Article

Effects of biological control on biodiversity of insects in citrus orchards of Babolsar, Mazandaran Province, Iran

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Abstract

In this research, insect populations in citrus orchards of Hadishahr, Babolsar, Mazandaran Province, Iran, under different pest managements for two seasons (summer and autumn) from late June to late December 2017 were evaluated by installation of sticky yellow cards and investigation of branches and leaves of trees and then biodiversity indices in different orchards were estimated. Analysis of data of foliage samples showed that in summer, the amount of Brillouin diversity index, species richness and frequency in free pesticides protocol orchard were more than the other two orchards, but the average of Simpson diversity index in low input orchard was the most. In autumn, the mean of Simpson and Shannon-Weiner diversity indices and all of the evenness indices in low input orchard were higher than the two conventional and free pesticides protocol orchards; however, the frequency in free pesticides protocol orchard showed higher amount than low input and conventional orchards.Diversity of natural enemies and pests in foliage and sticky yellow card samples, in free pesticides protocol orchard was more than other two orchards.

Keywords citrus orchards; different pest managements; insect biodiversity; mineral oils.

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1 Introduction

Excessive application of pesticides in conventional agriculture has led to numerous problems, such as the reduction of agricultural biodiversity (Stoateet al., 2001; Hooper et al., 2005; Butler et al., 2007). Modern agriculture often provides favorable conditions for pest populations, but it is harmful to beneficial arthropods (Greig Smith et al., 1992). The severe dependence on synthetic insecticides and herbicides over the past 40 years ago has been a major factor in reducing the population of some natural enemies in agricultural systems (Aebischer, 1991; Zhang, 2018). Berry et al. (1996) believed that continued reduction in biodiversity in agricultural ecosystems can make it difficult to regulate the pest populations with the help of natural enemies. For this reason, reducing pesticide use is recommended. Evidence suggests that biodiversity represents the sustainability of the ecosystems and on this basis, it is considered a key factor of the food security systems in the world. Therefore, reducing or eliminating biodiversity can be a serious threat to the survival of agricultural ecosystems and ultimately food security (MousawiToghani, 2015).

Mineral oils currently have become an essential part of many pest management programs for agricultural products around the world. Application of mineral oils is mainly due to their non-toxicity for vertebrates (Beattie and Smith, 1996), their relatively rapid degradation in the environment (Beattie et al., 1995) and the absence of resistance in pests and outbreak of secondary pests (Beattie and Smith, 1993). Mineral oils can control a wide range of pests and provide a good alternative for synthetic pesticides in organic orchards (Damavandian and Kiaeianmoosavi, 2014). Citrus is one of the most important products of Mazandaran Province, Iran (AbdallahiAhi, 2011). The presence of many natural enemies of citrus pests in orchards has been confirmed, but the use of chemical pesticides to control the citrus pests has caused inefficiencies of these natural enemies, and then resistance and outbreak of pests (Damavandian, 2007). Rae et al. (1996) suggested the use of mineral oils instead of synthetic insecticides and acaricides to protect natural enemies because they believed that the harmful effects of mineral oils on natural enemies compared to pesticides are low. On the other hand there are no reports of resistance of pests to mineral oils (Helmyet al., 2012).

In this study, the biodiversity of insects (natural enemies and pests) is compared in three different citrus orchards in Babolsar, Mazandaran province, which are managed by various pest management methods including 1- conventional or common use of pesticides, 2- low input or low pesticides application and 3- healthy or conservation biological control. In general, the main goal of this study is to obtain the best management practices for citrus orchards based on comparative results of biodiversity indicators of different agricultural systems.

2 Materials and Methods

In this research, three citrus orchards over twenty years old, thompson navel cultivar, each with an area of about one hectare, were selected in Hadishahr of Babolsar, Mazandaran Province, Iran. These three orchards are under different types of pest managements including the use of pesticides called a conventional orchard, conservation biological control as a healthy orchard and low application of pesticides as a low input orchard. In each orchard, three replications and 15 trees in each replication and a total of 45 trees were randomly selected for sampling. Sampling unit was considered as a 10 cm branch from the height range of 150 to 200 cm in four directions (North, South, East and west) and the center of the trees. In order to complete the sampling, 3 numbers of sticky yellow cards (10 × 30 cm) in each replication and totally 9 in each orchard at the height of 150 to 200 cm were randomly fitted. Sampling was carried out once every two weeks from late June 2017 to late December 2017 (summer and autumn). After collection and transferring to the laboratory, the specimens with valid references were identified as far as possible, at the level of the order, family or species and counted. Then these 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 Simpson, Shannon-Wiener and Brillouin diversity indices and Camargo, Simpson and Smith-Wilson evenness indices, richness and frequency) were then calculated (Table 1).The analysis of biodiversity indices during one year 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 5% level.

Table 1 Biodiversity indices.

Index	Formula	Comments	Reference
Simpson (Diversity)	$1 - D = 1 - \sum_{i=1}^{S} Pi^2$	S: Number of species in the sample, n_i: Number of individuals of species *i* in the community, Variable range from zero (without diversity) to approximately one (1-1/s), Sensitive to dominant species in sample,	Simpson (1949)
Shannon-Wiener (Diversity)	$H' = -\sum_{i=1}^{S} Pi(\log_2 Pi)$	Pi: Proporation of total sample belonging to *i*th species (it's introduced by ni/N), S: Number of species, The unit of H' is "bits/individual".	Shannon and Weaver (1949)
Brillouin (Diversity)	$\hat{H} = H_B = \frac{1}{N}\log\left(\frac{N!}{n_1!\, n_2!\, n_3!\ldots}\right) = \frac{\ln N! - \sum \ln n_i!}{N}$	N: Number of individuals. N_i: Number of species i (n_1: Number of species 1, n_2: Number of species 2 and …)	Margalef (1958)
Camargo (Evenness)	$\hat{E} = 1 - \left(\sum_{i=1}^{S}\sum_{j=i+1}^{S}\left[\frac{Pi - Pj}{S}\right]\right)$	S: Number of species in the sample, Pi and Pj: Proporation of individuals of species *i* and *j* in total sample, respectively.	Camargo (1993)
Simpson (Evenness)	$E_{1/D} = \frac{1/D}{S}$	D: Simpson index. S: Number of species in the sample.	

Smith-Wilson (Evenness)	$$E_{var} = 1 - \left(\frac{2}{\pi}\right)\left[\arctan\left\{\frac{\sum_{i=1}^{s}\left(\log_e(n_i) - \sum_{j=1}^{s}\log_e(n_j)/s\right)^2}{s}\right\}\right]$$	n_i: Number of species *i* in sample (i=1,2,3,…,S), n_j: Number of species *j* in sample (j=1, 2, 3,…, S), S: Number of species in entire samples	Smith & Wilson (1996)

From mid to late August, in conventional orchard, a mixture of acetamiprid (insecticide) and fenproeximate (acaricide) at the dose of 0.1% and 0.5% mineral oil; in low input orchard acetamiprid and fenoproximate at the dose of 0.05% and mineral oil at the dose of 0.5% and in healthy orchard only 0.5% of mineral oil was applied for pest control.

3 Results

3.1 Foliage samples

3.1.1 Summer

The results of variance analysis of data on foliage samples of three orchards with different managements showed that the Simpson diversity index, Simpson and the Camargo evenness indices and the species richness at the level of 5%, and the Brillouin diversity index and the frequency at the level of 1% had significant differences, but the Shannon-Weiner diversity index and the Smith-Wilson evenness index did not show any significant difference (Table 2). According to the results, the amount of the Brillouin diversity index, species richness and the frequency in healthy orchard were more than the other two orchards, but the average of Simpson diversity index in low input orchard was more than healthy orchard and in healthy orchard was more than conventional orchard. The mean of Camargo evenness index was similar in two low input and conventional orchards and more than the mean of this index in healthy orchard. Simpson evenness index also showed a higher value in low input orchard than in the other two orchards (Fig. 1 and 2).

Table 2 Variance analysis of biodiversity indices of foliage samples of three orchards in summer.

Variation sources	Degree of freedom	Diversity			Evenness			Frequency	Richness
		Simpson	Shannon-Wiener	Brillouin	Simpson	Camargo	Smith-Wilson		
Treatment	2	0.0029*	0.1407ns	0.3166**	0.0353*	0.0274*	0.1077ns	61009.3333**	12.4444*
Error	6	0.0006	0.0432	0.0230	0.0056	0.0034	0.0180	112.5556	2.0000
Coefficient of variation		2.96	8.29	6.83	12.13	9.94	24.46	9.22	17.43

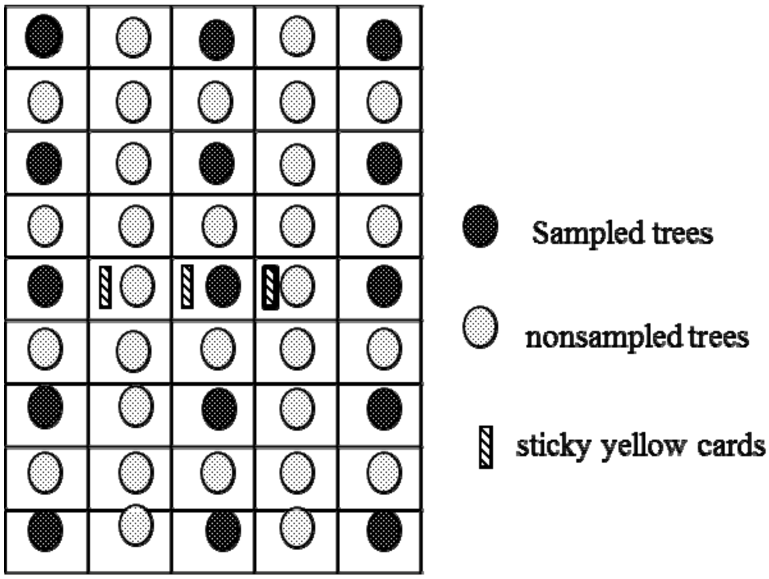


Fig. 1 Layout of sampling pattern.

In summer, the investigation of foliage samples showed that in healthy orchard there were 5 cottony cushion scales, 92 nymphs of *P. aurantii*, 18 egg sacs of *P. aurantii* and 10 *Chrysomphalusdictyospermi* (Hemiptera: Diaspididae) as pests and 169 phytoseiid mites and 13 Aphelinidae parasitoid wasps and 103 parasitized aphids as natural enemies. In low input orchard, there were 12 nymphs of *P. aurantii* and 8 numbers of red spider mites as pests and 1 *P. quatuordecimpunctata*, and 19 mites from family Phytoseiidae as natural enemies. In conventional orchard, one number of *P. aurantii* and 589 red spider mites and 13 phytoseiid mites were counted (Table 3).

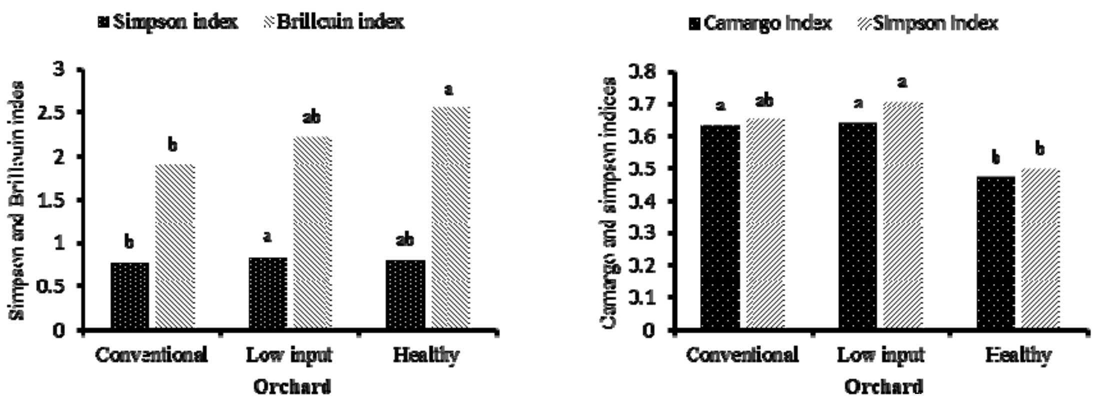


Fig. 2 The mean of diversity indices (Simpson and Brillouin) (left) and evenness indices (Camargo and Simpson) (right) in different orchards in summer.

Table 3 Observed natural enemies and pests in foliage samples in summer.

Insects and Mites	Healthy	Low input	Conventional
Icerya purchasi	5	-	-
Pulvinaria aurantii	92	12	1
Egg sacs of *P. aurantii*	18	-	-
Chrysomphalus dictyospermi	10	-	-
Panonychus citri	-	8	589
Propylea quatuordecimpunctata	-	1	-
Aphelinidae	13	-	-
Parasitised aphids	104	-	-
Phytoseiidae	169	19	13

3.1.2 Autumn

The results of variance analysis of the data obtained from the study of foliage in three orchards showed that the Simpson and the Shannon-Weiner diversity indices at the level of 5% and the all of the evenness indices and the frequency at the level of 1% had significant difference, but the Brillouin diversity index and the species richness did not have any significant difference (Table 4). The mean of Simpson and Shannon-Weiner diversity indices and all the evenness indices in low input orchard were higher than the two conventional and healthy orchards (Fig. 6); however, the frequency in healthy orchard showed higher amount than low input and conventional orchards (Fig. 3 and 4). By investigation the branches and leaves in autumn, 23 cottony cushion scales and 100 aphids from family Aphididae in healthy orchards; 36 red spider mites in low input orchard and 14 aphids from family Aphididae and four red spider mites in conventional orchard were found as pests. As natural enemies, in healthy orchard, 815, in low input orchard 82, and in conventional orchard, 90 phytoseiid mites were counted (Table 5).

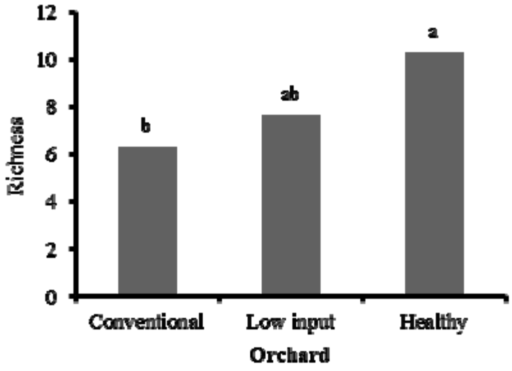
3.2 Sticky yellow card samples

3.2.1 Summer

By analyzing the obtained data from yellow cards in three different orchards, it was revealed that the indices of diversity and the species richness were significantly different at the level of 1% while none of the evenness indices and frequency was significantly different (Table 6).

Table 4 Variance analysis of biodiversity indices of foliage samples of three orchards in autumn.

Variation sources	Df	Diversity			Evenness			Frequency	Richness
		Simpson	Shannon-Wiener	Brillouin	Simpson	Camargo	Smith-Wilson		
Treatment	2	0.0822*	0.5130*	0.3453^{ns}	0.1099**	0.0827**	0.1052**	88412.44**	1^{ns}
Error	6	0.0145	0.0883	0.0846	0.0069	0.0025	0.0038	3392.0000	0.6667
Coefficient of variation		21.50	18.69	20.01	18.29	10.81	14.78	37.07	14.41



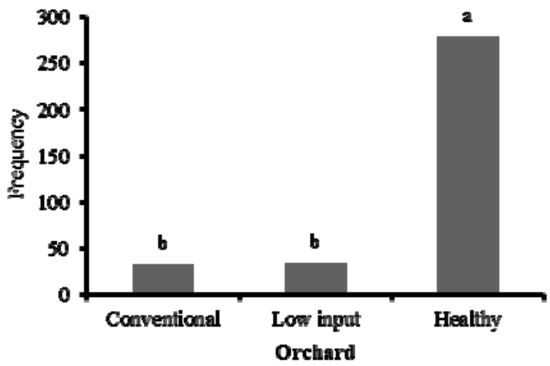
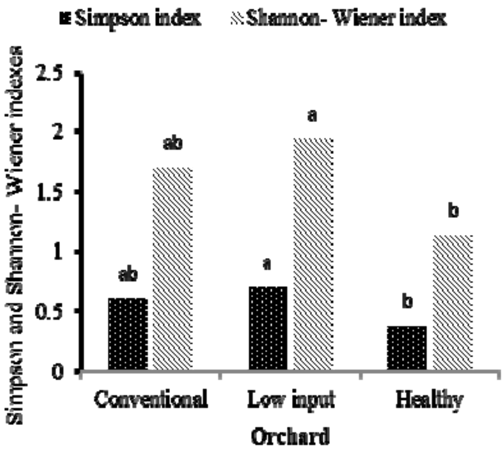


Fig. 3 The mean of species richness (left) and frequency (right) in different orchards in summer.



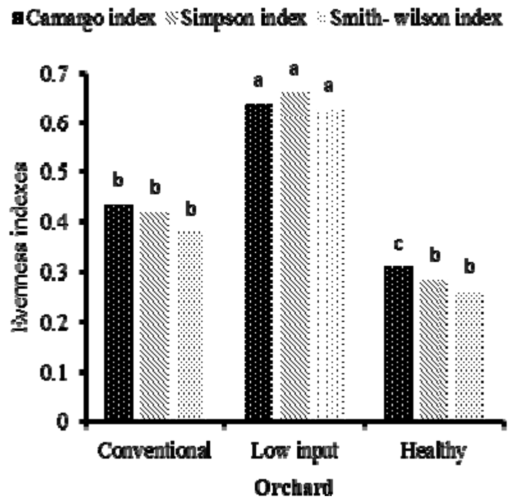


Fig. 4 The mean of diversity indices (Simpson and Shannon- Wiener) (left) and evenness indices (Camargo, Simpson and Smith-Wilson) (right) in different orchards in autumn.

Table 5 Observed natural enemies and pests in foliage samples in autumn.

Insects and Mites	Healthy	Low input	Conventional
Iceryapurchasi	23	-	-
Aphididae	100	-	14
Panonychuscitri	-	36	4
Phytoseiidae	815	82	90

Table 6 Variance analysis of biodiversity indices of yellow card samples of three orchards in summer.

Variation sources	df	Diversity			Evenness			Frequency	Richness
		Simpson	Shannon-Wiener	Brillouin	Simpson	Camargo	Smith-Wilson		
Treatment	2	0.0088**	0.4659**	0.4609**	0.0007ns	0.0003ns	0.0002ns	1092506.3ns	119.44**
Error	6	0.0006	0.0256	0.0242	0.0010	0.0008	0.0002	261237.889	7.5556
C.V.		3.15	5.67	5.57	16.09	13.98	6.95	19.67	10.39

The mean of diversity indices and species richness in healthy orchard were higher than low input and conventional orchards (Fig. 5). In summer, on yellow cards of healthy orchard, 539 in low input orchard 210, and in conventional orchard, 258 aphids from family Aphididae were observed. Also in healthy orchard, 55 *P. quatuordecimpunctata*, 5 *Scymnus sp.*, 45 *R. cardinalis* and 4 *Chilocorus sp.*werecounted; in the low input orchard, one *P. quatuordecimpunctata* and 3 *Scymnus sp.* and in conventional orchard, only one *P. quatuordecimpunctata* were observed in yellow cards (Table 7). The number of insects from order Hymenoptera and suborder Apocrita, family Formicidae from suborder Apocrita, *C. carnea* from net- winged insects and insects from order Mecoptera were highest in healthy orchard. Trombididae mites were observed only in healthy orchard (Table 7).

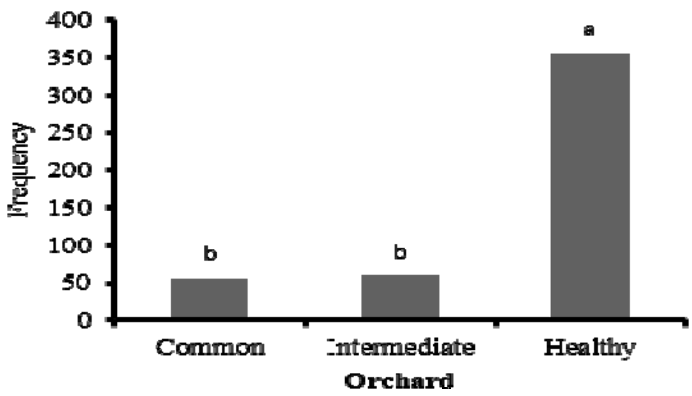


Fig. 5 The mean of frequency in different orchards in autumn.

Table 7 Observed pests and natural enemies on yellow card samples in summer.

Insects and Mites	Healthy	Low input	Conventional
Aphididae	539	210	258
Propylea quatuordecimpunctata	55	1	1
Scymnus sp	5	3	-
Rodalia cardinalia	45	-	-
Chilocorus sp	4	-	-
Tipulidae (Nematocera)	1	-	-
Psychodidae (Nematocera)	94	13	11
Others of Nematocera	2353	2928	2037

(Brachycera) Muscidae	14	2	10
Fannidae (Brachycera)	7	-	-
Tabanidae (Brachycera)	58	2	21
Others of Brachycera	1619	965	1795
Psocoptera	883	138	725
Thysanoptera	87	34	25
Hymenoptera (Apocrita)	1478	868	1195
Formicidae	1260	239	300
Chrysoperla carnea	80	7	29
Cicadellidae	129	106	72
Chrysomelidae	65	25	28
Cerambycidae	1	-	1
Staphylinidae	3	-	1
Trichoptera	16	-	10
Mecoptera	93	37	58
Odonata (Zygoptera)	13	4	3
Acrididae (teraOrthop)	1	-	-
Hemiptera	13	2	6
Trombididae	10	-	-

3.2.2 Autumn

Analysis of variance of data obtained from yellow cards in autumn showed that the all indices of diversity and the species richness in three orchards had significant difference at 1% level, while evenness indices and frequency in three orchards were not significantly different (Table 8). The mean of diversity indicess and species richness in healthy orchard were higher than low input and conventional orchards (Fig. 6). By investigation the yellow cards of autumn, in healthy orchard, 240 aphids from family Aphididae and 32 mediterranean fruit flies *Ceratitiscapitata* (Diptera: Tephritidae), in low input orchard 55 aphids, and in conventional orchard 178 aphids were observed. Also, in healthy orchard, 19 *P. quatuordecimpunctata*, one *R. cardinalis*, 2 *Chilocorus sp.* and one adult of *E. balteatus* were observed; however, in low input and conventional orchards, no natural enemies were observed on yellow cards (Table 9). The number of suborder Brachycera in conventional orchard was the highest, but suborder Apocrita from order Hymenoptera, *C. carnea*, order Mecoptera and Trombididae mites had higher populations in healthy orchard than the other two orchards (Table 9).

Table 8 Analysis of variance of biodiversity indices of yellow card samples of three orchards in autumn.

Variation sources	df	Diversity			Evenness			Frequency	Richness
		Simpson	Shannon-Wiener	Brillouin	Simpson	Camargo	Smith-Wilson		
Treatment	2	0.0207^{**}	0.7114^{**}	0.6955^{**}	0.0021^{ns}	0.0020^{ns}	0.0004^{ns}	226252.00^{ns}	125.44^{**}
Error	6	0.0018	0.0418	0.0415	0.0007	0.0005	0.0003	84157.00	1.7778
Coefficient of variation		5.82	7.91	7.96	15.93	11.43	11.15	9.59	5.50

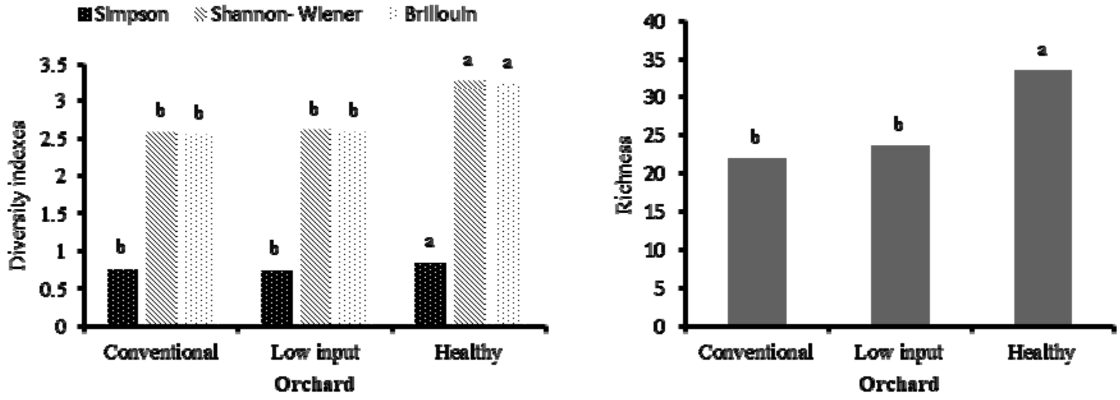


Fig. 6 The mean of diversity indices (Simpson, Shannon- Wiener and Brillouin) (left) and species richness (right) in different orchards in autumn.

Table 9 Observed pests and natural enemies on yellow card samples in autumn.

Insects and Mites	Healthy	Low input	Conventional
Aphididae	240	55	178
Ceratitis capitata	23	-	-
Propylea quatuordecimpunctata	19	-	-
Rodalia cardinalia	1	-	-
Chilocorus	2	-	-
Episyrphus balteatus	1	-	-
Culicidae (Nematocera)	63	61	55
Tipulidae (Nematocera)	46	52	-
Psychodidae (Nematocera)	61	1	32
Others of Nematocera	1716	1610	1949
(Brachycera) Muscidae	17	58	60
Fannidae (Brachycera)	10	2	-
Tabanidae (Brachycera)	5	-	-
Others of Brachycera	3914	4045	4489
Thysanoptera	51	35	45
Psocoptera	184	445	-
Chrysoperla carnea	21	-	2
Hymenoptera (Apocrita)	959	387	733
Formicidae	243	168	177
Cicadellidae	44	39	41
Chrysomelidae	53	11	21
Staphylinidae	5	-	-
Trichoptera	7	-	3
Mecoptera	1096	832	1050
Trombididae	23	-	8
Hemiptera	5	27	7
Odonata (zygoptera)	1	-	-

4 Discussion

In this research, insect populations for two seasons (summer and autumn) were investigated in citrus orchards under three different pests management (Conventional, Low input and Healthy) by installing sticky yellow cards and checking tree branches and leaves, and then biodiversity indices were estimated in different orchards. The results showed that the richness of the species in the orchard under the conservation biological control (Healthy orchard) washigher than the other two orchards. Analysis of summer data showed that evenness indices had lowest amount in healthy orchard that differences about Camargo and Simpson were significant but Smith- Wilson index had not significant differences (Fig. 1-Right). Species richness and frequency in healthy orchard was higher than the other two orchards (Fig. 2). Shannon- Wiener and Brillouin diversity indices had highest amount in healthy orchard but differences only about Brillouin were significant. Simpson diversity index had the highest amount in low input orchard and lowest amount in conventional orchard (Fig. 1-Left). In summer, despite the species richness and frequency in healthy orchard were much more than the other orchards, but evenness indices showed lowest amount in healthy orchard and abundance distribution in healthy orchard was not uniform; because as the number of species increases, the probability that the abundance of different species is similar, decreases. In this season, higher abundance of beneficial insects and mites such as parasitoid wasps from the family Aphelinidae and Phytoseiidae mites in healthy orchard than the conventional and low input orchards were observed (Table 3). Mid to late August, in conventional and low input orchrds, a mixture of insecticide, acaricide and mineral oil and in healthy orchard only mineral oil was applied for pest control.The application of synthetic pesticides results in destruction of beneficial predator mites and then outbreak of spider mites (Beattie et al., 1996). As can be seen from Table 3, despite the application of acaricide in conventional orchard in summer, the outbreak of red spider mite *P. citri* is observed but in healthy orchard was not found at all. There were 169, 19 and 13 Phytoseiidae mites in healthy, low input and conventional orchards respectively that revealed the lethal effects of synthetic pesticides on predaceous Phytoseiidae mites.Also, the population of *P. aurantii* was increased in three orchards and this pest had higher population in healthy orchard than conventional and low input orchards (Table 3), which was controlled in low input and conventional orchards by using the chemical pesticides and in healthy orchard by using the mineral oils and with the activity of natural enemies of *p.aurantii* such as mites from the family Phytoseiidae.

Several predator mites from Phytoseiidae family have been reported from Citrus orchards of Mazandaran province, some of them are polyphage (Faraji, 1992). Koss et al. (2005) studied the pest and predator communities in Washington potato fields under three types of managements including organic pest management, conventional by using selective insecticides (soft) and conventional by using wide spread insecticides (hard). The most taxas, were more abundant in organic management than conventional soft management and in conventional soft management were more than conventional hard management. The density of the total predators and the density of *Geocoris sp* and *Nabis sp* and the density of predator spiders in foliage samples and the total density of the predators and the density of Carabidae and Staphylinidae and spiders in soil samples, in organic and soft management were more than hard management. Despite the highest density of predators in organic farming, these farms had the highest density of major pests of that area, such as peach green aphid *Myzus persicae* (Sulzer) and Colorado potato beetle *Leptinotarsa decemlineata* (Say). The density of these two pests in organic farms was significantly higher than conventional soft and hard fields. Hilbeck and Kennedy (1996) also made comparisons of pests and predators density on non-insecticides farms and conventional farms in North Carolina, and achieved similar results. Amalinet al. (2009) examined the effects of pesticides on arthropod communities in Agricultural areas under the cultivation of native ornamental plants near the Everglades National Park in United States. The aim of this study was to compare the arthropod communities in two biological and chemical pest control systems. They separated the farm for two years into two spraying and none spraying sections. The results showed that there were more arthropod taxa in none spraying section than the spraying section, and higher biodiversity in non-spraying section was calculated. In non-spraying section, the abundance of predators such as Phytoseiidae and Coccinellidae was higher. Among the herbivore arthropods, there was no difference between the two sections in abundance of families Aphididae, Coccidae and Tenuipalpidae, but the frequency of families Diaspididae, Eriophyidae and larvae of the Lepidoptera was higher in non-spraying section. Families Tetranychidae and Tydeidae were more abundant in spraying section. The number of parasitized individuals from families Aphididae and Coccidae was similar in two sections. In general, the frequency of arthropods was higher in non-spraying areas. Diversity indices calculated from the obtained data also showed that the diversity of arthropod communities in non-spray areas was higher than spraying areas.

Analysis of autumn data showed that all indices of diversity and evenness in low input orchard had the highest amount and in healthy orchard had the lowest amount (Fig. 3); however, the species richness (without significant differences) and frequency in healthy orchard showed the highest value (Fig. 4). In autumn, species richness and frequency were highest in healthy orchard, but due to the high population of Phytoseiidae mites (815 numbers) in this orchard compared to low input orchard (82 numbers) and conventional orchard (90 numbers) (Table 5), the distribution of population between different species was not uniform in healthy orchard and therefore the evenness indices in this orchard showed less than other orchards. Due to this fact that diversity indices, are included measurement of evenness and species richness together, thus, less evenness in healthy orchard also affects diversity indices and the amount of these indices in healthy orchard has decreased. Regarding to that low input and conventional systems were more evenness than healthy system and the lack of significant differences of species richness between the three orchards, conventional and low input systems had higher biodiversity. During the autumn, the results were similar to those in the summer, and the number of phytoseiide mites in healthy orchard was significantly higher than in other orchards. Other natural enemies which were highly mobile and could not be counted on branch and leaf samples were trapped partially by sticky yellow cards. Pests such as *I. purchasi* and insects from family Aphididae also had higher population in healthy orchard than low input and conventional orchards but their population was under EIL and there was no need for control and activity of natural enemies was enough to control them (Table 5). The analysis of data of yellow cards in summer showed that the amount of evenness indices in healthy orchard was more than the other two orchards, but these differences were not significant (Table 6). Species richness and frequency had the highest amount in healthy orchard and lowest amount in conventional orchard, and these differences were significant in terms of richness but differences of frequency between three orchards were not significant (Table 6 and Fig. 5-Right). All diversity indices in healthy orchard were highest (Fig. 5-Left). According to these observations, it can also be concluded that biodiversity in summer in healthy orchard was higher than two other orchards. The number of aphids on yellow cards in low input and conventional orchards due to the use of chemical pesticides were lower than healthy orchard but were controlled by natural enemies (Table 7). The abundant of natural enemies such as *P. quatuordecimpunctata*, *R. cardinalis*, *Scymnus sp.*, *Chilocorus sp.*, *C. carnea* and predatory mites from family Trombididae was significantly higher in healthy orchard than the other two orchards; so that some of them were not found in conventional and low input orchards (Table 7). Aidooet al. (2016) believed that in orchards that use mineral oils for control of pests, a balance is gradually created between the population of pests and natural enemies that no longer requires chemical control of pests, because the presence of this density and the diversity of natural enemies causes the population of pests Lower than the economic injury level, in which case chemical control of pests is not cost-effective.Population of order lepidoptera in farms with conventional and organic managements in southern England was studied by Feberet al. (2006). The abundance of order Lepidoptera in organic farming was significantly higher than the conventional management. Some species were more abundant in conventional farms than organic farms, but this difference was not significant. The number of obtained species was more in organic management than conventional farms. The increased in evenness of farms and the expansion of agriculture, and the increased use of pesticides and fertilizers, are the main reasons for reducing the biodiversity of farms. Organic farming may be a way to help restore biodiversity. Analysis of yellow card data in autumn revealed that there were no significant differences in evenness indices in three orchards (Table 8). Species richness was most in healthy orchard (Fig. 6-Right). The amount of diversity indices in healthy orchard was significantly higher than the other two orchards (Fig. 6-Left). Although the frequency showed more amount in healthy orchard than the other two orchards, the difference between them was not significant. Due to the higher species richness in healthy orchard and the lack of significant differences in evenness, the healthy orchard had higher biodiversity.

In autumn yellow cards showed a low population of aphids in three orchards compared to summer and of course the population of natural enemies also decreased, but natural enemies in healthy orchard still had higher diversity but in low input and conventional orchards did not found at all or rarely found (Table 9). Pest damage and structure of arthropod communities in tomato production in organic and conventional conditions in California were studied by Letournaeu and Goldstein (2001). They observed that, contrary to the predictions that the removal of insecticides would increase the damage of pests in tomato fields, insect damage to leaves and fruits were not different in 18 commercially fields with different managements, and there were not significant differences in pest damage between organic and conventional farms. In fact, the average frequency of herbivorous insects was very similar in organic and conventional tomato farms. On the other hand, biodiversity and species richness of organic fields were more than conventional fields. The trapped natural enemies in two types of managements revealed that the abundance and diversity of natural enemies were the main differences between these two types of managements. Organic management may increases the diversity of herbivorous insects, but these insects are not dominant, and resources are shared among more species and could have lower impacts on pest damage levels of pest. The biological control of pest in organic management compensates the widespread application of chemical compounds that are used in conventional management. These two issues indicate that organic methods increase the protection of pest and non-pest arthropods. Chemical insecticides, in addition to harmful effects on human health, cause pollution of the environment, ground water and under ground water, and also reduce the frequency of some of the biological control factors, such as ladybirds, entomopathogens and mites from species *Allothrombium pulvinum* (Acari: Trombididae) that gradually cause a loss of environmental balance between pests and natural enemies, and as a result of the absence of natural enemies in the environment, pest outbreaks occur (Saboori et al., 2003; Damavandian, 2007). To maintain the biodiversity of insects in citrus orchards, management practices that have the least side-effects on beneficial insects, such as natural enemies, pollinators, and other insects, but control the pests effectively (such as using biological control factors) are necessary (Damavandian, 2007).

Studying during summer and autumn showed that the species richness and abundance of pests and natural enemies are higher in free pesticides protocol orchard than conventional and low input orchards. Pest control based on EIL and applying mineral oil instead synthetic pesticides can maintain the natural enemies and the activity of natural enemies can maintain the pest population under injury level without application of pesticides in Mazandaran province condition.

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References

AbdullahiAhi G. 2011. Demography and Functional response of *Cryptolaemus montrouzieri* Mulsant (Coleoptera: Coccinellidae), feeding on mealybugs, *Planococcus citri* (Risso) and *Pseudococcus viburni* (Signoret) under laboratory conditions. Dissertation, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran.

Aebischer NJ. 1991. Twenty years of monitoring invertebrates and weeds in cereal fields in Suffolk. In: The Ecology of Temperate Cereal Fields. 32nd Symposium of the British Ecological Society (Firbank LG, Carter N, Darbyshire JF, Potts GR, eds). Blackwell Scientific Publications, 305-331

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

Amalin DM, Pena J, Duncan R, Leavengood J, Koptur S. 2009. Effects of pesticides on the arthropod community in the agricultural areas near the Everglades national park. Proceedings of the Florida State Horticultural Society, 122: 429-437

Beattie GAC, Smith D. 1993. Citrus Leafminer. Agfact H2. AE.4 (2nd edition). New South Wales Agriculture and Fisheries, Orange, Australia

Beattie GAC, Liu Z, Watson D, Clift A, Jiang L. 1995. Evaluation of PSOs and polysaccharides for control of *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillaridae). Australian Journal of Entomology, 34 (4): 349-353

Beattie GA, Smith CD. 1996. Integrated pest management: sustainable pest control for the future based on the past? Proceedings of 8th International Society of Citriculture. 18-23, Sun City, South Africa

Berry NA, Wratten SD, McErlich A, Frampton C. 1996. Abundance and diversity of benefical arthropods in conventional and organic carrot crops in New Zealand. New Zealand Journal of Crop and Horticultural Science, 24: 307- 313

Butler SJ, Vickery JA, Norris K. 2007. Farmland biodiversity and the footprint of agriculture. Science, 315: 381-384

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

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, KiaeianMoosavi SF. 2014. Comparison of mineral spray oil, Confidor, Dursban, and Abamectin used for the control of *Phyllocnistis citrella* (Lepidoptera: Gracillaridae), and an evaluation of the activity of this pest in citrus orchards in northern Iran. Journal of Plant Protection Research, 54(2): 156-163

Faraji F. 1992. Biology of Citrus Red Mite: *Panonychus citri* McG. in the Eastern Side of Mazandaran Province. Msc. Thesis, Shahid Chamran University, Iran

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

Greig-Smith P, Frampton G,Hardy T. 1992. Pesticides, cereal farming and the environment. London, HMSO, 281 p.

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

Hilbeck A, Kennedy GG. 1996. Predators feeding on the Colorado potato beetle in insecticide-free plots and insecticide-treated commercial potato fields in Eastern North Carolina. Biological Control, 6: 273-282

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

Koss AM, Jensen AS, Schreiber A, Pike KS, Snyder WE. 2005. Comparison of predator and pest communities in Washington potato fields treated with broad- spectrum, selective, or organic insecticides. Environmental Entomology, 34(1): 87-95

Letournaeu DK, Goldstein B. 2001. Pest damage and arthropod community structure in organic vs. conventional tomato production in California. Journal of Applied Ecology, 38: 557-570

Margalef R. 1958. Information theory in ecology. General Systematics, 3: 36-71

MousawiToghani SY. 2015. Comparison of Biodiversity of Rice Agro-Ecosystems Under Different Management Systems. Ph.D Dissertation, Ferdowsiuniversity of Mashhad, Iran

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, and methomyl for citrus leafminer (Lep: Gracillaridae) control in southern China. Journal of Economic Entomology, 89: 493-500

Saboori AR, HosseiniM, 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

Stoate C, Boatman ND, Borralho RJ, CarvalhoRio C, De Snoo GR, Eden P. 2001. Ecological impacts of arable intensification in Europe. Journal of Environmental Management,63: 337-365

Zhang WJ. 2018. Global pesticide use: Profile, trend, cost / benefit and more. Proceedings of the International Academy of Ecology and Environmental Sciences, 8(1): 1-27