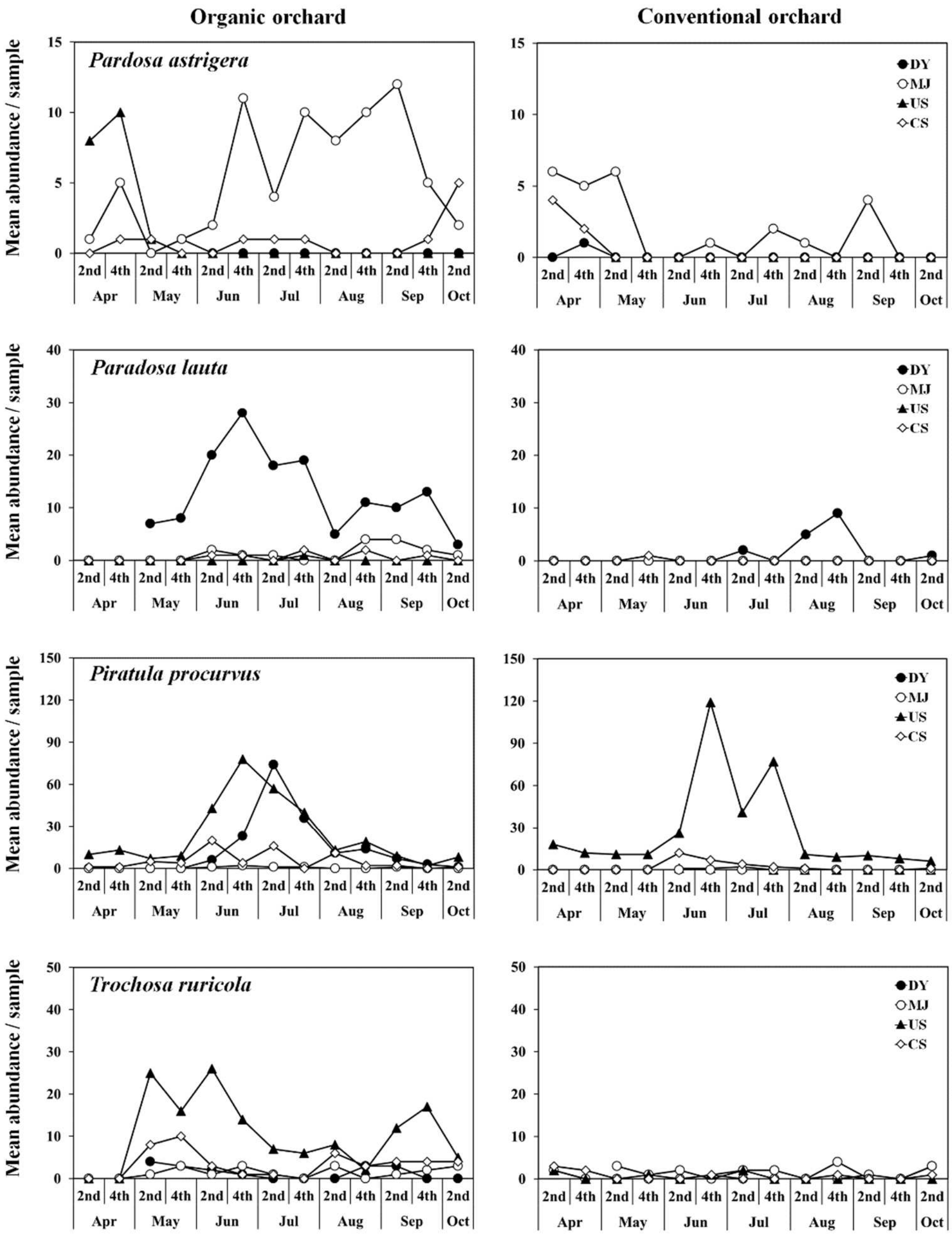


Fig. 46. Seasonality of dominant species belonging to Lycosidae in organic and conventional apple orchards (DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong).

2.4. Comparison of community structure

The results of similarity analysis based on the number of species and individuals to confirm the difference in the spider community structure between the study areas showed that the Danyang, Uiseong, and Cheongsong areas were statistically similar, showing similarity of 36.78% (SIMPROF test, P = 0.001), and Muju area showed structural heterogeneity. Uiseong and Cheongsong areas showed a high similarity of 55.78%, and these two areas and Danyang area showed a high similarity of 50.78% (SIMPROF test, P = 0.764) (Fig. 47).

Analyzing the spider community structure difference between organic and conventional orchards by study areas confirmed a statistical difference among the eight groups in the similarity of 46.23% (SIMPROF test, P = 0.001). At 33.53% similarity, it was divided into two organic farming groups and two conventional farming groups. It was also statistically significant (SIMPROF test, P = 0.001) (Fig. 48). The results of NMDS analysis using the similarity matrix data of spider communities according to regional farming systems showed no statistical difference. However, it was found that the spider community structure was generally affected by farming systems (Fig. 49).

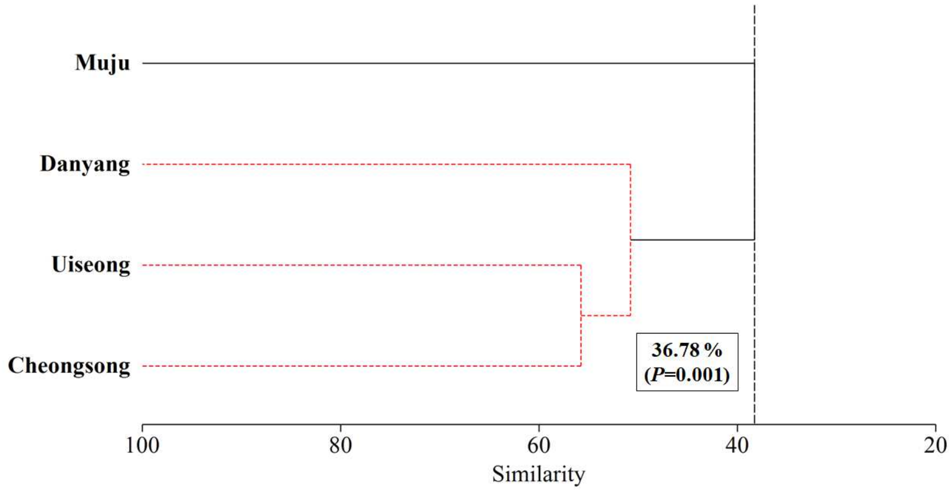


Fig. 47. Cluster analysis based on Bray-Curtis similarity index of spider community in study areas (Broken lines indicate the same group by SIMPROF test).

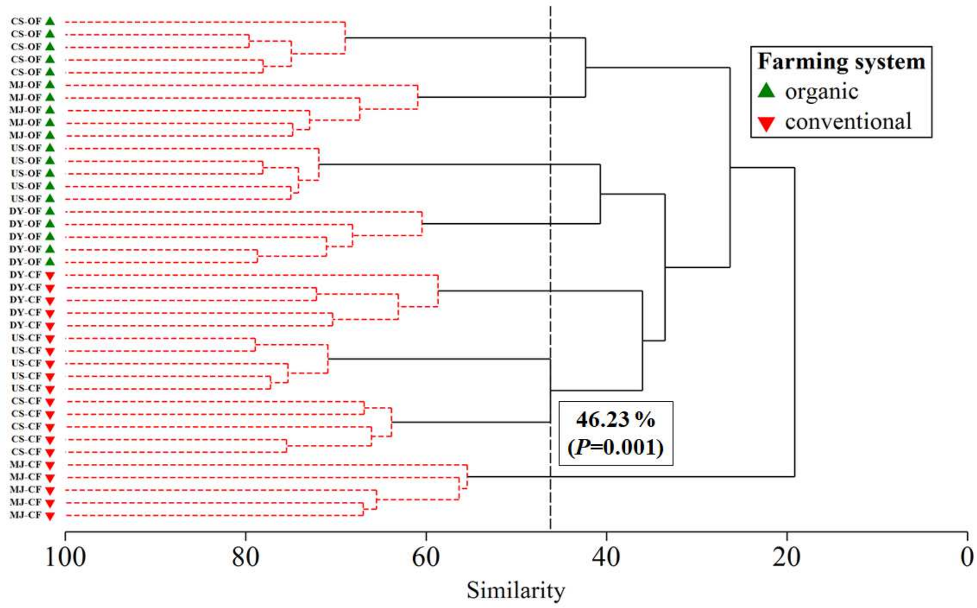


Fig. 48. Cluster analysis based on Bray-Curtis similarity index of spider community from organic and conventional apple orchards within study areas (Broken lines indicate the same group by SIMP□OF test; Each point represents a sampling trap in an individual orchard sampled).

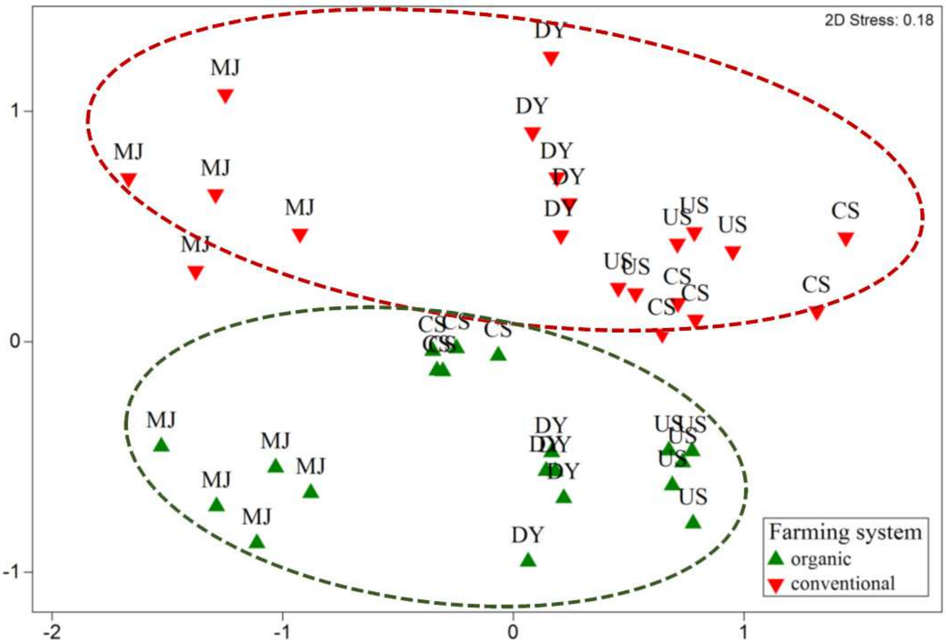


Fig. 49. Non-metric multi-dimensional scaling (NMDS) plot of the similarities in spider community by the farming system in apple orchards (Broken lines indicate the same group by SIMP□OF test; Each point represents a sampling trap in an individual orchard sampled).

3. The main arthropod species in Korean apple orchard

Regardless of the farming system, the arthropod communities surveyed in four areas were identified as 349 species in 103 families belonging to 13 orders. (Table 14). Of all arthropods collected, only 63 species were identified from all study areas (*Appendix* 3-4). Among them, 54 and 36 species were commonly sampled from all organic and conventional orchards in four areas. In addition, 27 arthropod species sampled from both farming systems in all areas were defined as the main arthropods adapted to the Korean apple orchards (Table 15). Since the 54 arthropods surveyed in all organic apple orchards were collected from at least one of the four conventional apple orchards, I could not identify the species investigated only in all organic apple orchards. A paired *t*-test was performed to compare the abundance of these main species between farming systems, and a statistically higher was found in organic apple orchards (t [107] = 2.07, $P < 0.05$) (Fig. 50).

Table 14. Summary of the total arthropod community in the apple orchard in study areas

Arthropod group	Farming system[a]	Community structure			
		No. of order	No. of families	No. of species	No. of individual
Acari, Collembola, Insecta (A)	OF	12	75	224	213,510
	CF	10	61	184	106,433
	Total	**12**	**81**	**255**	**319,943**
Spiders (B)	OF	1	21	72	3,194
	CF	1	21	65	1,469
	Total	**1**	**22**	**94**	**4,663**
Total (A+B)	OF	13	96	296	216,704
	CF	11	86	249	107,902
	Total	**13**	**103**	**349**	**324,606**

[a]OF, organic farming; CF, conventional farming

Table 15. Summary of the main arthropod species in the apple orchards

Order	Family	Species name	No. individuals	
			OF[a]	CF[b]
Araneae	Dictynidae	*Xysticus phippiatus*	9	32
	Lycosidae	*Trpochosa ruricola*	255	37
	Nesticidae	*Nesticella mogera*	58	38
	Thomisidae	*Xysticus ephippiatus*	29	15
	Ceratozetidae	Ceratozetidae sp.1	3,701	7,564
	Digamasellidae	Dendrolaelaps sp.1	3,022	198
Collembola	Entomobryidae	*Homidia mediaseta*	49,966	29,264
Coleoptera	Carabidae	*Anisodactylus punctatipennis*	585	553
		Harpalus discrepans	316	319
	Scolytidae	*Xylosandrus crasiussculus*	187	115
		Xylosandrus germanus	1,108	838
Diptera	Chironomidae	Chironomidae sp.1	9,204	4,902
	Drosophilidae	Drosophilidae sp.1	9,522	7,164
	Muscidae	Muscidae sp.2	624	727
	Phoridae	Phoridae sp.1	271	405
	Sciaridae	Sciaridae sp.1	12,463	8,582
		Sciaridae sp.2	470	1,255
Hemiptera	Aphididae	*Myzus malisuctus*	1,196	409
		Aphis spiraecola	1,146	1,051
Hymenoptera	Apidae	Apidae sp.1	38	39
	Chalcidoidea	Chalcidoidea sp.2	227	332
	Diapriidae	Diapriidae sp.1	495	213
	Formicidae	*Formica japonica*	1,123	221
		Nylanderia flavipes	1,614	672
	Ichneumonidae	Ichneumonidae sp.1	438	541
		Ichneumonidae sp.2	276	227
Thysanoptera	Thripidae	*Frankliniella* spp.1	11,362	5,127
Total individuals			**107,705**	**70,840**

[a]OF, organic farming; [b]CF, conventional farming

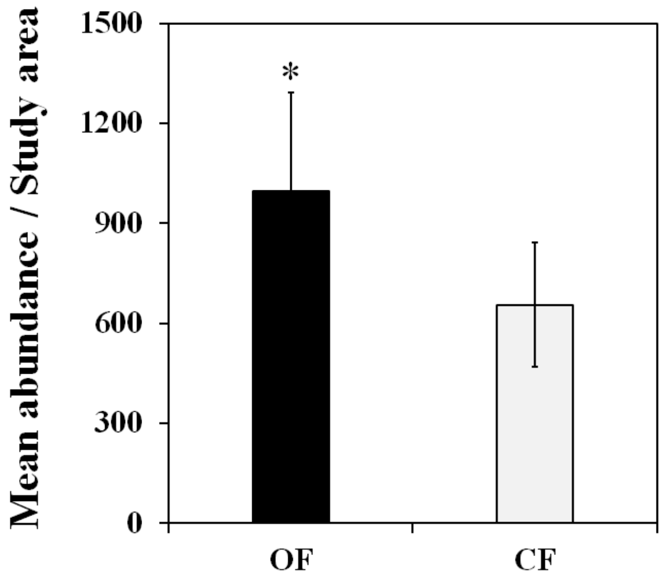


Fig. 50. Comparison of the abundance (mean±SE) of common arthropod species in apple orchards (OF, organic farming; CF, conventional farming) (Paired *t*-test, * 0.01 < *P* < 0.05, ** 0.001 < *P* < 0.01, *** *P* < 0.001).

Section ii. Comparison of ecological guild structure between organic and conventional apple orchards

1. Arthropod (Acari, Collembola, and Insecta) guilds

1.1. Comparison of relative richness and abundance

A total of 319,943 arthropods were collected during the survey period and categorized into five ecological guilds; Detritivores, Herbivores, Pollinators, Predators, and Parasitoids (Appendix 1-3). All five guilds appeared regardless of the survey area and farming system (Table 16, Fig. 51-52). Comparing the relative species richness and abundance of ecological guilds, there was no statistical difference between farming systems, except for herbivores in relative species richness (Table 17-18).

1.2. Comparison of dominant guilds

According to the farming method, the abundance of detritivores (t [19] = 5.38, P < 0.001), herbivores (t [19] = 2.34, P < 0.05), predators (t [19] = 11.28, P < 0.001), and parasitoids (t [19] = 3.25, P < 0.001) was a statistically significant higher in organic orchards. However, the abundance of pollinators was only higher in conventional orchards (t [19] = 3.25, P < 0.001) (Fig. 53-54).

Table 16. Summary of the arthropod guilds in apple orchards in study areas

Study area	Farming system[a]	Guild structure			
		No. of guilds	No. of families	No. of species	No. of individuals
Danyang	OF	5	53	116	68,394
	CF	5	48	95	27,488
	Total	**5**	**58**	**137**	**95,882**
Muju	OF	5	38	93	62,642
	CF	5	35	72	21,574
	Total	**5**	**41**	**99**	**84,216**
Uiseong	OF	5	54	146	45,506
	CF	5	44	104	28,859
	Total	**5**	**59**	**164**	**74,365**
Cheongsong	OF	5	46	119	28,512
	CF	5	41	100	36,968
	Total	**5**	**53**	**140**	**65,480**
Total	OF	5	75	224	213,510
	CF	5	65	184	106,433
	Total	**5**	**81**	**255**	**319,943**

[a]OF, organic farming; CF, conventional farming

Table 17. Comparison of relative species richness of arthropod guilds in apple orchards

Farming system[a]	OF	CF	Paired *t*-test		
Guild groups	(mean ± SE)	(mean ± SE)	*df*	*t*	*P*
Detritivores	22.03±1.01	22.45±2.63	3	0.42	0.699
Herbivores	10.68±1.59	13.67±1.36	3	4.65	0.018
Pollinators	50.41±2.50	47.47±5.81	3	1.34	0.273
Predators	11.29±2.39	11.07±3.10	3	0.32	0.771
Parasitoids	5.60±1.67	5.34±1.91	3	1.21	0.314

[a]OF, organic farming; CF, conventional farming

Table 18. Comparison of relative abundance of arthropod guilds in apple orchards

Farming system[a]	OF	CF	Paired *t*-test		
Guild groups	(mean ± SE)	(mean ± SE)	*df*	*t*	*P*
Detritivores	76.99±10.11	80.98±7.02	3	0.68	0.544
Herbivores	7.32±3.43	8.60±3.34	3	0.39	0.723
Pollinators	1.42±1.22	3.34±2.00	3	2.29	0.106
Predators	10.96±10.58	5.02±2.11	3	1.52	0.227
Parasitoids	3.31±4.61	2.06±1.72	3	0.60	0.589

[a]OF, organic farming; CF, conventional farming

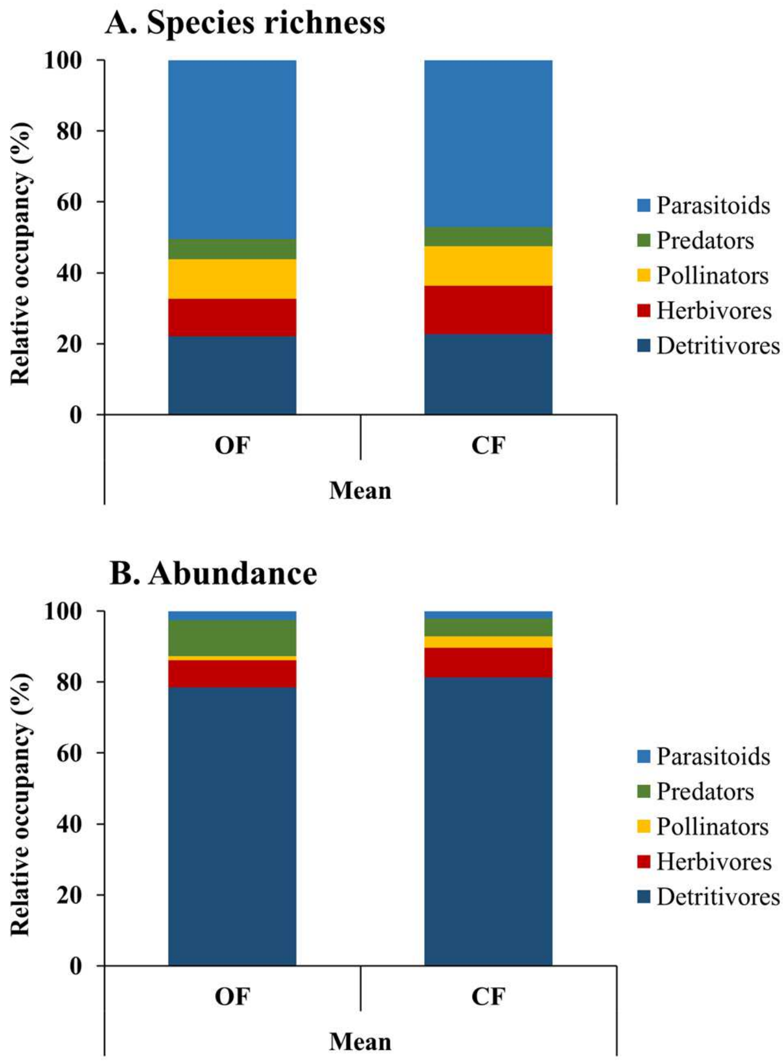


Fig. 51. The average relative species richness and abundance of arthropod guilds in the apple orchards (OF, organic farming; CF, conventional farming).

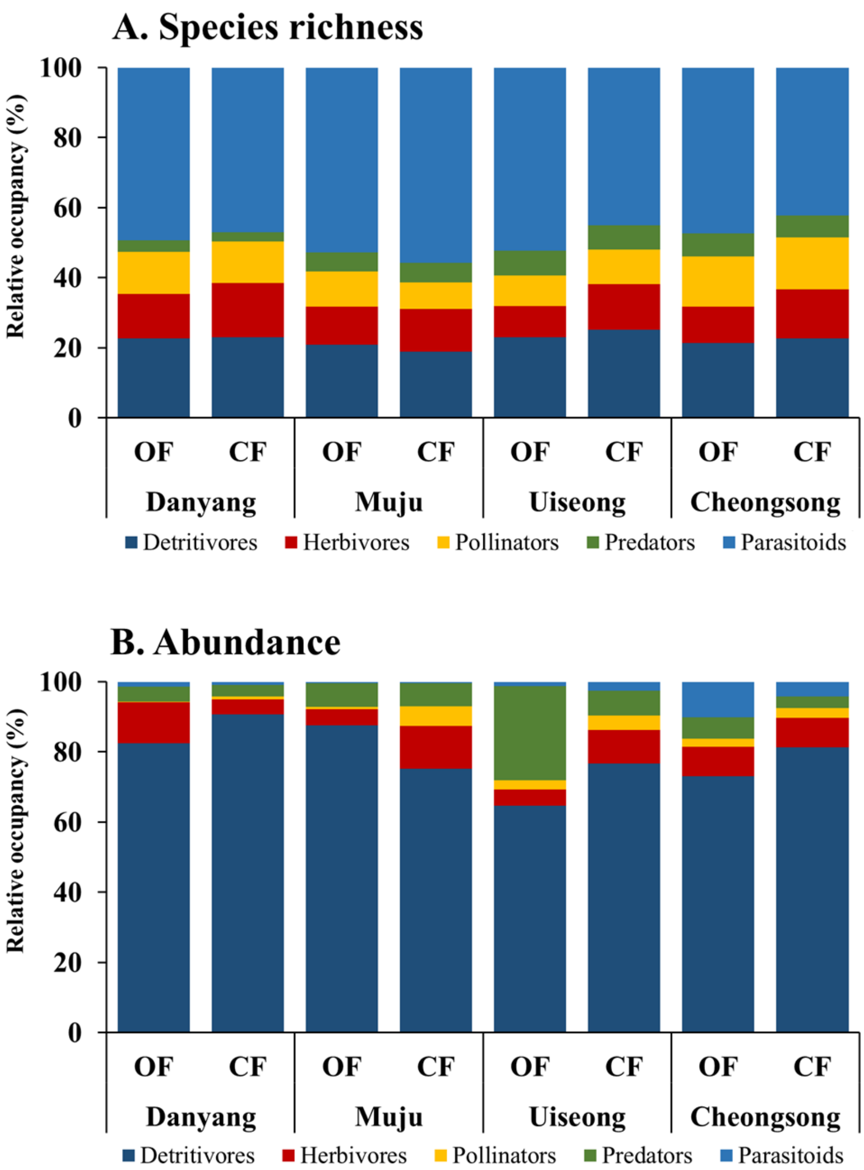


Fig. 52. The relative species richness and abundance of arthropod guilds sampled from apple orchards by study areas (OF, organic farming; CF, conventional farming).

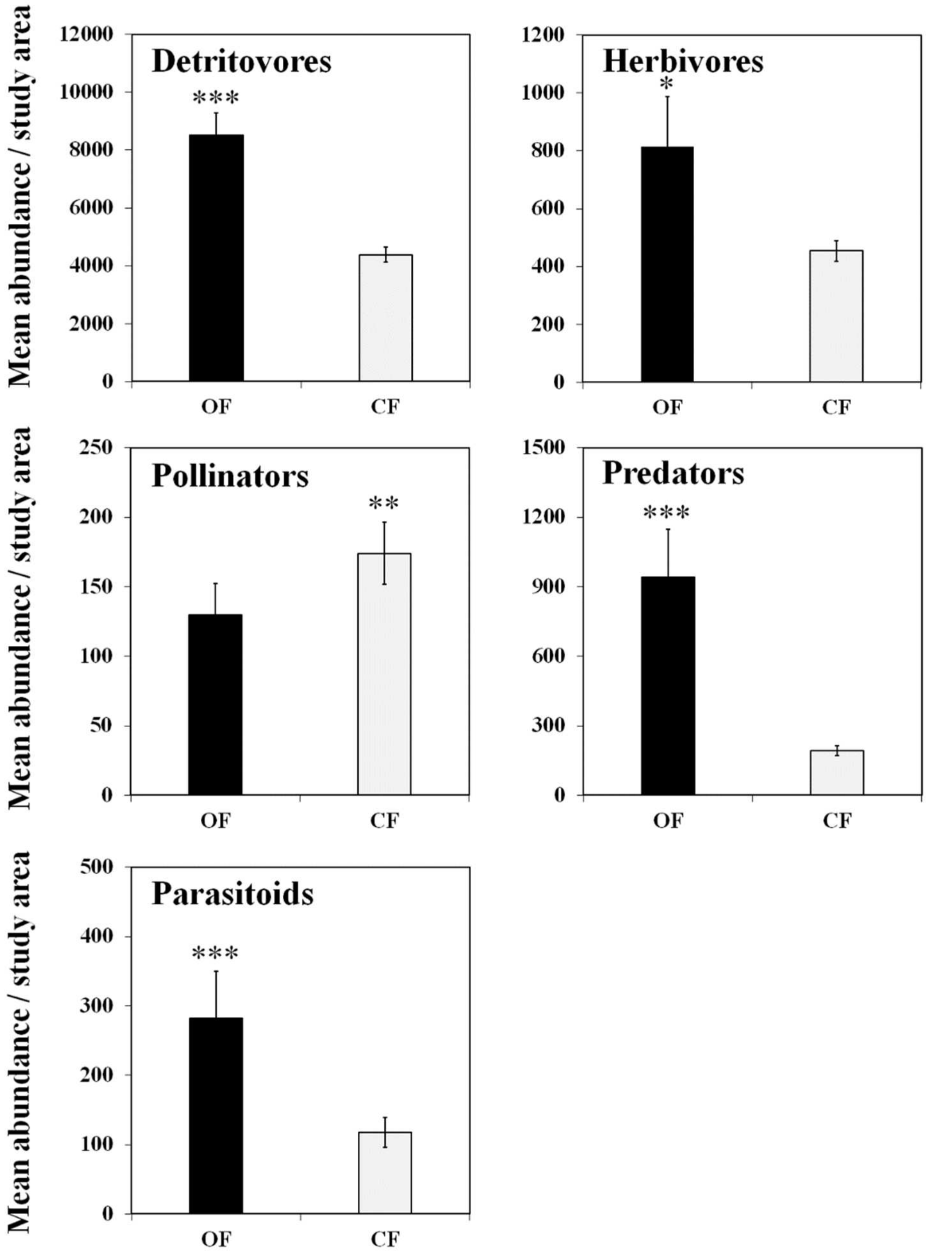


Fig. 53. Comparison of the average abundance (mean±SE) of dominant guilds in apple orchards (OF, organic farming; CF, conventional farming) (Paired *t*-test, * 0.01 < P < 0.05, ** 0.001 < P < 0.01, *** P < 0.001).

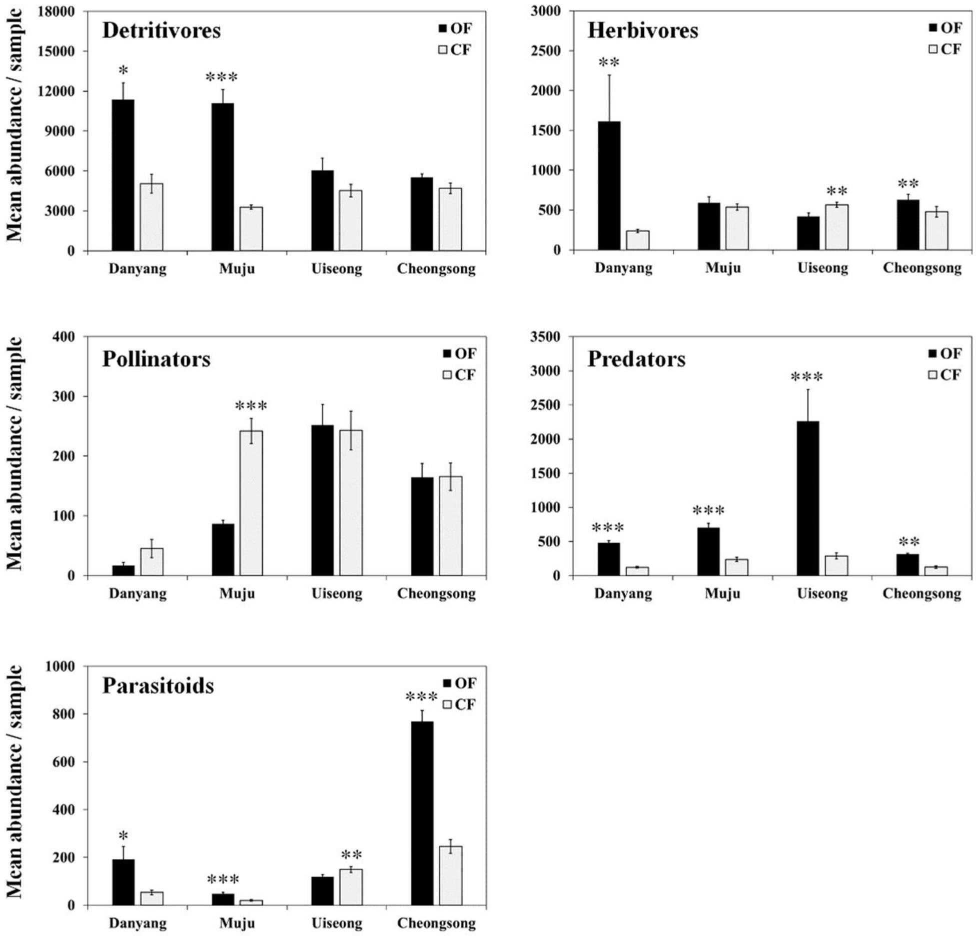


Fig. 54. Comparison of the abundance (mean±SE) of dominant guilds in apple orchards (OF, organic farming; CF, conventional farming) (Paired *t*-test, * $0.01 < P < 0.05$, ** $0.001 < P < 0.01$, *** $P < 0.001$).

1.3. Comparison of seasonal fluctuation of dominant guilds

The seasonal fluctuations of arthropod guilds were observed in organic and conventional orchards from zero to five peaks. The occurrence peak of detritivores appeared in the 4th of June and 4th week of September in organic orchards, the 4th week of June and 4th week of August in conventional orchards, and the occurrence of detritivores increased toward the second half of the survey in both orchards. The occurrence peak of herbivores appeared on the 2nd of August in organic orchards, and the occurrence of detritivores increased toward the second half of the survey. However, there was no distinct peak in conventional orchards and decreased toward the latter half of the investigation. In the case of pollinators, the most complex seasonal fluctuations with three to five peaks were observed in both orchards; that was in the 4th week of April, 2nd week of June, .2nd week of July, 2nd week of August, and 4th week of September in organic orchards with decreasing toward the latter half of the investigation, and 4th week of April, 2nd week of June, and 2nd week of September in conventional orchards with increasing toward the latter half of the investigation. The occurrence peak of predators appeared in the 2nd week of July and 4th week of August in organic orchards, increasing toward the latter half of the investigation. However, there was no distinct peak in the seasonal fluctuation of predators like herbivores in conventional orchards, decreasing toward the latter half of the investigation. No significant increase or decrease in parasitoids was observed during the entire survey period. The parasitoid occurrence peak appeared in the 2nd week of April, 4th week of June, 4th week of September in organic orchards, and 4th week of June in conventional orchards (Fig. 55-58).

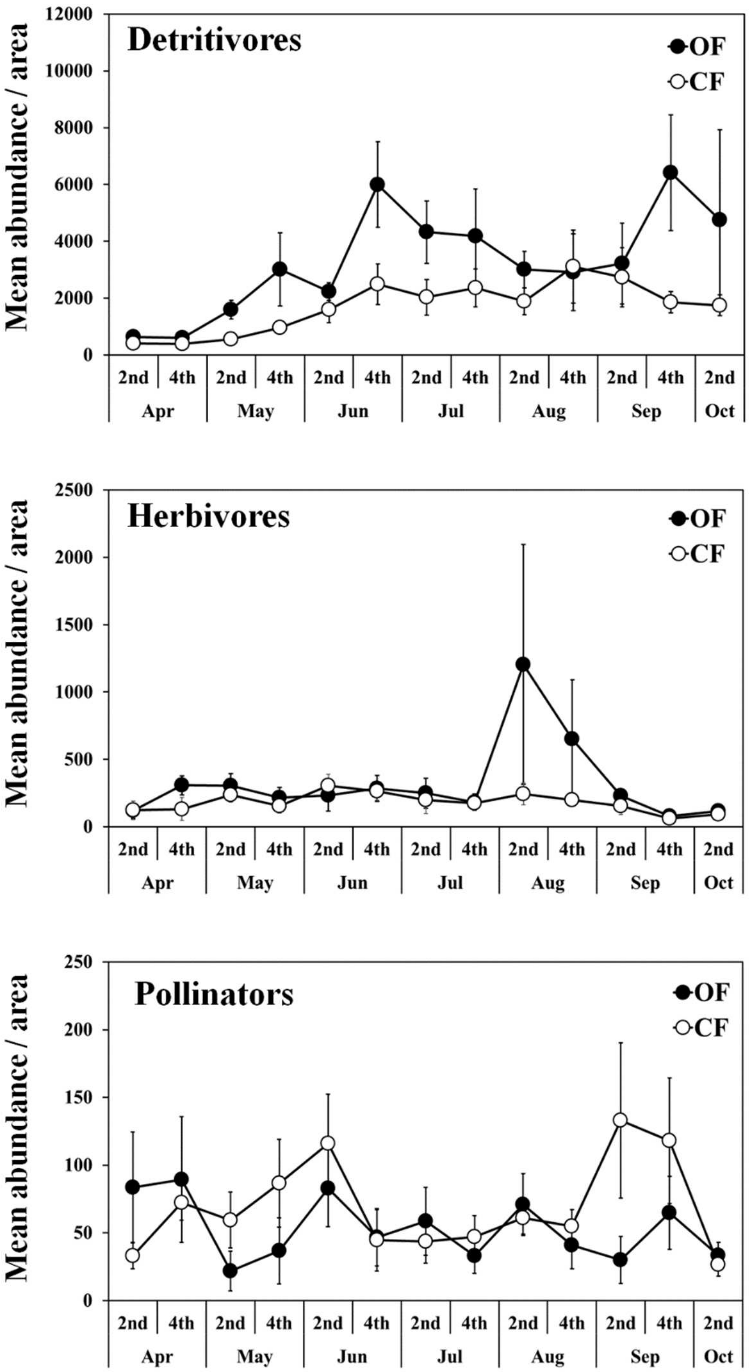


Fig. 55. Comparison of the average seasonality of dominant guilds (Detritivores, Herbivores, Pollinators) in organic and conventional apple orchards (DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong).

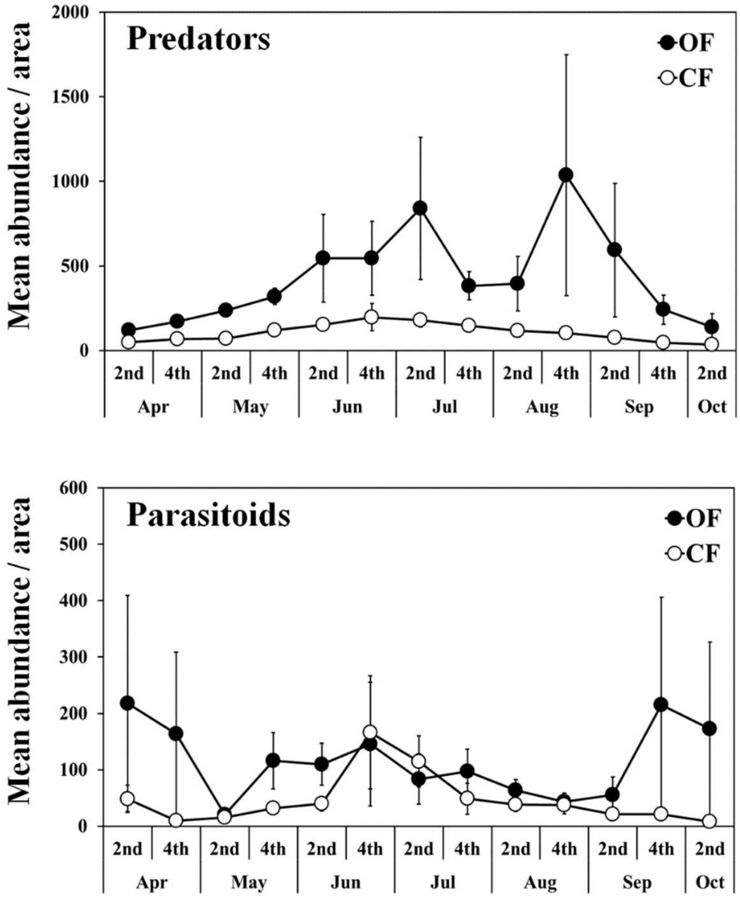


Fig. 56. Comparison of the average seasonality of dominant guilds (Predators, Parasitoids) in organic and conventional apple orchards (DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong).

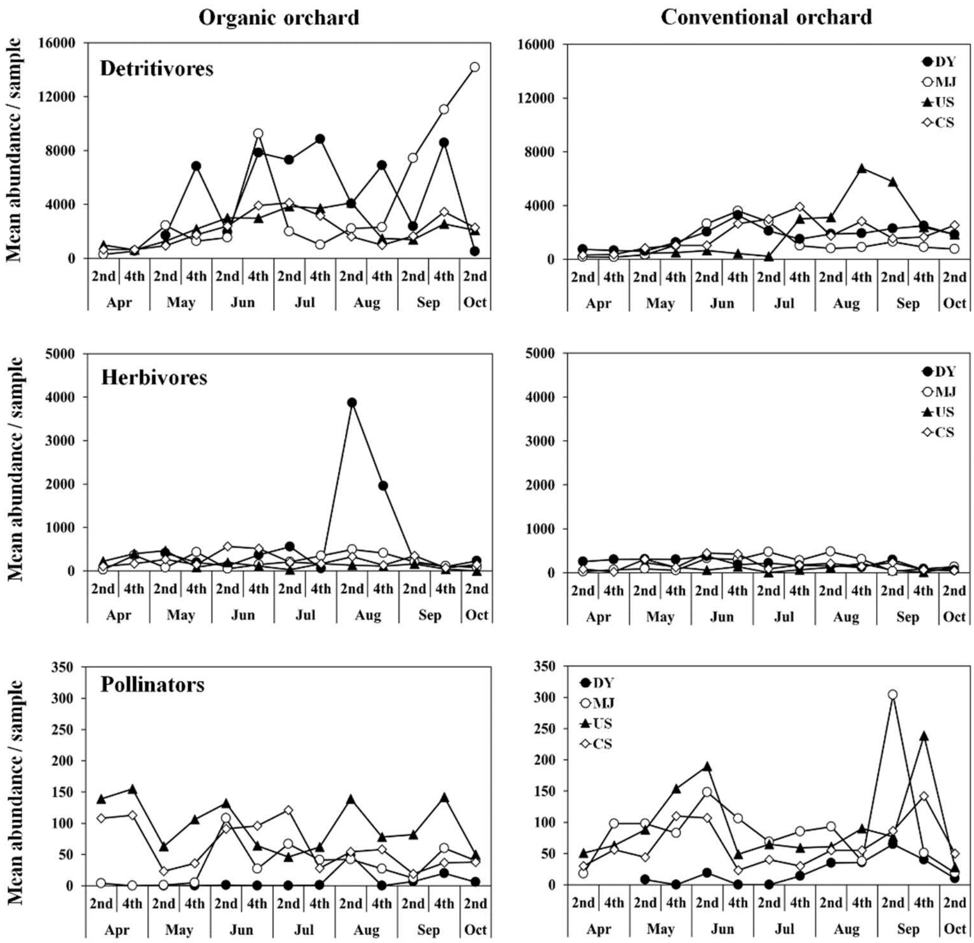


Fig. 57. Seasonality of dominant arthropod guilds (Hetritivores, Herbivores, Pollinators) in organic and conventional apple orchards (DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong).

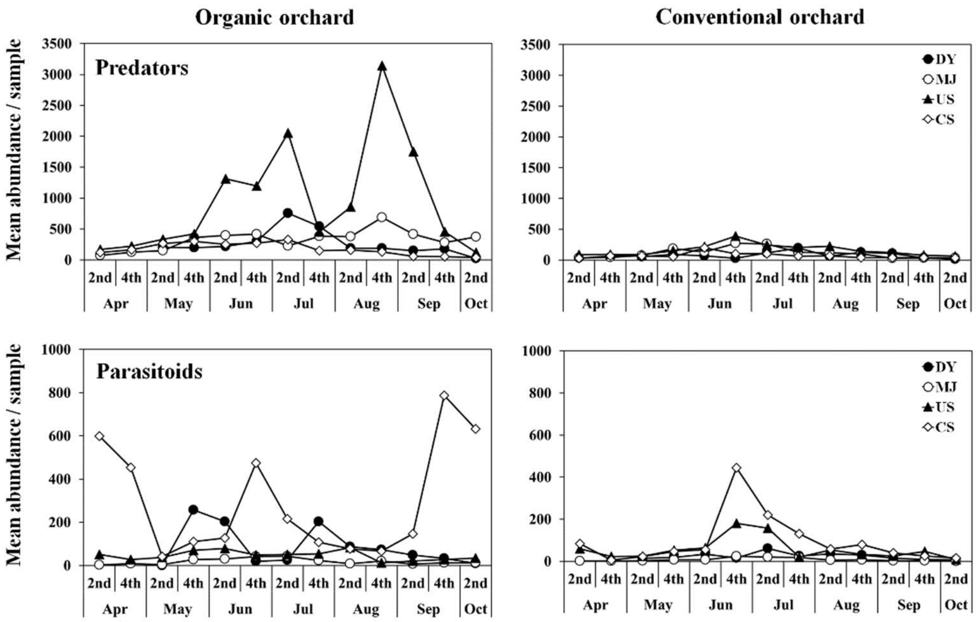


Fig. 58. Seasonality of dominant arthropod guilds (Predators, Parasitoids) in organic and conventional apple orchards (DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong).

1.4. Comparison of guilds structure

As a result of cluster analysis of the arthropod guilds, it was clustered into two groups Danyang and Muju areas and Uiseong and Cheongsong areas, and the similarity was high at 90.53% and 88.11%, respectively. The similarity between these two groups was 85.89%. However, as a result of the SIMPROF test for statistical verification between clusters, there was no significant difference between all groups (SIMPROF test, P = 0.612) (Fig. 59). Furthermore, the cluster analysis similarity of the arthropod guild structure according to the farming system showed that the three groups were similar at 83.97%. However, as a result of the SIMPER test for statistical verification between clusters, there was no significant difference between all groups (SIMPROF test, P = 0.703) (Fig. 60).

Similarly, in the NMDS analysis result, it was confirmed that there was a general difference in the arthropod guild structure between organic and conventional orchards (Fig. 61).

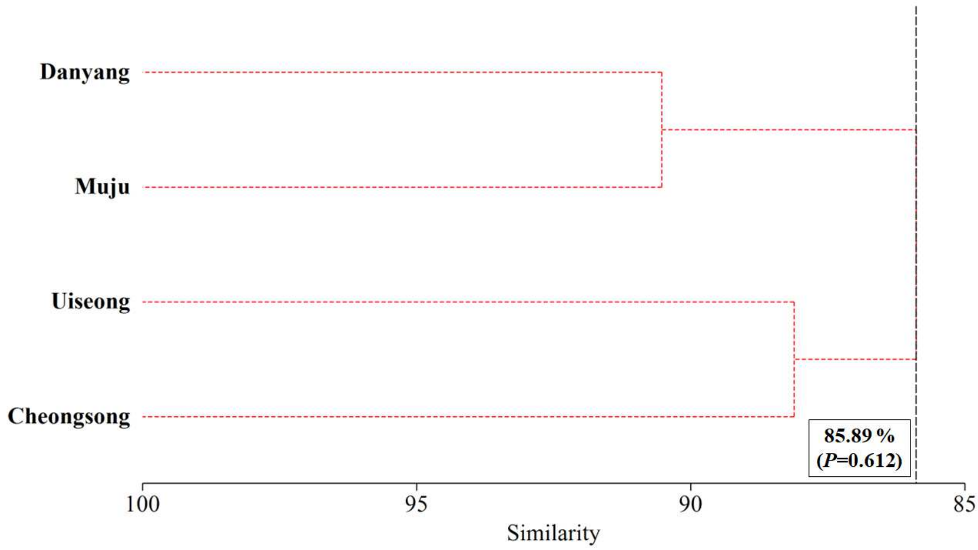


Fig. 59. Cluster analysis based on Bray-Curtis similarity index of arthropod guilds in study areas (Broken lines indicate the same group by SIMPROF test).

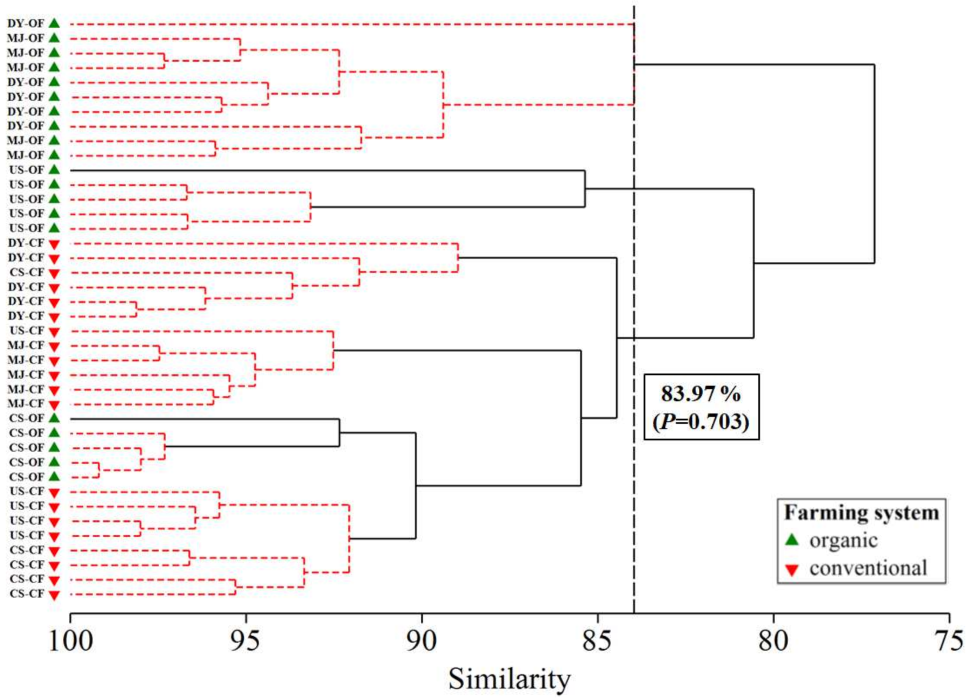


Fig. 60. Cluster analysis based on Bray-Curtis similarity index of arthropod guilds from organic and conventional orchards within study areas (Broken lines indicate the same group by SIMP□OF test; Each point represents a sampling trap in an individual orchard sampled).

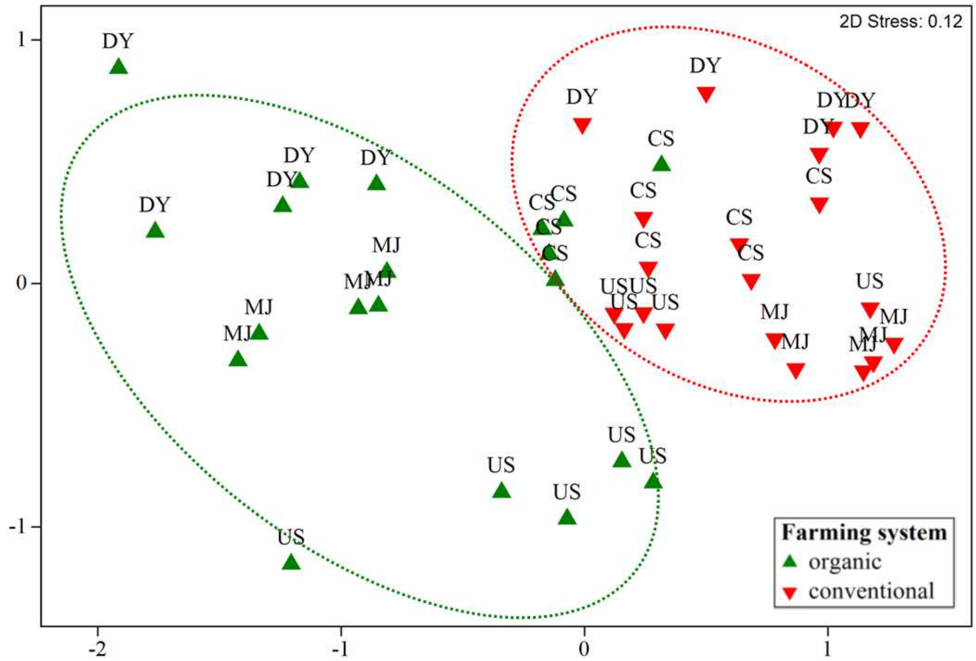


Fig. 61. Non-metric multi-dimensional scaling (NMDS) plot of the similarities in arthropod guilds by the farming system in apple orchards (Broken lines indicate the same group by SIMP□OF test; Each point represents a sampling trap in an individual orchard sampled).

2. Spider guilds

2.1. Comparison of relative richness and abundance

A total of 4,663 spiders were collected during the survey and categorized into eight ecological guilds; ambushers, foliage runners, ground runners, orb weavers, space web builders, stalkers, wandering sheet weavers, and wandering sheet web builders (Table 19, *Appendix* 4).

According to the farming system, all eight spider guilds were in organic and conventional orchards. Considering species richness and abundance, four guilds (ground runners, space web builders, wandering sheet weavers, and wandering sheet web builders) were dominant regardless of the study area or farming system. Comparing the relative species richness and abundance of four ecological guilds, there was no statistical difference between farming systems, except for space web builders in relative species richness (Table 20-21, Fig. 62).

The number of spider guilds by region in organic orchards was six-eight, and those in conventional ones were five-seven. In average, there were seven guilds in organic orchards and 6.3 in conventional ones, so spider guilds in organic orchards were more abundant than in conventional ones (Fig. 63). Of the eight spider guilds, foliage runners and orb weavers consist of two and one species, respectively, and were represented by <1.0%. These guilds represented 1.8% of the species richness and 0.2% of the abundance. Depending on the study area, the spider guilds were slightly different; six guilds were distributed in the Danyang area, and all eight guilds were distributed in Uiseong and Cheongsong areas (Fig. 63). According to the farming system, all eight spider guilds were in organic and conventional orchards. The number of spider guilds by region in organic orchards was six-eight, and those in conventional ones were five-seven.

Table 19. Summary of the spider guild structure in the apple orchard in study areas

Study area	Farming system[a]	Community structure		
		No. of guilds	No. of species	No. of individuals
Danyang	OF	6	35	533
	CF	5	22	286
	Total	**6**	**39**	**819**
Muju	OF	7	35	757
	CF	7	34	248
	Total	**7**	**53**	**1,005**
Uiseong	OF	8	36	1,177
	CF	6	27	652
	Total	**8**	**45**	**1,829**
Cheongsong	OF	7	35	727
	CF	7	28	283
	Total	**8**	**46**	**1,010**
Total	OF	8	72	3,194
	CF	8	65	1,469
	Total	**8**	**94**	**4,663**

[a]OF, organic farming; CF, conventional farming

Table 20. Comparison of relative species richness of spider guilds in apple orchards

Farming system[a]	OF	CF	Paired *t*-test		
Guild groups	(mean ± SE)	(mean ± SE)	*df*	*t*	*P*
Ground runners	38.75±1.84	40.21±7.02	3	0.43	0.694
Wandering sheet weavers	18.33±5.45	13.64±7.35	3	1.07	0.363
Ambushers	11.94±3.40	14.36±0.53	3	1.57	0.215
Space web builders	16.90±0.27	19.57±6.17	3	3.23	0.048
Wandering sheet web builders	5.63±2.33	8.03±4.33	3	0.72	0.526

[a]OF, organic farming; CF, conventional farming

Table 21. Comparison of relative abundance of spider guilds in apple orchards

Farming system[a]	OF	CF	Paired *t*-test		
Guild groups	(mean ± SE)	(mean ± SE)	*df*	*t*	*P*
Ground runners	61.76±27.76	46.41±22.95	3	0.96	0.409
Wandering sheet weavers	11.43±6.26	42.33±30.58	3	1.72	0.179
Ambushers	3.52±2.47	2.63±2.19	3	0.39	0.719
Space web builders	9.35±5.28	4.99±4.84	3	1.34	0.274
Wandering sheet web builders	8.71±8.55	0.84±1.08	3	1.99	0.140

[a]OF, organic farming; CF, conventional farming

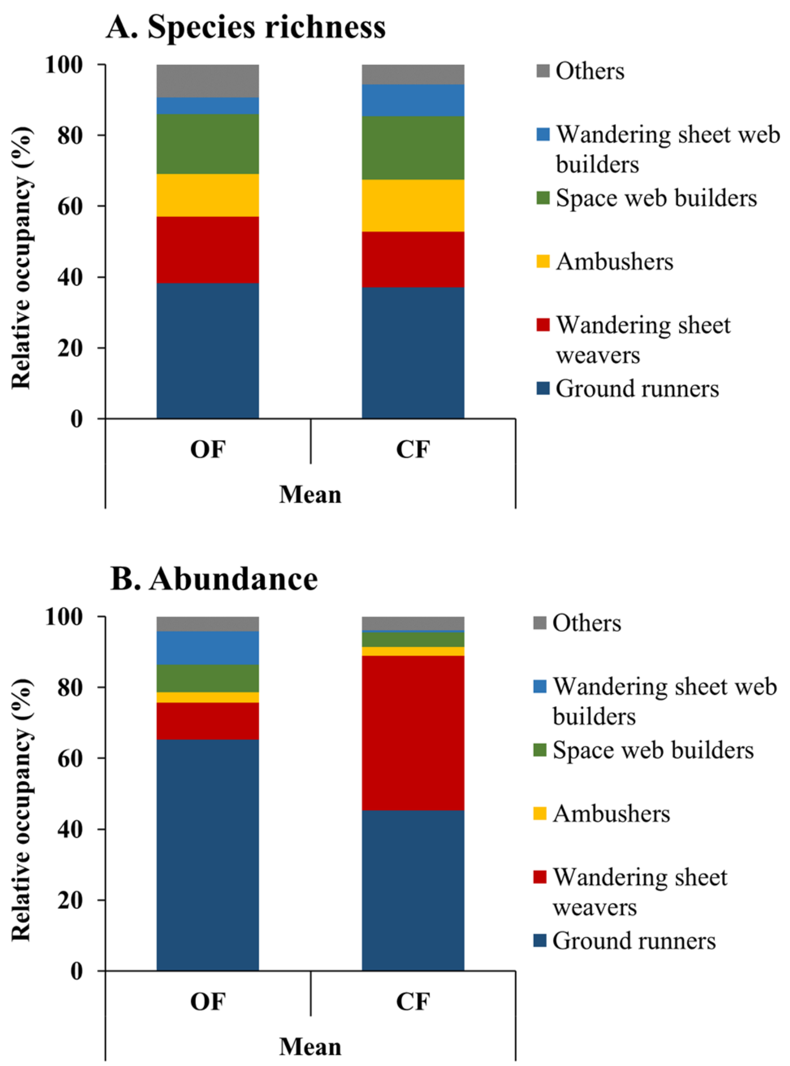


Fig. 62. The average relative species richness and abundance of spider guilds in the apple orchards (OF, organic farming; CF, conventional farming).

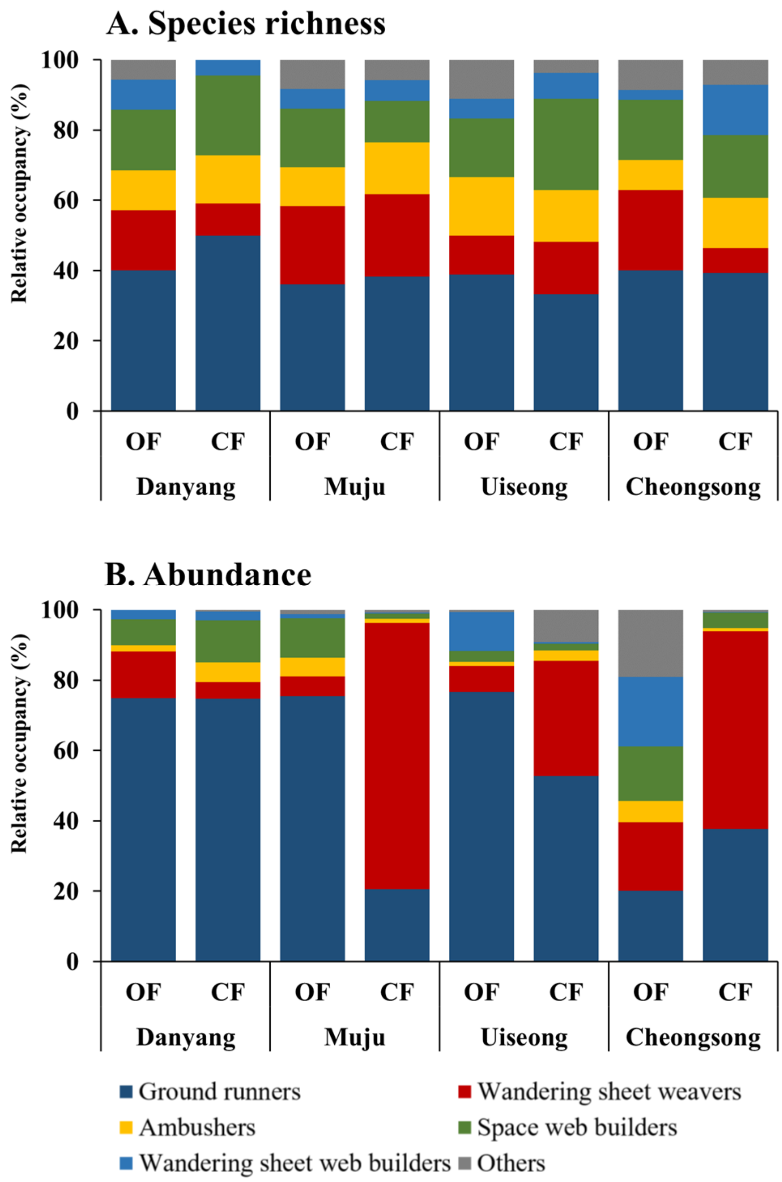


Fig. 63. The relative species richness and abundance of spider guilds sampled from apple orchards by study areas (OF, organic farming; CF, conventional farming).

2.2. Comparison of dominant guilds

Ground runners, wandering sheet weavers, and wandering sheet web builders were statistically different according to the farming method. Ground runners and wandering sheet weavers were statistically different (t [19] = 3.15, $P < 0.01$; t [19] = 5.34, $P < 0.001$) in organic orchards, whereas wandering sheet web builders were statistically significantly different in conventional orchards (t [19] = 3.33, $P < 0.01$) (Fig. 64-65).

2.3. Comparison of seasonal fluctuation of dominant guilds

The seasonal fluctuations of four dominant spider guilds were observed in serrated forms in organic and conventional orchards. The occurrence peak of ground runners appeared in the 2nd week of July in organic orchards and the 4th week of June in conventional orchards. And then, the occurrence of ground runners decreased toward the second half of the survey (Fig. 66). The peak of space web builders was the 2nd week of May and the 4th week of August in organic orchards, the 4th week of April, and the 2nd week of July in conventional orchards. The occurrence slightly increased toward the latter half of the survey, but in conventional orchards, it tended to decrease slightly (Fig. 66). The occurrence peak of wandering sheet weavers appeared in the 2nd week of July in both organic and conventional orchards. The abundance slightly decreased toward the latter half of the survey in both organic and conventional orchards (Fig. 67). In the case of wandering sheet web builders, the occurrence was significantly low, so no distinctive trend of seasonal fluctuation could be identified. However, in conventional orchards, the peak occurred in the 2nd week of September, and the occurrence increased markedly toward the latter half of cultivation (Fig. 67).

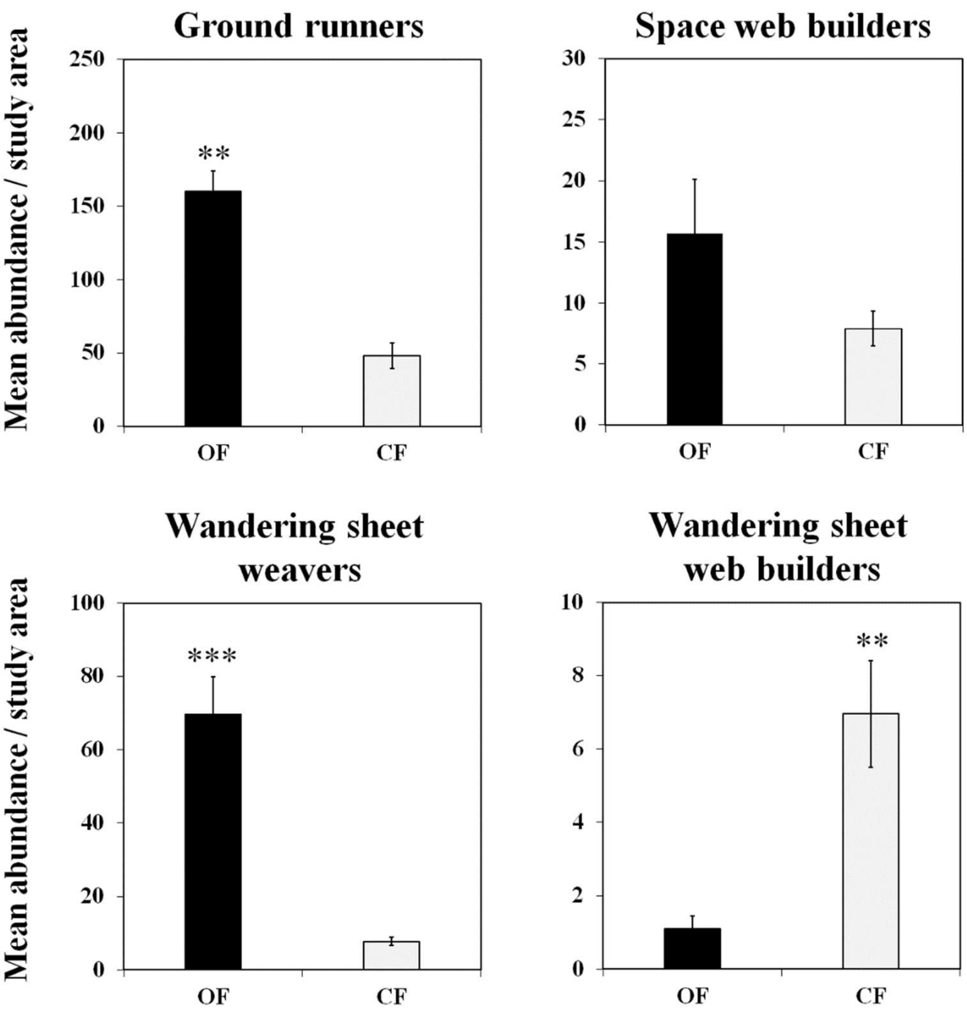


Fig. 64. Comparison of the abundance (mean±SE) of dominant spider guilds in apple orchards (OF, organic farming; CF, conventional farming) (Paired *t*-test, * $0.01 < P < 0.05$, ** $0.001 < P < 0.01$, *** $P < 0.001$).

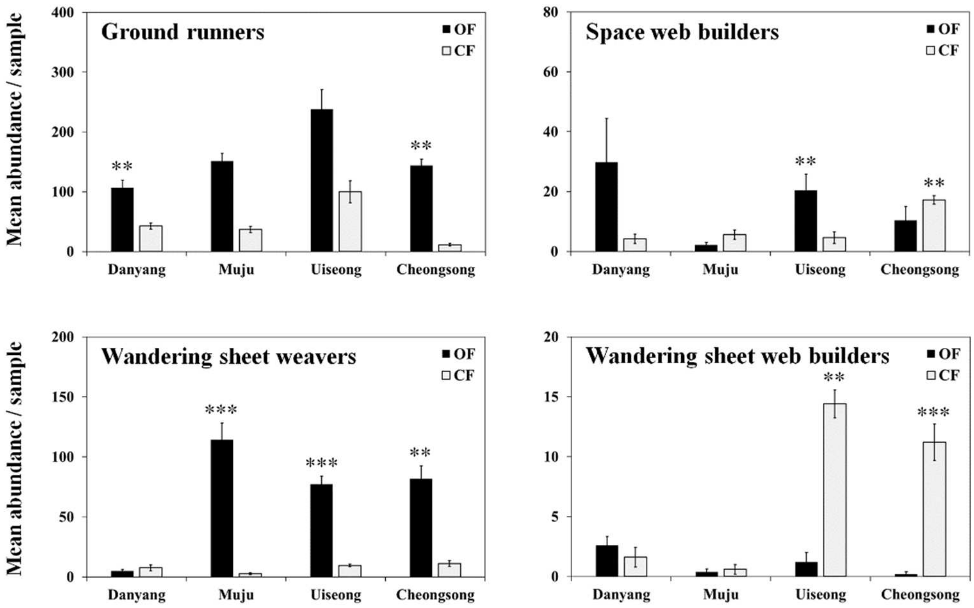


Fig. 65. Comparison of the abundance (mean±SE) of dominant spider guilds in apple orchards by study areas (OF, organic farming; CF, conventional farming) (Paired *t*-test, * $0.01 < P < 0.05$, ** $0.001 < P < 0.01$, *** $P < 0.001$).

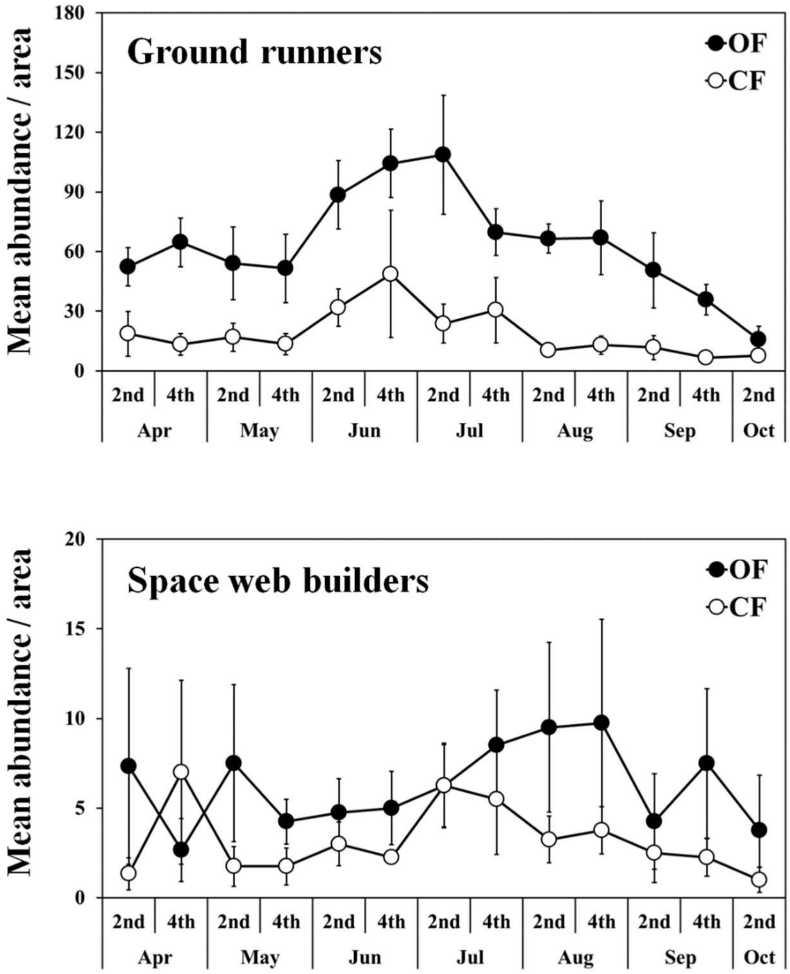


Fig. 66. Comparison of the average seasonality of dominant spider guilds (Ground runners, Space web builders) in organic and conventional apple orchards (DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong).

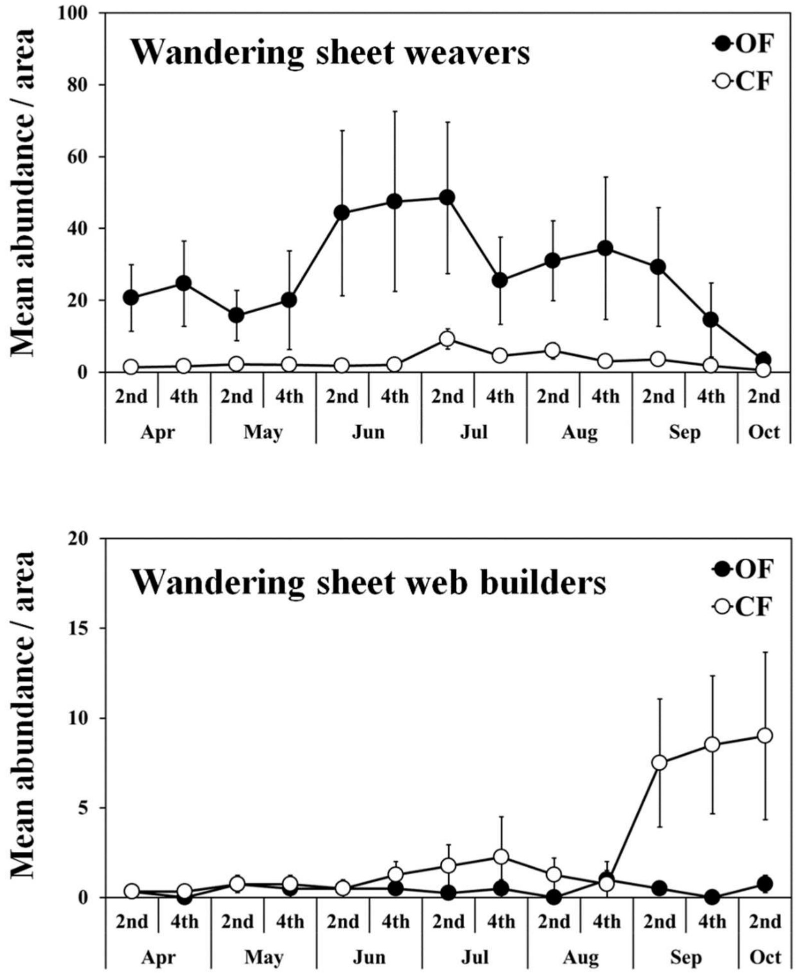


Fig. 67. Comparison of the average seasonality of dominant spider guilds (Wandering sheet weavers, Wandering sheet web builders) in organic and conventional apple orchards (DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong).

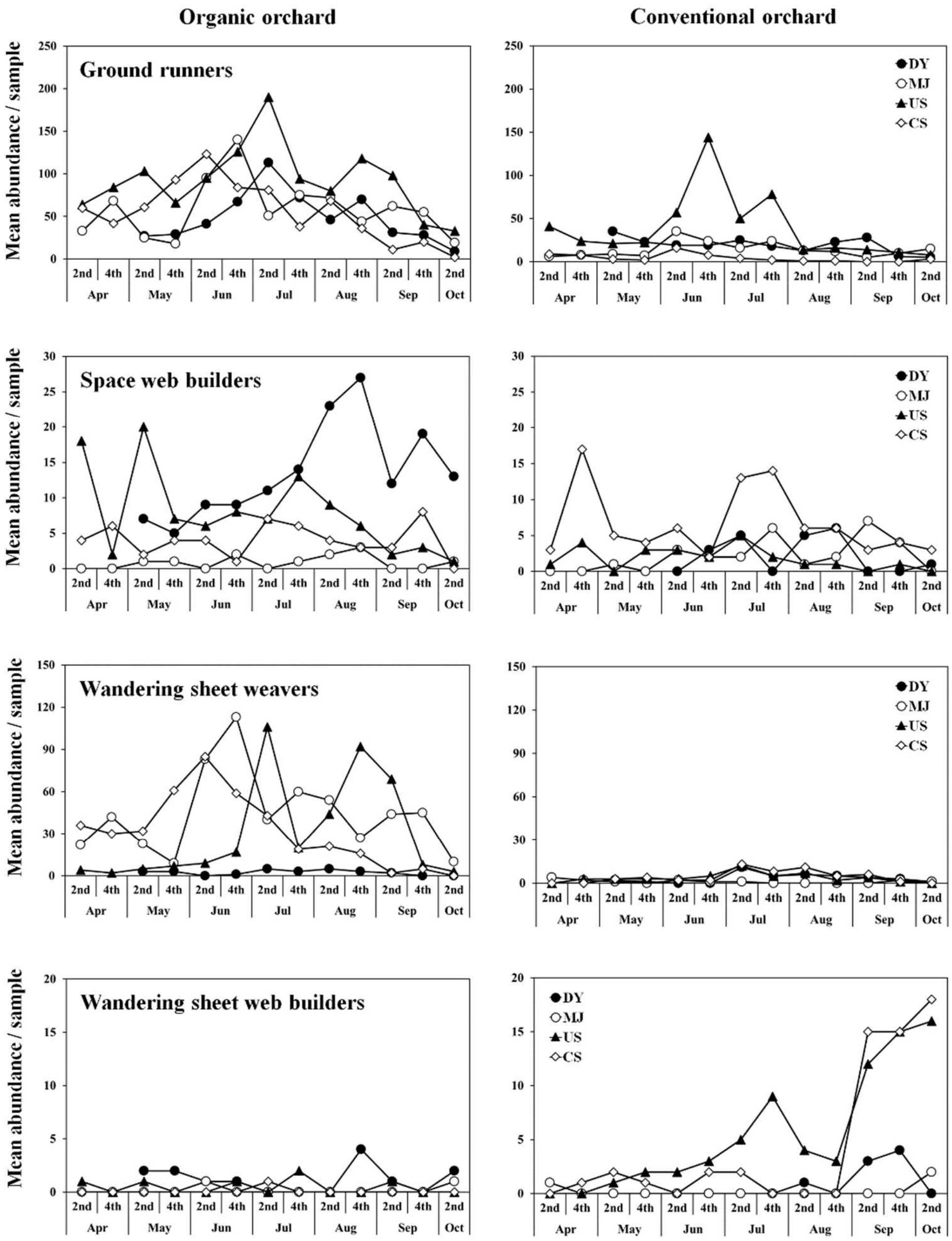


Fig. 68. Seasonality of dominant spider guilds in organic and conventional apple orchards (DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong).

2.4. Comparison of guilds structure

As a result of performing cluster analysis of the spider guild structure by study areas based on the Bray-Curtis similarity index, it was found that the spider guild structure was divided into two groups; (1) Danyang and Uiseong areas and (2) Muju and Cheongsong areas with a similarity of 76.12%. However, no statistically significant difference was confirmed in the significance difference test through the SIMPROF test (P = 0.624). Furthermore, though the spider guild structure of Muju and Cheongsong areas showed a high similarity of 88.79%, these two areas and Uiseong area showed a similarity of 81.66%, there was no statistically significant difference in all study areas (Fig. 69).

Analyzing the similarity of spider guild structures for each farming system using the Bray-Curtis similarity index-based cluster analysis and SIMPROF test, the spider guilds of organic and conventional apple orchards by region showed a statistical difference at a similarity of 59.64% (SIMPROF test, P = 0.023). Except for organic orchards in Danyang area. However, in general, it was found that the spider guild structure differed between organic and conventional orchards (Fig. 70). The result of performing NMDS analysis using a similarity matrix to understand the spider guild structure according to regional farming systems showed a significant difference. It was confirmed that the spider guild structure was generally affected by the farming system (Fig. 71).

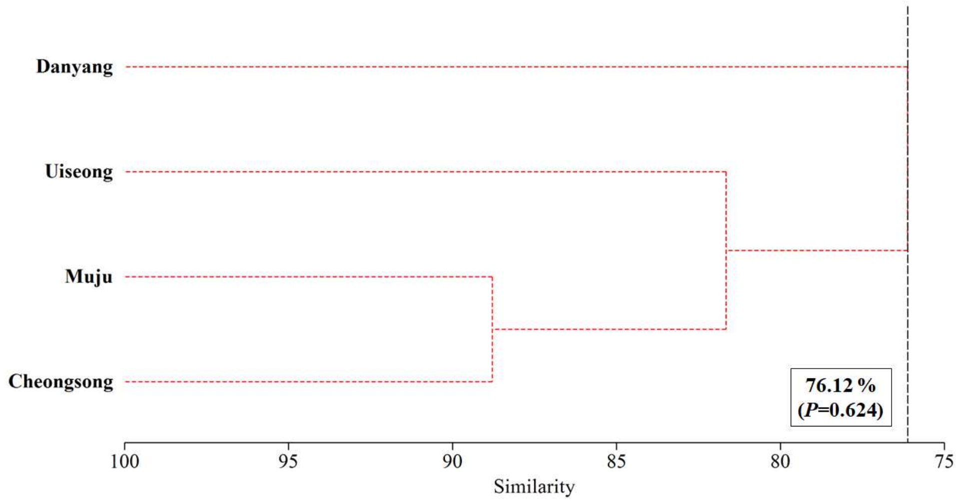


Fig. 69. Cluster analysis based on Bray-Curtis similarity index of spider guilds in study areas (Broken lines indicate the same group by SIMPROF test).

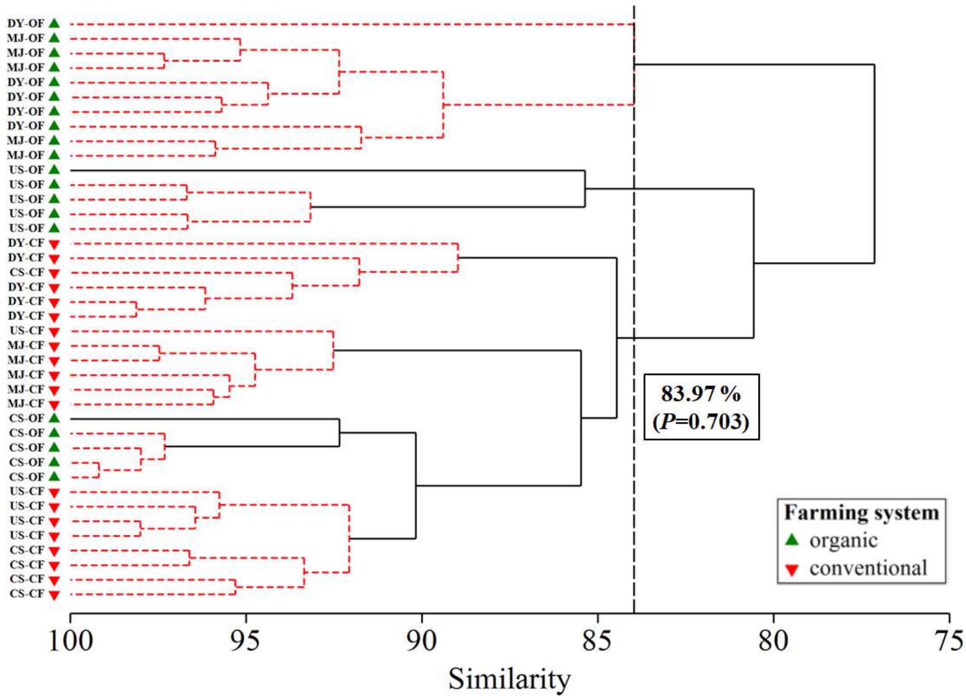


Fig. 70. Cluster analysis based on Bray-Curtis similarity index of spider guilds from organic and conventional orchards within study areas (Broken lines indicate the same group by SIMP□OF test; Each point represents a sampling trap in an individual orchard sampled).

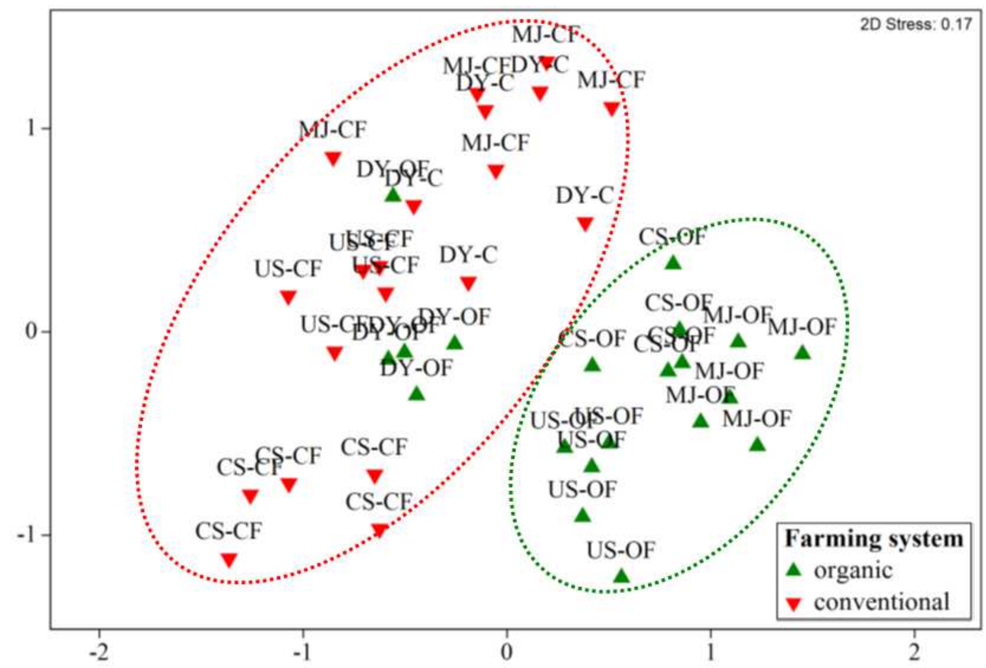


Fig. 71. Non-metric multi-dimensional scaling (NMDS) plot of the similarities in spider guilds by the farming system in apple orchards (Broken lines indicate the same group by SIMP□OF test; Each point represents a sampling trap in an individual orchard sampled).

Section iii. Comparison of arthropod communities and guilds in organic and conventional apple orchards

1. Arthropod (Acari, Collembola, and Insecta) communities and guilds

1.1. Comparison of biodiversity indices of arthropod communities

Overall, the species richness of arthropod communities was conspicuously higher in organic orchards than in conventional orchards (t [49] = 7.85, P < 0.001) (Table 22). The species richness in organic orchards ranged from 33.55±2.13 to 49.00±2.80 (mean±SE), with the highest in Uiseong area and the lowest in Danyang area, and that in conventional orchards was in the range of 25.31±1.93 to 40.54±1.98 (mean±SE) with the highest in Uiseong area and the lowest in Muju area (Table 2). The abundance of arthropod communities was almost double that of organic orchards compared to conventional orchards, and there was a statistical significance (t [49] = 5.51, P < 0.001 (Table 22). The abundance in organic orchards ranged from 2843.69±374.55 to 6217.64±1015.15 (mean±SE), with the highest in Danyang area and the lowest in Cheongsong area, and that in conventional orchards ranging from 1659.54±348.59 to 2498±692.63 (mean±SE) with the highest in Danyang area and the lowest in Muju area (Table 23). The Fisher's alpha diversity of arthropod communities was higher in organic orchards than in conventional orchards (t [49] = 5.87, P < 0.001) (Table 22). The Fisher's alpha diversity in organic orchards ranged from 5.24±0.37 to 8.23±0.48 (mean±SE), with the highest in Uiseong area and the lowest in Danyang area, and that in conventional orchards ranging from 4.54±0.41 to 7.17±0.36 (mean±SE) with the highest in Uiseong area and the lowest in Danyang area (Table 23).

Table 22. Comparison of the biodiversity indices of arthropod communities in organic and conventional orchards

Diversity index	Farming system[a]		Paired *t*-test		
	OF (mean ± SE)	CF (mean ± SE)	*df*	*t*	*P*
Species richness	41.08±1.29	31.54±1.34	49	7.85	< **0.001**
Abundance	4270.20±447.35	2128.66±203.33	49	5.51	< **0.001**
Species diversity	6.73±0.25	5.53±0.23	49	5.87	< **0.001**

[a]OF, organic farming; CF, conventional farming

Table 23. Comparison of the biodiversity indices of arthropod communities in organic and conventional orchards by study area

Diversity Index	Study area[a]	Farming system[b] OF (mean±SE)	CF (mean±SE)	*df*	*t*	*P*
Species richness	DY	35.55±2.13	27.27±2.97	10	2.47	**0.033**
	MJ	35.62±1.44	25.31±1.93	12	4.61	**<0.001**
	US	49.00±2.80	40.54±1.98	12	5.47	**<0.001**
	CS	43.31±1.69	32.38±1.70	12	8.69	**<0.001**
Abundance	DY	6217.64±1015.15	2498.91±692.63	10	2.84	**0.017**
	MJ	4818.62±1265.54	1659.54±348.59	12	3.42	**0.005**
	US	3500.46±403.73	2219.92±231.67	12	5.32	**<0.001**
	CS	2843.69±374.55	2193.23±326.75	12	2.25	**0.044**
Species diversity	DY	5.24±0.37	4.54±0.41	10	1.57	0.149
	MJ	5.77±0.27	4.62±0.40	12	2.84	**0.014**
	US	8.23±0.48	7.17±0.36	12	2.69	**0.019**
	CS	7.44±0.30	5.64±0.30	12	7.69	**<0.001**

[a]DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong
[b]OF, organic farming; CF, conventional farming

1.2. Comparison of biodiversity indices of arthropod guilds

The species richness of arthropod guilds was no statistical difference between farming system (t [49] = 1.43, P = 0.160) (Table 24). The guild richness of arthropods in organic orchards ranged from 4.45± 0.21 to 5.00± 0.00 (mean± SE), with the highest in Cheongsong area and the lowest in Danyang area, and that in conventional orchards ranging from 4.73± 0.14 to 5.00± 0.00 (mean± SE) with the highest in Uiseong and Cheongsong area, and the lowest in Danyang area (Table 25).

The guild abundance showed statistical significance between organic and conventional orchards (t [49] = 5.51, P < 0.001) (Table 24). The abundance in organic orchards ranged from 2843.69± 374.55 to 6217.64± 1015.15 (mean± SE), with the highest in Danyang area and the lowest in Cheongsong area, and that in conventional orchards ranging from 1659.54± 348.59 to 2498± 692.63 (mean± SE) with the highest in Danyang area and the lowest in Muju area (Table 25).

The guild diversity of arthropod guilds was higher in conventional orchards than in organic orchards (t [49] = 5.39, P < 0.001) (Table 24). The guild diversity in organic orchards ranged from 0.57± 0.01 to 0.60± 0.49 (mean± SE), with the highest in Danyang area and the lowest in Uiseong area, and that in conventional orchards ranging from 0.02± 0.03 to 0.66± 0.03 (mean± SE). The guild diversity in Danyang area had the highest, and the Uiseong area had the lowest from organic orchards, while that is the highest in Muju area and the lowest in Danyang area from conventional orchards (Table 25).

Table 24. Comparison of the biodiversity indices of arthropod guilds in organic and conventional apple orchards

Diversity index	Farming system[a]		Paired *t*-test		
	OF (mean ± SE)	CF (mean ± SE)	*df*	*t*	*P*
Guild richness	4.84±0.06	4.92±0.04	49	1.43	0.160
Abundance	4270.20±447.35	2128.66±203.33	49	5.51	**<0.001**
Guild diversity	0.56±0.01	0.63±0.01	49	5.39	**<0.001**

[a]OF, organic farming; CF, conventional farming

Table 25. Comparison of the biodiversity indices of arthropod guilds in organic and conventional orchards by study area

Diversity Index	Study area[a]	Farming system[b] OF (mean±SE)	CF (mean±SE)	*df*	*t*	*P*
Guild richness	DY	4.45±0.21	4.73±0.14	10	1.37	0.199
	MJ	4.92±0.08	4.92±0.08	12	0.00	1.000
	US	4.92±0.08	5.00±0.00	12	1.00	0.337
	CS	5.00±0.00	5.00±0.00	12	0.00	1.000
Abundance	DY	6217.64±1015.15	2498.91±692.63	10	2.84	**0.017**
	MJ	4818.62±1265.54	1659.54±348.59	12	3.42	**0.005**
	US	3500.46±403.73	2219.92±231.67	12	5.32	**<0.001**
	CS	2848.69±374.55	2193.23±326.75	12	2.25	**0.044**
Guild diversity	DY	0.60±0.49	0.02±0.03	10	2.91	**0.015**
	MJ	0.58±0.02	0.66±0.03	12	3.30	0.507
	US	0.57±0.01	0.62±0.01	12	4.26	**0.001**
	CS	0.60±0.01	0.63±0.02	12	2.18	0.050

[a]DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong
[b]OF, organic farming; CF, conventional farming

1.3. Comparison of seasonal fluctuation of arthropod communities

In the seasonal fluctuations on the biodiversity, the species richness and the abundance of arthropod communities showed a linear curve and mountain-shaped with two peaks in the survey. In the case of species diversity, a linear curve with a decreasing tendency was observed. Regardless of the farming system, species richness and diversity decreased toward the latter half of the survey, while abundance increased. The peak of species richness was observed in the 4^{th} week of June regardless of the farming system. In the seasonal fluctuations of abundance, two peaks were observed in the 4^{th} week of June and the 4^{th} week of September in the organic orchards, the 4^{th} week of June, and the 4^{th} week of August in the conventional orchards. However, for species diversity, regardless of the farming method, the initial time of the survey was the highest and continued to decrease toward the latter half of the survey (Fig. 72-73).

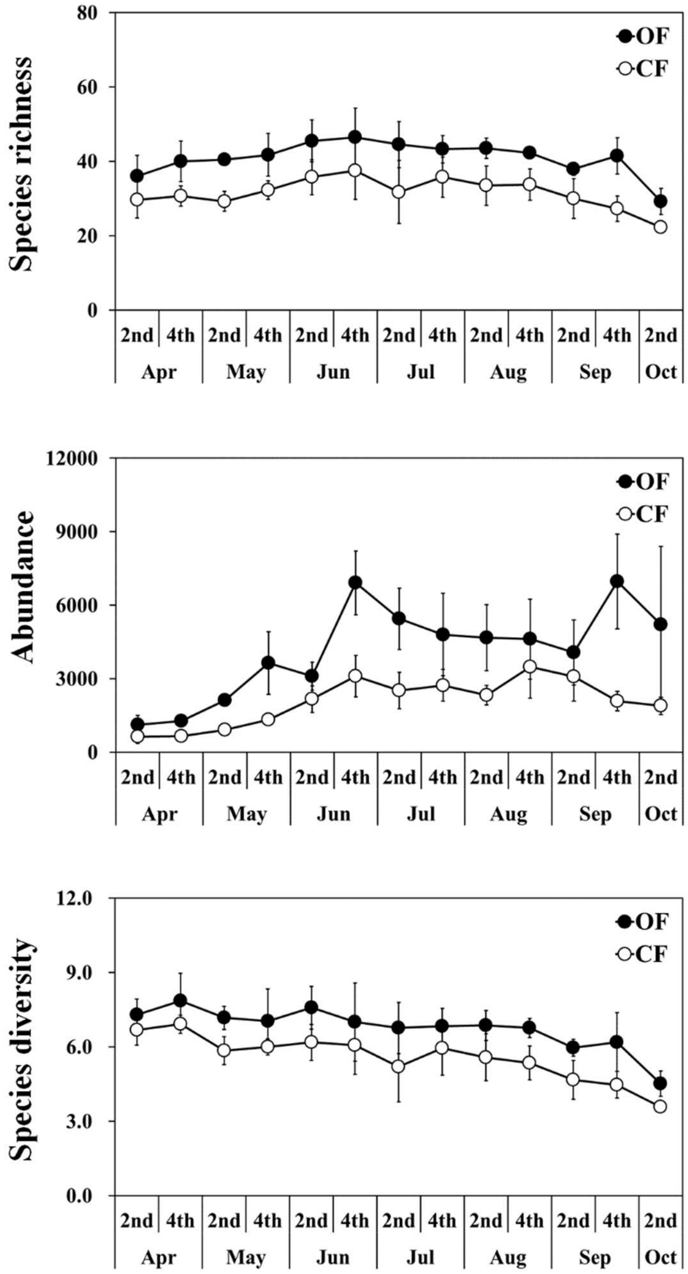


Fig. 72. Seasonality of biodiversity of arthropod community (mean±SE) in organic and conventional apple orchards (DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong).

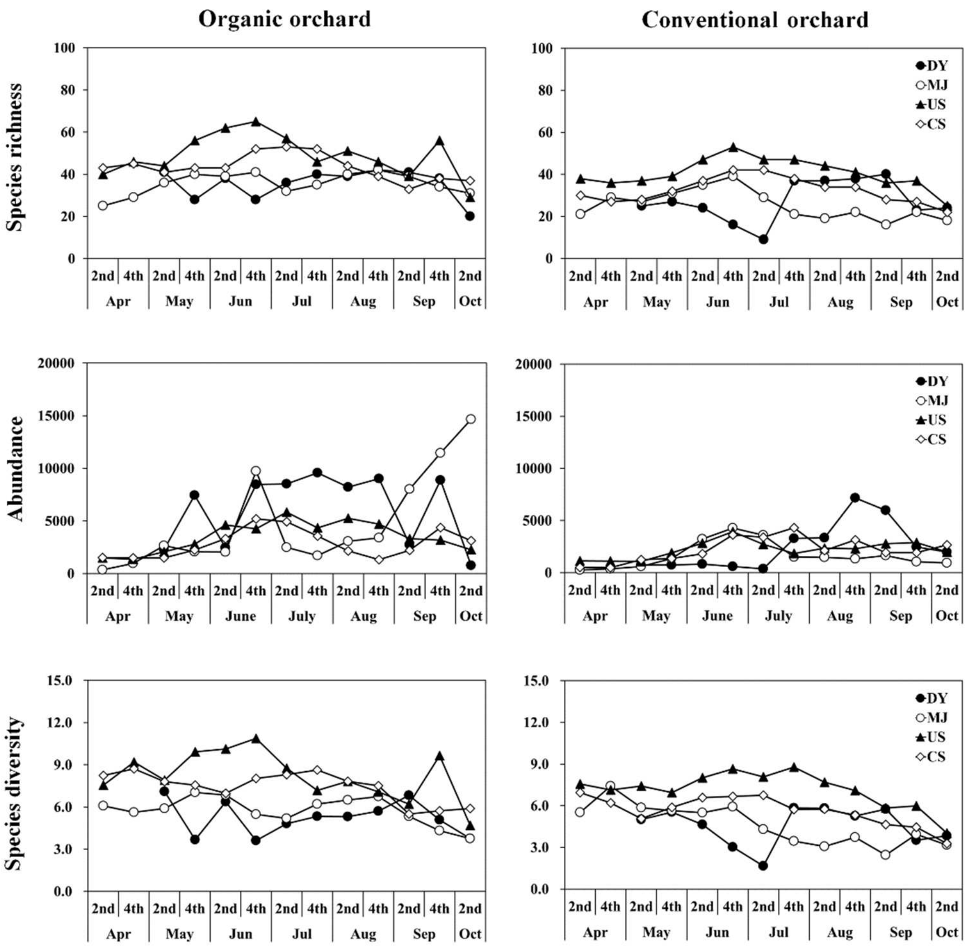


Fig. 73. Seasonality of biodiversity of arthropod community in organic and conventional apple orchards (DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong).

1.4. Comparison of seasonal fluctuation of arthropod guilds

The seasonal fluctuations of the guild richness of arthropods were not particularly variable in organic and conventional orchards (Fig. 74-75). In the case of guild diversity, a linear curve with a decreasing tendency was observed (Fig. 74-75). Regardless of the farming system, guilds diversity decreased toward the latter half of the survey while abundance increased. In the seasonal fluctuations of abundance, two peaks were observed in the 4th week of June and the 4th week of September in the organic orchards, the 4th week of June and the 4th week of August in the conventional orchards. For guild diversity, regardless of the farming method, the initial survey time was the highest, decreased toward the latter half of the survey and maintained a constant level (Fig. 74-75).

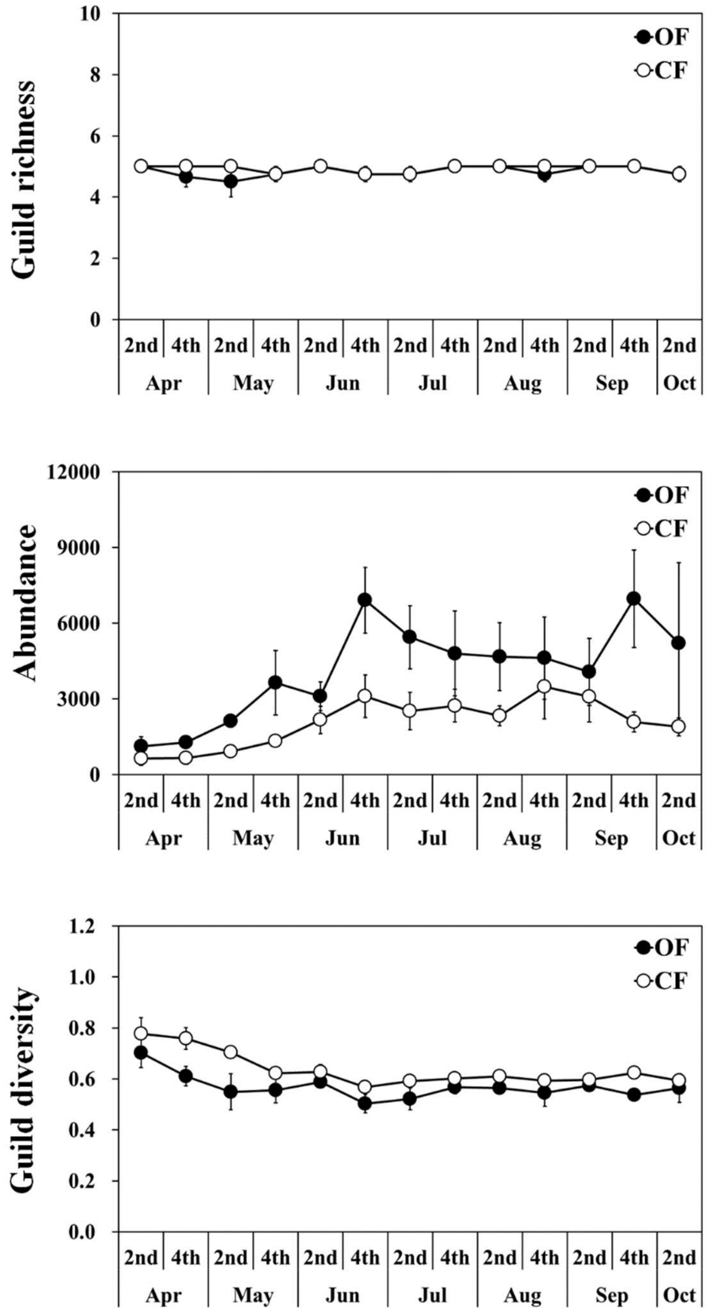


Fig. 74. Seasonality of biodiversity of arthropod guilds (mean±SE) in organic and conventional apple orchards (DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong).

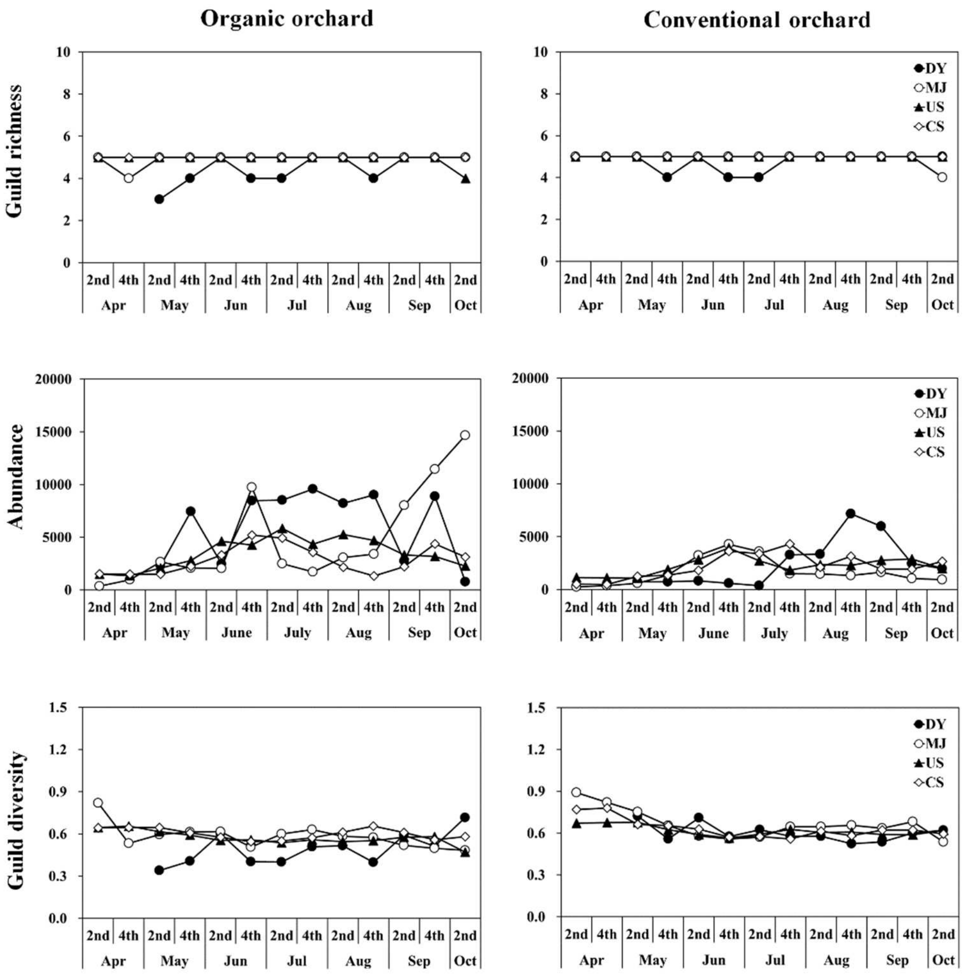


Fig. 75. Seasonality of biodiversity of arthropod guilds in organic and conventional apple orchards (DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong).

2. Spider communities and guilds

2.1. Comparison of biodiversity indices of spider communities

Overall, the species richness of spider communities was conspicuously higher in organic orchards than in conventional orchards (t [49] = 7.85, $P < 0.001$) (Table. 26-27). The species richness in organic orchards was in the range of 9.15±0.90 to 11.31±1.06 (mean±SE), with the highest in Cheongsong area and the lowest in Muju area, and that in conventional orchards was in the range of 6.15±0.56 to 7.46±0.80 (mean±SE) with the highest in Uiseong area and the lowest in Muju area. The abundance of spider communities was also found to be more than double that of organic orchards compared to conventional orchards (t [49] = 8.17, $P < 0.001$) (Table 26). The abundance in organic orchards was in the range of 106.60±12.40 to 235.40±33.25 (mean±SE), with the highest in Uiseong area and the lowest in Danyang area, and that in conventional orchards was in the range of 49.60±4.23 to 130.40±18.44 (mean±SE) with the highest in Uiseong area and the lowest in Muju area (Table 6). However, the species diversity of spider communities was statistical differences between organic and conventional orchards (t [49] = 2.33, $P < 0.05$) (Table 26). -The species diversity in organic orchards was in the range of 3.11±0.37 to 5.81±0.80 (mean±SE), with the highest in Danyang area and the lowest in Uiseong area, and that in conventional orchards was in the range of 2.79±0.40 to 4.71±0.72 (mean±SE) with the highest in Cheongsong area and the lowest in Uiseong area (Table 27).

Table 26. Comparison of the biodiversity indices of spider communities in organic and conventional orchards

Diversity index	Farming system[a]		Paired *t*-test		
	OF (mean ± SE)	CF (mean ± SE)	*df*	*t*	*P*
Species richness	10.38±0.48	6.86±0.33	49	8.65	**<0.001**
Abundance	63.88±5.37	29.38±3.45	49	8.17	**<0.001**
Species diversity	4.29±0.30	3.55±0.28	49	2.33	**0.024**

[a]OF, organic farming; CF, conventional farming

Table 27. Comparison of the biodiversity indices of spider communities in organic and conventional orchards by study area

Diversity Index	Study area[a]	Farming system[b] OF (mean±SE)	CF (mean±SE)	*df*	*t*	*P*
Species richness	DY	11.18±0.94	6.36±0.61	10	6.40	**<0.001**
	MJ	9.15±0.90	6.15±0.56	12	5.37	**<0.001**
	US	10.00±0.92	7.46±0.80	12	2.74	**0.017**
	CS	11.31±1.06	7.38±0.60	12	4.22	**0.001**
Abundance	DY	48.45±8.90	26.00±3.33	10	3.54	**0.005**
	MJ	58.23±9.40	19.08±2.54	12	7.65	**<0.001**
	US	90.54±11.68	50.15±10.87	12	3.94	**0.002**
	CS	55.92±9.41	21.77±1.98	12	3.05	**0.010**
Species diversity	DY	5.81±0.80	3.19±0.54	10	3.68	**0.004**
	MJ	3.51±0.43	3.45±0.37	12	0.00	0.998
	US	3.11±0.37	2.79±0.40	12	0.83	0.420
	CS	4.95±0.48	4.71±0.72	12	0.61	0.556

[a]DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong
[b]OF, organic farming; CF, conventional farming

2.2. Comparison of biodiversity indices of spider guilds

Unlike the results of the biodiversity analysis on the spider communities, spider guilds were no statistical difference in guild richness and diversity between farming systems except for abundance (Table 28). The guild richness in organic orchards was in the range of 3.31±0.33 to 4.54±0.31 (mean±SE), with the highest in Uiseong area and the lowest in Muju area, and that in conventional orchards was in the range of 3.00±0.30 to 4.00±0.32 (mean±SE) with the highest in Uiseong area and the lowest in Danyang area (Table 29). The abundance of spider guilds was also found to be more than double that of organic orchards compared to conventional orchards (t [49] = 8.17, $P < 0.001$) (Table 28). The abundance in organic orchards was in the range of 48.45±8.90 to 90.54±11.68 (mean±SE), and that in conventional orchards was in the range of 19.08±2.54 to 50.15±10.87 (mean±SE). In both organic orchards and conventional orchards, the abundance was highest in Uiseong area, but the lowest was in the Danyang area from organic orchards and Muju area from conventional ones, showing differences between farming methods (Table 29). The guild diversity in organic orchards was in the range of 0.88±0.15 to 1.23±0.13 (mean±SE), with the highest in Danyang area and the lowest in Muju area, and that in conventional orchards was in the range of 0.99±0.14 to 1.56±0.22 (mean±SE) with the highest in Cheongsong area and the lowest in Danyang area (Table 29).

Table 28. Comparison of the biodiversity indices of spider guilds in organic and conventional orchards

Diversity index	Farming system[a]		Paired *t*-test		
	OF (mean ± SE)	CF (mean ± SE)	*df*	*t*	*P*
Guild richness	3.88±0.18	3.54±0.15	49	1.27	0.208
Abundance	63.88±5.37	29.38±3.45	49	8.17	**<0.001**
Guild diversity	1.01±0.06	1.22±0.08	49	1.81	0.076

[a]DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong
[b]OF, organic farming; CF, conventional farming

Table 29. Comparison of the biodiversity indices of spider guilds in organic and conventional orchards by study area

Diversity Index	Study area[a]	Farming system[b] OF (mean±SE)	CF (mean±SE)	*df*	*t*	*P*
Guild richness	DY	4.27±0.38	3.00±0.30	10	2.16	0.056
	MJ	3.31±0.33	3.15±0.22	12	0.18	0.862
	US	4.54±0.31	4.00±0.32	12	1.41	0.184
	CS	3.46±0.29	3.92±0.31	12	1.09	0.296
Abundance	DY	48.45±8.90	26.00±3.33	10	3.54	**0.005**
	MJ	58.23±9.40	19.08±2.54	12	7.65	**<0.001**
	US	90.54±11.68	50.15±10.87	12	3.94	**0.002**
	CS	55.92±9.41	21.77±1.98	12	3.05	**0.010**
Guild diversity	DY	1.23±0.13	0.99±0.14	10	1.09	0.301
	MJ	0.88±0.15	1.19±0.12	12	1.80	0.096
	US	1.06±0.10	1.10±0.09	12	0.25	0.807
	CS	0.90±0.09	1.56±0.22	12	2.62	**0.022**

[a]DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong
[b]OF, organic farming; CF, conventional farming

2.3. Comparison of seasonal fluctuation of spider communities

In the seasonal patterns of the biodiversity of spider communities, the species richness and the abundance showed a mountain-shaped curve with a peak in the middle of the survey, and in the case of species diversity, multiple peaks were observed. Overall, the species richness, abundance, and diversity all tended to decrease toward the latter half of the survey. The peak of species richness appeared with one peak in the 4^{th} week of June in organic orchards and the 2^{nd} week of July in conventional orchards. Likewise, the abundance peak appeared with one peak in organic orchards in the 2nd week of July and the 4^{th} week of June in conventional orchards. However, the peak of species diversity was observed in the 2^{nd} week of May and in the 4^{th} week of July in the organic orchard, and three peaks in the 4^{th} week of May, the 4^{th} week of June, and the 2^{nd} week of August in the conventional orchard (Fig. 76-77).

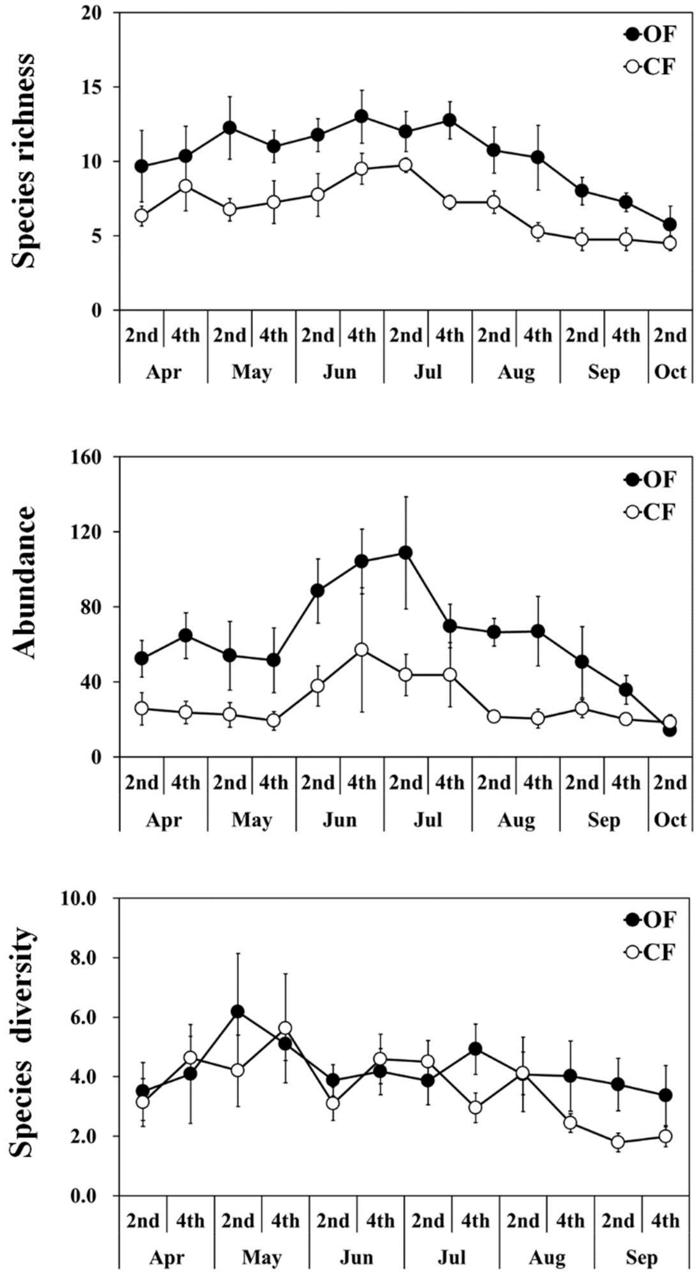


Fig. 76. Comparison of the average seasonality of biodiversity of spider communities (mean±SE) in organic and conventional apple orchards (DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong).

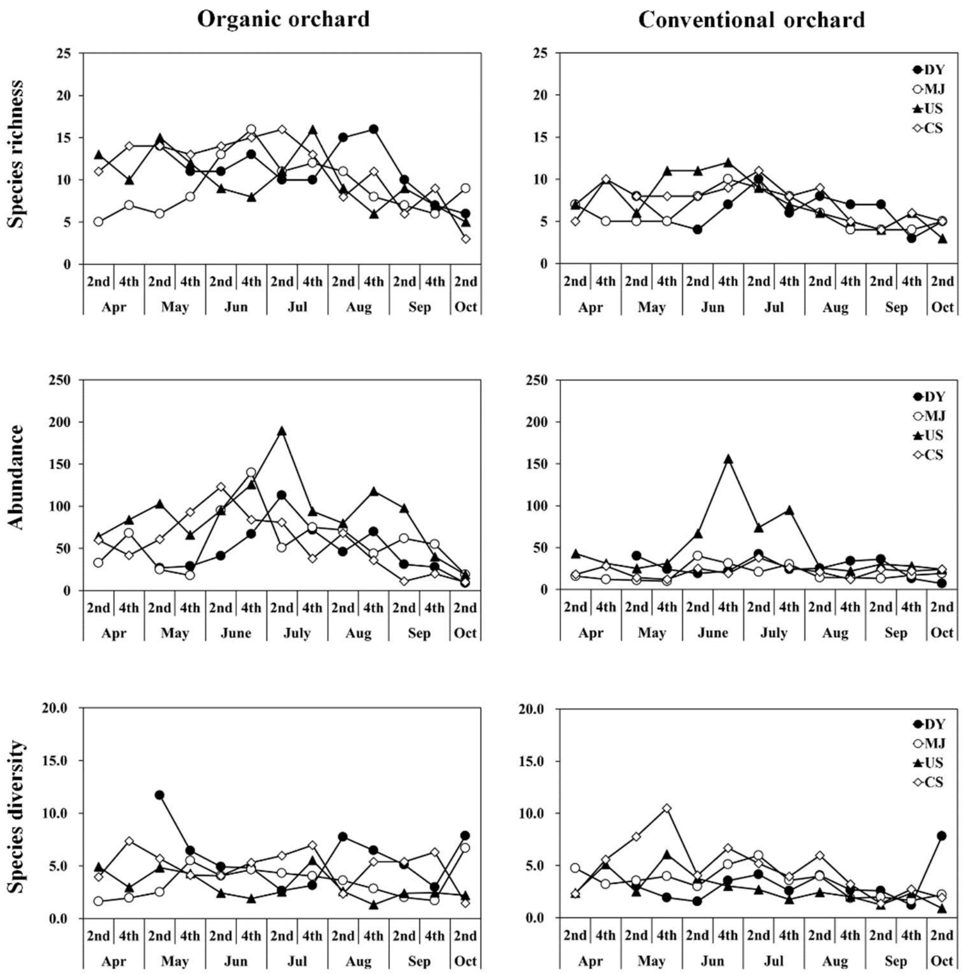


Fig. 77. Seasonality of biodiversity of spider communities in organic and conventional apple orchards (DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong).

2.4. Comparison of seasonal fluctuation of spider guilds

The seasonal fluctuations in the biodiversity of spider guilds were observed with similar results to that of spider communities. All the guild richness and abundance tended to decrease toward the latter half of the survey, similar to the tendency of the spider community. The peaks of guild richness were observed in organic and in conventional orchards in the 4th week of June in organic and in the 2nd week of July. The peaks of abundance were observed in organic and in conventional orchards in the 2nd week of July in organic and in the 4th week of June. However, the occurrence patterns of guild diversity in organic and conventional orchards differed. In organic orchards, three peaks were observed in the 2^{nd} week of April, the 4^{th} week of May, and the 2^{nd} week of September, but in conventional were observed in the 4^{th} week of May, the 2^{nd} week of July, and the 4^{th} week of September (Fig.78-79).

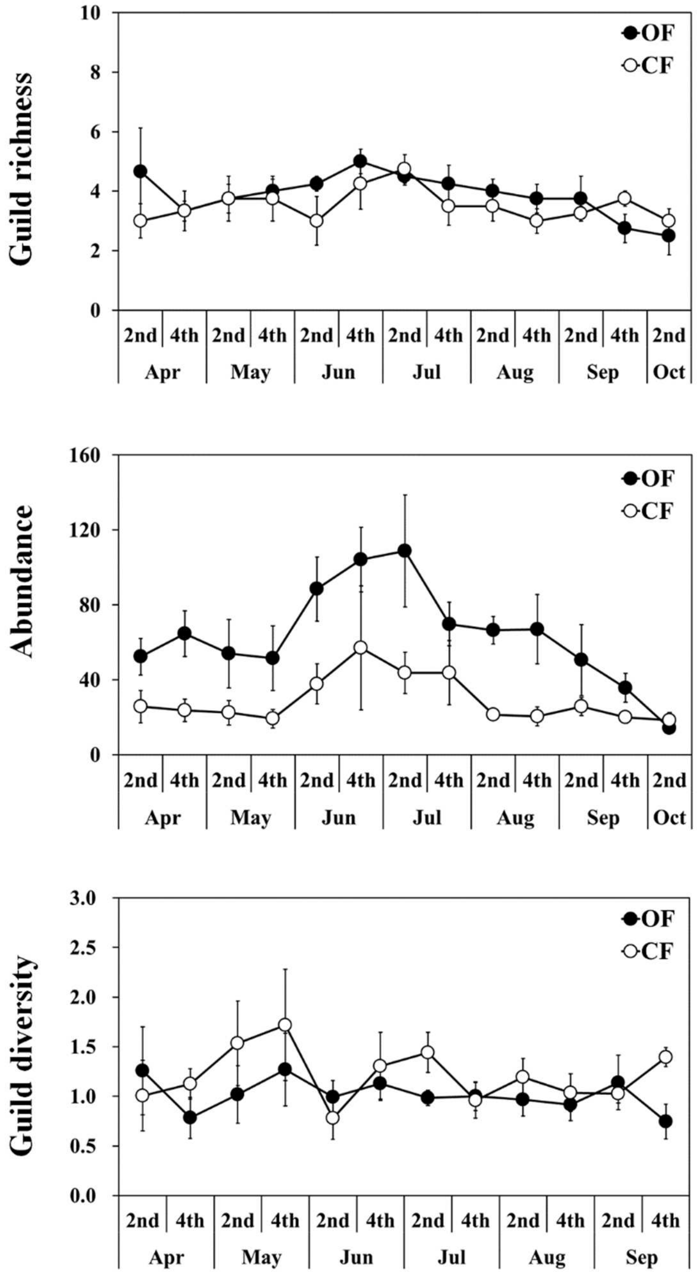


Fig. 78. Comparison of the average seasonality of biodiversity of spider guilds (mean±SE) in organic and conventional apple orchards (DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong).

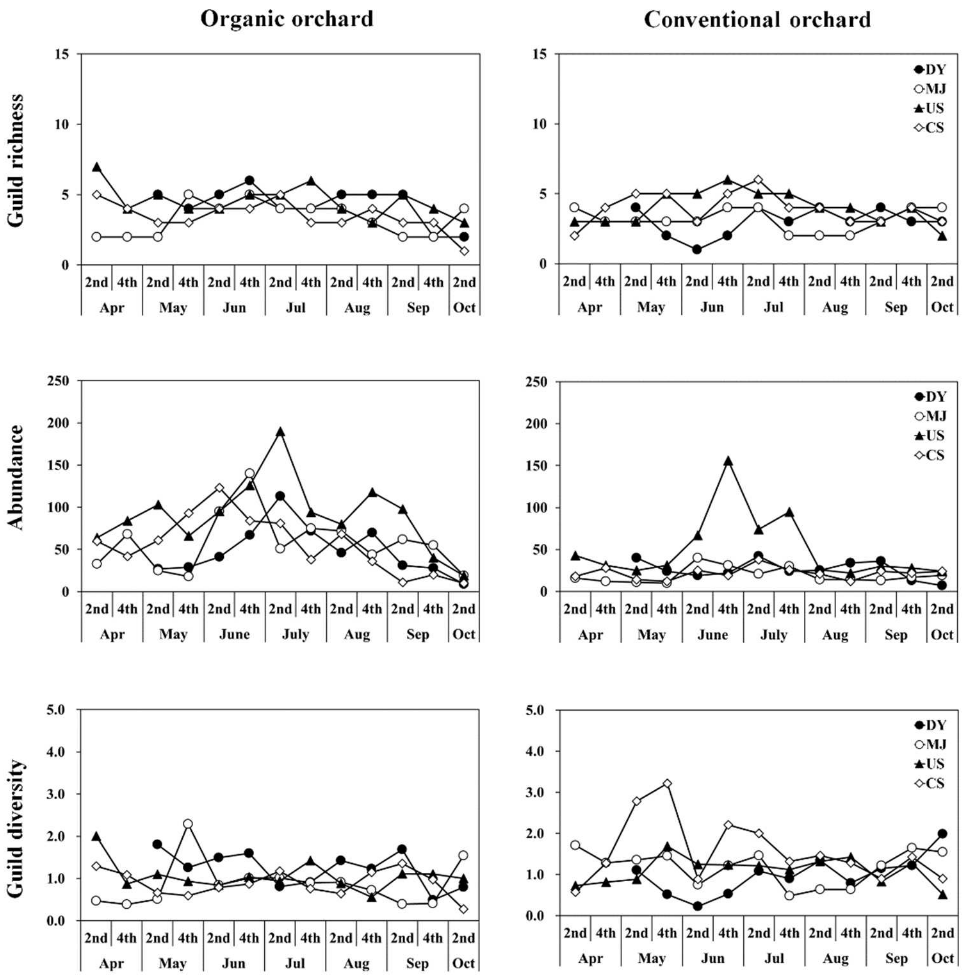


Fig. 79. Seasonality of spider guilds biodiversity of spider guilds in organic and conventional apple orchards (DY, Danyang; MJ, Muju; US, Uiseong; CS, Cheongsong).

IV. Discussion

Section i. Comparison of arthropod community structure between organic and conventional apple orchards

1. Arthropod (Acari, Collembola, and Insecta) communities

In most cases, both understory and arboreal habitats are present within orchards. The structural complexity and heterogeneity of the fruit tree thus favor the diversity of the arthropod community (Simon et al., 2010). Although it is known that orchards are favorable habitats for many arthropod species, systematic studies on the arthropod community in orchards worldwide are still insufficient. Also, there are few studies on arthropod communities in apple orchards in Korea. Research on the arthropod community in Korean apple orchards has been mainly focused on apple insect pests and natural enemies (Kim et al., 1995; Kim et al., 2003), and Lee et al. (1997) investigated the arthropod fauna in apple orchards during the winter period. The present study is differentiated because it is the first research to compare the arthropod community structure according to the apple orchard management method during the entire season of apples in Korea.

In the present study, six orders, i.e., Acari, Collembola, Coleoptera, Diptera, Hemiptera, and Hymenoptera, were dominant by showing high species richness and abundance regardless of the study area or farming system. In general, a habitat environment for arthropods similar to the current organic orchard is the abandoned apple orchard. Because the abandoned orchard is a stable environment without artificially substances applicated, it can be said that it is similar to the environment of an organic apple orchard where the input of synthetic chemical substances is suppressed. Šťastná and Psota (2013) surveyed the occurrence of arthropods in an abandoned apple orchard without management in the Czech Republic. Of the representatives of eleven orders, the Coleoptera was represented most frequently, followed by the Hymenoptera and Diptera, consistent with the present study results. In addition, there was a study on the arthropod community in the pear orchard as one of the environments similar to the apple orchard (Kim et al., 2011). They investigated arthropod communities in pear orchards and found that Collembola, Coleoptera, and Araneae dominate arthropod community structure among arthropods. Recently, in Korea, Kim and Jung (2021) reported that the Coleoptera was dominant in ground-dwelling assemblages of arthropods in organic and conventional apple orchards, and the abundance of carabid beetles which is truly epigean was higher in organic orchards than in conventional orchards, similar to the results of this study.

The six families, Ceratozetidae (Acari), Entomobryidae (Collembola), Carabidae and Staphylinidae (Coleoptera), Diapriidae, and Formicidae (Hymenoptera) were statistically different between the farming systems. Carabidae and Staphylinidae are representative natural enemies in the orchard ecosystem among these six dominant families. Although there was no difference in the treatment frequency for pest control in organic and conventional apple orchards, the natural enemy group showed higher abundance in organic farming. This is because the use of synthetic chemicals is regulated in organic farming.

Oribatid mites and Collembola represent decomposers responsible for organic matter and the material cycle (Behan-Pelletier, 1999). As a result of this study, the oribatid mite (Ceratozetidae) showed higher abundance in conventional farms, presumably because physical disturbance was severe in organic apple orchards where mowing was more frequent than in conventional farms using herbicides. In this regard, Seniczak et al. (2018) found no difference in the abundance of oribatid mites in conventional and organic vineyards in Spain, suggesting that they had herbicide tolerance. The mechanical cultivation practices were stronger in organic vineyards.

Entomobryidae of Collembola showed a higher abundance in organic orchards from the present study. The abundance of Collembola is known to be affected by low pH, high soil moisture, and organic matter content of the soil (Alvarez et al., 2001; Sousa et al., 2004; Zhimomi. et al., 2009; Begum et al. al., 2014). In addition, it has been reported that fermented cattle manure and organic fertilizer used in the organic orchards in this study increase the organic and phosphate content in the soil (Lee et al., 2012). Therefore, it is estimated that it positively affected the abundance of Collembola. Another reason for the low abundance of Collembola in conventional apple orchards is that chemical pesticides may have had a negative effect. When Collembola is exposed to chemical pesticides such as alpha-cypermethrin, its reproduction is severely affected (Styrishave et al., 2010). Exposure to fungicides such as carbendazim, propiconazole, and triadimenol have been reported to have also a negative effect on the growth of Collembola (Frampton and Wratten, 2000).

Carabidae and Staphylinidae of Coleoptera were representative natural enemies in apple orchards, and their abundance was high in organic orchards. It has been reported that these natural enemy groups have high species richness and abundance in organic orchards and are negatively affected by chemical pesticides (Epstein et al., 2001; Nasir et al., 2015). Staphylinidae showed a clear difference in abundance between organic and conventional orchards in the present study. Shah et al. (2003) reported that the greater mobility of staphylinids, which fly more readily than most carabids, may allow them to avoid pesticide applications in conventional fields. Among the dominant families, *A. curtula* (Staphylinidae) was one of the dominant species dominating the arthropod community in apple orchards and showed statistical differences between organic and conventional orchards. Unfortunately, studies on the ecology of Stphylinidae in Korea are insufficient. However, the genus *Aleochara*, to which *A. curtula* belongs, reported as the dominant species in this study, is an important biological control agent that inhibits the occurrence of dipteran pests in Canadian agricultural ecosystems (Klimaszewski et al., 2018). It is thought that additional basic research is needed to explore the potential natural enemies used in apple orchards.

The arthropod community structure between study areas was divided into two regions, Uiseong and Cheongsong, and Danyang and Muju, but no statistical difference was found. The farming system and landscape affect the reproduction, species richness, and abundance of arthropods in agricultural ecosystems (Diekötter et al., 2010). The arthropod community structure was generally different depending on the study area and the farming system, but it has not been clearly differentiated by the farming system. The results of similarity analysis by farming method showed heterogeneity of arthropod communities between organic and conventional orchards in all regions except for the Cheongsong area. This means that, even in the same area, the arthropod community structure can differ depending on the farming system. A study on changes in community structure also showed that the arthropod community structures were heterogeneous between organic farming and conventional farming within the same region (Lee et al., 2013; Kim et al., 2018). This study also confirmed that organic farming positively affects arthropod communities in agricultural ecosystems, including apple orchards. However, there is little research on how organic agricultural materials used to grow crops affect the arthropod community.

Through further systemic research, an organic farming system should be established by considering the use of organic materials and habitat management, which positively affect the arthropod community.

2. Spider communities

Spiders are important predators that play essential roles in suppressing pest populations in agricultural ecosystems (Shepard et al., 1974; Riechert and Lockley, 1984; Nyffeler and Sunderland, 2003). The species richness and abundance of spider communities in agricultural ecosystems can be as high as in natural ecosystems (Turnbull, 1973; Tanaka, 1989; Riechert, 1981). Among natural enemies occurring in orchards, spiders are the most abundant and diverse throughout the season in all strata, i.e., tree canopies, ground, and understory vegetation (Olszak et al., 1992; Salman et al., 2020).

Most of the collected spiders were epigean in this study. Therefore, the species richness and abundance of spiders inhabiting the above-ground are not expected to be as low as the study results, but many spider species may not be collected due to the lack of favorable habitat for shelter or food sources in above-ground stems. In addition, the vegetation survey around the above-ground leaves had to be collected by sweeping or beating, but it was impossible due to the growing conditions in apple orchards.

As a result of the survey of spider colonies in the apple orchard, both the species richness and the abundance were significantly higher in the organic orchard. This result is consistent with other studies on the spider community in different agricultural ecosystems. Studies have shown that insecticides in conventional farming reduce the population density of spiders (Vickerman and Sunderland, 1977; Basedow et al., 1985; Mansour et al., 1992; Stark et al., 1995). Especially, hunting spiders collected in this study are almost epigean and suffer more damage than webbing spiders (Specht and Dondale 1960, Legner and Oatman 1964, Bostanian et al. 1984). In addition, it is known that the high abundance of spiders is more effective in suppressing pests (Riechert and Lawrence, 1997; Symondson et al., 2002). The organic management system showed high variation in the community composition of spiders than the conventional system (Porcel et al., 2016).

So far, studies on spider communities in Korean orchards with similar environments to those in apple orchards have been conducted in mulberry orchards (Paik et al., 1973; An and Im, 1977, 1978, 1983; Im, 1983, 1984; An et al., 1985), pear orchard (Song et al., 2019), vineyard (Kim et al., 2002), and tangerine orchard (Kim et al., 1996). This is the first time to analyze the spider community in apple orchards. Of the 94 spider species, 16 species have been reported only in mountainous areas in Korea so far. 60 species have been reported from other orchards with similar environments to apple orchards, and 72 species are common in agricultural ecosystems, including rice fields, uplands, and mountain areas (Kim et al., 2016).

In conclusion, the analysis of spider communities shows that the domestic apple orchards are a semi-natural environment strongly influenced by the mountainous area and the surrounding agricultural ecosystem.

The Lycosidae and Linyphiidae are dominant spider families that are the most important biological control agents in temperate agroecosystems (Toft, 1989; Wise, 1993; Feber et al., 1998; Samu and Szinetar, 2002; Pfiffner and Luka, 2003). These two families also dominated our results from both organic and conventional orchards. The suppressive effects of spiders differ according to foraging strategies, i.e., webbing in Linyphiidae (sit and wait foraging strategy) and hunting in Lycosidae (pursue and kill foraging strategy) (Uetz, 1992).

In general, regardless of the ecosystem type, the occurrence peak of hunting spiders is earlier than that of webbing spiders. In this study, the peak period of the development of hunting lycosid spiders is faster than that of webbing linyphiid spiders and is related to the growth of vegetation within the orchard. The introduction of the Linyphiidae was delayed until a webbing space with vegetation development was formed. However, in general, seasonal fluctuations of arthropods, including spiders, vary depending on the region, and there is no clear trend even in areas where the same crop is grown. Probably, there are too many elements influencing the seasonal fluctuation of arthropods. Voltinisms may also affect the fluctuation. Relatively big spiders of the family Lycosidae mostly have one abundance peak in the growing season, but it fluctuates throughout the year for species belonging to the family Linyphiidae (Bel’skaya and Esyunin, 2003; Jõgar et al., 2004).

Phenological differences in the spider species depending on the environment type were also noted (Szymkowiak and Woźy, 1998; Samu and Szinetar, 2002). Kobayashi (1961) and Kiritani et al. (1972) reported that the peak in population density of spiders generally coincides with an increase in insect pests. The spider community structure between the study areas, the Danyang, Uiseong, and Cheongsong areas were statistically similar, and Muju area showed structural heterogeneity. As described above, the spider community is affected not only by the surrounding environment but also by the climate or topographical conditions of the area. A semi-natural environment such as an apple orchard has a locality of species composition different from other areas. Leasar and Umzicker (1978) showed that humidity and temperature are the most critical factors affecting the distribution of spiders. In general, farming systems within agricultural ecosystems are another important factor that changes the composition of the biological community either quantitatively or qualitatively, and agricultural ecosystems that cultivate the same crops have some commonality depending on the area. Many reports show that the occurrence density of natural enemies in organic farming is higher than in conventional farming (Hesler et al., 1993; Wyss et al., 1995; Hole et al., 2005). For epigeal spiders, several studies have reported that species richness and abundance are more abundant in organic farming than in conventional (Pfiffner and Luka, 2003; Cardenas et al., 2006; Pekar and Koucourek, 2004). However, even organic farming can have a different effect on the epigeal spider communities depending on the material used for pest control. Biological pesticides specific to pests are less toxic to spiders (Bajwa and Aliniazee, 2001), but a wide range of pesticides, such as spinosad or pyrethrin, can negatively affect the spider's abundant and specificity (Mazzia et al., 2015). For example, biopesticides that only act on specific pests, such as *Bacillus thuringiensis* or granulosis virus, are less toxic to epigeal spider communities (Bajwa and Aliniazee, 2001), but a broad-spectrum insecticide, such as spinosad or pyrethrin, can negatively affect their abundance and species richness (Bahlai et al., 2010).

Although the organic apple orchards surveyed in this study used different agricultural materials, the abundance of Linyphiidae and Lycosidae, the dominant natural enemies of the apple orchard, was higher in the organic orchard than in conventional ones. These results suggest that the application of organic farming, including the agricultural materials used, positively preserved the spider community. Further studies on the effects of agricultural materials used in organic farming and farming practices such as weed and soil management on spider communities may help stabilize their communities and curb the occurrence of natural pests.

3. The main arthropod species in Korean apple orchard

In the present study, 324,606 arthropod (Acari, Collembola, Insecta, and Spider) individuals were identified as 349 species in 103 families belonging to 13 orders through two sampling methods (leaf sampling, yellow sticky trap) in ground-above and one sampling method (pitfall trap) in the ground in apple orchards.

Among them, the above-ground arthropod samplings were identified as 67,026 individuals in 96 species, 48 families, and 10 orders, while 257,580 individuals in 327 species, 93 families, and 11 orders were identified as in the ground, showing a significant difference. These results confirm that the ground-above sampling method used in this study is unsuitable for collecting specific taxonomies, such as Coleoptera and Spider, whereas the ground sampling method is biased toward them.

Only 27 species collected from all surveyed orchards in this study were selected as the main arthropod species of the Korean apple orchard. Of these, 16 species were collected both above-ground and ground, and 11 species were sampled only on the ground. Even though the bias of the sampling method was evident, it was encouraging that the consistent conclusion was that the abundance of arthropod species collected and the m

3ain arthropod species in organic orchards were higher than in conventional orchards.

Within the orchards, arthropods the above-ground were generally sampled by beating the branch, vacuuming the tree foliage, hand-collecting, and placing yellow sticky traps in the canopies (Bassett et al., 1997; Wallis and Shaw, 2008; Yi et al., 2012). Beat sampling may be suitable for collecting arthropods inhabiting canopy or flying insects. However, this method was impossible due to the growing conditions in apple orchards. Taxa composition varies depending on sampling methods, and recommended using multiple methods to estimate community assemblages by minimizing sampling bias (Shanovich et al., 2020). In further studies, the above-ground survey in apple orchards, through the application of various sampling methods, will contribute to a detailed comparative study of arthropod community structure according to the farming systems along with the selection of main arthropod species in apple orchards.

Section ii. Comparison of ecological guild structure between organic and conventional apple orchards

1. Arthropod (Acari, Collembola, and Insecta) guilds

The arthropods in organic and conventional orchards were categorized into five ecological guilds (detritivores, herbivores, pollinators, predators, and parasitoids). All five guilds appeared regardless of the survey area and farming system. However, the abundance of detritivores, predators, and parasitoids was higher in organic orchards. These results suggest that the supply of preferred habitat and food sources was more abundant in organic orchards than in conventional orchards. Although weeds in the agricultural environment are classified as agricultural pests, they play an essential role in the agroecosystem by providing valuable ecological services for arthropods and their natural enemies (Norris and Kogan, 2005; Haddad et al., 2011). In general, organic orchards in the present study area were mowed 2 -5 times between the 4th week of April to the 2nd week of May and the 2nd week of August to the 4th week of September, and except for this time, the ground surface around the apple tree was covered with various weeds. It can be said that weeds were more frequently distributed in organic orchards than in conventional apple orchards due to herbicide applications in later orchards. Möller et al. (2020) found similarly that parasitoids' abundance and species richness were higher in the weed conservation area. The abundance and diversity of natural enemies in perennial crops may be affected positively by the surrounding habitats, although the patterns are less clear regarding the effect on species assemblage composition. Regional abiotic factors such as temperature and precipitation regimes have been shown in some instances to outweigh other factors in influencing the composition of predator communities in fruit orchards (Bogya et al., 2000).

There was no statistically significant difference in the present study, but the species richness of pollinators was higher in organic orchards and abundance in conventional orchards, respectively. The high abundance of pollinators in conventional orchards was due to the large-scale occurrence of Muscidae sp. between the 2nd and 4th weeks of September in Muju and Uiseong areas. Muscidae has been reported as a pollinator of apple orchards (Boucher et al., 2021), and it is estimated that the cause of large-scale occurrence in each study area is that the environmental conditions of micro-habitat related to their occurrence were suitable for, or many individuals are introduced from the outside following the environment preferred.

The arthropod guild structure was divided into two groups by study areas, Danyang and Muju, and Uiseong, Cheongsong, and clustered into organic and conventional orchards by the farming system.

The present study analyzed that the abundance of predators and parasitoids in organic orchards was higher than in conventional orchards. However, organic orchards are restricted to the use of agricultural materials for pest control, so it is generally difficult to respond when secondary pests occur. In order to minimize the negative impact on non-target organisms by the input of agricultural materials for pest control, a systematic long-term study on the ecological role of potential natural enemies and management measures that can increase the functions of these natural enemies is needed.

2. Spider guilds

In general, high taxonomic diversity results in a high functional diversity of spiders (Michalko and Pekar, 2016). There have been numerous attempts to classify spiders as guilds based on their diverse foraging behaviors and life-history traits with varying degrees of specificity (Uetz et al., 1991). Each spider guild divides and uses the biological resources and space they need in their habitat, and the more diverse the guild, the more comprehensive the range of insect pests they can control. Therefore, to actively use spiders in the agricultural ecosystem, it is essential to analyze the ecological guilds of these spiders. The spiders in organic and conventional orchards were categorized as eight ecological guilds (Ambushers, Foliage runners, Ground runners, Orb weavers, Space web builders, Stalkers, Wandering sheet weavers, and Wandering sheet web builders), and four guilds, ground runners, space web builders, wandering sheet weavers, and wandering sheet web builders were dominant regardless of the study area or farming system considering species richness and abundance. The most prevalent family was Lycosidae in ground runners, Theridiidae in space web builders, Linyphiidae in wandering sheet weavers, and Agelenidae in wandering sheet web builders.

The diversity and density of guilds were generally observed to be higher in organic orchards than in conventional orchards. These results suggest that organic orchards provided a variety of habitats for spiders due to more diverse vegetation structures than conventional orchards. The three guilds, space web builders, wandering sheet weavers, and wandering sheet web builders, broadly belongs to webbing spiders, and ground runners belong to hunting spiders. These four dominant guilds are ecologically mainly composed of species that use the ground or near-ground vegetation structures and are largely divided into those that use webs and those that do not use webs, and they rely on vegetation for some period of their lives, either for finding food, retreats or for web building. The vegetation structure is therefore expected to influence the diversity of spiders found in the habitat. Uetz (1991) suggests structurally more complex plants can support a more diverse spider community. Downie et al. (1999) and New (1999) have demonstrated that spiders are extremely sensitive to small changes in the habitat structure, including habitat complexity and microclimate characteristics. Thus, the physical structure of the environment has an important influence on the habitat preferences of spider species, especially webbing spider species (Hurd and Fagan, 1992). Recent studies also revealed that the functional diversity of natural enemies, including spiders, was altered by the management type (Mazzia et al., 2015). Moreover, a recent meta-analysis showed that among various pest-control systems, the organic one had an overall positive effect on spider abundance (Garratt et al., 2011).

The seasonal fluctuations of four dominant spider guilds appeared in serrated forms in organic and conventional orchards without clear trends, and the reason for this phenomenon was broadly discussed in Section i. The abundance and diversity of natural enemies in perennial crops may be affected positively by the surrounding habitats, although the patterns are less clear regarding the effect on species assemblage composition. Regional abiotic factors such as temperature and precipitation regimes have been shown in some instances to outweigh other factors in influencing the composition of predator communities in fruit orchards (Bogya et al., 1999b; D'Alberto et al., 2012).

The spider guild structure was divided into two groups by study areas, Danyang area and Uiseong, Muju, and Cheongsong areas, and clustered into organic and conventional orchards by the farming system. The results on the cluster of the spider guild by study areas were different from that of the community, which is thought to be because the spider guild was sensitive to the habitat structure depending on the difference in the topography and vegetation structure of the study area, the surrounding ecosystem, and the management system of the orchard. From the results, vegetation structure and farming system seem to influence the spider guild composition on the family level because similar families cluster within a similar habitat type. Overall, the role of spiders as predators increases in areas where the guild is diverse. Therefore, a spider assemblage containing species from diverse guilds may provide better control of crop pests due to their ability to utilize a broader range of prey and habitat types (Marc and Canard, 1999).

Section ⅲ. Comparison of biodiversity of arthropod communities and guilds in organic and conventional apple orchards

1. Arthropod (Acari, Collembola, Insecta) communities and guilds

Biodiversity is a simple contraction of biological diversity and is the total of all biotic variation from the level of genes to ecosystems (Purvis and Hector, 2000). Biodiversity is essential for the processes that support all life and is a measure of variation. In the present study, the species richness, abundance, and species diversity of arthropod communities were conspicuously higher in organic orchards than in conventional orchards. Several studies showed that organic farming systems positively impacted richness and abundance compared with conventional ones (Benegtsson et al., 2005; Hole et al., 2005; Crowder and Jabbour, 2014). Organic management increases the abundance, diversity, and service of natural enemies in various perennial and annual crop systems (Muneret et al., 2018; Todd et al., 2011). The positive effects of biodiversity on the orchard system are related to pest control and are mainly based on increased plant diversity. Arthropods in charge of ecosystem services, including natural enemies, are positively affected by species richness and abundance as the habitat heterogeneity is high, and the habitat heterogeneity strongly depends on plant diversity (Janzen, 1987).

Biodiversity in apple orchards can increase by appropriately managing surrounding vegetation, insect pests, and weeds. Therefore, additional research should be conducted to develop these various management techniques so that major ecological functional groups such as arthropod community structures and predators and decomposers can contribute to sustainable agriculture.

2. Spider communities and guilds

Spiders (Order, Araneae) are distinctive and one of the most diverse predators, abundant in virtually any terrestrial ecosystem with over 50,000 described species in 131 families (World Spider Catalog, 2022). Spiders contribute significantly to biodiversity in agroecosystems and are essential components of natural pest control programs (Symondson et al., 2002). As mentioned above, spiders are one of the most important predator groups that inhabit all terrestrial ecosystems, and a high diversity of spiders in the agricultural ecosystem is essential (Riechert et al., 1997).

Although there was no statistical difference in the guild richness and guild diversity of spiders depending on the farming system, the species richness, abundance, and species richness of spider communities were significantly higher in organic fields than in conventional orchards, indicating that the role of spiders, a critical predator group in the agricultural ecosystem, is much stronger than that of conventional orchards. It can be said that their role as biological control agents for insect pest suppression is very high. Because many spider species occupy various habitats in agroecosystems and prey upon a wide range of insect pests of various sizes, making them useful agents in biological control (Mansour et al., 1981; Nyffeler and Benz, 1987; Nentwig, 1989; □iechert and Bishop, 1990). Species richness, abundance, and diversity of natural enemies are also affected by different elements of the agroecosystem (Öberg, 2009; Martin et al., 2016), similar to the composition of the spider community. These elements include abiotic and biotic factors at the local and regional scales, agricultural practices by farming systems, and the structure and diversity of habitats in the surrounding landscape. The characteristics of the vegetation, its heterogeneity and complexity both within and adjacent to the crop, can affect the diversity and abundance of the natural enemy populations (Bianchi et al., 2006; Martin et al., 2016). Most of the apple orchards in Korea were built close to the mountainous areas. The presence of an adjacent woody habitat like a mountain was shown to positively affect the abundance and diversity of many groups of predators in apple orchards (Sackett et al., 2008; Lefebvre et al., 2016).

Spider assemblages and their diversity are often used as indicators of management practices because their species composition and abundance are affected by changes in habitat structure (Gunnarsson, 1990; Uetz, 1991; Wise, 1993) and microclimate (Bell et al., 2001; Marc et al., 1999). Species diversity is calculated based on the number of species and abundance. Therefore, studying the biodiversity of a specific biological group in the agricultural ecosystem is desirable throughout the entire cultivation period. However, if the purpose of the study is a simple comparative evaluation of the agricultural ecosystem, it is necessary to shorten the monitoring time, manpower, and cost. Based on the results of this study, it is determined that it is desirable to conduct a spider survey at the apple orchard in May and July when the peaks of the diversity index are shown. The critical point in strengthening biological control by spiders and preserving their biodiversity is considered to be pest control methods. Species richness, abundance, and diversity of spiders are known to be significantly higher than in organic farming, where no chemical pesticides are used (Hesler et al., 1993; Way and Heong, 1994; Wyss et al., 1995, Hole et al., 2005). The present study results are also consistent with reports on the positive effects on spider biodiversity.

The study of spider community structure and biodiversity is expected to provide important ecological information for effective use of natural enemies and is necessary to maintain useful arthropod biodiversity in orchard ecosystems.

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Appendices

Appendix 1. *Acari captured in organic farming and conventional farming throughout the studied period*

Family	Scientific name	Studied area[a]								Ecological guild[b]	Sampling method[c]	Total
		Danyang		Muju		Uiseong		Cheongsong				
		OF	CF	OF	CF	OF	CF	OF	CF			
Anystidae	*Anystidae* sp.1	267	20	15	1	52				Pre	PT	355
	Anystidae sp.2					11				Pre	PT	11
Ceratozetidae	Ceratozetidae sp.1	334	1730	447	5213	2412	192	508	429	Det	PT	11265
	Ceratozetidae sp.2					5	882	144	2194	Det	PT	3225
	Ceratozetidae sp.3					6	3737		127	Det	PT	3870
Digamasellidae	*Dendrolaelaps* sp.1	185	16	33	41	2755	4	49	137	Pre	PT	3220
	Dendrolaelaps sp.2					11	29	25	61	Pre	PT	126
	Dendrolaelaps sp.3					2	4	5		Pre	PT	11
	Dendrolaelaps sp.4					90	302			Pre	PT	392
Galumnidae	Galumnidae sp.1					4114	2908			Det	PT	7022
	Galumnidae sp.2					2276	2782			Det	PT	5058
	Galumnidae sp.3						110			Det	PT	110
Oppiidae	*Oppiella nova*	868	2965	2058	1892	6		768	266	Det	PT	8823
	Oppiidae sp.1						23			Det	PT	23
Phytoseiidae	*Neoseiulus womersleyi*	6		42	8	6	16			Pre	PT, LS	78
Scheloribatidae	*Scheloribatidae* sp.1					44	98			Det	PT	142
Tetranychidae	*Panonychus ulmi*	3		181		5		4		Her	LS	193
	Tetranychus urticae	22	110	240	238		217	9	70	Her	PT,YT,LS	906
Total		**1685**	**4841**	**3016**	**7393**	**11795**	**11304**	**1512**	**3284**	-	-	**44830**

[a]OF: organic farming, CF: conventional farming; [b]DET: Detritivore, Her: Herbivore, Par: Parasitoid, Pre: Predator, Pol: Pollinator; [c]LS: Leaf sampling, PT: Pitfall trap, YT: Yellow sticky trap

Appendix 2. *Collembola captured in organic farming and conventional farming throughout the studied period*

Family	Scientific name	Studied area[a]								Ecological guild[b]	Sampling method[c]	Total
		Danyang		Muju		Uiseong		Cheongsong				
		OF	CF	OF	CF	OF	CF	OF	CF			
Dicyrtomidae	*Ptenothrix* sp.1	7	734			698				Det	PT	1439
	Ptenothrix sp.2	32								Det	PT	32
	Ptenothrix sp.3					3				Det	PT	3
Entomobryidae	*Entomobrya vigintiseta* -	915		16617				1070		Det	PT	18602
	Homidia koreana -			3319	65	184	412	1390	73	Det	PT	5443
	Homidia mediaseta -	27952	14915	7231	2640	4851	379	9932	11330	Det	PT	79230
	Homidia sp.1					71	81		20	Det	PT	172
Hypogastruridae	*Ceratophysella* sp.1					158	115		47	Det	PT	320
Isotomidae	*Desoria* sp.1	19505	10	21439	808	583	487			Det	PT	42832
	Desoria sp.2			464		5		31	14	Det	PT	514
	Desoria sp.3					3	53	165		Det	PT	221
Katiannidae	*Sminthurinus* sp.1	40	9		39	2203		7		Det	PT	2298
	Sminthurinus sp.2	29				211				Det	PT	240
	Sminthurinus sp.3	845								Det	PT	845
Tomoceridae	Tomoceridae sp.1					9		271		Det	PT	280
Total		**49325**	**15668**	**49070**	**3552**	**8979**	**1527**	**12866**	**11484**	**-**	**-**	**152471**

[a]OF: organic farming, CF: conventional farming; [b]DET: Detritivore, Her: Herbivore, Par: Parasitoid, Pre: Predator, Pol: Pollinator; [c]LS: Leaf sampling, PT: Pitfall trap, YT: Yellow sticky trap

Appendix 3. *Insecta captured in organic farming and conventional farming throughout the studied period*

Order	Family	Scientific name	Studied area[a]								Ecological guild[b]	Sampling method[c]	Total
			Danyang		Muju		Uiseong		Cheongsong				
			OF	CF	OF	CF	OF	CF	OF	CF			
Coleoptera	Carabidae	*Amara congrua*			98	40				13	Pre	PT	151
		Amara giganteus					10				Pre	PT	10
		Amara simplicidens				20					Pre	PT	20
		Amara sp.1	14	3	11	40	4	1			Pre	PT	73
		Amara sp.2	3	3			3				Pre	PT	9
		Anisodactylus punctatipennis	90	35	72	252	102	194	321	72	Pre	PT,YT	1138
		Anisodactylus signatus brunneipennis					7				Pre	PT	7
		Anisodactylus tricuspidatus					4				Pre	PT	4
		Chlaenius micans			16	14	3	10	32		Pre	PT	75
		Chlaenius virgulifer								8	Pre	PT	8
		Chlaenius costiger					2				Pre	PT	2
		Chlaenius micans						28			Pre	PT	28
		Chlaenius naeviger	15	3	1		1				Pre	PT	20
		Coptolabrus smaragdinus					9	2			Pre	PT	11
		Cosmodiscus platynotus					5				Pre	PT	5
		Dolichus halensis	9	2	15	30	54		1	6	Pre	PT	117
		Eucarabus sternbergi					3				Pre	PT	3
		Harpalus tridens	27	31	105	11	5180				Pre	PT	5354
		Harpalus bungii	1		2					2	Pre	PT	5
		Harpalus chalcentus	11	2	19	5	38	2	5		Pre	PT,YT	82
		Harpalus discrepans	13	17	52	114	106	76	145	112	Pre	PT	635

Appendix 3. *Continued*

Order	Family	Scientific name	Studied area[a]								Ecological guild[b]	Sampling method[c]	Total
			Danyang		Muju		Uiseong		Cheongsong				
			OF	CF	OF	CF	OF	CF	OF	CF			
Coleoptera	Carabidae	*Harpalus griseus*						4			Pre	PT	4
		Harpalus niigatanus			227	19	5				Pre	PT	251
		Harpalus roninus					11				Pre	PT	11
		Harpalus sinicus	1	5	385	48			78	18	Pre	PT	535
		Harpalus sp.1		7							Pre	PT	7
		Harpalus tinctulus luteicornoides			31						Pre	PT	31
		Harpalus vicarious			30	8					Pre	PT	38
		Lesticus magnus	4								Pre	PT	4
		Nebria coreica						4			Pre	PT	4
		Nebria chinensis					1		2	1	Pre	PT	4
		Planetes puncticeps	15	3							Pre	PT	18
		Poecilus nitidicollis							1	3	Pre	PT	4
		Pterostichus microcephalus	9		29	7					Pre	PT,YT	45
		Synuchus arcuaticollis					1	37		2	Pre	PT	40
		Synuchus nitidus	10				2				Pre	PT	12
		Synuchus orbicollis						4			Pre	PT	4
	Coccinellidae	*Coccinella septempunctata*					8	1	2	1	Pre	YT	12
	Curculionidae	*Shirahoshizo rufescens*		5							Her	PT	5
		Hylobius haroldi	1								Her	PT	1
		Sipalinus gigas	4				1	1			Her	PT	6

Appendix 3. *Continued*

Order	Family	Scientific name	Studied area[a]								Ecological guild[b]	Sampling method[c]	Total
			Danyang		Muju		Uiseong		Cheongsong				
			OF	CF	OF	CF	OF	CF	OF	CF			
Coleoptera	Elateridae	*Agrypnus binodulus coreanus*	11				5				Pre	PT	16
		Ludioschema vittiger		2							Pre	PT	2
		Melanotus cete		1							Pre	PT	1
	Latridiidae	Latridiidae sp.1	23	2	12	14					Det	PT,YT	51
		Latridiidae sp.2	1	1	25	4					Det	PT	31
	Melolonthidae	*Maladera infuscata*	1								Her	PT	1
	Nitidulidae	*Glischrochilus ipsoides*	2	1							Det	PT	3
		Nitidulidae sp.1	67	4							Det	PT,YT	71
		Nitidulidae sp.2	7		3						Det	PT	10
		Nitidulidae sp.3		3	11						Det	PT	14
		Nitidulidae sp.4		3							Det	PT	3
	Scarabaeidae	*Aphodius sordidus*	1								Det	PT	1
		Aphodius uniplagiatus	1								Det	PT	1
		Onthophagus fodiens	42				23		3		Det	PT	68
		Onthophagus punctator					29				Det	PT	29
	Scolytidae	*Ambrosiodmus rubricollis*	13		5	2	33	136	3	3	Her	PT	195
		Euwallacea validus	70	12	1	2			2	3	Her	PT	90
		Scolytidae sp.1						3			Her	YT	3
		Xyleborinus saxeseni			1		11	80	75	161	Her	PT	328
		Xyleborus apicalis			11	2					Her	PT	13

Appendix 3. *Continued*

Order	Family	Scientific name	Studied area[a]								Ecological guild[b]	Sampling method[c]	Total
			Danyang		Muju		Uiseong		Cheongsong				
			OF	CF	OF	CF	OF	CF	OF	CF			
Coleoptera	Scolytidae	*Xylosandrus crasiussculus*	19	3	7	24	19	18	142	70	Her	PT	302
		Xylosandrus germanus	172	128	18	21	535	534	383	155	Her	PT,YT	1946
	Silphidae	*Necrophila jakowlewi* jakowlewi	29				9				Det	PT	38
	Staphylinidae	*Acrotona* sp.1					3				Pre	PT	3
		Aleochara curtula	247	21	46		261		94	5	Pre	PT	674
		Aleocharinae sp.1							6		Pre	PT	6
		Anotylus lewisius	6	16			4	19			Pre	PT	45
		Anotylus sp.1	87	58	80	21	1	57	4		Pre	PT,YT	308
		Anotylus sp.2	61	2	99	3	6	1	1		Pre	PT,YT	173
		Anotylus sp.3					2	1			Pre	PT	3
		Anotylus sp.4		5							Pre	PT	5
		Atheta euryptera					5		17		Pre	PT	22
		Atheta koreana					1	8	26	1	Pre	PT	36
		Atheta sp.1					17		17		Pre	PT	34
		Atheta sp.2							15	1	Pre	PT	16
		Athetini sp.1	85	2	31	5	331	2			Pre	PT	456
		Athetini sp.2	1		10	2					Pre	PT	13
		Falagria caesa			4	7					Pre	PT	11
		Lordithon Thomson sp.1					101				Pre	PT	101
		Ocypus nigroaeneus					3		8		Pre	PT	11

Appendix 3. *Continued*

Order	Family	Scientific name	Studied area[a]								Ecological guild[b]	Sampling method[c]	Total
			Danyang		Muju		Uiseong		Cheongsong				
			OF	CF	OF	CF	OF	CF	OF	CF			
Coleoptera	Staphylinidae	*Ocypus* sp.1	5	1							Pre	PT	6
		Ocypus weisei					9		6		Pre	PT	15
		Oxypoda sp.1	1								Pre	PT	1
		Paederus sp.1							5		Pre	PT	5
		Philonthus sp.1	4	2					126	13	Pre	PT	145
		Philonthus sp.2	45	18	13		12	2	34		Pre	PT	124
		Philonthus sp.3			1		8		17		Pre	PT	26
		Platydracus brevicornis	222	1	15		201	7		8	Pre	PT	454
		Platystethus cornutus							9	1	Pre	PT	10
		Proteinus crassicornis						5	4	2	Pre	PT	11
		Stenus sp.1			4						Pre	PT	4
		Zyras sp.1					3		18		Pre	PT	21
	Tenebrionidae	*Misolampidius* sp.1		7							Pre	PT	7
		Tenebrionidae sp.1	2								Det	PT	2
Dermaptera	Anisolabididae	*Anisolabella marginalis*		3							Pre	PT	3
	Forficulidae	*Anechura japonica*	3								Pre	PT	3
	Labiduridae	*Labidura riparia japonica*		3							Pre	PT	3
Diptera	Anthomyiidae	Anthomyiidae sp.1	456	315			28	19			Det	PT,YT	818
		Anthomyiidae sp.2			466	168	64	25	115	18	Det	PT,YT	856
		Anthomyiidae sp.3					17				Det	YT	17

Appendix 3. *Continued*

Order	Family	Scientific name	Studied area[a]								Ecological guild[b]	Sampling method[c]	Total
			Danyang		Muju		Uiseong		Cheongsong				
			OF	CF	OF	CF	OF	CF	OF	CF			
Diptera	Bibionidae	Bibionidae sp.1	100	122	140	1	62				Det	PT,YT	425
	Calliphoridae	Calliphoridae sp.1	23		18	228	92	95	3	66	Pol	PT,YT	525
		Calliphoridae sp.2		106	87	35	52	12	14	32	Pol	PT,YT	338
		Calliphoridae sp.3					40	47	48	31	Pol	PT,YT	166
	Chironomidae	Chironomidae sp.1	288	8	1197	1691	2393	2225	5326	978	Det	PT,YT	14106
		Chironomidae sp.2				2351	106	143	41	48	Det	PT,YT	2689
	Drosophilidae	Drosophilidae sp.1	1137	2567	505	56	2955	2417	2925	2124	Det	PT,YT	14686
		Drosophilidae sp.2	1		28	56	1997	197	304	18	Det	PT,YT	2601
		Drosophilidae sp.3	33	26	9		27	6	65	40	Det	PT,YT	206
		Drosophilidae sp.4		411			36		25		Det	PT,YT	472
	Fanniidae	Fanniidae sp.1		11	45						Det	PT	56
	Heleomyzidae	Heleomyzidae sp.1			3				139		Det	PT,YT	142
	Lauxaniidae	Lauxaniidae sp.1	42				7	10	8	4	Det	PT,YT	71
	Muscidae	Muscidae sp.1	51		5	327	671	809	411	515	Pol	PT,YT	2789
		Muscidae sp.2	2	120	162	269	242	195	218	143	Pol	PT,YT	1351
		Muscidae sp.3			5		45		60		Pol	PT,YT	110
		Muscidae sp.4			155	346					Pol	PT,YT	501
	Phoridae	Phoridae sp.1	115	54	73	14	19	157	64	180	Det	PT,YT	676
		Phoridae sp.2	12	174		5	28	128	524	260	Det	PT,YT	1131
		Phoridae sp.3			13	123	31	89	77	46	Det	PT,YT	379

Appendix 3. *Continued*

Order	Family	Scientific name	Studied area[a]								Ecological guild[b]	Sampling method[c]	Total
			Danyang		Muju		Uiseong		Cheongsong				
			OF	CF	OF	CF	OF	CF	OF	CF			
Diptera	Phoridae	Phoridae sp.4		11						9	Det	PT	20
		Phoridae sp.5							9		Det	PT	9
	Psychodidae	Psychodidae sp.1	21	59			23	918	300	1579	Det	PT,YT	2900
	Sarcophagidae	Sarcophagidae sp.1							18		Det	YT	18
	Sciaridae	Sciaridae sp.1	3721	820	1261	425	4420	3844	3061	3493	Det	PT,YT	21045
		Sciaridae sp.2	209	237	23	826	107	109	131	83	Det	PT,YT	1725
		Sciaridae sp.3						8			Det	YT	8
	Simuliidae	Simuliidae sp.1					2	68	66	10	Det	PT	146
		Simuliidae sp.2							36	17	Det	PT	53
		Simuliidae sp.3							29	23	Det	PT	52
	Sphaeroceridae	Sphaeroceridae sp.1						1			Det	PT	1
	Stratiomyidae	Stratiomyidae sp.1			8			3		2	Det	PT	13
	Syrphidae	Syrphidae sp.1	2				15	35	25	16	Pol	PT,YT,LS	93
		Syrphidae sp.2					32		7		Pol	PT,YT	39
		Syrphidae sp.3					39				Pol	PT,YT	39
	Tipulidae	Tipulidae sp.1					3	4			Det	YT	7
Hemiptera	Alydidae	*Riptortus pedestris*	13	5		1	2	5		3	Her	PT,YT	29
	Anthocoridae	*Orius* sp.1	4	2	57	1	5		9		Pre	PT,YT	78
	Aphididae	Aphididae sp.1						9			Her	YT	9
		Aphis spiraecola	682	364	409	118	25	194	30	375	Her	PT,YT,LS	2197

Appendix 3. *Continued*

Order	Family	Scientific name	Studied area[a]								Ecological guild[b]	Sampling method[c]	Total
			Danyang		Muju		Uiseong		Cheongsong				
			OF	CF	OF	CF	OF	CF	OF	CF			
Hemiptera	Aphididae	*Eriosoma lanigerum*					18				Her	PT	18
		Myzus malisuctus	172	58	380	191	64	53	580	107	Her	PT,YT	1605
	Aphrodinae	Aphrodinae sp.1	13	3							Her	YT	16
	Cicadellidae	*Bothrogonia ferruginea*	97	45			33	19	47	15	Her	PT,YT	256
	Coreidae	*Hygia lativentris*	7								Her	PT	7
	Cydnidae	*Macroscytus japonensis*								17	Her	PT	17
	Lygaeidae	*Panaorus albomaculatus*								14	Her	PT	14
Hymenoptera	Apidae	Apidae sp.1	6	1	2	5	12	13	18	20	Pol	PT,YT	77
		Apidae sp.2					9	7	18	5	Pol	YT	39
		Apis mellifera						1			Pol	PT	1
	Aphelinidae	*Aphelinidae* sp.1			15	11			52		Par	PT,YT	78
	Argidae	*Argidae* sp.1							6		Her	YT	6
	Braconidae	Braconidae sp.1	210	8	27	8	32	72	112		Par	PT,YT	469
		Braconidae sp.2	14	21	8		23	5	116		Par	PT,YT	187
		Braconidae sp.3	70	1							Par	PT,YT	71
		Braconidae sp.4	6	4	2	7					Par	PT,YT	19
	Chalcidoidea	Chalcidoidea sp.1	24		54	19	121	123	173	210	Par	PT,YT	724
		Chalcidoidea sp.2	19	10	59	3	86	160	63	159	Par	PT,YT	559
		Chalcidoidea sp.3	50	10	3		27	43	204	100	Par	PT,YT	437
		Chalcidoidea sp.4	2	66			19		6	17	Par	PT,YT	110

Appendix 3. *Continued*

Order	Family	Scientific name	Studied area[a]								Ecological guild[b]	Sampling method[c]	Total
			Danyang		Muju		Uiseong		Cheongsong				
			OF	CF	OF	CF	OF	CF	OF	CF			
Hymenoptera	Chalcidoidea	Chalcidoidea sp.5		24					5	9	Par	PT,YT	38
		Chalcidoidea sp.6								11	Par	YT	11
		Chalcidoidea sp.7								13	Par	YT	13
		Chalcidoidea sp.8								7	Par	YT	7
		Chalcidoidea sp.9								11	Par	YT	11
	Cynipidae	Cynipidae sp.1	2	8		16	4	10		3	Her	PT,YT	43
		Cynipidae sp.2		7			12	60	138	30	Her	PT	247
		Cynipidae sp.3							42	18	Her	PT	60
	Diapriidae	Diapriidae sp.1	222	58	29	30	131	71	113	54	Par	PT,YT	708
		Diapriidae sp.2	1				12	14	82	60	Par	PT,YT	169
		Diapriidae sp.3	21		7		8	15	48	21	Par	PT,YT	120
		Diapriidae sp.4	2	1					17		Par	PT,YT	20
		Diapriidae sp.5					3		5	1	Par	PT	9
		Diapriidae sp.6					9		2	1	Par	PT	12
	Encyrtidae	Encyrtidae sp.1						19	2372	54	Par	PT,YT	2445
	Formicidae	*Cryptopone sauteri*							4		Pre	PT	4
		Ectomomyrmex javana	4								Pre	PT	4
		Formica japonica	328	20	74	32	713	162	8	7	Pre	PT	1344
		Lasius alienus	2								Pre	PT	2
		Lasius hayashi							25	6	Pre	PT	31

Appendix 3. *Continued*

Order	Family	Scientific name	Studied area[a]								Ecological guild[b]	Sampling method[c]	Total
			Danyang		Muju		Uiseong		Cheongsong				
			OF	CF	OF	CF	OF	CF	OF	CF			
Hymenoptera	Formicidae	*Lasius niger*	96	144			181	361	232		Pre	PT,YT	1014
		Messor aciculatus	4								Pre	PT	4
		Nylanderia flavipes	471	99	195	439	766	35	182	99	Pre	PT,YT	2286
		Pheidole fervida		37			50	51			Pre	PT	138
		Solenopsis japonica							19	1	Pre	PT	20
		Tetramorium tsushimae		25	1696	19	20	9	18	42	Pre	PT	1829
	Ichneumonidae	Ichneumonidae sp.1	79	1	3	14	100	145	256	381	Par	PT,YT	979
		Ichneumonidae sp.2	198	53	12	9	13	62	53	103	Par	PT,YT	503
		Ichneumonidae sp.3	1	2			3	14	81	10	Par	PT,YT	111
		Ichneumonidae sp.4	8				6		8		Par	PT,YT	22
		Ichneumonidae sp.5							57		Par	PT	57
	Philanthidae	Philanthidae sp.1	7				9				Pre	PT	16
	Pompilidae	Pompilidae sp.1					3				Par	YT	3
		Pompilidae sp.2							1		Par	YT	1
	Proctotrupidae	Proctotrupidae sp.1			22				17	8	Par	PT,YT	47
		Proctotrupidae sp.2						5			Par	YT	5
	Sphecidae	Sphecidae sp.1			1						Par	YT	1
	Tenthredinidae	Tenthredinidae sp.1	8	4	5	4	3		1		Her	PT,YT	25
	Tiphiidae	Tiphiidae sp.1	30	8							Par	PT,YT	38
		Tiphiidae sp.2	2								Par	PT	2

Appendix 3. *Continued*

Order	Family	Scientific name	Studied area[a]								Ecological guild[b]	Sampling method[c]	Total
			Danyang		Muju		Uiseong		Cheongsong				
			OF	CF	OF	CF	OF	CF	OF	CF			
Hymenoptera	Vespidae	*Vespa mandarinia*	1								Pre	PT	1
		Vespa simillima					13				Pre	PT	13
		Vespidae sp.1	35	3			11				Pre	PT,YT	49
		Vespidae sp.2					7			4	Pre	PT,YT	11
		Vespula sp.1					77	1			Pre	PT	78
Lepidoptera	Gracillariidae	*Phyllonorycter ringoniella*		1				36	112	4	Her	YT,LS	153
	Nymphalidae	Nymphalidae sp.1					7				Pol	YT	7
		Nymphalidae sp.2					2				Pol	YT	2
Neuroptera	Chrysopidae	Chrysopidae sp.1					2		3		Pre	PT,YT	5
Odonata	Libellulidae	Libellulidae sp.1					2				Pre	YT	2
Orthoptera	Gryllidae	*Gryllotalpa orientalis*		1	15						Her	PT	16
		Loxoblemmus magnatus	29	2					3		Det	PT	34
		Loxoblemmus sp.1	10		82				22	3	Det	PT	117
		Loxoblemmus sp.2			14						Det	PT	14
		Teleogryllus emma			8	6					Det	PT	14
	Rhaphidophoridae	*Diestrammena unicolor*	5								Det	PT	5
		Tachycines sp.1		3						2	Det	PT	5
Thysanoptera	Thripidae	*Frankliniella* spp.1	6761	424	1678	1979	1344	1413	1579	1311	Her	PT,YT	16489
		Frankliniella occidentalis			6	81		40		32	Her	YT	159
Total			**68394**	**27488**	**62642**	**21574**	**45506**	**28859**	**36968**	**28512**			**319943**

[a]OF: organic farming, CF: conventional farming; [b]DET: Detritivore, Her: Herbivore, Par: Parasitoid, Pre: Predator, Pol: Pollinator; [c]LS: Leaf sampling, PT: Pitfall trap, YT: Yellow sticky trap

Appendix 4. *Spiders (Araneae) captured in organic farming and conventional farming throughout the studied period*

Family	Scientific name	Studied area[a]								Ecological guild[b]	Sampling method[c]	Total
		Danyang		Muju		Uiseong		Cheongsong				
		OF	CF	OF	CF	OF	CF	OF	CF			
Agelenidae	*Alloclubionoides kimi*						1			Wswb	PT	1
	Alloclubionoides lunatus	5								Wswb	PT	5
	Draconarius coreanus				1					Wswb	PT	1
	Draconarius kayasanensis			1		1				Wswb	PT	2
	Iwogumoa insidiosa			1						Wswb	PT	1
	Iwogumoa interuna								3	Wswb	PT	3
	Iwogumoa songminjae	7	8		2	5	71	1	50	Wswb	PT	144
	Pireneitega spinivulva								2	Wswb	PT	2
Araneidae	*Gibbaranea abscissa*					1				Ow	YT	1
Clubionidae	*Clubiona coreana*					1				Fr	PT	1
	Clubiona rostrata								1	Fr	PT	1
Ctenidae	*Anahita fauna*	13	2		1	1	3	7		Gr	PT	27
Cybaeidae	*Cybaeus mosanensis*	1								Wswb	PT	1
	Dolichocybaeus whanseunensis								1	Wswb	PT	1
Dictynidae	*Cicurina japonica*	3	6	1	1	1	6	4	19	Swb	PT	41
Gnaphosidae	*Cladothela tortiembola*				1					Gr	PT	1
	Drassodes serratidens	18	3			16		2	4	Gr	PT	43
	Drassyllus biglobus			1	8					Gr	PT	9
	Drassyllus coreanus	1								Gr	PT	1
	Drassyllus sanmenensis					1				Gr	PT	1

Appendix 4. *Continued*

Family	Scientific name	Studied area[a]								Ecological guild[b]	Sampling method[c]	Total
		Danyang		Muju		Uiseong		Cheongsong				
		OF	CF	OF	CF	OF	CF	OF	CF			
Gnaphosidae	*Drassyllus sasakawai*	2								Gr	PT	2
	Drassyllus yaginumai			1	4					Gr	PT	5
	Gnaphosa hastata		22							Gr	PT	22
	Gnaphosa kompirensis	14	35	1	1	11	4			Gr	PT	66
	Odontodrassus hondoensis						1		5	Gr	PT	6
	Sernokorba pallidipatellis					1				Gr	PT	1
	Zelotes davidi	3							1	Gr	PT	4
	Zelotes exiguus								1	Gr	PT	1
	Zelotes wuchangensis	1		1						Gr	PT	2
Hahniidae	*Hahnia corticicola*			2		89	2		50	Swb	PT	143
	Neoantistea quelpartensis					12				Swb	PT	12
Linyphiidae	*Agyneta rurestris*	6	1	2						Wsw	PT	9
	Bathyphantes gracilis			28	3	2		51		Wsw	PT	84
	Ceratinella brevis				1					Wsw	PT	1
	Collinsia inerrans	10	37	7		75	31	135	37	Wsw	PT	332
	Doenitzius pruvus	1								Wsw	PT	1
	Eldonnia kayaensis				1					Wsw	PT	1
	Erigone prominens	6		504	5	1		100		Wsw	PT	616
	Gnathonarium dentatum			15	1			75		Wsw	PT	91

Appendix 4. *Continued*

Family	Scientific name	Studied area[a]								Ecological guild[b]	Sampling method[c]	Total
		Danyang		Muju		Uiseong		Cheongsong				
		OF	CF	OF	CF	OF	CF	OF	CF			
Linyphiidae	*Neriene oidedicata*	1			1					Wsw	YT	2
	Nippononeta projecta			1						Wsw	PT	1
	Nippononeta ungulata	1		9	1					Wsw	PT	11
	Oia imadatei						2			Wsw	PT	2
	Paikiniana vulgaris							2		Wsw	PT	2
	Solenysa geumoensis							1		Wsw	PT	1
	Syedra oii						1			Wsw	PT	1
	Ummeliata feminea					308	14	36	18	Wsw	PT	376
	Ummeliata insecticeps			6	1			9		Wsw	PT	16
Liocranidae	*Agroeca bonghwaensis*								1	Gr	PT	1
Lycosidae	*Alopecosa moriutii*			20	4	2		16		Gr	PT	42
	Arctosa ipsa			5	50					Gr	PT	55
	Arctosa pungcheunensis			3	64					Gr	PT	67
	Arctosa yasudai	3	112		14	1	124	105	2	Gr	PT	361
	Lycosa coreana							2		Gr	PT	2
	Pardosa astrigera	1		71	25	19	1	11	6	Gr	PT	134
	Pardosa herbosa			1						Gr	PT	1
	Pardosa laura	142	17	15		1		7	1	Gr	PT	183
	Pirata subpiraticus	1						1		Gr	PT	2

Appendix 4. *Continued*

Family	Scientific name	Studied area[a]								Ecological guild[b]	Sampling method[c]	Total
		Danyang		Muju		Uiseong		Cheongsong				
		OF	CF	OF	CF	OF	CF	OF	CF			
Lycosidae	*Piratula procurvus*	175	4	6		308	359	67	27	Gr	PT	946
	Trochosa ruricola	16	10	30	13	164	6	45	8	Gr	PT	292
Miturgidae	*Prochora praticola*		3			2				Gr	PT	5
Nesticidae	*Nesticella brevipes*						2			Swb	PT	2
	Nesticella mogera	32	5	5	24	8	5	13	4	Swb	PT	96
Philodromidae	*Philodromus subaureolus*						1			Am	PT	1
	Thanatus miniaceus			1						Am	PT	1
	Thanatus nipponicus				1					Am	PT	1
Phrurolithidae	*Corealithus coreanus*			1		6	1	5		Gr	PT	13
	Pennalithus pennatus		1					1		Gr	PT	2
	Phrurolithus sinicus	8	5		1	87		4	1	Gr	PT	106
Pisauridae	*Dolomedes sulfureus*					1	1			Am	PT	2
	Pisaura ancora								1	Am	PT	1
	Pisaura lama	1	1		2	2	1			Am	PT	7
Tetragnathidae	*Pachygnatha clercki*				1					Ow	PT	1
	Pachygnatha quadrimaculata							2		Ow	PT	2
	Pachygnatha tenera			2						Ow	PT	2
Theridiidae	*Enoplognatha abrupta*			1				11		Swb	PT	12
	Enoplognatha caricis	5								Swb	PT	5

Appendix 4. *Continued*

Family	Scientific name	Studied area[a]								Ecological guild[b]	Sampling method[c]	Total
		Danyang		Muju		Uiseong		Cheongsong				
		OF	CF	OF	CF	OF	CF	OF	CF			
Theridiidae	*Paidiscura subpallens*	15	1	1		6		1		Swb	PT	24
	Parasteatoda tabulata	3	2		1		6	2	3	Swb	PT	17
	Steatoda erigoniformis						1			Swb	PT	1
	Stemmops nipponicus	6			2	8	1			Swb	PT	17
	Ebrechtella tricuspidata					1				Am	PT	1
	Ozyptila nongae			1	4	1		3	8	Am	PT	17
	Tmarus punctatissimus	1								Am	PT	1
	Xysticus ephippiatus	9	2	6	4	12	4	2	5	Am	PT	44
	Xysticus saganus	19	2	1	2	17		1	3	Am	PT	45
Titanoecidae	*Nurscia albofasciata*		7	4				1	18	Swb	PT	30
Trachelidae	*Orthobula crucifera*						1			Gr	PT	1
	Trachelas japonicus				1			1		Gr	PT	2
Salticidae	*Euophrys kataokai*							2		St	PT	2
	Evarcha albaria					2				St	PT	2
	Neon reticulatus			1						St	PT	1
	Pseudeuophrys iwatensis				2					St	PT	2
	Sibianor pullus	1		1				1		St	PT	3
	Synagelides agoriformis	2				3	2		3	St	PT	10
Total		**533**	**286**	**757**	**16**	**1177**	**652**	**727**	**283**	**-**	**-**	**4,431**

[a]OF, organic farming, CF, conventional farming; [b]Am, ambushers; Fr, foliage runners; Gr, ground runners; Ow, orb weavers; Swb, space web builders; St, stalkers; Wsw, wandering sheet weavers; Wswb, wandering sheet web builders; [c]LS, Leaf samping; PT, pitfall trap; YT, yellow sticky trap

Abstract in Korean

유기재배와 관행재배 사과 과수원 간의 절지동물 군집 비교

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농생명공학부 곤충학전공

임 재 성

사과는 다년생 작물로 농업생태계의 생물다양성을 유지하는데 중요한 역할을 하고 있다. 유기농과 관행농의 영농 방식은 절지동물 군집에 다른 영향을 미칠 수 있다. 본 연구는 4 개의 다른 지역의 유기농과 관행농 사과원에서 함정트랩, 황색점착트랩, 사과잎 조사를 통하여 절지동물 군집을 조사하였다.

거미류를 제외한 응애류, 톡토기류, 곤충류의 국내 절지동물 군집은 12 목 81 과 255 종 319,943 개체로 조사되었다. 전체 절지동물 군집의 풍부도는 유기농에서 높았으며 응애강, 톡토기목, 딱정벌레목, 파리목, 노린재목, 벌목이 상대적인 종수와 풍부도가 높은 우점목으로 조사되었다.

응애강의 잔날개응애과, 톡토기목의 털보톡토기과, 딱정벌레목의 딱정벌레과, 반날개과, 파리목의 파리과, 검정날개버섯파리과, 벌목의 염주벌과, 개미과는 사과원의 우점과로 조사되었으며 영농 방식 간에 통계적 유의차를 보였다. 우점종으로 조사된 반날개과의 홍딱지바수염반날개, 개미과의 스미스개미, 그리고 염주벌과의 염주벌류 sp.1 은 유기농에서 통계적으로 높은 풍부도를 나타내었다. 절지동물 군집 구조의 유사도 분석 결과, 영농 방식과 상관없이 지역에 따라 군집화 되었다.

조사기간 동안 채집된 절지동물은 분해자, 식식자, 화분매개자, 포식자, 기생포식자의 5 개 생태학적 길드로 분류하였다. 5 개 길드는 영농 방식에 상관없이 모든 사과원에서 조사되었다. 분해자, 식식자, 포식자, 기생포식자의 풍부도는 유기농 사과원에서 유의하게 높았다. 영농 방식에 따른 절지동물 길드

구조의 유사도 분석 결과, 대체적으로 영농 방식에 따라 군집화 됨을 확인하였다.

전반적으로 절지동물 군집의 종수, 풍부도, 다양도 지수는 관행 사과원 대비 유기농 사과원에서 현저히 높았다. 그러나 절지동물 길드의 다양도 지수는 관행농 사과원에서 통계적으로 높았다. 절지동물 군집의 생물다양성 변동에서 종수와 풍부도는 조사 중간에 한번의 정점이 있는 산형 형태를 보인 반면, 종 다양도는 여러 개의 정점이 관찰되었다.

조사기간 동안 총 4,663 개체의 거미가 채집되었으며 21 과 70 속 94 종으로 동정되었다. 영농 방식에 따라 유기사과원 거미의 풍부도는 관행사과원보다 통계적으로 높았다. 5 개 과(게거미과, 늑대거미과, 접시거미과, 수리거미과, 굴아기거미과)는 조사 지역과 영농 방식에 상관없이 상대적인 종수와 풍부도가 높았는데 특히 늑대거미과와 접시거미과는 다른 우점과보다 두드러졌다. 접시거미과의 흑갈톱날애접시거미, 늑대거미과의 별늑대거미, 가시늑대거미, 좀늑대거미, 촌티늑대거미의 풍부도는 유기농에서 통계적으로 높았다. 영농 방식에 따른 거미 군집 구조의 유사도 분석 결과, 대체적으로 영농 방식에 따라 군집화 됨을 확인하였다.

조사기간 채집된 거미를 8 개의 생태 길드로 분류하였다. 8 개 거미 길드 중 ground runners, space web builders, wandering sheet weavers, wandering sheet web builders 는 사과원의 우점길드로 확인되었다. Ground runners 와 wandering sheet weavers 는 유기농 사과원에서 풍부도가 통계적으로 높았던 반면, wandering sheet web builders 는 관행농에서 통계적으로 높았다. 영농 방식에 따른 거미 길드의 유사성 분석 결과, 대체적으로 영농 방식에 따라 군집화 됨을 확인하였다.

전반적으로 거미 군집의 종수, 풍부도, 다양도 지수는 유기농에서 현저히 높았다. 그러나, 길드의 종수와 다양도 지수는 영농 방식 간에 차이가 없었다. 거미 군집의 생물다양성 계절적 변동에서 종수와 풍부도는 조사 중간에 1 번의 정점을 갖는 산형 곡선을 보였고 종 다양도는 여러 개의 정점이 관찰되었다. 거미 길드의 생물다양성 계절적 변동은 거미 군집의 결과와 유사한 양상을 보였다.

영농 방식과 상관없이 모든 조사 지역의 사과원에서 채집된 절지동물은 총 27 종으로 이들을 한국 사과원의 주요 종으로 정하였으며 이들의 풍부도를 종합하여 비교한 결과, 유기농 사과원에서 통계적으로 높았다.

주요어 : 유기농, 관행농, 사과원, 절지동물, 거미, 길드

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