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Effect of ploughing and pesticide application on oribatid mite communities

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ABSTRACT

The impact of conventional pesticide treatment and deep ploughing on oribatid mite communities was investigated in an abandoned arable land. The experimental plots were divided in "pesticide and ploughed" (PPL), "ploughed" (PL) and a" meadow" as control (Ctr). Soil samples were taken monthly during the vegetation period (March-August) and once in three months (October and January) in a period without vegetation. Seventy-seven species of oribatid mites were determined. Species numbers were highest in Ctr (55 species), lower in PPL (53) and lowest in PL (41). Oribatid communities were dominated by sexually reproducing Brachypylina. Some of the generally frequent parthenogenetic species (e.g. *Acrotritia ardua* and *Oppiella nova*) were rare at the Ctr sites while stress-tolerant species (both, sexual and asexual, e.g. *Protoribates capucinus, Punctoribates punctum, Ramusella clavipectinata, Tectocepheus velatus*) were dominant. Pesticide application did not show any effect on oribatid mite community beyond the ploughing, whereas some species like *P. capucinus, P. punctum, R. clavipectinata* and *T. velatus* reached high abundances at PPL sites. Community structure of oribatid mites did not change significantly compared with Ctr sites, suggesting that the study area is inhabited by stress tolerant oribatid communities shaped by past agricultural disturbance.

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Oribatid mites; pesticide application; ploughing; arable land; agriculture

Introduction

Microarthropods are playing a primary role in soil processes such as decomposition, nutrient cycling and soil formation and by that they represent a significant part of the soil food web (Lavelle and Spain 2001; Coleman et al. 2004; Walter and Proctor 2013). Having limited dispersal abilities (Lehmitz et al. 2011, 2012) soil microarthropods cannot easily escape from unfavourable conditions. Therefore, they quickly respond to habitat changes that frequently result in changes in soil food webs (Skubała 1997; Maraun et al. 1998; Skubała and Gulvik 2005; Andrès and Mateos 2006). This is especially problematic in arable lands where permanent perturbations affect soil microarthropods directly and indirectly. Mechanical disturbances (such as ploughing, harrowing and trampling) as well as non-mechanical disturbances (including removal of plant material and chemical applications) affect soil organisms either directly by killing them, or indirectly by diminishing their food resource and physiological resilience and reducing suitable space (Rodrigues et al. 2006). However, the feedback and magnitude of soil microarthropods to all these factors separately and in combination can be taxon specific and temporarily non-consistent (Sánchez-Bayo 2011). While profound knowledge of the effects of perturbation on soil systems can help to mitigate soil degradation and help sustainable agricultural development, there are still many questions left unanswered with this respect. According to Turner (2015) there are up to 900 chemicals and much more pesticide compounds in use worldwide and a great deal of them is not tested for nontarget fauna adequately (Sánchez-Bayo 2011). For instance, oribatid mites (Acari, Oribatida), that are one of the most species-rich and abundant taxon among soil microarthropods (Coleman et al. 2004; Walter and Proctor 2013), are influenced by agricultural processes significantly (Behan-Pelletier 1999, 2003; Cortet et al. 2002a). Although the diversity of the oribatid mite community (and microarthropods in general) can decline in response to agricultural practice, we do not know an explicit mechanism behind. Most of previous experimental studies investigating the effects of selected chemicals on oribatid communities show that oribatid mites probably respond more adversely to mechanical perturbations than to pesticide application (Cockfield and Potter 1983; Krogh 1991; Al-Assiuty and Khalil 1995; Schrader and Lingnau 1997; Cortet et al. 2002a, 2002b; Bedano et al. 2006; Adamsky et al. 2007, 2009; Anbarashan and Gopalswamy 2013; Al-Assiuty et al. 2014 but see also Prinzing et al. 2002), at least in a short term (for instance single treatment) perspective. However, different oribatid groups (for instance sexual vs parthenogenetic) may respond differently to agricultural practice. Indeed, since the sexually reproducing species more easily cope with adverse (or changing) environmental conditions (Toman and Flegr 2017) the changes of community structure might largely be due to parthenogenetic species. In addition, we notice a gradual impoverishment of mite communities (i.e. a decrease of species diversity and a change in species abundance distribution) after regular cultivation and pesticide application. Though pesticide application might not have a significant direct effect on mite communities (Krogh 1991; Sterk et al. 1999; Cortet, Ronce et al. 2000; Frampton et al. 2006; Jänsch et al. 2006; Badji et al. 2007; Anbarashan and Gopalswamy 2013), other taxa (such as fungi, plants and some animals) are still vulnerable. As different taxa of mites occupy different trophic levels (can be phytophagous, primary and secondary decomposers, predators, scavengers and omnivores) (Coleman et al. 2004; Schneider et al. 2004), the effect of agricultural practice on soil food web and community composition is expected to be more pronounced in the long-term perspective (Behan-Pelletier 1999).

The aim of this work was to investigate the magnitude and direction of changes in oribatid mite communities during regular agricultural practice in an abandoned arable land. In particular, we were seeking the answers to the following questions: (a) Does pesticide application strengthen changes in oribatid mite communities over the mechanical process? (b) How do those effects

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vary over time? (c) Are parthenogenetic species more affected by agricultural practice compared to sexuals?

Material and method

Study area

A study area was established in homogeneous abandoned arable land in Patardzeuli village, Eastern Georgia (N41.73694882°, E45.248295118° 803 m a.s.l.), which was not in use (neither for cultivation nor for pasture purposes, just mowing) for more than 20 years. To observe the response of oribatid mite community to the common agricultural practice vs only mechanical perturbation, we set up the following experimental design: an area of 144 m² was divided into three equally sized parts (each 48 m² and separated from each other with plastic fence) from which one was used as a control (intact meadow indicated hereafter as Ctr) and the remaining two were deeply ploughed. Later on, one ploughed site was planted with potato tubers (PPLs). Planted sites were further cultivated and treated by pesticides in a conventional manner. In particular, instead of testing single or two specific pesticides, we applied pesticide application scheme as currently used for potato plantations in Georgia recommended by the Movement of Georgian Agrarians (www.georgianels.ge) that includes six different chemicals over the whole vegetation period (Table 1). By this approach, all oribatid mites extracted from PPL sites, were exposed to all applied chemicals (Table 1). Thereby, we aimed to assess the impact of a full cycle of pesticide application on non-target oribatid mite fauna. The third part (PL) was ploughed and no extensive cultivation or chemical applications were used.

Soil sampling and species identification

Sampling was performed on a monthly basis during the vegetation period from March to August. In the end of vegetation period, after harvesting potatoes, sampling was done once in three months (in October and in January). The sampling and treatment scheme was repeated twice in 2016 and 2017. At each sampling, six soil samples (per treatment type: PL, PPL, Ctr) were collected randomly using a soil corer with 5 cm diameter and 10 cm depth. That made 18 samples in total. Samples were placed in plastic bags and transported to the laboratory for extraction. Extraction of soil mites was performed using modified Berlese-Tullgren apparatus during one week (Coleman et al. 2004). Extracted mites (Oribatida and Gamasina) were stored in 70% alcohol and oribatid mites were identified using keys of Ghilarov and Krivolutsky (1975) and Weigmann (2006). Reproductive mode of species was ascribed according to literature (Palmer and Norton 1991; Norton et al. 1993; Domes-Wehner 2004; Cianciolo and Norton 2006; Domes et al. 2007; Fischer et al. 2010; Wehner et al. 2014).

For this investigation only adult oribatid mites were identified and counted.

Data analyses

Our experimental design does not allow running parametric tests for group differences due to temporal non-independence of samples and pseudoreplicated design. Considering these limitations, we applied Friedman's rank test (non-parametric alternative design for repeated measures ANOVA) (Friedman 1937) using the R wrapper provided by Galili (2010) using R programming environment (R Core Team 2018).

Temporal trend in species richness and evenness distribution were explored by means of trend diagrams. Species richness (averaged over treatment plots for each sampling event) was plotted against time. To examine the trend of the distribution of species mean abundance over time, we calculated evenness measure after Hayek and Buzas (2010) using following formula: $E = e^{H - \ln(S)}$, where *H* is the Shannon's diversity measure and *S* is species number in a sample. We used raw count of species as a measure of species richness and the density of mites were calculated for a square meter based on single corer data (i.e. 100 times the number of individuals captured in a single corer sample).

The overall structure of the studied community of oribatid mites was explored by Detrended Correspondence Analysis (DCA) using CANOCOv5 (Jongman et al. 1995; TerBraak 1995, 2012). Single- and doubletons were excluded from the calculation and treatments and sampling dates were incorporated in DCA ordination as supplementary variables (i.e. variables were posthoc mapped on the community ordination plot).

Results

In total 77 species of oribatid mites were identified in all sampling events (Supplement 1, Table 2). Brachypylina oribatids strongly dominated the community comprising more than 85% of the total diversity (Figure 1). The most abundant 10 species (all Brachypylina) included three parthenogenetic species from which *Protoribates capucinus* (Berlese 1908) was absolutely dominant at PPL sites (21%) while the other two (*Tectocepheus punc-tulatus* Djaparidze 1985 and *T. velatus* (Michael 1880)) had a similar abundance distribution in all treatments.

The lowest number of species (41 species) was recorded in PL sites, followed by PPL (53 species) and Ctr (55 species). Friedman's test did not recover significant differences in species richness, density or evenness distribution between treatment types (in all cases p > 0.05). However, sampling time had some influence on plot species richness distribution (but not on total density). In particular, species richness tended to be higher in the periods from March to July than the rest of the year and the Ctr sites were usually hold more species in average then the others (Figure 2). On the other hand, community evenness dropped in PL sites in the course of time, compared to PPL and Ctr sites (Figure 3).

In contrast to sexually reproducing species, the number of parthenogens as well as their individual density tended to be higher in the colder period of year (October, January and March). Species richness and density per square metre of raw number or percentage of parthenogenetic species were indistinguishable

Table 1. Scheme of pesticide application for potatoes on experimental plot (after www.georgianels.ge).

			J -	
Period of treatment	Type of chemical applied	Commercial name of chemical	Concentration in 100 l of water	Active ingredient
Treatment of potato tubers before seed	Fungicide	Rovral Aquaflo	400 ml	Iprodione
Seedlings are 10 cm long	Fungicide	Bravo	600 ml	Chlorothalonil
Seedlings are 20 cm long	Fungicide	Ridomil Gold	500 g	Mefenoxam
Seedlings cover the ground	Fungicide	Ridomil Gold plus	1 kg	390 g/kg Copper
				50 g/kg Metalaxyl-M
Flower buttons appear	Fungicide	Ridomil Gold	1 kg	Mefenoxam
Mass flowering	Fungicide	Pergado	800 g	50 g/kg Mandipropamid
				600 g/kg Mankozeb
The end of flowering period	Fungicide	Bravo	600 ml	Chlorothalonil
20 days before harvest	Fungicide	Bordeaux mixture	1 kg	Copper sulphate, lime, and water

Table 2. List of identified species^a sampled in the Patardzeuli (Georgia) study plots with the abbreviations for the species names and the reproductive mode.

	Samplea in the Fatarazean (Geo	gia, staa) plots man are apprenditions for	and species numes and the	reproductive model
Infraorder/Hyperorder	Family	Species	Abbreviation	Reproductive mode
Enarthronota	Lohmanniidae	Papillacarus aciculatus	Papi-aci	Parthenogenetic
	Epilohmanniidae	Epilohmannia cylindrica	Epil-cyl	Parthenogenetic
Mixonomata		Epilohmannia gigantea	Epil-gig	Parthenogenetic
	Euphthiracaridae	Acrotritia ardua	Acro-ard	Parthenogenetic
		Oribotritia serrata	Orib-ser	Parthenogenetic
	Phthiracaridae	Hoplophthiracarus illinoisensis	Hopl-ill	Sexual
		Phthiracarus ferruaineus	Phth-fer	Sexual
		Steganacarus carinatus	Steq-car	Sexual
		Steaanacarus spinosus	Steg-spi	Sexual
Nothrina	Crotoniidae	Camisia spinifer	Cami-spi	Parthenogenetic
		Platynothrus peltifer	Plat-pel	Parthenogenetic
Brachypilina	Hermanniidae	Hermannia aibba	Herm-gib	Sexual
	Nothridae	Nothrus annauniensis	Noth-ann	Parthenogenetic
		Nothrus parvus	Noth-par	Parthenogenetic
		Nothrus palustris	Noth-pal	Parthenogenetic
	Trhypochthoniidae	Trhypochthonius tectorum	Trhy-tec	Parthenogenetic
	Hermanniellidae	Hermanniella punctulata	Herm-pun	Sexual
	Aleurodamaeidae	Aleurodamaeus setosus	Aleu-set	Sexual
	Gymnodamaeidae	Arthrodamaeus femoratus	Arth-fem	Sexual
	Damaeidae	Relba dubinini	Belb-dub	Sevual
	Damacidae	Metahelha flagelliseta	Meta-fla	Sexual
		Metabelha nseudoitalica	Meta-nse	Sexual
		Metabelha nulveroca	Meta-nul	Sexual
		Metabelha rara	Meta-rar	Sexual
	Compactozatidao	Funtarotogagus ornatissimus	Funt-orn	Sovual
	Microzotidaa	Lupieroregueus Ornalissinnus Rarlasazatas cuspidatus	Eupt-oni Borl-cus	Sovual
	Amorobalbidaa	Mongaillardia arandiaani	Mong gro	Soxual
	Ameropeipidae	wongamaraia grandjeani	wong-gra	Sexual
	Caleremaeldae	Caleremaeus monilipes	Cale-mon	Sexual
	Damaeolidae	Damaeoius ornatissimus	Dama-orn	Sexual
	E	Fosseremus laciniatus	Foss-lac	Parthenogenetic
	Eremaeidae	Eueremaeus oblongus	Euer-obl	Sexual
	Liacaridae	Dorycranosus spledens	Dory-spl	Sexual
		Liacarus brevilamellatus	Liac-bre	Sexual
		Xenillus tegeocranus	Xeni-teg	Sexual
	Peloppiidae	Ceratoppia quadridentata	Cera-qua	Sexual
	Autognetidae	Conchogneta dalecarlica	Conc-dal	Sexual
	Epimerellidae	Epimerella smirnovi	Epim-smi	Sexual
	Oppiidae	Berniniella silvatica	Bern-sil	Sexual
		Dissorhina ornata	Diss-orn	Sexual
		Graptoppia paraanalis	Grap-par	Sexual
		Lasiobelba pori	Lasi-por	Sexual
		Oppiella fallax	Oppi-fal	Sexual
		Oppiella neerlandica	Oppi-nee	Sexual
		Oppiella nova	Oppi-nov	Parthenogenetic
		Oppiella similifallax	Oppi-sim	Sexual
		Ramussela clavipectinata	Ramu-cla	Sexual
		Ramusella insculpta	Ramu-ins	Sexual
		Striatoppia weigmanni	Stri-wei	Sexual
	Suctobelbidae	Suctobelba granulata	Suct-gra	Parthenogenetic
		Suctobelbella subtrigona	Suct-sub	Parthenogenetic
	Tectocepheidae	Tectocepheus punctulatus	Tect-pun	Parthenogenetic
		Tectocepheus velatus	Tect-vel	Parthenogenetic
	Phenopelopidae	Eupelops acromios	Eupe-acr	Sexual
	-	Eupelops tardus	Eupe-tar	Sexual
		Eupelops torulosus	Eupe-tor	Sexual
		Peloptulus phaenotus	Pelo-pha	Sexual
	Achipteriidae	Parachipteria fanzagoi	Para-fan	Sexual
	Tegoribatidae	Tectoribates ornatus	Tect-orn	Sexual
	Oribatellidae	Oribatella nigra	Orib-nig	Sexual
	Haplozetidae	Protoribates capucinus	Prot-cap	Parthenogenetic
	Oribatulidae	Lucoppia burowsi	Luco-bur	Sexual
		Oribatula tibialis	Orib-tib	Sexual
		Oribatula (Zygoribatula) exilis	Zygo-exi	Sexual
		Oribatula (Z) skrjabini	Zygo-skr	Sexual
	Scheloribatidae	Liebstadia Ionaior	Lieb-lon	Sexual
		Liebstadia pannonica	Lieb-pan	Sexual
		Scheloribates laeviaatus	Sche-lae	Sexual
		Scheloribates latines	Sche-lat	Sexual
	Ceratozetidae	Ceratozetes conjunctus	Cera-con	Sexual
	contocentuic	Ceratozetes mediocris	Cera-med	Sexual
		Trichoribates naltschicki	Tric-nal	Sexual
		Trichoribates trimaculatus	Tric-tri	Sexual
	Chamobatidae	Chamohates kieviensis	Cham-kie	Sexual
	Punctoribatidae	Minunthozetes neudofusiaer	Minu-nse	Sexual
		Punctoribates nunctum	Punc-nun	Sevual
	Galumnidae	Peradumna pervoca	Porg-nor	Sexual
	Galummuae	i ciguiuiiiiu neivosu	i cig lici	Jenuar

Galumnidae

^aClassification scheme follows Schatz et al. (2011).



Figure 1. Distribution of oribatid mites among the infraorders.

between treatment types and comprised 24% of all individuals and 24% of all species respectively (Table 3).

Sexually reproducing species dominated over parthenogens both in species richness and in abundance, irrespective to treatment type. Only in few sampling periods (especially in colder periods of year), the proportion of parthenogenetic species and individuals approached or even exceeded that of sexuals (Supplement 1). Treatment type did not have any influence on the proportion of parthenogenetic species number or abundance (Friedman test p > 0.05 in both cases). Moreover, DCA indicated that the parthenogenetic species are mostly associated with PL/ PPL sites rather than with Ctr sites (Figure 4) though the trend is not statistically significant (F test, p > 0.05). In contrast, several ubiquitous species (e.g. Punctoribates punctum (C.L. Koch 1839) (36%), Tectocepheus velatus (Michael 1880) (9%), P. capucinus (8%)) were abundant in Ctr. Ten dominant species comprised 78% of total abundance, when in PPL or PL sites their abundance was 85% and 88% respectively.



Figure 2. Species richness of oribatid mites along the period of investigation. Whiskers indicating the standard deviation.



Figure 3. Evenness of oribatid mites along the period of investigation.

Table 3. Sample species richness and abundance of oribatid mites on studied sites.

Treatment	Species	Maximum (sample)	Density ind/m ²	Maximum (samples)	Proportion of parthenogenetic	Proportion of parthenogenetic
type	richness	richness	(SD)	density	individuals (SD)	species (SD)
Ctr	55	18	26 (27)	135	22% (27%)	21% (21%)
PPL	53	19	21 (23)	126	26% (27%)	23% (19%)
PL	43	12	17 (15)	55	17% (19%)	21% (15%)

Ctr - meadow control; PPL - ploughed + pesticide application; PL - ploughed only; SD - Standard Deviation



Figure 4. Detrended Correspondence Analyses (DCA) ordination graph of oribatid mite species. The treatment sites (red) and the sampling dates (green) were included as supplementary variables. Eigenvalues (and length of gradients) of axes 1 and 2 are 0.54 and 0.46, respectively. Parthenogenetic taxa are marked blue and the 10 most abundant species are underlined. See supplement 2 for full names of species.

Discussion

Our results show no clear difference between treated sites (PL and PPL) indicating no profound effect of pesticides (mainly fungicides) on oribatid density and species richness. A low lethal effect of fungicides on oribatids and other arthropod fauna was also shown by Adamsky et al. (2007) who found most Mesostigmata and Oribatida to be tolerant to mancozeb. This phenomenon was described by the authors as "non omnia (Animalia) moriantur - not all animals will die". No or low effects of various pesticides on soil microarthropods, and in particular on oribatid mites, were shown by other authors as well (Krogh 1991; Sterk et al. 1999; Cortet, Ronce et al. 2000; Frampton et al. 2006; Jänsch et al. 2006; Badji et al. 2007; Anbarashan and Gopalswamy 2013; see also the overview by Behan-Pelletier 2003). Ubiquitous species such as P. capucinus, P. punctum, Ramusella clavipectinata (Michael 1885) and T. velatus were constantly encountered in pesticide-applied plots in high abundance. Populations of T. velatus were also reported as numerous in sites with organophosphate or chlorinated hydrocarbon application (Smith et al. 1980 in Behan-Pelletier 2003). Acrotritia ardua (C.L. Koch 1841) which is also known as tolerant to pesticide applications (Al-Assiuty and Khalil 1995) was also frequently found but in low numbers. In our previous studies (Murvanidze et al. 2008, 2013), we indicated these species as tolerant to various types of disturbance, and this study confirms their status as indicators of stressed ecosystems including application of pesticides.

According to our investigation, pesticides also seem to have no prolonged effect on soil fauna after two years of treatment. Application of chemicals stopped in August 2017, and oribatids were sampled two months after the treatment. No significant decrease of the number of identified species and their quantity was observed. This result is in accordance with Adamsky et al. (2009) who found no significant difference between applied and control sites after six months of a single pesticide application. Broadbent and Tomlin (1982) also report no long-term effects of carbofuran application under conventional tillage on soil microarthropods.

While negative effects of pesticide application on oribatid mites are controversially discussed (see Stark 1992 in Behan-Pelletier 1999; Cortet et al. 2002a for negative views), the effect of mechanical disturbance like deep ploughing is assumed to have more adverse effects. Cortet et al. (2002b) showed effects of pesticides to be minor compared to tillage, and that deep tillage had a more adverse effect on oribatid fauna than minimum tillage. About 50% of total soil mite fauna was lost immediately after tillage in an open field experiment (Hülsmann and Wolters 1998) and soil fauna was less abundant in conventionally managed fields compared to the fields with no-tillage (Rodrigues et al. 2006). In our study, the lowest overall number of oribatid mite species was observed in the ploughed-only site. P. capucinus, P. punctum and R. clavipectinata dominated there, while more sensitive species of the families Belbidae, Ceratozetidae and Liacaridae were found in minor numbers. Low species number and abundance suggest that

ploughing has indeed negative effects on oribatid mite community and they do not recover even two years after soil disturbance. It however seems controversial why species richness/density in PPL sites which were regularly cultivated and sprayed with pesticides after initial deep ploughing exceeded (or at least was not less) those of PL sites. One of the plausible hypothesis is that the pesticide applications are destroying predator communities (such as beetles or Gamasina mites) and support the increase of density and higher species number of stress tolerant oribatid taxa. Adamsky et al. (2007) also found that mesostigmatid mites were as tolerant to mancozeb application as Oribatida; however, later Adamsky et al. (2009) observed the significant decline of Gamasina mite abundance after the repeated spraying of mancozeb or diflubenzuron. Krogh (1991) also announced high mortality of mesostigmatid and prostigmatid mites, but no effect on oribatid mites after isophenfos and benomyl applications. Moreover, since predatory species (Mesostigmata) represent the third or higher trophic level, they may easily accumulate pesticides (Adamsky et al. 2007). In our study, oribatid species such as P. capucinus, R. clavipectinata, Dorycranosus splendens (Coggi 1898), O. (Z) skrjabini and Oribatula tibialis (Nicolet 1855) (all of them belong to the 10 top dominant species) have increased their abundance significantly in PPL while others (i.e. P. punctum) declined. Overall, total densities were not significantly different between treatments, while at PPL sites they tended to be more abundant. Though no significant decrease in species richness or community evenness was observed in PPL sites towards the end of the experimental period, there was some observable change in dominance structure of communities. To understand the indirect effect of pesticide application on mite community fluctuations, additional experimental studies are needed.

We did not find evidence that parthenogenetic species were more severely affected by tillage or pesticide application compared to the sexual ones. Dominance of sexually reproducing oribatids in soil samples is possibly a result of resource scarcity (Fischer et al. 2010, 2014; Maraun et al. 2013; Bluhm et al. 2016; but see Wehner et al. (2014); Gergocs et al. (2015) for alternative views). Indeed, agricultural and dry meadow soils have fewer resources available than forest floor where parthenogenetic taxa are present in high proportion (Maraun et al. 2003, 2013; Fischer et al. 2014). The experimental grassland area in Patardzeuli village was for more than 20 years not affected by agricultural practices (except mowing); however, even mowing seems to affect oribatid fauna significantly. This is supported by the low overall proportion of generally numerous and frequent parthenogenetic oribatid species (e.g. A. ardua, O. nova) and dominance of species (both, sexual and asexual) that are known to be tolerant to various types of disturbance (e.g. P. capucinus, P. punctum, R. clavipectinata or T. velatus) at control sites. Therefore, the lack of strong effects of agricultural activities on parthenogenetic species richness or abundance in the study area might be due to the existence of communities shaped by disturbance (mowing) regime. A slight increase of the proportions of asexual species in colder periods of the year when no pesticide applications and tillage procedures were performed indicates the appearance of favourable conditions for asexual species when anthropogenic pressure was minimized.

In summary, pesticide (with prevalence of fungicides) application on agricultural plots does not have dramatic direct effects on oribatid mite communities. Pesticide applications in cultivated soil might even trigger an increase in the abundance of several species (such as *P. capucinus, P. punctum, R. clavipectinata* and *T. velatus*) and therefore total density as well. The structure of oribatid mite communities in pesticide applied plots did not show significant changes over time (2 years' period). Overall, the low proportion of parthenogenetic species indicates the existence of agricultural stress tolerant communities in the study area (existing at least 20 years after abandoning). Accordingly, oribatid communities of agricultural area may therefore not serve as an early indicator tool for soil ecosystem degradation.

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Disclosure statement

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Supplementary material

Supplemental data for this article can be accessed here.

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