Article

Effects of different pest managements on biodiversity of insects in citrus orchards of Babolsar and Hadishahr districts in Iran

Sahar Sorkhabi Abdolmaleki[1], **Ahad Sahragard**[1], **Mohammad Reza Damavandian**[2], **Seyed Yousof Moosavi Toghani**[3]

[1]Department of Plant Protection, Faculty of Agricultural Sciences, University of Guilan, Rasht, Iran

[2]Department of Plant Protection, Sari Agricultural Sciences and Natural Resources University, Sari, Mazandaran, Iran

[3]Department of Agronomy, Faculty of Cultural Science, Sari Agricultural Sciences and Natural Resources University, Sari, Iran

E-mail: m.r.damavandian@gmail.com

Received 11 Feburary 2023; *Accepted 12 March 2023*; *Published online 10 April 2023*; *Published 1 September 2023*

Abstract

In this research, insect populations in citrus orchards of Hadishahr, Babolsar, Mazandaran Province, Iran, under different types of pest management including conventional orchard (CO), low input orchard (LIO) and free pesticides protocol orchard (FPPO) in winter and spring seasons during December 22, 2017 to June 21, 2018 were evaluated by installation of pitfall traps, sticky yellow cards and branch and leaf samples. The results on foliage samples in winter showed that the highest Shanon-Weiner index, Brilloun index, species richness and species frequency was obtained for LIO. In spring, the highest values of diversity indices, species richness and frequency was also calculated for LIO. The highest eveness indices was obtained for CO in winter and spring. Mean comparisons on data collected by sticky yellow cards showed that in winter and spring, the highest values of diversity indices, species richness and frequency was estimated for LIO, while in winter, the values of eveness indices for CO was significantly more than those for FPPO and LIO, and in spring, the highest values of eveness indices belonged to FPPO. Based on the results related to pitfall traps, the highest values of diversity indices, species richness and frequency was obtained for LIO, while the values of eveness indices calculated for CO was higher than those for FPPO and LIO.

Keywords citrus; pest management; diversity index; eveness index; species richness.

Arthropods
ISSN 2224-4255
URL: http://www.iaees.org/publications/journals/arthropods/online-version.asp
RSS: http://www.iaees.org/publications/journals/arthropods/rss.xml
E-mail: arthropods@iaees.org
Editor-in-Chief: WenJun Zhang
Publisher: International Academy of Ecology and Environmental Sciences

1 Introduction

The community of plant and animal populations in an area is called the biodiversity of that area. More species diversity in an ecosystem results in longer nutritional chains and more complex vital networks and then the environment becomes more stable and have more self- regulatory conditions (Ejtehadi et al., 2009).

Agricultural systems in the world face the challenge of providing the growing population’s needs. In the common systems for more production per unit area and supplying food needs, more inputs are consumed (Hole et al., 2005). Increasing use of agricultural inputs has negative impacts on biodiversity (Crowder and Jabbour, 2014). It is believed that habitat loss and the reduction in quality of remaining habitats and increased use of pesticides and fertilizers are the major factors of biodiversity reduction in agricultural areas (Firbank, 2005 and Feber et al., 2006). Biodiversity reduction by reducing in number of species (reducing in richness) (Hooper et al., 2005; Cardinale et al., 2006) and reducing in species evenness (Hillebrand et al., 2008) weakens biological control. According to the harmful effects of common agriculture, the focus on other methods that results in sustainability of agricultural ecosystems, increased (Tilman, 1999; Hooper et al., 2005; Foley et al., 2011). There are several methods to control pests such as integrated pest management (IPM) and organic agriculture that their principles are based on achievement an acceptable level of exposure to the pest populations with the least effect on non- target species (Mickeal et al., 2015). The calculations have shown that the economic value of agricultural pest control using natural enemies in the United States, was $ 4.5 billion (Losey and Vaughan, 2006).

Huang et al. (2018) investigated the economic value of ladybeetles as natural enemies of aphids in cotton fields for farmers in the northern plains of China. They estimated marginal value of natural enemies, which includes reducing pesticide application, reducing labor use and increasing cotton yield due to its effect on pest density. They estimated that at high levels of insecticide application, with addition of a ladybeetle, farmers gain an economic profit of approximately USD 0.01 and doubling density of this natural enemies could provide about USD 300 million of benefit for farmers.

Mazandaran province has 36.78% of Iran's citrus cultivation (Damavandian, 2016). According to the age and extent of citrus orchards in mazandaran province, the activity of various pests and natural enemies in them is expected. Despite that many researchers have confirmed the presence of predators and parasitoids of pests in citrus orchards, citrus trees are still sprayed with chemical pesticides which has resulted the inefficiency of natural enemies, resistance and insurgence of pests (Damavandian, 2007). Application of mineral oils instead the use of insecticides and acaricides is one way of protecting natural enemies (Rae et al., 1996). Since the harmful effects of mineral oils on natural enemies compared with pesticides are little (Rae et al., 1996) and there is not any report from resistance of pests to mineral oils (Helmy et al, 2012), so their application on the one hand can support the natural enemies such as predators and parasitoids and on the other hand, the potential for resistance of pests also decreases by reducing in the use of pesticides (Damavandian, 2016).

Insects due to their significant biomass (Groombridge, 1992), species richness (Ervin, 1991) and having a prominent role in ecosystem performance (Folgarait, 1998) are considered as the most important component of global biodiversity.

In this study the biodiversity of insects (pests and natural enemies) in Babolsar citrus orchards, which are under the different pest managements (1 - conventional or common use of chemical pesticides, 2 - low input or low pesticides application and 3 - conservation biological control or free pesticide protocol) has been compared. In general, the purpose of this research is to provide a practical approach for citrus growers based on ecological principles in order to create sustainable ecosystems. In other words, based on the results of comparing the indices of biodiversity of different managements, the optimal management of citrus orchards and moving toward sustainable agriculture will be proposed.

2 Materials and Methods

In this research, three 1 ha citrus orchards were selected in Hadishahr of Babolsar, Mazandaran province, Iran. Citrus trees were 20- years- old of Thompson navel on *citrus aurantium* root stock. These three orchards were managed under various pest management programs including the use of pesticides called conventional orchard

(CO), conservation biological control as free pesticide protocol orchard (FPPO) and low application of pesticides as low input orchard (LIO). In each orchard, three replications and 15 trees in each replication and a total of 45 trees were systematically selected for sampling. Sampling was conducted in three methods. In first methods, sampling unit was considered as a 10 cm branch from the height range of 150 to 200 cm in four directions and the center of the trees. In second method, three sticky yellow cards (10 × 30 cm) in each replication and totally nine cards in each orchard were installed randomly on the trees at the height of 150 to 200 cm. In third method, specimens was collected by using pitfall traps. For this purpose, pitfall traps with a diameter of 14 cm and a height of 20 cm were used. For sampling, 10 traps were installed in each orchard along two diameters of the orchard and at a distance of 20 m from each other. To install the traps in the orchards, first, using a shovel, create a hole in the soil at the size of the trap (20 cm deep), and then the traps are placed inside the hole so that the soil level is higher than the trap. Two-thirds of the volume of the traps was filled using a 50% ethyl glycol solution as a preservative, and the solution was changed at each visit. Sampling was carried out once every two weeks from december 22, 2016 to June 21, 2017 (winter and spring seasons). After collecting the samples and transfering to the laboratory, the specimens were identified with valid references as far as possible, at the level of order, family or species and then counted. The data (number of species and frequency of each species) were recorded in the relevant tables and, in proportion, were categorized in Excel 2010 software. Using the ecological software, first the highest species richness was estimated by Jackknife method. The biodiversity indices (including the Shannon-Wiener diversity index, Simpson evenness index, richness and frequency) were then calculated. The analysis of biodiversity indices during two seasons study was done using SAS 9.1 software in a one-way analysis of variance. The comparison of the averages was done using the Tukey test at the level of 5%.

In late February, spraying the pesticides and mineral oils in CO and LIO and occasionally spraying the mineral oils in FPPO was carried out. For spraying in CO, 1.5% dose of mineral oil, 0.1% dose of Acetamiprid insecticide and 0.2% dose of Fenproxymate acaricide were applied. In LIO, 1.5% dose of mineral oil, 0.05% dose of Acetamiprid insecticide and 0.05% dose of Fenproxymate were used. In FPPO, only 1.5% of the mineral oil was applied.

In early April spraying using 0.1% fenproxymate acaricide in CO was conducted. Early to mid- May, in LIO and CO spraying was conducted that used acetamiprid at the dose of 0.2% in CO and at the dose of 0.05% in LIO. FPPO was not sprayed during spring.

3 Results

3.1 Branch and foliage samples

3.1.1 Winter

The results of analysis of variance of data on foliage samples of three orchards indicate that there was a significant difference between three orchards in diversity indices, Camargo and Simpson evenness indices and species richness ($p<0.05$), but species frequencies and Smith-Wilson index calculated for three orchards had no significant differences with each other ($p>0.05$) . Regarding the mean comparison of treatments, the highest values of Simpson diversity index, Camargo and Simpson eveness indices was calculated for CO with the averages of 0.6413, 0.5893 and 0.6410, respectively. In the other hand, the highest values of Shanon-Weiner and Brilloun indices was obtained in LIO, with the averages of 1.6670 and 1.5870, respectively, which were not significantly different from values of these indices in CO. Based on the results, species richness calculated for FPPO had the highest value (Table 1).

In winter, in FPPO, 18 cottony cushion scales, *Icerya purchasi* (Hemiptera: Monophlebidae), three red spider mites *Panonychus citri* (Prostigmata: Tetranychidae), one *Propylea quatuordecimpunctata* and 94 predator mites from the family Phytoseiidae were counted. LIO, one cottony cushion scale, three red spider mites and 41 phytoseiidae mites were observed. In CO, 574 red spider mites and 18 phytoseiidae mites were counted (Table 2).

Table 1 Mean comparison of diversity and eveness indices, species richness and species frequency for branch and foliage samples collected from three orchards studied in winter.

Orchard	Diversity index			Eveness index			Species richness	Species frequency
	SimpsonD	Shanon-Weiner	Brilloun	Camargo	SimpsonE	Smith-Wilson		
CO	0.6413a	1.6537a	1.5753a	0.5893a	0.6410a	0.4867a	4.3333b	131.33a
FPPO	0.4997c	1.2997b	1.2380b	0.4830b	0.4963b	0.3967a	4.0000b	159.67a
LIO	0.6083b	1.6670a	1.5870a	0.4023c	0.4013c	0.2807a	6.3333a	183.67a
F value	73.37**	66.61**	65.19**	17.73**	22.16**	1.75^{ns}	21.50**	1.08^{ns}

ns shows a nonsignificant difference between the orchards.
** shows a significant difference between the orchards 1% probability level.

Table 2 Observed natural enemies and pests in foliage samples of three orchards in winter.

Insects and Mites	FPPO	LIO	CO
Icerya purchasi	18	1	-
Panonychus citri	3	3	574
Propylea quatuordecimpunctata	1	-	-
Phytoseiidae	94	41	18

3.1.2 Spring

The results of analysis of variance of data on branch and foliage samples collected from the three orchards showed that diversity indices, species richness and species frequency obtained for three orchards were significantly different ($p<0.05$), while eveness indices did not show a significant difference in three orchards ($p>0.05$).

Based on the mean comparison, LIO yielded the highest values of Simpson, Shanon-Weiner, Brilloun diversity indices, species richness and species frequency with the averages of 0.6097, 2.0533, 1.9870, 15.3330 and 585.00, respectively. The lowest values of diversity indices calculated for FPPO with the averages of 0.3160, 1.0957 and 1.0443, respectively. Also, the lowest species richness obtained for FPPO (7.6670), while there was not a significant difference between FPPO and CO in terms of species richness. In the other hand, the lowest species frequency with the average of 233.00 obtained for CO. Based on the variance analysis, there was no significant difference between eveness indices calculated for three orchards ($p>0.05$), but the highest values of Camargo, Simpson E and Smith-Wilson indices was estimated for CO with the averages of 0.2977, 0.2207 and 0.3403, respectively (Table 3). During spring, in FPPO 57 cottony cushion scales, 48 nymphs of *Pulvinaria aurantii*, 18 egg sacs of *P. aurantii* and 1843 aphids from the family Aphididae were observed as pests, but in LIO, 21 cottony cushion scales and 359 aphids were counted. In CO, there were two cottony cushion scales and 548 aphids. As the natural enemies in FPPO, one *P. decimpunctata*, 13 Aphelinidae parasitoid wasps and 133 parasitized aphids, 37 larvae of the aphid midge *Aphidoletes aphidimyza* (Diptera: Cecidomyiidae), 13 Larvae of *Episyrphus balteatus* (Diptera: Syrphidae) and 164 phytoseiidae mites were observed; but in LIO, only 15 parasitized aphids and 19 phytoseiidae mites were found, and in CO 17 parasitized aphids, One parasitoid wasp Aphelinidae and 25 phytoseiidae mites were counted (Table 4). In LIO and CO, no aphid midge (*A. aphidimyza*) and Syrphidae families were observed around the aphid colonies on the trees and the number of parasitized aphids were very low. According to observations, the diversity and frequency of natural enemies and pests in FPPO were more than the other two orchards.

Table 3 Mean comparison of diversity and eveness indices, species richness and species frequency for branch and foliage samples collected from three orchards studied in spring.

Orchard	Diversity index			Eveness index			Species richness	Species frequency
	SimpsonD	Shanon-Weiner	Brilloun	Camargo	SimpsonE	Smith-Wilson		
CO	0.4423b	1.4790b	1.3953b	0.2977a	0.2207a	0.3403a	8.6670b	233.00c
FPPO	0.3160c	1.0957c	1.0443c	0.2533a	0.1920a	0.2763a	7.6670b	350.67b
LIO	0.6097	2.0533a	1.9870a	0.2117a	0.1510a	0.2350a	15.3330a	585.00a
F value	28.27**	38.83**	40.32**	2.50ns	2.16ns	2.72ns	22.33**	73.40**

ns shows a nonsignificant difference between the orchards.
** shows a significant difference between the orchards 1% probability level.

Table 4 Observed natural enemies and pests in foliage samples of three orchards in spring.

Insects and Mites	FPPO	LIO	CO
Icerya purchasi	57	21	2
Pulvinaria aurantii	48	-	-
Egg sacs of *P. aurantii*	18	-	-
Aphididae	1843	359	548
Panonychus citri	-	1	6
Propylea quatuordecimpunctata	1	-	-
Aphelinidae	13	-	1
Parasitised aphids	133	15	17
Aphidoletes aphidimyza	37	-	-
Episyrphus balteatus	13	-	-
Phytoseiidae	164	19	25

3.2 Sticky yellow card samples

3.2.1 Winter

The results of variance analysis of data obtained from sticky yellow cards in three orchards in winter showed that the diversity indices and species richness calculatd for the orchards was significantly different at 1% probability level ($p<0.05$). Also, there was a significant difference at 5% probability level between three orchards studied in terms of the eveness indices ($p<0.05$). in the other hand, no significant difference was observed between species frequencies in three orchards ($p>0.05$) (Table 5).

Means comparison of data showed that Simpson D, Shanon-Weiner and Brilloun diversity indices, and species richness calculated for LIO with the averages of 0.8787, 3.4683, 3.4197 and 30.333, respectively, were significantly more than CO and FPPO (Table 5). The results indicated that there was no significant difference between CO and FPPO in diversity indices and species richness (Table 5). Mean comparisons of eveness indices showed that the highest values of Camargo, Simpson E and Smith-Wilson indices with the averages of 0.2763, 0.2750 and 0.1873, respectively, was obtained for LIO, but no significant difference was observed between LIO and CO in these indices (Table 5).

Table 5 Mean comparison of diversity and eveness indices, species richness and species frequency for samples collected by sticky yellow cards in three orchards studied in winter.

Orchard	Diversity index			Eveness index			Species richness	Species frequency
	SimpsonD	Shanon-Weiner	Brilloun	Camargo	SimpsonE	Smith-Wilson		
CO	0.8047b	2.7930b	2.7593b	0.2680a	0.2613a	0.1700a	19.667b	1826.00a
FPPO	0.7693b	2.6130b	2.5813b	0.2310b	0.2163b	0.1593b	20.333b	1927.30a
LIO	0.8787a	3.4683a	3.4197a	0.2763a	0.2750a	0.1873a	30.333a	1937.00a
F value	24.11**	35.41**	36.38**	2.70*	2.82*	2.84*	16.91**	0.23^{ns}

ns shows a nonsignificant difference between the orchards.
* shows a significant difference between the orchards 5% probability level.
** shows a significant difference between the orchards 1% probability level.

Table 6 Observed insects and mites on yellow card samples of three orchards in winter.

Insects and Mites	FPPO	LIO	CO
Aphididae	6	8	28
Scymnus sp	3	-	1
Rodalia cardinalis	1	-	-
Trombididae	15	-	-
Culicidae (Nematocera)	198	650	875
Tipulidae (Nematocera)	119	41	67
Psychodidae (Nematocera)	117	26	240
Others of Nematocera	412	784	897
Muscidae (Brachycera)	2	-	-
Others of Brachycera	1194	897	2087
Psocoptera	15	246	43
Thysanoptera	25	48	19
Hymenoptera (Apocrita)	382	102	320
Formicidae	22	1	5
Chrysoperla carnea (Neuroptera: Chrysopidae)	1	-	-
Chrysomelidae	27	1	15
Cicindellinae (Carabidae)	2	-	-
Staphylinidae	4	-	-
Mecoptera	20	-	12
Trichoptera	12	7	2
Cicadellidae	45	80	44

By investigation the sticky yellow cards in winter, we found that the diversity of arthropods collected from the FPPO was more than the other two orchards, but the abundance of insects in FPPO was less than two others. The diversity and frequency of natural enemies in FPPO were higher than the other two orchards and some species only in FPPO were observed (Table 6).

3.2.2 Spring

The analysis of data collected from sticky yellow cards in spring indicated that the diversity indices, Smith-Wilson eveness index and species richness in these three orchards were significantly different at 1% probability level. Also, a significant difference at 5% probability level was observed between these orchards in Camargo and Simpson eveness indices and species frequency (Table 7).

Table 7 Mean comparison of diversity and eveness indices, species richness and species frequency for samples collected by sticky yellow cards in three orchards studied in spring.

Orchard	Diversity index			Eveness index			Species richness	Species frequency
	SimpsonD	Shanon-Weiner	Brilloun	Camargo	SimpsonE	Smith-Wilson		
CO	0.8127b	2.9150b	2.8767b	0.2253b	0.2103b	0.1563b	25.333b	1973.00b
FPPO	0.8223b	2.9577b	2.9187b	0.2507a	0.2417a	0.1747a	23.333b	1873.70b
LIO	0.8693a	3.5110a	3.4690a	0.2270b	0.2023b	0.1720a	38.000a	2783.30a
F value	81.08**	154.40**	165.84**	4.45*	4.58*	4.34**	53.37**	10.70*

* shows a significant difference between the orchards 5% probability level.
** shows a significant difference between the orchards 1% probability level.

The results of mean comparison indicated that the values of Simpson, Shanon-Weiner and Brilloun diversity indices, species richness and species frequency for LIO were significantly more than those obtained for CO and FPPO. In the other hand, no significant difference was observed between CO and FPPO in mentioned indices (Table 7). Based on the results, the highest values of Camargo and Simpson eveness indices was obtained for FPPO and there was a significant difference between FPPO and other orchards (Table 7). Also, the highest Smith-Wilson eveness index with the average of 0.1747 was obtained for FPPO and there was no significant difference between FPPO and LIO, but the value of this index in CO was significantly lower than other (Table 7).

In spring, frequency of aphids from family Aphididae collected by yellow cards, in CO was higher than the other two orchards. The diversity and frequency of natural enemies in FPPO were higher than LIO and CO (Table 8). The number of order Diptera collected by yellow cards in LIO was more than the other two orchards. Trombididae mites were found only in FPPO (Table 6).

Table 8 Observed pests and natural enemies on yellow card samples of three orchards in spring.

Insects and Mites	FPPO	LIO	CO
Aphididae	468	328	900
Propylea quatuordecimpunctata	11	-	3
Scymnus sp	13	2	1
Rodalia cardinalis	15	-	-
Episyrphus balteatus	4	-	-
Culicidae (Nematocera)	733	2173	2588
Tipulidae (Nematocera)	90	25	29
Psychodidae (Nematocera)	95	88	69
Others of Nematocera	3297	7347	4650
Fannidae (Brachycera)	3	-	-
Others of Brachycera	3974	12875	4460
Psocoptera	781	649	448
Thysanoptera	69	44	70
Chrysoperla carnea (Chrysopidae: Neuroptera)	67	10	31
Hymenoptera (Apocrita)	1431	5	918
Formicidae	307	83	157
Chrysomelidae	13	11	7
Staphylinidae	30	1	11
Cerambycidae	46	21	42
Cicadellidae	26	27	22
Mecoptera	1217	325	828
Trichoptera	7	2	4
Trombididae	7	-	2
Acrididae (Orthoptera)	2	-	-
Odonata (Anisoptera)	1	-	-
Odonata (Zygoptera)	-	-	1

3.3 Pitfall samples

3.3.1 Winter

The results of variance analysis of data obtained by pitfall traps in three orchards in winter showed that diversity and eveness indices in three orchards studied was not significantly different from each other ($p>0.05$), but there was a significant difference between three orchards in terms of species richness and frequency ($p<0.05$) (Table 9). Despite the fact that no significant difference was seen in diversity indices, the highest Simpson, Shanon-Weiner and Brilloun diversity indices was obtained for LIO with the averages of 0.9113, 3.5540 and 3.0450, respectively (Table 9). On the other hand, Camargo, Simpson and Smith-Wilson eveness indices in CO were higher than those in FPPO and LIO with the averages of 0.6250, 0.6647 and 0.6907, respectively (Table 9). Based on the mean comparison, the highest values of species richness and frequency was obtained for LIO with the averages of 15.667 and 56.00, respectively. Also, there was no significant difference between FPPO and Co in the mentioned indices (Table 9).

By investigation the sticky yellow cards in winter, the number of aphids and Mediterranean fruit fly *Ceratitis capitata* (Diptera: Tephritidae) in FPPO were more than the other two orchards. Also the diversity and frequency of natural enemies in FPPO were higher than LIO and CO (Table 10). The highest number of Nematocera were found in CO and the highest number of Brachycera were found in LIO. The population of Apocrita suborder from Hymenoptera order in FPPO were more than the other two orchards (Table 10).

Table 9 Mean comparison of diversity and eveness indices, species richness and species frequency for samples collected by pitfall traps in three orchards studied in winter.

Orchard	Diversity index			Eveness index			Species richness	Species frequency
	SimpsonD	Shanon-Weiner	Brilloun	Camargo	SimpsonE	Smith-Wilson		
CO	0.8410a	2.7590a	2.2673a	0.6250a	0.6647a	0.6907a	9.333b	30.00b
FPPO	0.8597a	2.9380a	2.4717a	0.5873a	0.6030a	0.6483a	10.333b	38.33b
LIO	0.9113a	3.5540a	3.0450a	0.5850a	0.6117a	0.6470a	15.667a	56.00a
F value	1.58^{ns}	2.64^{ns}	2.91^{ns}	1.46^{ns}	1.36^{ns}	0.96^{ns}	4.74**	5.91**

ns shows a nonsignificant difference between the orchards.
** shows a significant difference between the orchards 1% probability level.

Table 10 Observed insects and mites in pitfall samples of three orchards in winter.

Insects and Mites	FPPO	LIO	CO
Ceratitis capitata	17	1	0
Aphididae	558	95	268
Scymnus sp	2	-	-
Cryptolaemus montrozieri	1	-	-
Propylaea quatuordecimpunctata	2	-	-
Syrphidae	1	-	-
Trombididae	13	-	-
Culicidae (Nematocera)	693	1049	2180
Tipulidae (Nematocera)	112	108	85
Psychodidae (Nematocera)	72	17	8
Others of Nematocera	1044	947	1078
Muscidae (Brachycera)	5	8	-
Others of Brachycera	1524	1842	1425
Psocoptera	151	61	30
Thysanoptera	34	13	6
Hymenoptera (Apocrita)	694	339	335
Formicidae	103	12	18
Chrysoperla carnea (Neuroptera: Chrysopidae)	37	9	15
Chrysomelidae	26	2	-
Staphylinidae	5	-	1
Mecoptera	45	224	194
Trichoptera	2	-	-
Cicadellidae	87	52	13
Cerambycidae	9	22	74

3.3.2 Spring

The analysis of data obtained from pitfall traps in spring indicates that the diversity indices calculated for three orchards were no significantly different from each other (p>0.05). on the other hand, differences observed in Camargo and Smith-Wilson evenness indices, species richness and frequency in three orchards were significant at 5% probability level. Also, a significant difference was observed in Simpson eveness index between three orchards at 1% probability level (p<0.05) (Table 11).

Despite the fact that no significant difference was observed in diversity indices, the highest Simpson diversity index was obtained for FPPO with the average of 0.7900. Also, the values of Shanon-Weiner and Brilloun diversity indices obtained for LIO were more than those for FPPO and CO (Table 11). The highest values of Camargo, Simpson and Smith-Wilson eveness indices was obtained for CO with the averages of 0.5777, 0.5760 and 0.6067, respectively. Based on the results, there was no significant difference between CO and FPPO in Camargo and Simpson eveness indices (Table 11). On the other hand, the highest species richness and frequency was calculated for LIO with the averages of 15.667 and 77.67, respectively (Table 11).

In spring, aphids in FPPO were more abundant than the other two orchards. Also in FPPO, the most diversity and abundant of natural enemies were observed in yellow cards (Table 12). The number of suborder Nematocera of Diptera collected by yellow cards in CO, but the number of suborder Brachycera of Diptera and suborder Apocrita of Hymenoptera in FPPO were the most (Table 12).

Table 11 Mean comparison of diversity and eveness indices, species richness and species frequency for samples collected by pitfall traps in three orchards studied in spring

Orchard	Diversity index			Eveness index			Species richness	Species frequency
	SimpsonD	Shanon-Weiner	Brilloun	Camargo	SimpsonE	Smith-Wilson		
CO	0.7777a	2.4653a	2.0727a	0.5777a	0.5760a	0.6067a	8.333b	34.67b
FPPO	0.7900a	2.4650a	2.0717a	0.5303a	0.5437a	0.5463b	8.333b	35.33b
LIO	0.7353a	2.7670a	2.5320a	0.4093b	0.2503b	0.5450b	15.667a	77.67a
F value	0.28^{ns}	0.30^{ns}	0.88^{ns}	7.13*	20.10**	0.24*	4.36*	4.17*

ns shows a nonsignificant difference between the orchards.
* shows a significant difference between the orchards 5% probability level.
** shows a significant difference between the orchards 1% probability level.

Table 12 Observed insects and mites in pitfall samples of three orchards in spring.

Insects and Mites	FPPO	LIO	CO
Aphididae	589	140	265
Propylea quatuordecimpunctata	38	-	-
Scymnus sp	20	-	-
Chilocorus sp	4	-	-
Rodalia cardinalis	7	-	-
Episyrphus balteatus	5	-	-
Culicidae (Nematocera)	408	450	1074
Tipulidae (Nematocera)	248	122	234
Psychodidae (Nematocera)	34	6	8
Others of Nematocera	2041	1905	1578

Muscidae (Brachycera)	12	8	3
Others of Brachycera	2261	2020	1629
Psocoptera	333	91	60
Thysanoptera	60	41	30
Chrysoperla carnea (Chrysopidae: Neuroptera)	96	3	10
Hymenoptera (Apocrita)	1364	859	433
Formicidae	211	86	106
Chrysomelidae	20	12	8
Staphylinidae	8	1	-
Cerambycidae	206	26	86
Cicadellidae	86	49	33
Mecoptera	136	53	12
Trichoptera	15	1	9
Trombididae	48	1	1
Odonata (Anisoptera)	1	1	4
Odonata (Zygoptera)	4	-	-
Agonum dorsale (Carabidae)	4	-	-
Harpalus rufipes (Carabidae)	4	-	-

4 Discussion

Pesticides are one of the important agents of decreasing biodiversity. In this research, insect populations in citrus orchards under different pest managements were evaluated by installation of pitfall traps and sticky yellow cards and investigation of branches and leaves of trees and then biodiversity indices in different orchards were estimated. Results showed that during two seasons, the highest values of diversity indices, species richness and frequency was obtained for LIO. Among the communities with equal evenness, the community that has a greater species richness is more diverse (Ejtehadi et al., 2009). On the other hand, the highest values of eveness indices was calculated for CO.

High population of *P. citri* in CO was observed which indicates the dominance of this pest in this orchard. It seems that one of the important reasons for outbreak of this pest in CO is the low activity of natural enemies which is obvious in obtained data. There were 574 individuals of *P. citri* in CO which was very high number compared to LIO and FPPO by having 3 numbers of this pest; but the number of collected Phytoseiidae mites in CO was very low compared to the other two orchards, and there were only 18 numbers of this family of mites in CO but there were 41 and 94 Phytoseiidae mites in LIO and FPPO respectively.

In late February, spraying the pesticides and mineral oils in CO and LIO and occasionally spraying the mineral oils in FPPO was carried out. The main goal of winter spraying in citrus orchards is the control of *P. citri* which regarding the high population of this pest and low population of natural enemies in CO, farmers has to apply a high dose of pesticides to control the population of this pest in CO but in FPPO due to the activity of natural enemies such as Phytoseiidae mites, *P. citri* did not have high population.

Damavandian (2010) also showed that the population of predator Phytoseiidae mites in orchards under mineral oils spraying is considerably higher than orchards under synthetic pesticides spraying. According to Damavandian observations, the population of predator Phytoseiidae and their population growth after pest control in orchards under the mineral oils application were much higher and faster than orchards under the synthetic pesticide application. Most of predatory mites are able to survive in low- food environments and before serious outbreak of pests can properly control them (Helyer et al., 2003). According to Helyer et al. (2003), predator Phytoseiids are susceptible to synthetic insecticides (Pyrothroids) and should avoid using these compounds to increase the population of predator mites. In contrast, Bedford et al. (1998) reported that by using mineral oils, predator mites can maintain their population and suffer less damage. But the use of synthetic pesticides causes the death of predator mites, resulting outbreak of red spider mites.

In spring in all orchards, outbreak of aphids from the family Aphididae was observed but the population of this pest in FPPO was much higher than the other orchards and this has also affected the evenness. Interestingly, despite the very high population of aphids in FPPO, natural enemies were very active. parasitoid wasps from the family Aphelinidae, larvae of the aphid midge *Aphidoletes aphidimyza* (Diptera: Cecidomyidae) and larvae of the hoverfly *Episyrphus balteatus* (Diptera: Syrphidae) around the colonies of aphids were observed and these natural enemies controlled the aphid populations without application of any pesticides. Despite the considerable population of aphids in LIO and CO, only small numbers of parasitoid wasps and parasitized aphids were found around the colonies of aphids on trees and in these orchards, farmers had to apply synthetic insecticides to control damages.

Bengtsson et al. (2005) studied the effects of organic agriculture on species richness and abundance of different organisms. They observed that predatory insects in organic farming systems had higher species richness and abundance compared to conventional systems; but the species richness and abundance of nonpredatory insects and pests in organic agriculture were lower than conventional farming systems. Since that pesticide application in conventional agriculture is much more than organic farming, so they concluded that the impacts of natural enemies in organic agriculture has caused a balance in pest populations (Bengtsson et al., 2005; Hole et al., 2005). In early April, in CO, acaricide spraying and in Early to mid- May, in LIO and CO, insecticide spraying were conducted. FPPO was not sprayed during spring.

In terms of natural enemies and pests, FPPO had the highest number of phytoseiidae mites and the lowest number of *P.citri*, and LIO had the lowest number of phytoseiidae mites and the highest number of *P. citri*. In fact in FPPO the pest population was under the control of natural enemies. In late February 2018, synthetic pesticides and mineral oil spraying was carried out to control the red spider mite in CO and LIO and farmer did not apply any synthetic pesticide in FPPO. In spring 2018, as in spring 2017, aphid population outbreak was observed, which was controlled in FPPO by a collection of natural enemies without synthetic pesticides and oil spraying; however, in LIO and CO, two stages of spraying were done once in April and once in late May. In CO fenpyroximte and acetamiprid, each one with a dose of 0.1% and in LIO fenpyroximate, acetamiprid, and buprofezin (from the group of insect growth inhibitors) with the doses of 0.05%, 0.05% and 0.75%, were applied respectively.

During sampling, the population of Culicidae from the order Diptera in CO and LIO was always significantly higher than FPPO, and on the other hand, the species richness in two orchards was always less than FPPO. It seems that by damaging the species richness in CO and LIO, some species were eliminated and the conditions for population growth of other species like Culicidae family were provided. In other words the removal of some species from ecosystem and disruption of biological balance will lead to outbreak of some remaining species. In FPPO species richness of natural enemies was higher than the other two orchards. *R. cardinalis*, Trombididae mites and *C. carnea* were found only on yellow cards of FPPO.

Hole et al. (2005) reviewed studies that compared one or more taxonomic groups in organic and conventional management. In 66 cases, organic farming had a positive effect on species richness and frequency; in 25 cases, no differences were observed between the different managements, and only eight cases found that organic farming had negative impact on species richness and frequency.

By counting natural enemies and pests, it was found that the number of aphids on yellow cards in CO was more than the other two orchards and in LIO was the lowest; however, the frequency and diversity of natural enemies in FPPO were the highest. *P. quatuordecimpunctata*, *Scymnus*, *E. balteatus*, Trombididae mites and other natural enemies had higher population in FPPO or some of them were not found in LIO and CO.

In foliage samples of spring, there were *I. purchasi* in all three orchards but the population of this pest in FPPO samples was more than the other two orchards (57 numbers in FPPO, 21 numbers in LIO and 2 numbers in CO); and on yellow cards of FPPO of spring, there were 15 numbers of *R. cardinalis* which is the natural enemy of *I. purchasi*; but in LIO and CO this lady bird was not found.

Data collected by sticky yellow cards in winter showed that the species richness in LIO was higher than FPPO and CO. Therefore, due to the high species richness in LIO compared to the other two orchards and the lack of significant differences in evenness, the diversity index were also higher in LIO than the other two orchards. The variety and frequency of natural enemies and pests in FPPO were still higher than in other two orchards. In general, according to the analysis of yellow card data, in this season, biodiversity of LIO was more than FPPO and CO.

On yellow cards in FPPO, variety and frequency of pests and natural enemies was very high. According to the data obtained from the study of branches and leaves in this season, the yellow cards also showed a higher frequency of aphids in FPPO than the CO and LIO; but the abundance of natural enemies was also larger in FPPO compared to in other orchards. Large abundance of Coccinellidae beetles and lace wings controlled large abundance of aphids.

Sonoda et al. (2011), in a study, examined the species richness and abundance of insects in peach orchards under conventional, low pesticides, and organic managements. Shannon-Wiener index was compared in different sampling sites. The results showed that in general, the species richness and the number of trapped insects were higher in orchards with less insecticide applications. For example, organic orchards had higher species richness and number of trapped insects (frequency) than low input orchards.

Drinkwater et al. (1995) studied the differences between organic and conventional tomato farming systems in California. They found that the species richness of herbivorous insects and the species richness and the number of parasitoids and predators in commercially organic farms is more than conventional farms; but differences in damage to leaves and fruits were not significant in two types of managements.

The destructive effects of synthetic pesticides in long time will destroy the environmental balance between pests and natural enemies, with the emptying of the environment from the natural enemies, the condition needs for outbreak of pests will be provided (Aidoo et al, 2016). For example, Mediterranean fruit fly (*C. capitata*) was reported from the citrus orchards of Mazandaran province about ninety years ago (Bahrami, 1934), but for the past few years we have witnessed an increase in the population of this pest and also increasing in its damage to the orchards.

Citrus red mite is one of the most important pests of citrus in Mazandaran and Phytoseiidae mites are predators and natural enemies of some pests in citrus orchards. In FPPO, Phytoseiidae mites were active in high frequency almost in both two years and controlled the pest at the low levels. In this orchard, only a low peak of population of citrus red mites was observed in February 2018, at the same point, the population of Phytoseiidae mites was also at its peak. Phytoseiidae mites had peaks in other months in addition to February, and this high population of Phytoseiidae mites was particularly important in controlling other citrus pests because some species of this family of mites are polyphagous and are natural enemies of other citrus pests. In CO with the constant use of chemical pesticides, the pest and natural enemy populations were kept at very low levels. In two years, two citrus red mite peaks were observed in February, but Phytoseiidae mites had low population at that time and could not control the pest population, which was controlled by the application of synthetic pesticides.

To protect insect species in citrus orchards, management mechanisms that have no adverse effects on natural enemies, pollinators and other insects, but effectively control the population of pests (using biological control agents and limiting the use of herbicides), can be adopted (Damavandian, 2007).

5 Conclusions

In conclusion, the studying during two seasons (winter and spring) showed that synthetic pesticide application, negatively affects the biodiversity of insects and mites in citrus orchards. Different pests of citrus can be controlled without the application of synthetic pesticides and just with activity of natural enemies in orchards. Frequency and species richness of pests and natural enemies in FPPO were higher than CO with synthetic pesticide application.

References

Aidoo OF, Kyerematen R, Akotsen-Mensah C, Afreh-Nuamah K. 2016. Abundance and Diversity of Insects Associated with Citrus Orchards in Two Different Agroecological Zones of Ghana. American Journal of Experimental Agriculture, 13(2): 1-18

Bahrami T. 1934. Agriculture. General directorate of Agriculture Press, Tehran, Iran

Bedford ECG, Vandenberi MA, De Villiers EA. 1998. Citrus pests in the Republic of South Africa. Second Edition (revised). Dynamic AD, Nelspruit, Republic of South Africa

Bengtsson J, Ahnstrom J, Weibull AC. 2005. The effects of organic agriculture on biodiversity and abundance: a meta-analysis. Journal of Applied Ecology, 42: 261-269

Camargo JA. 1993. Must dominance increase with the number of subordinate species in competitive interactions? Journal of Theoretical Biology, 161: 537-542

Cardinale BJ, Srivastava DS, Duffy JE, Wright JP, Downing AL, Sankaran M, Jouseau C. 2006. Effects of biodiversity on the functioning of trophic groupsand ecosystems. Nature, 443: 989-992

Crowder DW, Jabbour R. 2014. Relationships between biodiversity and biological control in agroecosystems: Current status and future challenges. Biological Control, 72: 8-17

Damavandian MR. 2007. Laboratory and field evaluation of mineral oil spray for the control of citrus red mite, *Panonychus citri* McGregor. Acta Agriculturae Scandinavica, Section B- Soil and Plant Protection Science, 57: 92-96

Damavandian MR. 2010. Comparison of current insecticides with mineral oil for the control of *Pulvinaria aurantii* Comstock in Mazandaran citrus orchards and their efficacy on Phytoseiid mites. Journal of Plant Pests and Diseases, 78(1): 81-97

Damavandian MR. 2016. Comparison of mineral oil spray with current synthetic pesticides to Control important pests in citrus orchards and their side effects. Arthropods, 5(2): 56-64

Drinkwater LE, Letourneau DK, Wrokneh F. 1995. Fundamental differences between conventional and organic tomato agroecosystems in California. Ecological Application, 5: 1098-1012

Ejtehadi H, Sepehri A, Akkafi HR. 2009. Methods of Measuring Biodiversity. Ferdowsi University of Mashhad Press, Mashhad, Iran

Ervin TL. 1991. How many species are there?. Revisit Conservation Biology, 5: 330-333

Feber RE, Johnson PJ, Firbank LG, Hopkins A, Macdonald DW. 2006. A comparison of butterfly populations on organically and conventionally managed farmland. Journal of Zoology, 273: 30-39

Firbank LG. 2005. Striking a new balance between agricultural production and biodiversity. Annual Applied Biology, 146: 163-175

Foley JA, Ramankutty N, Brauman KA, Cassidy ES, Gerber JS, Johnston M, Mueller ND, O'Connell C, Ray

DK, West PC, Balzer C, Bennett EM, Carpenter SR, Hill J, Monfreda C, Polasky S, Rockstrom J, Sheehan J, Siebert S, Tilman D, Zaks DPM. 2011. Solutions for a cultivated planet. Nature, 478: 337-342

Folgarait PJ. 1998. Ant biodiversity and its relationship to ecosystem functioning: a review. Biodiversity Conservation, 7: 1221-1244

Groombridge B. 1992. Global Biodiversity, Status of The Earth’S Living Resources. Chapman and Hall Press, London, UK

Helmy EI, Kwaiz FA, El-Sahn OMN. 2012. The usage of mineral oils to control insects. Egyptian Academic Journal of Biological Sciences, 5(3): 167-174

Helyer N, Brown K, Cattlin ND. 2003. Biological control in plant protection. Manson publishing, London, UK.

Hillebrand H, Bennett DM, Cadotte MW. 2008. Consequences of dominance: a review of evenness effects on local and regional ecosystem processes. Ecology, 89: 1510-1520

Hole DG, Perkins AJ, Wilson JD, Alexander IH, Grice F, Evans AD. 2005. Does organic farming benefit biodiversity? Biological Conservation, 122: 113-130

Hooper DU, Chapin FS, Ewel JJ, Hector A, Inchausti P, Lavorel S, Lawton JH, Lodge DM, Loreau M, Naeem S, Schmid B, Setala H, Symstad AJ, Vandermeer J, Wardle DA. 2005. Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. Ecological Monographs, 75: 3-35

Huang J, Zhou K, Zhang W, Deng X, van der Werf W, Lu Y, Wu K, Rosegrant MW. 2018. Uncovering the economic value of natural enemies and true costs of chemical insecticides to cotton farmers in China. Environmental Research Letters, 13

Leonard PG. 2010. Pesticide use and biodiversity conservation on farms. CropLife Foundation

Losey JE, Vaughan M. 2006. The economic value of ecological services provided by insects. Bioscience, 56: 311-323

Mickael H, Christophe M, Thibaud D, Johanne N, Benjamin P, Jodie T, Yvan C. 2015. Orchard management influences both functional and taxonomic ground beetle (Coleoptera, Carabidae) diversity in South- East France. Applied Soil Ecology, 88: 26-31

Rae DJ, Watson DM, Liang WG, Tang BL, LI M, Huang MD, Ding Y, Xiong JJ, DU DP, Tang J, Beattie GAC. 1996. Comparison of petroleum spray oils, abamactin, cartap and methomyl for citrus leafminer (Lep: Gracillaridae) control in southern China. Journal of Economic Entomology, 89: 493-500.

Saboori AR, Hosseini M, Hatami B. 2003. Preference of adults of *Allothrombium pulvinum* Ewing *(*Acari*:* Trombidiidae) for eggs of *Planococcus citri* Risso and *Pulvinaria aurantii* Cockerell on citrus leaves in the laboratory. Systematic and Applied Acarology, 8: 49-54

Shannon CE, Weaver W. 1949. The Mathematical Theory of Communication. University of Illinois Press, Urbana, USA

Simpson EH. 1949. Measurement of diversity. Nature, 163: 688

Smith B, Wilson JB. 1996. A consumer’s guide to evenness indices. Oikos, 76: 70-82

Sonoda S, Izumi Y, Kohara Y, Koshiyama Y, Yoshida H. 2011. Effects of pesticide practices on insect biodiversity in peach orchards. Applied Entomology and Zoology, 46: 335-342

Tilman D. 1999. Global environmental impacts of agricultural expansion: the need for sustainable and efficient practices. Proceeding of National Academic Science, USA, 96: 5995-6000