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Comparative faunistic analysis of mite species on neglected and conventional pome fruit trees in Turkey

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Original research

ABSTRACT

The paper presents the comparative faunistic analysis of leaf inhabiting mite species on neglected and conventionally grown pome fruit trees in Turkey as well as their diversity and distributions. For this purpose, twelve sampling areas were chosen in the Ordu region of Turkey. The study was carried out on four fruit tree species, apple (*Malus domestica*), pear (*Pyrus communis*), quince (*Cydonia oblonga*), and loquat (*Eriobotrya japonica*), between 2014 and 2019. In the study, a total of 42 mite species were identified from 12 families belonging to two orders. 92.43% of all species were found on the neglected trees, while 7.57% were reported in the conventional orchards. Among phytophagous mites, *Cenopalpus pulcher* on the neglected trees and *Amphitetranychus viennensis* in the conventional orchards showed the greatest overall constancy. The most abundant and common predatory species were *Phytoseius finitimus* on the neglected trees and *Transeius wainsteini* in the conventional orchards. A high faunistic similarity was found between the conventionally grown apple fruit trees and neglected apple, pear, quince, loquat trees. Considering together predatory and tetranychoid mites, the highest interspecific association index was revealed for the pair *T. wainsteini* – *C. pulcher*. Additionally, the pair *Z. mali* – *T. wainsteini* within the predatory mites and *A. viennensis* – *C. pulcher* within the tetranychoid mites had the highest index of association.

Keywords coefficient of constancy; diversity; Jaccard index; mite; Sorensen's index; species complexes

Introduction

Pome fruits are members of the family Rosaceae and subfamily Pomoideae (Özçağıran *et al.* 2005). In the world, the total production of pome fruits is approximately 113,750,265 tons per year on 7,485,379 hectares of land (FAO 2019). In Turkey, pome fruits are grown on 211.961 hectares of the 23.199.945 hectares of agricultural land. Pome fruits with an annual production of 5,056,672 tons constitute the second group in order of importance in Turkish fruit cultivation (TUIK 2021).

Pome fruits contribute significantly to the Turkish economy. This fruit group's revenue derived from exports has been approximately 200 million US Dollars (YMS Reports 2021). Besides the significant economic importance, these fruits are intended for fresh consumption but also in processed forms. They also supply the raw material for industry (Milic *et al.* 2016). However, even today, world pome fruit production suffers significant losses due to plant pests, diseases and weeds, despite all scientific advances (Özsayın 2012). Phytophagous mites are potentially one of the major pest groups of pome fruits (Hoy 2011).

Many studies on mite species associated with pome fruits were conducted in various countries. For example, mite species on apple trees in England (Collyer 1956), Michigan

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(USA) (Strickler *et al.* 1987), Finland (Tuovinen and Rokx 1991), Israel (Palevsky *et al.* 1996), Slovakia (Praslicka and Bartekova 2008), Iran (Rahmani *et al.* 2010), Syria (Dahiah *et al.* 2011), Serbia (Stojnic *et al.* 2014) and Egypt (Hussian *et al.* 2018); pear mite fauna in Britain (Bergh and Weiss 1993), Egypt (Ismailia) (Osman and Mahmoud 2008); mite species on both apple and pear trees in Slovakia (Praslicka *et al.* 2009) and India (Singh *et al.* 2016) were determined.

Other studies detected the mite species on pome fruits in different regions of Turkey (Çobanoğlu 1993 a, b, c, d; İncekulak and Ecevit 2002; Yanar and Ecevit 2005; Kasap and Çobanoğlu 2007; Kumral and Kovancı 2007; Yanar and Ecevit 2008; Kasap *et al.* 2013; Kasap *et al.* 2015; Akyazı *et al.* 2017). However, as far as we know, no previous research has investigated mite species on apple, pear, quince and loquat in Ordu province. Although there are conventional pome fruit orchards in Ordu, fruit production is generally carried out in small gardens without using pesticides, in contrast to conventional orchards. So, our initial hypothesis is that a high diversity of mite species is expected to be found in the non-treated orchards.

The study also presents the result of a faunistic analysis of the phytophagous and predatory mite communities found in this area. Kumral and Kovancı (2007) studied the similarity indexes of mite species on apple, pear, and quince trees in conventional and agrochemical-free orchards in Bursa province of Turkey. In Serbia, the species assemblages of tetranychid and phytoseiid mites on cultivated and wild apple trees were researched by Stojnic *et al.* (2014).

Thus, the purpose of the current study is to present the comparative faunistic analysis of mite species on conventional and neglected apple, pear, quince, and loquat trees in 12 municipalities of Ordu province in Turkey as well as their diversity and distributions.

Material and methods

Sampled area and sampling of pome fruit species

The survey was conducted in selected neglected (naturally growing trees without using agrochemicals) and conventional pome fruit orchards (trees grown using synthetic chemical fertilizer, pesticides, herbicides, and other continuous inputs). Leaf samples were collected from 12 different sampling areas (Altınordu, Fatsa, Kabadüz, Perşembe, Ulubey, Ünye, Akkuş, Çatalpınar, Çaybaşı, Çamaş, Gürgentepe and Gülyalı) in Ordu, Black Sea region (Turkey) (Figure 1). Geographical coordinates were recorded using a GPS mobile device (Garmin Etrex 30).

The surveys were carried out on four different pome fruit species; apple (*Malus domestica* Borkhausen), pear (*Pyrus communis* L.), quince (*Cydonia oblonga* Miller), and loquat [*Eriobotrya japonica* (Thunberg) Lindley] (Rosaceae). The samples were collected from 271 different coordinate points located at 176 villages. A total of 2.141 samples were collected: 1.077 conventional trees and 1.064 neglected trees.

Samplings were carried out between April and November each year at 10–15 day intervals from 2014 to 2016. The number of sampled trees per site was determined according to the total number of trees in each orchard (Table 1). On each sampling date, approximately 20 leaves per tree were taken from different parts of the tree canopy, i.e., lower, middle, and upper canopy. The samples were put into paper bags placed inside plastic bags, labeled, and transferred to the laboratory, where they were kept in a refrigerator at 4 °C for future examination.

Extraction, mounting, and identification of mite specimens

Mites found on the adaxial and abaxial surfaces of the leaves were collected with a paintbrush (5/0) under a stereomicroscope (Leica S8 APO). Subsequently, the leaf samples were also placed in Berlese-Tullgren funnels for 24 hours to extract all mites. The specimens were preserved in vials containing 70% ethanol. All mites were cleared in a Lacto-phenol medium.

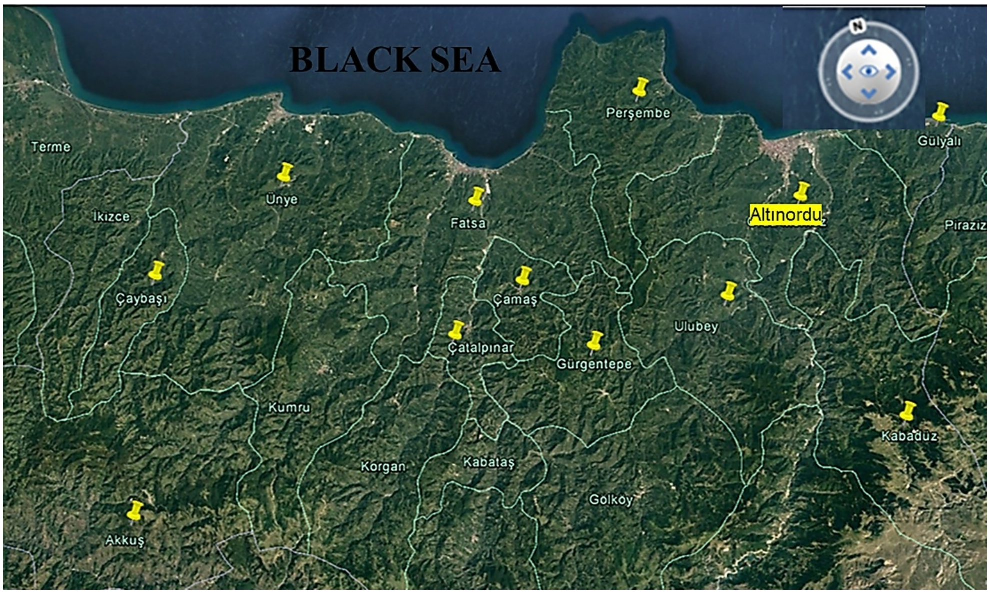

Figure 1 Twelve sampled areas in Turkey (Black Sea Region, Ordu).

Each mite was mounted in a drop of Hoyer's medium on microscope slides according to the method of Krantz and Walter (2009). On the other hand, the eriophyoid specimens were cleared in Keifer's booster medium and mounted using an "F" medium as suggested by Amrine and Manson (1996). The slides were dried in an oven (Ecocell EC111) at 50 °C for 5–7 days.

The identification of mites was performed using a light microscope equipped with phase contrast (Leica DM 2500, Heerbrugg, Switzerland). The species identifications were confirmed by Dr. Farid Faraji (Phytoseiidae), Prof. Dr. Serge Kreiter (Phytoseiidae), Prof. Dr. Eddie A. Ueckermann (Tydeidae, Stigmaeidae, Iolinidae, Triophtydeidae, Cunaxidae, Cheyletidae, Blattisociidae), Prof. Dr. Owen Seeman (Tenuipalpidae), Dr. Philippe Auger (Tetranychidae), Dr. Mariusz Lewandowski (Eriophyidae), and Prof. Dr. Antonio C. Lofego (Tarsonemidae).

Data analysis

The percentage of each species detected during the sampling period was calculated according to Yu *et al.* (2015) as follows:

Percentage of each species (%) = (Number of each mite species / Total number of collected mites) × 100

For the faunistic analysis of the similarity between the mite communities on pome fruits and to evaluate β- diversity, Sorensen's index (QS) or similarity coefficient was used. The value

Table 1 The number of sampled trees according to the total number of trees in each sampling area (Madanlar 1991).

Total number of trees in each sampling location	The number of sampled trees
0– 50	All trees
51–200	50 trees
201–400	60 trees
More than 400	20% of the total number of trees

of Sorensen's index ranges from 0 to 1. Sorensen's index was calculated using the following formula (Southwood 1968):

QS = 2j / [a + b]

a = the number of species in habitat A

b = the number of species in habitat B

j: the number of common species in both habitats

To determine the frequency of mite species in individual sites, the coefficient of constancy (frequency of occurrence) index (C%) (Dajoz 1977) was used. According to C indexes, the species were classified as accidental, accessory, constant, euconstant, or close species associated with the considered habitat. C index values greater than 50% represent a close species associated with the considered habitat while those with values less than 25% represent accidental, 25.1–50% represent accessory, 50.1–75% for constant, and 75.1–100% euconstant species. C value was calculated using the following formula:

C = (Na / n) 100

Na = The number of samples containing species A

n = The total number of samples of all species

Jaccard index (JI) (Ludwig and Reynolds 1988) was used to determine the association for each pair of species (A and B). Interspecific associations between the 10 most predominant predaceous and phytophagous mite species were examined. The index was calculated using the following formula:

JI: a/ (a + b + c)

a = number of samples in which both species occur

b = number of samples in which only species A occur

c = number of samples in which only species B occur

d = number of samples in which neither A nor B occur

To examine the significance of obtained JI values, the Chi-square test was used. According to Ludwig and Reynolds (1988), if $\chi 2 > 3.84$, species A and B are significantly associated (*), if $\chi 2 > 6.64$, species A and B are very significantly associated (**). Chi-square values were calculated using the following formula (Ludwig and Reynolds 1988):

$$\chi^2 = N(ad\text{-}bc)^2 / mnrs$$

m = a+b; n =c+d; r = a+c; s = b+d

N = total number of samples (a + b + c + d)

The expected frequency of both species in the samples was calculated using the following formula (Ludwig and Reynolds, 1988):

$E(a) = f(B)\ (a+b) = F(A)\ (a+c)$

$F(A) = (a+b)/N$

$F(B) = (a+c)/N$

There is a negative association when E(a) > c; a positive association when E(a) < c and no association when E(a) = c.JI (Ludwig and Reynolds 1988).

By association, it is meant the propensity of any pair of species to be found on the same leaf together. Any pair of species is positively associated if they occupy together more leaves than expected from random chance. On the contrary, any pair of species is negatively associated if they occupy together fewer leaves than expected from random chance.

Results

During the study, a total of 3407 mite specimens were collected. A total of 42 species belonging to two super-orders were detected (Table 2). The mites were grouped into 2 orders, 12 families and 30 genera. Member of the family Phytoseiidae (16 species, 40.56%) were the most abundant mites collected, followed by Tenuipalpidae (1 species, 20.37%), Tetranychidae (4 species, 19.58%), Tydeidae (5 species, 5.58%), Stigmaeidae (2 species, 4.93%), Triophtydeidae (1 species, 2.76%), Iolinidae (3 species, 2.03%), Cunaxidae (2 species, 1.41%), Tarsonemidae

Table 2 Mite species collected from pome fruit trees during the 2014–2016 growing season in the 12 different sampling areas in Ordu, Black Sea Region (Turkey).

Superorder	Order/Family/Species	Abundance						Percentage of mites			
		Neglected trees (N)			Conventional Trees (C)			N+C (GT)	PN (%)	PC (%)	GP (%)
		♀	♂	TN	♀	♂	TC				
Acariformes	Trombidiformes										
	Tetranychidae			584			83	667	18.55	32.17	19.58
	Amphitetranychus viennensis	275	15	290	50	5	55	345	9.21	21.32	10.13
	Bryobia rubrioculus	96	-	96	2	-	2	98	3.05	0.78	2.88
	Panonychus ulmi	21	1	22	26	-	26	48	0.7	10.08	1.41
	Tetranychus urticae	173	3	176	-	-	0	176	5.59	0	5.17
	Tenuipalpidae			678			16	694	21.53	6.2	20.37
	Cenopalpus pulcher	678	-	678	16	-	16	694	21.53	6.2	20.37
	Tarsonemidae			36			7	43	1.14	2.71	1.26
	Tarsonemus confuses	4	-	4	2	-	2	6	0.13	0.78	0.18
	Tarsonemus hermes	9	-	9	1	-	1	10	0.29	0.39	0.29
	Tarsonemus rakowiensis	20	-	20	4	-	4	24	0.64	1.55	0.7
	Tarsonemus stammeri	1	-	1	-	-	0	1	0.03	0	0.03
	Tarsonemus waitei	2	-	2	-	-	0	2	0.06	0	0.06
	Eriophyidae			19			11	30	0.6	4.26	0.88
	Epitrimerus pyri	19	-	19	11	-	11	30	0.6	4.26	0.88
	Cheyletidae			15			0	15	0.48	0	0.44
	Cheletomimus berlesei	15	-	15	-	-	0	15	0.48	0	0.44
	Stigmaeidae			140			28	168	4.45	10.85	4.93
	Agistemus sp.	6	6	12	4	4	8	20	0.38	3.1	0.59
	Zetzellia mali	86	42	128	15	5	20	148	4.06	7.75	4.34
	Cunaxidae			41			7	48	1.3	2.71	1.41
	Cunaxa sp.	9	-	9	-	-	0	9	0.29	0	0.26
	Cunaxoides sp.	32	-	32	7	-	7	39	1.02	2.71	1.14
	Tydeidae			181			9	190	5.75	3.49	5.58
	Brachytydeus sp.	18	-	18	2	-	2	20	0.57	0.78	0.59
	Brachytydeus paraobliqua	42	-	42	1	-	1	43	1.33	0.39	1.26
	Tydeus sp.	31	-	31	1	-	1	32	0.98	0.39	0.94
	Tydeus californicus	48	-	48	4	-	4	52	1.52	1.55	1.53
	Tydeus goetzi	42	-	42	1	-	1	43	1.33	0.39	1.26
	Triophtydeidae			90			4	94	2.86	1.55	2.76
	Triophtydeus triophthalmus	90	-	90	4	-	4	94	2.86	1.55	2.76
	Iolinidae			64			5	69	2.03	1.94	2.03
	Homeopronematus anconai	62	-	62	5	-	5	67	1.97	1.94	1.97
	Neopronematus sp.	1	-	1	-	-	0	1	0.03	0	0.03
	Pronematus ubiquitous	1	-	1	-	-	0	1	0.03	0	0.03
Parasitiformes	Mesostigmata										
	Phytoseiidae			1294			88	1382	41.09	34.11	40.56
	Amblyseius bryophilus	10	2	12	2	1	3	15	0.38	1.16	0.44
	Amblyseius herbicolus	16	-	16	-	-	0	16	0.51	0	0.47
	Aristadromips masseei	1	-	1	-	-	0	1	0.03	0	0.03
	Euseius finlandicus	56	5	61	7	-	7	68	1.94	2.71	2
	Euseius stipulates	-	-	0	3	-	3	3	0	1.16	0.09
	Galendromus longipilus	4	-	4	1	-	1	5	0.13	0.39	0.15
	Kampimodromus aberrans	10	-	10	-	-	0	10	0.32	0	0.29
	Neoseiulella tiliarum	12	-	12	-	-	0	12	0.38	0	0.35
	Neoseiulus californicus	1	-	1	2	-	2	3	0.03	0.78	0.09
	Paraseiulus triporus	1	-	1	-	-	0	1	0.03	0	0.03
	Phytoseius echinus	15	2	17	1	-	1	18	0.54	0.39	0.53
	Phytoseius finitimus	615	71	686	23	8	31	717	21.78	12.02	21.04
	Phytoseius salicis	27	-	27	-	-	0	27	0.86	0	0.79
	Transeius wainsteini	299	68	367	34	3	37	404	11.65	14.34	11.86
	Typhlodromus rapidus	58	4	62	-	-	0	62	1.97	0	1.82
	Typhlodromus tiliae	17	-	17	3	-	3	20	0.54	1.16	0.59
	Blattisociidae			7			0	7	0.22	0	0.21
	Lasioseius sp.	7	-	7	-	-	0	7	0.22	0	0.21
	Total	2930	219	3149	232	26	258	3407	92.43	7.57	100

TN: Total number of collected mites from neglected trees; TC: Total number of mites from commercial trees; GT: Total number of mites from neglected and commercial trees
PN: Percentage of mites from neglected trees; PC: Percentage of mites from commercial trees GP: General Percentage of all collected mites

Table 3 Mite species according to pome fruit species in neglected and conventional sites.

Species	Neglected								Conventional			
	Apple		Pear		Quince		Loquat		Apple		Pear	
	n	%	n	%	n	%	n	%	n	%	n	%
Amphitetranychus viennensis	240	12.75	45	8.70	5	1.13	0	0.00	49	21.12	6	23.08
Bryobia rubrioculus	91	4.83	5	0.97	0	0.00	0	0.00	2	0.86	0	0.00
Panonychus ulmi	17	0.90	4	0.77	1	0.23	0	0.00	26	11.21	0	0.00
Tetranychus urticae	159	8.44	17	3.29	0	0.00	0	0.00	0	0.00	0	0.00
Cenopalpus pulcher	428	22.73	181	35.04	45	10.20	24	7.79	14	6.03	2	7.69
Tarsonemus confusus	2	0.11	1	0.19	1	0.23	0	0.00	2	0.86	0	0.00
Tarsonemus hermes	7	0.37	1	0.19	1	0.23	0	0.00	1	0.43	0	0.00
Tarsonemus rakowiensis	15	0.80	4	0.77	1	0.23	0	0.00	2	0.86	2	7.69
Tarsonemus stammeri	1	0.05	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Tarsonemus waitei	1	0.05	1	0.19	0	0.00	0	0.00	0	0.00	0	0.00
Epitrimerus pyri	0	0.00	19	3.68	0	0.00	0	0.00	0	0.00	11	42.31
Cheletomimus berlesei	0	0.00	0	0.00	0	0.00	15	4.87	0	0.00	0	0.00
Agistemus sp.	6	0.32	0	0.00	2	0.45	4	1.30	8	3.45	0	0.00
Zetzellia mali	114	6.05	4	0.77	7	1.59	3	0.97	20	8.62	0	0.00
Cunaxa sp.	1	0.05	0	0.00	3	0.68	5	1.62	0	0.00	0	0.00
Cunaxoides sp.	23	1.22	1	0.19	8	1.81	0	0.00	7	3.02	0	0.00
Brachytydeus sp.	2	0.11	0	0.00	7	1.59	9	2.92	2	0.86	0	0.00
Brachytydeus paraobliqua	20	1.06	21	4.06	1	0.23	0	0.00	1	0.43	0	0.00
Tydeus sp.	14	0.74	5	0.97	6	1.36	6	1.95	1	0.43	0	0.00
Tydeus californicus	18	0.96	23	4.45	5	1.13	2	0.65	4	1.72	0	0.00
Tydeus goetzi	10	0.53	23	4.45	6	1.36	3	0.97	1	0.43	0	0.00
Triophtydeus triophthalmus	42	2.23	4	0.77	43	9.75	1	0.32	3	1.29	1	3.85
Homeopronematus anconai	25	1.33	25	4.84	12	2.72	0	0.00	1	0.43	4	15.38
Neopronematus sp.	0	0.00	1	0.19	0	0.00	0	0.00	0	0.00	0	0.00
Pronematus ubiquitus	0	0.00	1	0.19	0	0.00	0	0.00	0	0.00	0	0.00
Amblyseius bryophilus	12	0.64	0	0.00	0	0.00	0	0.00	3	1.29	0	0.00
Amblyseius herbicolus	3	0.16	7	1.35	1	0.23	5	1.62	0	0.00	0	0.00
Aristadromips masseei	0	0.00	0	0.00	0	0.00	1	0.32	0	0.00	0	0.00
Euseius finlandicus	32	1.70	12	2.32	9	2.04	8	2.60	7	3.02	0	0.00
Euseius stipulatus	0	0.00	0	0.00	0	0.00	0	0.00	3	1.29	0	0.00
Galendromus longipilus	3	0.16	1	0.19	0	0.00	0	0.00	1	0.43	0	0.00
Kampimodromus aberrans	6	0.32	0	0.00	4	0.91	0	0.00	0	0.00	0	0.00
Neoseiulella tiliarum	6	0.32	0	0.00	6	1.36	0	0.00	0	0.00	0	0.00
Neoseiulus californicus	0	0.05	0	0.00	0	0.00	0	0.00	2	0.86	0	0.00
Paraseiulus triporus	1	0.05	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Phytoseius echinus	17	0.90	0	0.00	0	0.00	0	0.00	1	0.43	0	0.00
Phytoseius finitimus	257	13.65	1	0.19	216	48.98	212	68.83	31	13.36	0	0.00
Phytoseius salicis	27	1.43	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Transeius wainsteini	227	12.06	91	17.60	39	8.84	10	3.25	37	15.95	0	0.00
Typhlodromus rapidus	37	1.96	18	3.48	7	1.59	0	0.00	0	0.00	0	0.00
Typhlodromus tiliae	14	0.74	1	0.19	2	0.45	0	0.00	3	1.29	0	0.00
Lasioseius sp.	4	0.21	0	0.00	3	0.68	0	0.00	0	0.00	0	0.00
Total	1883		517		441		308		232		26	
%	55.27		15.17		12.94		9.04		6.81		0.76	

(5 species, 1.26%), Eriophyidae (1 species, 0.88%), Cheyletidae (1 species, 0.44%) and Blattisociidae (1 species, 0.21%) (Table 2).

A total of 92.43% of all species were found on the neglected trees, while 7.57% were collected from the conventional orchards. Twenty-six species were found both on the neglected and conventional trees, 15 species were reported only on the neglected trees and only one species, *Euseius stipulatus* (Athias-Henriot) (Phytoseiidae), was found in just the conventional orchards (Table 2).

On neglected trees, the highest number of mites were found on apple (1883; 55.27%) followed by pear (517; 15.17%), quince (441; 12.94%), and loquat (308; 9.04%) (Table 3). In conventional orchards, the number of mites on apples (232; 6.81%) was higher than on pears (26; 0.76%) (Table 3).

The highest faunistic similarity was detected between the mite species on apple and quince in the neglected trees ($QS_{An/Qn}$ = 0.825), and the lowest was found between pear and loquat ($QS_{Pn/Ln}$ = 0.476). On the other hand, there was a low faunistic similarity between the mite complexes on apple and pear trees in the conventional orchards ($QS_{Ac/Pc}$ = 0.313). When the conventional and neglected trees were compared, it can be clearly seen that there was a high faunistic similarity between the conventional apple trees and neglected apple, pear, quince, and loquat trees ($QS_{Ac/An,\ Pn,\ Qn,\ Ln}$ = 0.537–0.794) (Table 4).

Table 4 The Sorensen's Index (QS) of faunistic similarity between the mite communities on neglected and conventional pome fruit trees in Ordu (Black Sea Region, Turkey).

		Neglected Trees				Conventional Trees	
		A	**P**	**Q**	**L**	**A**	**P**
Neglected Trees	A						
	P	0.750					
	Q	0.825	0.755				
	L	0.500	0.476	0.634			
Conventional Trees	A	0.794	0.755	0.769	0.537		
	P	0.279	0.364	0.313	0.190	0.313	

(A: apple; P: pear; Q: quince; L: loquat)

Among phytophagous mites, *Amphitetranychus viennensis* (Zacher) (Tetranychidae) was the predominant (21.32%) and most frequent (45%) species in the conventional orchards, whereas the second most abundant (9.21%) and common (15.5%) on the neglected trees (Tables 2, 5). It was a constant species (60%) in the conventional pear orchards, an accessory species on the neglected (34.2%), and conventional (40%) apple trees (Table 5). It was found on all pome fruit species sampled except loquat (Table 3).

Cenopalpus pulcher (Camestrini & Fanzago) was the only species identified from the family Tenuipalpidae. It was the most abundant (21.53%) and common (24.4%) phytophagous species on the neglected trees and the third most abundant (6.20%) and second most frequent (25%) in the conventional orchards (Tables 2, 5). It was an accessory species on the neglected (39.2%) and conventional (26.7%) apple trees (Table 5).

Other phytophagous mite species from the families Tarsonemidae and Eriophyidae showed highly overall lower abundance and frequency on pome fruit trees (Tables 2, 5). A total of three predatory mite species belonging to three genera of the family Stigmaeidae were detected. The most dominant (4.34%) and frequent (9%) species was *Zetzellia mali* (Ewing). It was the accessory species (53.3%) in the conventional apple orchards while it was proportionally less frequent on the neglected apple (20.6%). This predatory mite held less importance in terms of frequency (1.1–2.5%) on the other sampled neglected and conventional fruit trees. Moreover, it was not found in conventional pear orchards (Table 2, 5). Regarding the mite species from the family Phytoseiidae, the most abundant species, *Phytoseius finitimus* Ribaga and *Transeius wainsteini* (Gomelauri), (Table 2) showed the greatest overall constancy on pome fruits (Table

5). Both species were found on the neglected apple, pear, quince, loquat, and conventional apple trees, but not in the conventional pear orchards. *Phytoseius finitimus* was accessory species on the neglected apple (27.1%), loquat (48.9%), and conventional apple (40%) trees. *Transeius wainsteini* was constant in the conventional apple orchards (53.3%) and accessory on the neglected apple trees (38.7%). The rest of phytoseiids were less common (Table 5).

Table 5 Constancy (C%) of leaf inhabiting mite species on the neglected and conventional pome fruit trees in Ordu (Black Sea Region, Turkey).

Mite Species	The coefficient of constancy index (C %) *								
	Neglected Trees					Conventional Trees			Σ (N+C)
	A	P	Q	L	ΣN	A	P	ΣC	
Amphitetranychus viennensis	34.2	11.6	2.5	0	15.5	40	60	45	16.4
Bryobia rubrioculus	17.1	2.8	2.5	0	7.1	13.3	0	10	7.2
Panonychus ulmi	4	1.1	0.8	0	1.9	26.7	0	20	2.4
Tetranychus urticae	19.6	7.7	2.5	0	9.4	0	0	0	9.1
Cenopalpus pulcher	39.2	23.8	14.8	6.5	24.4	26.7	20	25	24.4
Tarsonemus confuses	1	0.6	0.8	0	0.7	6.7	0	5	0.8
Tarsonemus hermes	2	0.6	0.8	0	1	6.7	0	5	1.1
Tarsonemus rakowiensis	2.5	1.1	0.8	0	1.3	13.3	20	15	1.8
Tarsonemus stammeri	0.5	0	0	0	0.2	0	0	0	0.2
Tarsonemus waitei	0.5	0.6	0	0	0.3	0	0	0	0.3
Epitrimerus pyri	0	1.7	0	0	0.5	0	20	5	0.7
Cheletomimus berlesei	0	0	0	4.3	0.7	0	0	0	0.7
Agistemus sp.	0.5	0	0.8	1.1	0.5	6.7	0	5	0.7
Zetzellia mali	20.6	1.1	2.5	1.1	7.9	53.3	0	40	9
Cunaxa sp.	0.5	0	1.6	3.3	1	0	0	0	1
Cunaxoides sp.	6	0.6	4.1	0	3	26.7	0	20	3.6
Brachytydeus sp.	1	0	2.5	1.1	1	6.7	0	5	1.1
Brachytydeus paraobliqua	7.5	5	0.8	0	4.2	6.7	0	5	4.2
Tydeus sp.	4	1.7	3.3	3.3	3	6.7	0	5	3.1
Tydeus californicus	2	5	1.6	1.1	2.7	6.7	0	5	2.8
Tydeus goetzi	2.5	4.4	3.3	2.2	3.2	6.7	0	5	3.3
Triophtydeus triophthalmus	9	2.2	15.6	1.1	7.1	13.3	20	15	7.3
Homeopronematus anconai	5.5	3.9	5.7	0	4.2	6.7	20	10	4.4
Neopronematus sp.	0	0.6	0	0	0.2	0	0	0	0.2
Pronematus ubiquitous	0	0.6	0	0	0.2	0	0	0	0.2
Amblyseius bryophilus	3	0	0	0	1	13.3	0	10	1.3
Amblyseius herbicolus	1	2.2	0.8	2.2	1.5	0	0	0	1.5
Aristadromips masseei	0	0	0	1.1	0.2	0	0	0	0.2
Euseius finlandicus	5.5	4.4	3.3	1.1	4	6.7	0	5	4.1
Euseius stipulatus	0	0	0	0	0	6.7	0	5	0.2
Galendromus longipilus	1	0.6	0	0	0.5	6.7	0	5	0.7
Kampimodromus aberrans	1	0	1.6	0	0.7	0	0	0	0.7
Neoseiulella tiliarum	1	0	2.5	0	0.8	0	0	0	0.8
Neoseiulus californicus	0.5	0	0	0	0.2	6.7	0	5	0.3
Neoseiulus cucumeris	0.5	0	0	0	0.2	0	0	0	0.2
Paraseiulus triporus	0.5	0	0	0	0.2	0	0	0	0.2
Phytoseius echinus	2	0	0	0	0.7	6.7	0	5	0.8
Phytoseius finitimus	27.1	22.7	2.5	48.9	24.1	40	0	30	24.3
Phytoseius salicis	1.5	0	0	0	0.5	0	0	0	0.5
Transeius wainsteini	38.7	19.9	14.8	4.3	22.7	53.3	0	40	23.3
Typhlodromus rapidus	4.5	4.4	1.6	0	3.2	0	0	0	3.1
Typhlodromus tiliae	2	0.6	1.6	0	1.2	6.7	0	5	1.3
Lasioseius sp.	1	0	0.8	0	0.5	0	0	0	0.5

*C < 25% represent accidental species; C = 25.1-50% represent accessory species; C = 50.1-75% represent constant species; C = 75.1-100% represent euconstant species.
(A: apple; P: pear; Q: quince; L: loquat; N: Neglected; C: Conventional)

Other predatory species from the families Cunaxidae and Cheyletidae were also considerably less abundant and common on pome fruit trees.

Among tydeoid mites, the accidental species *Tydeus triophthalmus* (Oudemans) (20%) and *Homeopronematus anconai* (Baker) (20%) in the conventional pear orchards had the highest coefficient of constancy. Interestingly, any other tydeoid mite was not observed in these orchards. All other species held less importance on all sampled neglected and conventional trees (Table 5).

Associations between the ten most predominant predaceous and phytophagous mite species were examined (Table 6). A very highly significant positive association was obtained in sixteen pairs of species whereas a significant association was detected for seven pairs. Associations were found in the pair of eleven species of tetranychoid and predatory mites, pairs of six tetranychoid mite species, and pairs of six predatory mite species.

The pair of *T. wainsteini-C. pulcher* (JI = 0.289**) within predatory and tetranychoid mites, *T. wainsteini – Z. mali* (JI = 0.192**) within the predatory species, and *A. viennensis-C. pulcher* (JI = 0. 195**) within the tetranychoid mites had the highest interspecific association index (Table 6).

Table 6 Interspecific association of pair of predaceous (Acari: Phytoseiidae, Stigmaeidae) and phytophagous (Acari: Tetranychidae, Tenuipalpidae) mite species found on apple, pear, quince, and loquat trees in Ordu (Black Sea Region, Turkey).

	Predaceous Mites					**Phytophagous Mites**				
Species	**EF**	**PF**	**TW**	**TR**	**ZM**	**AV**	**BR**	**PU**	**TU**	**CP**
EF										
PF	0,024									
TW	**0,070***	**0,090***								
TR	**0,100****	0,000	0,019							
ZM	**0,067***	0,086	**0,192****	**0,072****						
AV	0,050	0,093	**0.200 ****	**0,062***	**0,191****					
BR	**0,117****	0,080	0,081	**0,070***	**0,102****	**0,144****				
PU	0,026	**0,045***	0,032	0,000	0,061	**0,064****	0,018			
TU	0,040	0,058	**0,166****	0,029	**0,113****	0,069	**0,092***	0,015		
CP	0,061	0,169	**0,289****	0,050	**0,192****	**0,195****	**0,129****	0,019	**0,134****	

*: Significantly associated (χ2 > 3.84); **: Very significantly associated (χ2 > 6.64); Significant and very significant values were bolded.
EF: *Euseius finlandicus* , PF: *Phytoseius finitimus* , TW: *Transeius wainsteini* , TR: *Typhlodromus rapidus* , ZM: *Zetzellia mali* , AV: *Amphitetranychus viennensis* , BR: *Bryobia rubrioculus* , PU: *Panonychus ulmi* , TU: *Tetranychus urticae* , CP: *Cenopalpus pulcher*

Discussion

All the species detected during the current study were collected from different habitats in previous research in different regions of Turkey (Öksüz and Özman, 1999; Çobanoğlu 2000; 2004, Özman and Çobanoğlu 2001; İncekulak and Ecevit 2002; Akyazı and Ecevit 2003; Yanar and Ecevit 2005; 2008; Kasap and Çobanoğlu 2007; Kumral and Kovancı 2007; Kasap *et al.* 2013; Kasap *et al.* 2015; Kumral and Çobanoğlu 2015; Akyazı *et al.* 2017; 2022; Denizhan 2018; Soysal and Akyazı 2018; Altunç and Akyazı 2019; Çobanoğlu *et al.*, 2020). Our results showed that pome fruits growing in agrochemical-free sites of Ordu were extremely rich in beneficial mite fauna, especially phytoseiids. İncekulak and Ecevit (2002) reported that spider mite populations were suppressed by predators in unsprayed apple orchards in Turkey (Amasya). Szabo *et al.* (2014) noted that phytoseiid mites were generally absent on nursery trees due to excessive use of insecticides and fungicides. Kasap (2011) and Kasap *et al.* (2019) indicated that in unsprayed apple orchards, the density of spider mites was very low because of the presence of predatory mites. Our results also are in agreement with Van de Vrie (1985), Amano and Chant (1990), Hardman *et al.* (1997), and Yanar and Ecevit (2008).

A high faunistic similarity indicates a non-selective distribution of mite species within pome fruit species. Unlike the conventional orchards, neglected trees generally exhibited strong and medium similarities in terms of mite fauna distribution. Contrary to conventional pear orchards, there was a high faunistic similarity between the conventional apple trees and all neglected trees. Stojnic *et al.* (2014) also found a great similarity between the cultivated and neglected apple orchards in Serbia. They added that the lowest similarity was found between the cultivated apple orchards and wild apples. Kumral and Kovancı (2007) found that the diversity of mites in conventional pome fruit orchards weakly resembled the diversity of agrochemical-free orchards in Turkey (Bursa). There were strong and medium relations among agrochemical-free orchards. Conventional orchards also generally exhibited strong and medium similarities in terms of mite fauna distribution.

The dominant phytophagous species in the conventional orchards was *A. viennensis* followed by *Panonychus. ulmi* (Koch) (Tetranychidae) and *C. pulcher,* while in the agrochemical-free sites the predominant species was *C. pulcher* followed by *A. viennensis* and *Tetranychus urticae* Koch (Tetranychidae). Yanar and Ecevit (2008) found that the dominant phytophagous mites in the sprayed apple orchard were *A. viennensis* and *P. ulmi*, whereas *C. pulcher* and also *Eotetranychus uncatus* Garman (Tetranychidae) were abundant in the unsprayed apple orchard in Turkey (Tokat). İncekulak and Ecevit (2002) also observed that the population of *C. pulcher* was able to reach high densities only in pesticide-free apple orchards in Turkey (Amasya). It was absent or its density was extremely low in the sprayed orchards. These data are confirmed by Çiftçi *et al.* (1985) who state that *C. pulcher* is very sensitive to pesticides. Contrary to our findings, Kumral and Kovancı (2007) found that *A. viennensis* was most frequently collected in the agrochemical-free deciduous orchard whereas *P. ulmi* and *T. urticae* were dominant in the conventional orchards in Turkey (Bursa). On the other hand, they noted that *C. pulcher* also was the dominant pest mite of agrochemical-free sites. In Serbia, it had been already mentioned that *P. ulmi* was the dominant pest mite species in cultivated and neglected apple orchards (Stojnic 2001). Kishimoto (2002) demonstrated that the dominant pest mites were *A. viennensis* in the agrochemical-free pear orchard, *Panonychus citri* (McGregor) (Tetranychidae) in the pesticide-free orchard, and *T. urticae* in the conventionally controlled pear orchard in Japan. Stojnic *et al.* (2014) declared that *A. viennensis* was accidental in the neglected apple orchards and accessory on wild apple trees.

Moreover, it was not determined any tetranychid mite species except *A. viennensis* in the conventional pear orchards in the current study. Stojnic *et al.* (2014) did not detect *A. viennensis* in the cultivated apple orchards. Interestingly, it was not detected any plant-parasitic mite species except *C. pulcher* on the neglected loquat trees in the current study. Hatzinikolis and Emmanouel (1987) reported loquat as a host for *C. pulcher.* It was also noted that this mite is an important pest on apple, quince, loquat, and pear by NAPPO (2008), Biosecurity Australia (2009), Beard et al (2012).

Phytoseius finitimus was the most abundant and common predatory species on pome fruits, followed by *T. wainsteini* and *Z. mali*. It is a very common phytoseiid species on pome fruit trees in Turkey. It was detected on apple trees in Sakarya, Giresun (Swirski and Amitai 1982), Ankara, Adapazarı, Niğde, Tokat, Burdur (Düzgüneş and Kılıç 1983), Gümüşhane, Bursa, İstanbul, Nevşehir, Isparta, Konya, Tokat (Çobanoğlu 1993d) and Amasya (İncekulak and Ecevit 2002), on apple, quince, medlar in Çanakkale and Balıkesir (Kasap *et al.* 2013), on persimmon in Ordu (Akyazı *et al.* 2017) in Turkey. It was also found commonly in Europe's apple orchards. (Nicotina 1996; Papaioannou-Souliotis *et al.* 1999; Kreiter *et al.* 2000; Ragusa and Tsolakis 2000). In the present study, it was generally collected from agro-chemical free sites. Moreover, it was not detected in conventional apple orchards. These data are in agreement with those of Duso and Vettorazzo (1999), who declared that *P. finitimus* proved to be susceptible to various pesticides.

Our findings showed that *T. wainsteini* was generally found on the neglected trees, especially apple, rather than in conventional sites. So far, *T. wainsteini* has been detected on rosehip (Faraji *et al.* 2011), persimmon (Akyazı *et al.* 2016), some vegetables (Soysal and Akyazı 2018) and stone fruits (Altunç and Akyazı 2019) in Turkey. Rahmani *et al.* (2010) found it on wild apple (*Malus* sp.) in Fandogloo. Tajmiri *et al.* (2014) detected *T. wainsteini* as dominant species in the plum orchards, adjacent raspberry hedgerows, and dominant orchard floor vegetation in Northern Iran (Guilan province).

The third most abundant and common predatory mite, *Z. mali,* was found in lower proportion on the agrochemical-free sites. Our result is in agreement with Kasap and Çobanoğlu (2006) and Kasap *et al.* (2019). They detected that *Z. mali* was the most abundant predatory mite species associated with *B. rubrioculus* in Van (Turkey) and with *P. ulmi* in Çanakkale (Turkey) in sprayed apple orchards. Abroad, it was found in the sprayed and unsprayed orchards (Woolhouse and Harmsen 1985; Strickler *et al.* 1987; Thistlewood 1991; Croft 1993). Santos (1976) and Clements and Harmsen (1993) found that *Z. mali* can have a high reproduction rate on *P. ulmi*.

Considering together phytoseiid and tetranychoid species, it was detected that *T. wainsteini* had a greater tendency to be found together with *C. pulcher*, *A. viennensis* and *T. urticae* (positive association). The pair of *E. finlandicus* – *B. rubrioculus* was also found very significantly associated. Significant positive associations were also found for the pairs of *Typhlodromus rapidus* Wainstein & Arutunjan (Phytoseiidae) – *Bryobia. rubricolus*(Scheuten) (Tetranychidae),*T. rapidus* – *A. viennensis*, and *P. finitimus* – *P. ulmi*. *Transeius wainsteini* was collected among the *P. ulmi* and *Aceria* sp. (Eriophyidae) populations on wild apple trees by Rahmani *et al.* (2010). On the other hand, it was found associated with *T. urticae* in hazelnut orchards and sunflowers by them. *Euseius* spp. are classified as Type IV Lifestyle – pollen feeding generalist predators by McMurtry *et al.* (2013). *Euseius finlandicus* is known to feed on tetranychid, eriophyid, tyroglyphid and tarsonemid species, pollen, fungal hyphae and spores, eggs and larvae of insects, honeydew, and plant liquids (Schausberger 1992; Kostiainen and Hoy 1994; Abdallah *et al.* 2001). *Typhlodromus rapidus* Wainstein & Arutunjan was detected on apple and oak trees in Russia (Wainstein and Arutunjan 1968), *Betula* spp., and *Quercus* spp. in Latvia (Salmane and Petrova 2002), *Corylus* sp. in İzmit (Çobanoğlu 1997) and walnut trees in Samsun in Turkey. Species in the genus *Typhlodromus* are classified as Subtype III-a – generalist predators living on pubescent leaves by McMurtry *et al.* (2013). *Phytoseius finitimus* had also positive and very significant associations with *P. ulmi*. It is a generalist phytoseiid mite (Pappas *et al.* 2013; Tixier *et al.* 2017). Its food range includes tetranychids, eriophyoids, and pollen (Nomikou *et al.* 2001; Momen and El-Borolossy 2010).

Within predatory species complex, the pair of *Z. mali* – *T. wainsteini* had the greatest tendency to be found together. The pairs of *E. finlandicus* – *T. rapidus* and *T. rapidus* – *Z. mali* had also very highly positive associations. It is known that *Z. mali* may feed on other predator mite eggs (Kain and Nyrop 1995). Croft (1993) noted that it can prey on eggs of the predatory phytoseiid mites *Galendromus* (*Galendromus*) *occidentalis* (Nesbitt) and *Typhlodromus* (*Typhlodromus*) *pyri* Scheuten and other *Z. mali*. Schausberger (1997) declared that *E. finlandicus* showed the great tendency to interspecific predation on motile immatures of *T. pyri* and *Kampimodromus aberrans* (Oudemans) (Phytoseiidae).

Considering only the tetranychoid mites, positive and very significant associations were observed for the pair *A. viennensis* – *B. rubrioculus*, *A. viennensis* – *P. ulmi*, *C. pulcher* – *A. viennensis*, *C. pulcher* – *B. rubrioculus*, and *C. pulcher* – *T. urticae*. As far as we know, these are previously unstudied.

Conclusions

Our results demonstrate a strong effect of agrochemicals on the diversity and distribution of mite species. The main conclusion can be drawn that richer beneficial mite fauna occurs on pome fruit trees in the agrochemical-free sites compared to the conventional orchards. In addition, dominant phytophagous and predatory species of agrochemical-free sites and conventional orchards were different. Moreover, some species could only be found in the commercial orchards, whereas some only in neglected ones, and some in both areas. Very significantly positive association indexes were found for mite pairs within the predatory and phytophagous species complex. The finding may help to determine the potential predatory species for the applied biological control approaches of phytophagous mites in the pome fruit orchards. Finally, the economic importance of phytophagous mites detected on the pome fruit trees in the Ordu region can be considered to be negligible because these mites are vulnerable to predatory mites and pesticides.

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