

## Article

# Intercropped Plants Provide a Reservoir of Predatory Mites in Coffee Crop

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**Abstract:** Conservation biological control of pests may be achieved using a variety of integrated strategies based on crop diversification. We investigated whether the insertion of the intercropped plants species (IPS) *Inga edulis*, *Senna macranthera*, and *Varronia curassavica* modified the abundance of mites, their feeding behavior, and the dissimilarity of predator and herbivore mites over a gradient of distance from the IPS on coffee. To accomplish this, we recorded the mite species on coffee plants along transects of 16 m extending from the IPS, including on the IPS. A total of 8946 specimens were sampled. Tenuipalpidae was the most abundant family on coffee, followed by Tydeidae, while Eriophyidae was the most abundant on the IPS, followed by Phytoseiidae. The abundance and richness of mites differed between their feeding behavior and distance. The dissimilarity of predators and herbivores increased along a gradient of distance. Furthermore, the IPS harbored several mite species and the diversity of predator and herbivore mites among the IPS was different. The findings suggest that the intercropped plant species can attract and serve as a reservoir of predatory mites on coffee crops, which could improve the biocontrol of pest mites on coffee.

**Keywords:** conservation biological control; agroecosystem diversification; ecosystem service; herbivores; natural enemies; integrated pest management

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## 1. Introduction

Brazil is the largest coffee producer and exporter in the world. The covered area is 1.75 million hectares, from which Minas Gerais has the largest cultivated area (1.22 million hectares); the most cultivated coffee species in the country is *Coffea arabica* L. (Rubiaceae) [1]. Minas Gerais is the state with the largest crop area, corresponding to 71.7% of the occupied area of this species nationwide [1]. Pests and diseases normally cause economic and quality losses on coffee crops [2]. The most frequent strategy in controlling them is the use of chemical inputs such as fungicides, insecticides, and acaricides [3,4]. However, the impact of these pesticides does not only affect the target pest species but also beneficial organisms that play important roles in this agroecosystem due to the ecological services they provide, such as pollination and biocontrol [5–7]. In addition to the impact on biodiversity, the continued use of pesticides also reduces the quality of human life, due to the loss of ecosystem services, increase in food production costs, and health concerns [8–12].

Conservation biological control is defined as the enhancement of natural enemy populations in the agroecosystem, which could be an alternative to conventional practices to control pests in the crop [13–15]. This management can be performed with a variety of integrated strategies using the local biodiversity [16,17]. One strategy is the introduction of intercropped plants that are effective in attracting and favoring key natural enemies without attracting pests in the main crop [18,19]. Among the characteristics used to select the intercropped plants is the presence of extrafloral nectar and pollen, which are important sources of energy to attract natural enemies and pollinators (i.e., wasps, ants, mites, bees, and chrysopids) [20–27]. Because of their beneficial properties, trees of the genus *Inga* and *Senna* are intercropped with coffee by farmers in some Brazilian regions [28–30]. In addition to providing shade and wood, and fixing nitrogen, these trees also possess extrafloral nectaries that enhance pest control [22,23,31,32]. In addition, *Varronia curassavica* Jacq. is an aromatic perennial shrub that provides pollen during the whole year [33]. Together in the system, they can be a good strategy for conservative biological control by providing alternative food to natural enemies [22,23,28,30,34].

Increasing plant diversity enhances coffee productivity and soil quality, attracts natural enemies, and increases predation and parasitism in this agroecosystem [22,23,35,36]. Some predatory mites, such as phytoseiids from the genus *Amblyseius*, *Euseius*, *Neoseiulus*, *Galendromus*, and *Iphiseiodes*, prey on herbivore mites and also feed on some plant sources, such as pollen and nectar [37–39]. In some studies, predatory mites have been associated with nectar, pollen, and spontaneous plants that grow naturally intercropped with the main crop [20,21,25,40–43]. However, little is known about the effect of intercropped plants with nectaries and pollen on herbivores and predatory mites in coffee crops [25,34,44].

Coffee plants house mites with different food habits, such as predators, mycophagous, herbivores, and other species that do not have a well-known food source reported [4,45–48]. Some of the most common predatory mites found on these plants are from the families Phytoseiidae, Ascidae, Stigmaeidae, Cunaxidae, Cheyletidae, and Anystidae [4,45,47–52], with phytoseiid mites being one of the most well-known and studied [37]. The most economically important herbivore mite in this culture is *Oligonychus ilicis* (McGregor) (Tetranychidae). It causes significant economic losses due to defoliation, premature leaf drop, and reduction in plant photosynthesis [53,54]. The second most important pest is *Brevipalpus phoenicis* (Geijskes) (Tenuipalpidae). Although both mites occur throughout the year, dry periods are the most favorable for their development [55]. Additionally, *B. phoenicis* can transmit the coffee ringspot virus, which causes defoliation of the plants [55,56]. This last species comprises several cryptic species [57,58] divided into a complex of eight species. Before this division, *B. phoenicis* was the only species recorded on this crop. Subsequently, there are only records of *B. yothersi* Baker and *B. papayensis* Baker as species belonging to the *B. phoenicis* species complex and being able to transmit the coffee ringspot virus [4,47,48,51,52,58–60]. Additionally, *Polyphagotarsonemus latus* (Banks) (Tarsonemidae) is a pest on coffee that damages the leaves, curling them downward [16,56,61–65]. This species is found in higher densities in rainy seasons [55].

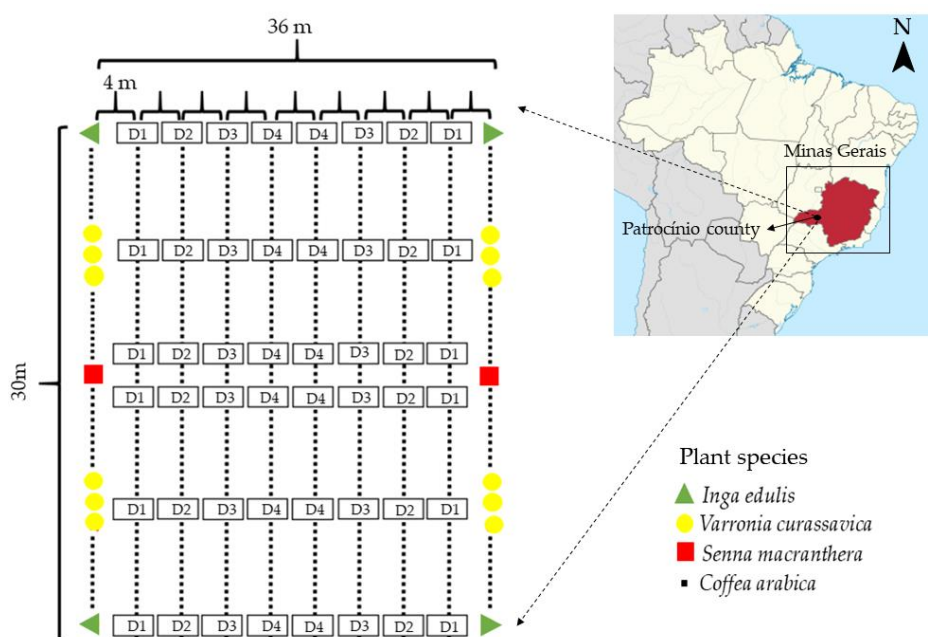
Our aim in this work was to evaluate if the distance from intercropped plants affects the communities of mites present in coffee crops. For this, we used an established intercropped coffee system and evaluated whether the insertion of the intercropped plants providing nectar and pollen modifies (I) the abundance and richness of mites and their feeding behavior, and (II) the dissimilarity of predator and herbivore mites over a gradient of distance from these plants. We also evaluated whether (III) the selected intercropped plants are able to harbor different communities of predator and herbivore mites, considering that the intercropped plants can provide food resources for them [25,44]. We hypothesized that coffee plants closer to the intercropped plants will have more predators, and consequently, fewer pest mites. We also hypothesized that the mite community of these groups tends to become more distinct in coffee plants as the distance from the intercropped plants increases. Finally, we predict that different intercropped plant species may

harbor different mite communities, which could contribute to a conservation biological control strategy in coffee systems.

## 2. Materials and Methods

### 2.1. Study Area

The experiment was carried out at the EPAMIG Experimental Farm Station, in Patrocínio county (18°59′52.0″ S 46°58′59.8″ W), Minas Gerais, Brazil, in the Cerrado biome (Figure 1). The region is located at the mesoregion of Triângulo Mineiro and Alto Paranaíba [66]. The sample area was characterized by a diversified system (1080 m<sup>2</sup>) with 3 replicated plots in 3 random locations in the planting at least 200 m from each other. The diversified system is surrounded by two rows of three intercropped plant species (IPS): two *Inga edulis* Mart. (Fabaceae) trees, one *Senna macranthera* (Dc. ex collad.) H.S. Irwin and Barnaby (Fabaceae) tree, and six shrubs of *Varronia curassavica* (Cordiaceae) in each row (Figure 1). The amount of each IPS was determined according to the size of the plot and the plants. *Inga edulis* and *S. macranthera* have extrafloral nectaries that produce nectar all day long and year-round, and *V. curassavica* produces flowers during the whole year [31–33]. No pesticides were applied in the study plots. Fertilization was made with chemical fertilizers and the spontaneous plant growth was controlled by a brush cutter.



**Figure 1.** Map showing the spatial arrangement of the sampling plot, diversified coffee system (1080 m<sup>2</sup>), at Patrocínio county, Minas Gerais, Brazil. Green triangles represent *Inga edulis*, yellow circles represent *Varronia curassavica*, red squares represent *Senna macranthera*, and black squares represent coffee plants. D1, D2, D3, and D4 represent the coffee plants sampled in their respective distances from the IPS: D1 represents distance 1 from the IPS (4 m); D2 represents distance 2 from the IPS (8 m); D3 represents distance 3 from the IPS (12 m); and D4 represents distance 4 from the IPS (16 m). Figure adapted from [24].

### 2.2. Data Collection

To evaluate the effect of intercropped plants on mite communities along a distance gradient in coffee crops, we sampled coffee plants four, eight, twelve, and sixteen meters from the intercropped plants (Figure 1). In each plant, we detached four leaves, beginning with the third leaf pair from the distal end of the shoot; this was conducted for two shoots on each plant. Two branches in the middle third of each bush facing both sides of the coffee rows were sampled (adapted [67]). A total of four plants were sampled every four

meters, which corresponded to consecutive coffee rows from each IPS (Figure 1). A total of 192 leaves were sampled per plot totaling 576 leaves in this experiment. Because the mite species repeated themselves at each time point, the fourth and fifth sampling followed the same procedure but instead of four leaves per plant, just 25% of the material was sampled, which means one leaf per plant. A total of 48 leaves/plot was sampled, totaling 144 leaves (adapted from Ref. [45]). To sample the IPS, five leaves of each plant species were detached randomly per row for a total of 10 leaves per plant species/plot, totaling 90 leaves. The material was collected at five time points: June 2020 and September 2020 (dry season), and October 2020, November 2020, and February 2021 (rainy seasons). The samples were placed separately in paper bags and kept at low temperatures with Gelo-X® inside a cooler box until they arrived at the laboratory of Acarology at the Department of Entomology at the Federal University of Viçosa, Minas Gerais (20°45'37.0" S 42°52'07.0" W). At the laboratory, samples were kept in a refrigerator at approximately 10 °C for a period of up to 10 days. The leaves were examined with a stereoscopic microscope and all mites were mounted on glass slides in Hoyer's medium for identification [68]. Morphological identification was made on a microscope with phase contrast using a dichotomous key [58,69–76].

Different amounts of leaves were sampled at different time points because only 25% of the leaves were sampled in the fourth and fifth sampling. So, to maintain a consistent identification pattern, from the first to third sampling, 25% of each slide was identified and in the fourth and fifth all the slides were identified. To accomplish this, the cover slide was divided into four identical quadrants, each one corresponding to 25% of the slide. The identified quadrant was raffled. If in the raffled quadrant there were no mites, the identified was the anterior one.

Females, males, and immature mites were included to analyze abundance. To richness, only females were included because it was not possible to identify or morphotype males. When assessing Eriophyoidea mites, some individuals were mounted on microscope slides with modified Berlese's medium [77] for morphotyping, and some individuals were preserved in 70% ethanol for posterior identification. To measure the abundance, all Eriophyoidea from the first sample were counted. From the second up to the fifth sample, we used the mean number of mites per leaf. Hence, all individuals of the same morphospecies were counted in a 1 cm<sup>2</sup> quadrant in the abaxial surface of each leaf in the region near to petiole and midrib. So, the leaves were measured and the number of specimens per leaf was estimated. Only for this superfamily were all specimens included in richness.

All specimens were deposited in the mite reference collection of the Laboratory of Acarology at the Department of Entomology at the Federal University of Viçosa, Minas Gerais, Brazil.

### 2.3. Statistical Analyses

We tested the effect of the distance gradient on the abundance of the herbivorous and predatory mites using generalized linear mixed models (GLMMs) with a Poisson error structure (and a log-link function) with the "lme4" v.3.1-147 package [78]. In the full model for each response variable, we specified a fixed polynomial effect of the distance gradient (i.e., including a quadratic term in the regression function) to account for potential non-uniformity in response. Each model included a random intercept for "plot" ( $n = 3$ ) to account for the non-independence of the samples located within each plot. We used the Gaussian distribution, and no overdispersion was found for the best-fitting models. For the construction of the full model for the abundance of mites, we carried out a model simplification process using the "AICcmodavg" package [79]. We determined the minimum adequate model(s) by comparing akaike information criterion corrected (AICc) values and AICc weights (AICcWt) for sub-models consisting of (1) a polynomial DG \* behavior model, (2) a polynomial DG + behavior model, (3) a linear DG \* behavior model, (4) a linear DG + behavior model, or (5) a null intercept-only model. Models within 2

$\Delta$ AICc units of the top model (i.e., the model with the lowest AICc and highest AICcWt values) were considered to have equivalent explanatory power [80]. For the final model, we used the approach of Nakagawa and Schielzeth [81] to estimate absolute model fit using marginal R<sup>2</sup> GLMM (variance explained by just the fixed effects) and conditional R<sup>2</sup> GLMM (variance explained by both fixed and random effects). To evaluate the difference of abundance among gradient distance and/or food behavior, we used the Analysis of Deviance e (Type III) performed with package “car” version 3-1.0 [82] and Contrast Analysis with package “lsmeans” version 2.30-0 [83].

To investigate changes in the composition of mite communities along the distance gradient, a species dissimilarity matrix based on the Bray–Curtis distance metric was calculated among the plots [84]. From this, we calculated the average pairwise dissimilarity of each sample to the centroid of the first distance of the coffee plant sampled using the function “vegdist” in the “vegan” v.5-5 package [85]. This response measure, therefore, reflects “dissimilarity to distance of IPS” in terms of species composition. We tested the effect of the distance gradient on mite “dissimilarity to distance of IPS” using separate linear models (LMs) with a gaussian error structure (and an identity link function). We specified a fixed polynomial effect of the distance gradient and, as described above, we carried out model simplification using AIC comparisons of polynomial, linear, and null sub-models. Finally, we estimated the coefficient of determination of final models using the “rsq” v.1.1 package [86].

We tested the variation in the composition of predators and herbivores among plants with the permutational analysis of multivariate dispersions (PERMDISP) and the permutational multivariate analysis of variance (PERMANOVA) using the function *betadisper* and *adonis*, respectively, both from the “vegan” package version 2.4-2 [87]. When we found differences in composition among treatments, we performed a pairwise comparison using the pairwise *adonis* function with a Bonferroni correction [88]. All analyses were performed in R version 3.5.1 [89].

### 3. Results

#### 3.1. Abundance and Richness of Mites

In total, we collected 8946 specimens belonging to 13 families and 37 species, divided into 4 feeding behaviors: generalist, mycophagous, herbivores, and predators. Out of the thirty-seven species found, three were generalists (Tydeidae), five were mycophagous (Acaridae, Glycyphagidae, Tarsonemidae, and Winterschmidtidae), twelve were herbivores (Eriophyidae, Diptilomiopidae, Tarsonemidae, Tenuipalpidae, and Tetranychidae), and sixteen were predators (Iolinidae, Phytoseiidae, and Stigmaeidae). On coffee, Tenuipalpidae was the most abundant family ( $n = 656$ ) but only one species was reported, followed by Tydeidae ( $n = 126$ ) with three species and Tetranychidae ( $n = 96$ ) with two species found. On the IPS, Eriophyidae was the most abundant family recorded ( $n = 6252$ ) with four species, followed by Phytoseiidae ( $n = 282$ ) with twelve species and Tenuipalpidae ( $n = 257$ ) with one species (Tables 1 and 2).

**Table 1.** Richness and composition of mite species in the intercropped coffee systems between June 2020 and February 2021: *Vc* *Varronia curassavica*, *Sm* *Senna macranthera*, *Ie* *Inga edulis*, *Ca1* *Coffea arabica* row 1, *Ca2* *C. arabica* row 2, *Ca3* *C. arabica* row 3, and *Ca4* *C. arabica* row 4.

Feeding Behavior	Mite Family	Mite Species	Plant Species						
			<i>Vc</i>	<i>Sm</i>	<i>Ie</i>	<i>Ca1</i>	<i>Ca2</i>	<i>Ca3</i>	<i>Ca4</i>
Generalists	Tydeidae	<i>Lorryia formosa</i> Cooreman	1	1	48	1		1	
	Tydeidae	<i>Lorryia</i> sp1	3	34	8	14	7	22	10
	Tydeidae	<i>Lorryia</i> sp2			5	1			1
Mycophagous	Acaridae	<i>Tyrophagus putrescentiae</i> (Schrank)	26	27	84	7	10	12	16
	Astigmatina *	Astigmatina sp.	3						
	Glycyphagidae	<i>Lepidoglyphus destructor</i> (Schrank)			1				1
	Tarsonemidae	<i>Daidalotarsonemus savanicus</i> Rezende, Lofego and Ochoa			4	1			
	Tarsonemidae	<i>Tarsonemus confusus</i> Ewing			7	6	11	1	2
	Winterschmidtidae	Winterschmidtidae sp.	4		1				
Herbivores	Eriophyidae	<i>Aculus</i> sp.	1200						
	Eriophyidae	Eriophyidae sp1			4885				
	Eriophyidae	Eriophyidae sp2	70						
	Eriophyidae	Eriophyidae sp3	97						
	Diptilomiopidae	Diptilomiopidae sp.	18						
	Tarsonemidae	<i>Polyphagotarsonemus latus</i> (Banks)	65						
	Tenuipalpidae	<i>Brevipalpus yothersi</i> Baker	15	144	77	95	152	110	100
	Tetranychidae	<i>Atrichoproctus uncinatus</i> Flechtmann	12	7	12				
	Tetranychidae	<i>Mononychellus planki</i> (McGregor)		3					
	Tetranychidae	<i>Oligonychus coffeae</i> (Nietner)				7	4	12	4
	Tetranychidae	<i>Oligonychus ilicis</i> (McGregor)			1	1	1	4	2
	Tetranychidae	<i>Tetranychus</i> sp.			2				
	Predators	Iolinidae	<i>Pseudopronematus nadirae</i> Silva, Da-Costa and Ferla	41	61	1	5	7	10
Iolinidae		<i>Pausia</i> sp.	5	7					
Phytoseiidae		<i>Amblyseius</i> aff. <i>chiapensis</i>	1		2				
Phytoseiidae		<i>Amblyseius</i> aff. <i>impressus</i>				1			
Phytoseiidae		<i>Amblyseius</i> sp.			1				
Phytoseiidae		<i>Euseius alatus</i> DeLeon			4				
Phytoseiidae		<i>Euseius citrifolius</i> (Denmark and Muma)	5	6	7	4	2	2	1
Phytoseiidae		<i>Euseius concordis</i> (Chant)	1	1	11	4	5	3	3
Phytoseiidae		<i>Euseius sibelius</i> (De Leon)	1	6	1				
Phytoseiidae		<i>Iphiseiodes zuluagai</i> Denmark and Muma			32			2	2
Phytoseiidae		<i>Galendromus annectens</i> (De Leon)		4	2				
Phytoseiidae		<i>Neoseiulus tunus</i> (De Leon)	6						
Phytoseiidae		<i>Typhlodromalus aripo</i> DeLeon	4	4	1				
Phytoseiidae		<i>Typhlodromips mangleae</i> De Leon			1	4			
Stigmaeidae		<i>Agistemus floridanus</i> Gonzalez	38	13	78	1		1	1
Stigmaeidae		<i>Agistemus brasiliensis</i> Matioli, Ueckermann and Oliveira	2						

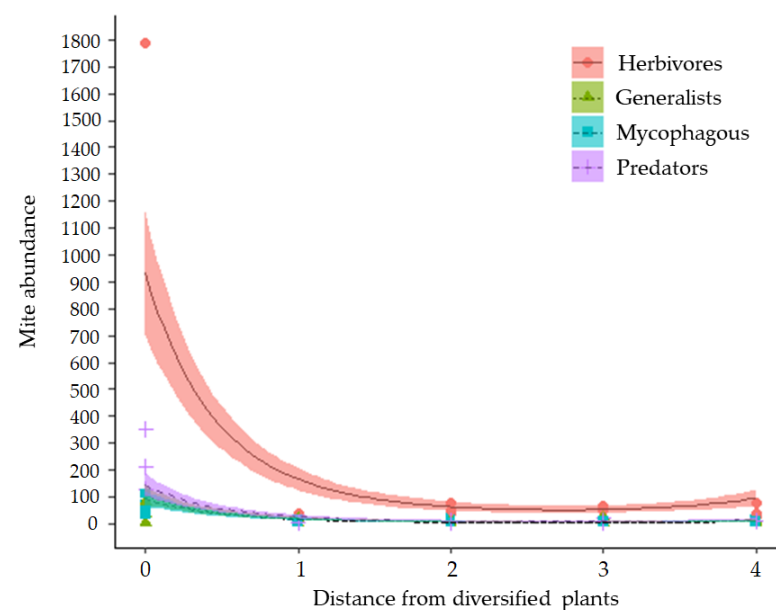
\* Cohort.

**Table 2.** Abundances of mite species in the intercropped coffee systems between June 2020 and February 2021: *Vc* *Varronia curassavica*, *Sm* *Senna macranthera*, *Ie* *Inga edulis*, *Ca1* *Coffea arabica* row 1, *Ca2* *C. arabica* row 2, *Ca3* *C. arabica* row 3, and *Ca4* *C. arabica* row 4.

Feeding Behavior	Mite Family	Plant Species						
		<i>Vc</i>	<i>Sm</i>	<i>Ie</i>	<i>Ca1</i>	<i>Ca2</i>	<i>Ca3</i>	<i>Ca4</i>
Generalists	Tydeidae	6	37	76	35	19	50	22
Mycophagous	Acaridae	32	37	109	19	17	19	25
	Astigmatina *	3						
	Glycyphagidae			1				1
	Tarsonemidae	111	14	23	7	12	3	4
	Winterschmidtidae	4		1				
Herbivores	Eriophyidae	167	1200	4885				
	Diptilomiopidae	18						
	Tarsonemidae	108						
	Tenuipalpidae	15	158	84	130	208	171	147
	Tetranychidae	19	14	18	16	14	27	39
Predators	Iolinidae	85	134	2	8	12	20	11
	Phytoseiidae	37	53	192	16	15	15	21
	Stigmaeidae	48	20	129	1		1	1

\* Cohort.

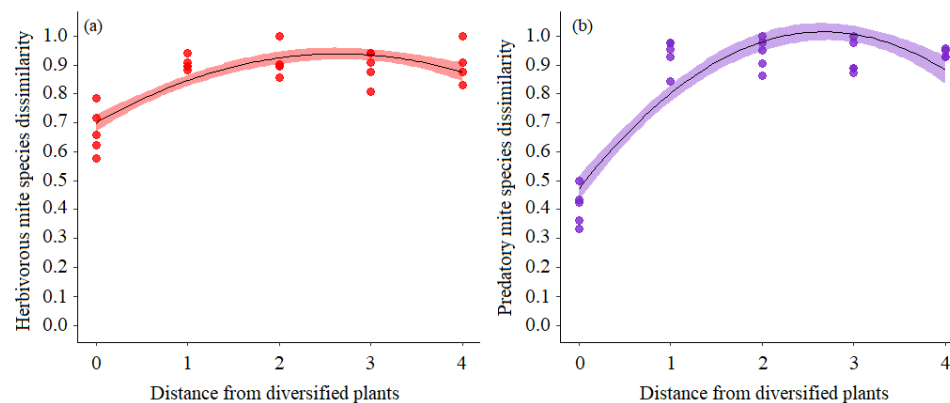
The best model that described the mite abundance was the polynomial with predictors *behavior + distance* ( $R^2(m) = 0.74$ ,  $R^2(C) = 0.74$ ,  $AICc = 542.01$  and  $AICcWt = 0.89$ ) (Table S1). We found an abundance of mites differed among their feeding behavior ( $X^2 = 68.637$ ,  $df = 3$ ,  $p < 0.001$ ) and along the gradient distance from intercropped plants ( $X^2 = 104.825$ ,  $df = 2$ ,  $p < 0.001$ , Figure 2). Regarding the difference in abundance among the feeding behavior along the distance gradient, the abundance of herbivores was higher than the other feeding behaviors ( $p < 0.0001$ ). Additionally, no variation among predators, mycophagous, and generalist mites were observed ( $p > 0.05$ ).



**Figure 2.** Mite abundance of different feeding behaviors along a distance gradient. Distance 0 refers to mites on the IPS and distance 1 to 4 refers to the mites on coffee plants at their respective distances.

### 3.2. Dissimilarity of Mites

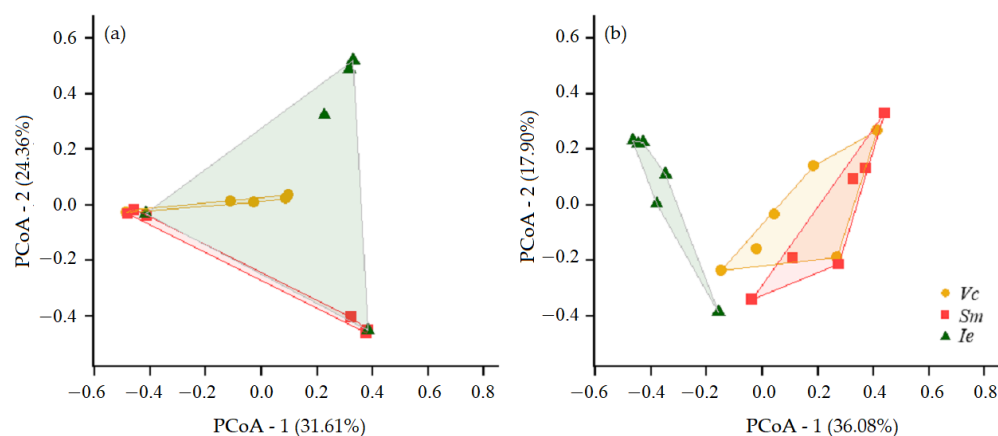
The dissimilarity of species along the distance gradient for both herbivorous and predatory mites presented the polynomial model as the most adjusted (see Table S1). We found that the dissimilarity of herbivores and predators increased over the distance gradient ( $F = 22.534$ ,  $p < 0.0001$ ,  $R^2 = 0.63$ , Figure 3a and  $F = 44.464$ ,  $p < 0.0001$ ,  $R^2 = 0.80$ , Figure 3b, respectively).



**Figure 3.** Variation in (a) herbivorous mite community dissimilarity and (b) predatory mite community dissimilarity from the IPS. Distance 0 refers to mites on the IPS and distance 1 to 4 refers to the mites on coffee plants at their respective distances.

### 3.3. Communities of Herbivorous and Predatory Mites on the IPS

The composition of herbivorous mites on IPS was different (PERMDISP:  $F = 0.21$ ,  $p = 0.80$ ; PERMANOVA:  $R^2 = 0.22$ ,  $p < 0.05$ , Figure 4a). *Inga edulis* was different from *S. macranthera* ( $R^2 = 0.32$ ,  $p = 0.001$ ) and *V. curassavica* ( $R^2 = 0.32$ ,  $p = 0.002$ ), but *V. curassavica* and *S. macranthera* were not different ( $R^2 = 0.09$ ,  $p = 0.36$ ).



**Figure 4.** Principal coordinate analysis (PCoA) plot based on the Bray–Curtis dissimilarity index from samples of predatory and herbivorous mites composition between the IPS. Composition of herbivores (a) and predators (b) from the IPS. Yellow circles represent *Varronia curassavica* (*Vc*), red squares represent *Senna macranthera* (*Sm*), and green triangles represent *Inga edulis* (*Ie*).

The composition of predators on IPS was also different (PERMDISP:  $F = 0.18$ ,  $p = 0.83$ ; PERMANOVA:  $R^2 = 0.33$ ,  $p < 0.001$ , Figure 4b). *Inga edulis* was different from *V. curassavica* ( $R^2 = 0.32$ ,  $p = 0.002$ ) and *S. macranthera* ( $R^2 = 0.32$ ,  $p = 0.003$ ), but *V. curassavica* and *S. macranthera* were not different ( $R^2 = 0.09$ ,  $p = 0.37$ ).



The predatory mite species found in all IPS were *Pseudopronematus nadirae* Silva, Da-Costa, and Ferla, *Euseius citrifolius* (Denmark and Muma), *E. concordis* (Chant), *E. sibiensis* (De Leon), *Typhlodromalus aripo* DeLeon, and *Agistemus floridanus* Gonzalez. In general, *I. edulis* houses more predator species than the other IPS, with *Amblyseius* sp., *E. alatus* DeLeon, *Iphiseiodes zuluagai* Denmark and Muma, *Agistemus brasiliensis* Matioli, Uecker-mann, and Oliveira occurring only on this plant species. *Varronia curassavica* has only one exclusive species (*Neoseiulus tunus* (De Leon)) and *S. macranthera* did not have any exclusive species.

*Brevipalpus yothersi* and *Atrichoproctus uncinatus* Flechtmann were the only herbivore species common in all IPS. Eriophyidae sp1., *O. ilicis* and *Tetranychus* sp. are the species exclusive to *I. edulis*. Eriophyidae sp2 and sp3, Diptilomiopidae sp., and *P. latus* were the species that occur only on *V. curassavica*, and *Aculus* sp. and *Mononychellus planki* (McGregor) were the only two species exclusive from *S. macranthera*. The number of Eriophyidae on *I. edulis* was high (4885), despite having only one eriophyid species in this plant, while *V. curassavica* and *S. macranthera* had different species in a much lower number. It is important to notice that despite being a pest on coffee, *P. latus* only occurred on *V. curassavica* with no records on coffee.

#### 4. Discussion

The data presented here show that the intercropped plants are a reservoir of natural enemies, as they harbor several species of predators. The abundance of mites differed in their feeding behavior and distance with the dissimilarity of predators and herbivores increasing along a gradient of distance.

Diversified coffee production systems attract predators, mostly wasps and parasitoids, increase biological control, improve soil quality, and decrease spontaneous plants [22,23,25,35,36,44,90]. Studies with *Inga* spp. demonstrate the positive effects of this plant intercropped with coffee, increasing natural control of coffee berry borers, coffee leaf miners, and important coffee pests by attracting wasps and parasitoids due to the provision of nectar, and consequently enhancing the coffee yield [22,23]. So, in this work, we observed that not just *I. edulis*, but also *V. curassavica* and *S. macranthera* house predators. All predatory mites found on coffee were also found on the IPS (except for *A. aff impressus* that has only one individual recorded), meaning that coffee plants are benefiting from the IPS harboring predators that could control their pest mites. In addition to providing additional food sources, such as pollen and nectar, the intercropped plants also can provide shelter, a favorable microclimate, and a habitat where prey is present [91].

The composition of herbivorous and predatory mites was different in *I. edulis* and similar in *V. curassavica* and *S. macranthera*. *Inga* plants harbored many more predators than other IPS, did not harbor *P. latus*, and only harbored a few *O. ilicis* ( $n = 1$ ), two herbivore pests of economic impact on coffee crops. *Senna macranthera* did not house any of these pest species but also harbored some predators. This is an important finding because these plants have the potential of harboring different natural enemies and do not attract coffee pest mites. Thus, due to the differences in natural enemies' species in each IPS, the use of the three plants together in coffee crop systems stimulated the diversity of predators. The natural enemies found in this work belong to the families Stigmaeidae, Iolinidae, and Phytoseiidae, with the latter having the greatest number of species. Most of the species found here are known to feed and reproduce on a wide range of prey and Phytoseiidae, for example, also feed on pollen and nectar that can constitute an important part of their diet [37,38,92–96]. Phytoseiidae is an important predatory family that is extensively studied and used for the biological control of pests [97]. Species of the genus *Amblyseius*, *Neoseiulus*, *Galendromus*, and *Typhlodromalus* have records of feeding on pollen, but also on Eriophyidae, Tarsonemidae, Tetranychidae, Tydeoidea, and other herbivore families [37,38]. Additionally, species of the genus *Euseius* and *Iphiseiodes* are pollen feeders and are also generalists that prey on a range of mites, and *B. phoenicis* is one of them [38,98–100]. Additionally, *I. zuluagai* can feed on sugary substances and it is able to be reared on

a range of alternative food sources [100,101]. At the time of the studies cited above, *B. phoenicis* was not divided into a species complex yet [58], and all the species of this complex were called *B. phoenicis*. So, we cannot be certain which species of these complexes were recorded in those studies.

The feeding habits of Tydeoidea are diverse [102], and Iolinidae are associated with several herbivorous species, preying on Eriophyidae, Tenuipalpidae, and Tetranychidae [92,94–96]. Other mites that feed on Eriophyoidea are Stigmaeidae, which can also feed on Tetranychidae [93,103]. In this work, there were a great amount of Eriophyidae and other herbivorous species belonging to Diptilomiopidae, Tenuipalpidae, Tarsonemidae, and Tetranychidae. Thus, the larger number of herbivores in the system is mainly due to the high number of eriophyids found on the IPS (Tables 1 and 2). Additionally, referring to mycophagous mites, there are some species that belong to the family Acaridae, Glyciphagidae, Winterschmidtidae, and Tarsonemidae, which in coffee may be associated with the presence of domatia, influencing the distribution and abundance of the group [104]. Knowing that the pests on coffee vary in quantity during the year, the mites on the IPS and also those on coffee plants can probably be preyed on and serve as alternative food by the predators recorded here, mainly when the pests on coffee are in a low population [45,55,105]. Furthermore, the IPS stimulates the diversity of natural enemies of other insect pests in this crop [22,23,106].

Thus, these results suggest that the IPS attracts predatory and herbivorous mites that are not pests on coffee. These herbivores could be alternative prey to increase the population of predators on these plants that could later migrate to coffee plants and control their pest mites. Once this happens, it could enhance the conservation of biological control in the area. Understanding the dynamics of predators and prey in this system would facilitate management practices and favor the establishment of sustainable pest mite control on coffee crops.

**Supplementary Materials:** The following supporting information can be downloaded at <https://www.mdpi.com/article/10.3390/agriculture13020285/s1>, Table S1: Comparison of the likelihood of model fit for null, linear, and polynomial models of the response variable to the distance gradient (DG) and behavior. AICc: akaike information criterion corrected;  $\Delta$ AICc: difference in AICc between the model and the model with the smallest AICc; AICcWt: model weight according to  $\Delta$ AICc. Values in bold represent the best models.

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## References

1. CONAB. Acompanhamento Da Safra Brasileira. *Safra 2021*, 2021; Volume 8, p. 59. Available online: [http://www.sapc.embrapa.br/arquivos/consorcio/levantamento/Conab\\_safra\\_2021\\_n2.pdf](http://www.sapc.embrapa.br/arquivos/consorcio/levantamento/Conab_safra_2021_n2.pdf) (accessed on 13 February 2021).
2. Avelino, J.; Allinne, C.; Cerda, R.; Willocquet, L.; Savary, S. Multiple-Disease System in Coffee: From Crop Loss Assessment to Sustainable Management. *Annu. Rev. Phytopathol.* **2018**, *56*, 611–635. <https://doi.org/10.1146/annurev-phyto-080417-050117>.
3. de Aparecido, L.E.O.; de Rolim, G.S.; da Silva Cabral De Moraes, J.; Costa, C.T.S.; de Souza, P.S. Machine Learning Algorithms for Forecasting the Incidence of *Coffea arabica* Pests and Diseases. *Int. J. Biometeorol.* **2020**, *64*, 671–688. <https://doi.org/10.1007/s00484-019-01856-1>.
4. Spongowski, S.; Reis, P.R.; Zacarias, M.S. Acarofauna Da Cafeicultura de Cerrado Em Patrocínio, Minas Gerais. *Cienc. Agrotec.* **2005**, *29*, 9–17. <https://doi.org/10.1590/S1413-70542005000100001>.
5. Tasei, J. Impact of Agrochemicals on Non-Apis Bees. In *Honey Bees: Estimating the Environmental Impact of Chemicals*; Taylor & Francis, London, UK, 2002; pp. 101–131. Available online: [https://books.google.com.au/books?hl=zh-TW&lr=&id=yov\\_MkEt6EwC&oi=fnd&pg=PA101&ots=uJUEKmhDvT&sig=mBRHh51nr4hZkRxdI0GNBIQ9Qak#v=onepage&q&f=false](https://books.google.com.au/books?hl=zh-TW&lr=&id=yov_MkEt6EwC&oi=fnd&pg=PA101&ots=uJUEKmhDvT&sig=mBRHh51nr4hZkRxdI0GNBIQ9Qak#v=onepage&q&f=false) (accessed on 15 March 2021).
6. Desneux, N.; Decourtye, A.; Delpuech, J.M. The Sublethal Effects of Pesticides on Beneficial Arthropods. *Annu. Rev. Entomol.* **2007**, *52*, 81–106. <https://doi.org/10.1146/annurev.ento.52.110405.091440>.
7. Giglio, A.; Cavaliere, F.; Giulianini, P.G.; Mazzei, A.; Talarico, F.; Vommaro, M.L.; Brandmayr, P. Impact of Agrochemicals on Non-Target Species: *Calathus fuscipes* Goeze 1777 (Coleoptera: Carabidae) as Model. *Ecotoxicol. Environ. Saf.* **2017**, *142*, 522–529. <https://doi.org/10.1016/j.ecoenv.2017.04.056>.
8. Perfecto, I.; Rice, R.A.; Greenberg, R.; van der Voort, M.E. Shade Coffee: A Disappearing Refuge for Biodiversity. *Bioscience* **1996**, *46*, 598–608. <https://doi.org/10.2307/1312989>.
9. Perfecto, I.; Vandermeer, J. Biodiversity Conservation in Tropical Agroecosystems: A New Conservation Paradigm. *Ann. N. Y. Acad. Sci.* **2008**, *1134*, 173–200. <https://doi.org/10.1196/annals.1439.011>.
10. Khan, S.; Khan, M.; Hanjra, M.; Mu, J. Pathways to Reduce the Environmental Footprints of Water and Energy Inputs in Food Production. *Food Policy* **2009**, *34*, 141–149. <https://doi.org/10.1016/j.foodpol.2008.11.002>.
11. Pedlowski, M.A.; Canela, M.C.; da Costa Terra, M.A.; Ramos de Faria, R.M. Modes of Pesticides Utilization by Brazilian Smallholders and Their Implications for Human Health and the Environment. *Crop Prot.* **2012**, *31*, 113–118. <https://doi.org/10.1016/j.cropro.2011.10.002>.
12. Sales, E.F.; Ernesto Méndez, V.; Caporal, F.R.; Faria, J.C. Agroecological Transition of Conilon Coffee (*Coffea canephora*) Agroforestry Systems in the State of Espírito Santo, Brazil. *Agroecol. Sustain. Food Syst.* **2013**, *37*, 405–429. <https://doi.org/10.1080/10440046.2012.712633>.
13. Tixier, M.S. Predatory Mites (Acari: Phytoseiidae) in Agro-Ecosystems and Conservation Biological Control: A Review and Explorative Approach for Forecasting Plant-Predatory Mite Interactions and Mite Dispersal. *Front. Ecol. Evol.* **2018**, *6*, 1–21. <https://doi.org/10.3389/fevo.2018.00192>.
14. Ratnadass, A.; Fernandes, P.; Avelino, J.; Habib, R. Plant Species Diversity for Sustainable Management of Crop Pests and Diseases in Agroecosystems: A Review. *Agron. Sustain. Dev.* **2012**, *32*, 273–303. <https://doi.org/10.1007/s13593-011-0022-4>.
15. Letourneau, D.K.; Armbrrecht, I.; Rivera, B.S.; Lerma, J.M.; Jimé, E.; Carmona, N.; Daza, M.C.; Escobar, S.; Vi, V.; Galindo, V.; et al. Does Plant Diversity Benefit Agroecosystems? A Synthetic Review. *Ecol. Appl.* **2011**, *21*, 9–21. <https://doi.org/10.1890/09-2026.1>.
16. Venzon, M.; Amaral, D.S.S.; Togni, P.H.B.; Rezende, M.Q.; Perez, A.L. Manejo de Pragas Na Agricultura Orgânica. In *Tecnologias para Produção Orgânica*; EPAMIG Zona da Mata: Viçosa, Brazil, 2011; pp. 107–128.
17. Zehnder, G.; Gurr, G.M.; Kühne, S.; Wade, M.R.; Wratten, S.D.; Wyss, E. Arthropod Pest Management in Organic Crops. *Annu. Rev. Entomol.* **2006**, *52*, 57–80. <https://doi.org/10.1146/annurev.ento.52.110405.091337>.
18. Begg, G.S.; Cook, S.M.; Dye, R.; Ferrante, M.; Franck, P.; Lavigne, C.; Lövei, G.L.; Mansion-Vaquie, A.; Pell, J.K.; Petit, S.; et al. A Functional Overview of Conservation Biological Control. *Crop Prot.* **2017**, *97*, 145–158. <https://doi.org/10.1016/j.cropro.2016.11.008>.
19. Venzon, M.; Sujii, E.R. Conservative Biological Control. *Inf. Agropecu.* **2009**, *30*, 7–16.
20. Pemberton, R.; Vandenberg, N. Extrafloral Nectar Feeding by Ladybird Beetles (Coleoptera: Coccinellidae). *Proc. Entomol. Soc. Washingt.* **1993**, *95*, 139–151.
21. van Rijn, P.C.J.; Tanigoshi, L.K. The Contribution of Extrafloral Nectar to Survival and Reproduction of the Predatory Mite *Iphiseius degenerans* on *Ricinus communis*. In *Ecology and Evolution of the Acari*; Springer: Dordrecht, The Netherlands, 1999; pp. 405–417.
22. Rezende, M.Q.; Venzon, M.; Perez, A.L.; Cardoso, I.M.; Janssen, A. Extrafloral Nectaries of Associated Trees Can Enhance Natural Pest Control. *Agric. Ecosyst. Environ.* **2014**, *188*, 198–203. <https://doi.org/10.1016/J.AGEE.2014.02.024>.
23. Rezende, M.Q.; Venzon, M.; dos Santos, P.S.; Cardoso, I.M.; Janssen, A. Extrafloral Nectary-Bearing Leguminous Trees Enhance Pest Control and Increase Fruit Weight in Associated Coffee Plants. *Agric. Ecosyst. Environ.* **2021**, *319*, 107538. <https://doi.org/10.1016/J.AGEE.2021.107538>.
24. Botti, J.M.C. Role of Green Lacewings and Ants on Coffee Berry Borer Predation. Level of Ph.D. thesis, Universidade Federal de Viçosa, Viçosa, Brazil, 2021.

25. da Rosado, M.C.; de Araújo, G.J.; Pallini, A.; Venzon, M. Cover Crop Intercropping Increases Biological Control in Coffee Crops. *Biol. Control* **2021**, *160*, 104675. <https://doi.org/10.1016/J.BIOCONTROL.2021.104675>.
26. Martins, E.F.; Franzin, M.L.; Perez, A.L.; Schmidt, J.M.; Venzon, M. Is *Ceraeochrysa cubana* a Coffee Leaf Miner Predator? *Biol. Control* **2021**, *160*, 104691. <https://doi.org/10.1016/j.biocontrol.2021.104691>.
27. Wäckers, F.; van Rijn, P.; Bruin, J. *Plant-Provided Food for Carnivorous Insects: A Protective Mutualism and Its Applications*; Cambridge University Press: Cambridge, UK, 2005.
28. Cardoso, I.M.; Guijt, I.; Franco, F.S.; Carvalho, A.F.; Ferreira Neto, P.S. Continual Learning for Agroforestry System Design: University, NGO and Farmer Partnership in Minas Gerais, Brazil. *Agric. Syst.* **2001**, *69*, 235–257. [https://doi.org/10.1016/S0308-521X\(01\)00028-2](https://doi.org/10.1016/S0308-521X(01)00028-2).
29. Grossman, J.M. *Inga Oerstediana in Organic Coffee Agroecosystems: Nitrogen Fixation, Nodulation and Farmer Knowledge of Soil Processes in Chiapas, Mexico—ProQuest*; University of Minnesota: Minneapolis, MN, USA, 2003.
30. Souza, H.N.; Cardoso, I.M.; Fernandes, J.M.; Garcia, F.C.P.; Bonfim, V.R.; Santos, A.C.; Carvalho, A.F.; Mendonça, E.S. Selection of Native Trees for Intercropping with Coffee in the Atlantic Rainforest Biome. *Agrofor. Syst.* **2010**, *80*, 1–16. <https://doi.org/10.1007/s10457-010-9340-9>.
31. Koptur, S. Floral and Extrafloral Nectars of Costa Rican Inga Trees: A Comparison of Their Constituents and Composition. *Biotropica* **1994**, *26*, 276–284. <https://doi.org/10.2307/2388848>.
32. Melo, Y.; Córdoba, E.; Machado, S.; Alves, M. Morfologia de Nectários Em Leguminosae Senso Lato Em Áreas de Caatinga No Brasil. *Acta Bot. Bras.* **2010**, *24*, 1034–1045. <https://doi.org/10.1590/S0102-33062010000400018>.
33. Brandão, D.S.; Mendes, A.D.R.; Santos, R.R.; Rocha, S.M.G.; Leite, G.L.D.; Martins, E.R. Biologia Floral e Sistema Reprodutivo Da Erva-Baleeira (*Varronia curassavica* Jacq.). *Rev. Bras. Plantas Med.* **2015**, *17*, 562–569. [https://doi.org/10.1590/1983-084X/14\\_011](https://doi.org/10.1590/1983-084X/14_011).
34. Teodoro, A.V.; Klein, A.M.; Tschardtke, T. Temporally Mediated Responses of the Diversity of Coffee Mites to Agroforestry Management. *J. Appl. Entomol.* **2009**, *133*, 659–665. <https://doi.org/10.1111/j.1439-0418.2009.01422.x>.
35. Androcioli, H.G.; Hoshino, A.T.; de Menezes Júnior, A.O.; Morais, H.; Bianco, R.; Caramori, P.H. Coffee Leaf Miner Incidence and Its Predation by Wasp in Coffee Intercropped with Rubber Trees. *Coffee Sci.* **2018**, *13*, 389–400. <https://doi.org/10.25186/CS.V13I3.1487>.
36. de Souza, G.S.; Alves, D.I.; Dan, M.L.; de Lima, J.S.S.; da Fonseca, A.L.C.C.; Araújo, J.B.S.; de Guimarães, L.A.O.P. Soil Physico-Hydraulic Properties under Organic Conilon Coffee Intercropped with Tree and Fruit Species. *Pesqui. Agropecu. Bras.* **2017**, *52*, 539–547. <https://doi.org/10.1590/S0100-204X2017000700008>.
37. McMurtry, J.A.; Croft, B.A. Life-Styles of Phytoseiid Mites and Their Roles in Biological Control. *Annu. Rev. Entomol.* **1997**, *42*, 291–321. <https://doi.org/10.1146/annurev.ento.42.1.291>.
38. McMurtry, J.A.; De Moraes, G.J.; Sourassou, N.F. Revision of the Lifestyles of Phytoseiid Mites (Acari: Phytoseiidae) and Implications for Biological Control Strategies. *Syst. Appl. Acarol.* **2013**, *18*, 297–320. <https://doi.org/10.11158/saa.18.4.1>.
39. Croft, B.; Blackwood, J.; McMurtry, J. Classifying Life-Style Types of Phytoseiid Mites: Diagnostic Traits. *Exp. Appl. Acarol.* **2004**, *33*, 247–260. <https://doi.org/10.1023/B:APPA.0000038622.26584.82>.
40. Pemberton, R. Observations of Extrafloral Nectar Feeding by Predaceous and Fungivorous Mites. *Proc. Entomol. Soc. Washingt.* **1993**, *95*, 642–643.
41. White, N.D.; Laing, J.E. Some Aspects of the Biology and a Laboratory Life Table of the Acarine Predator *Zetzellia mali*. *Can. Entomol.* **1977**, *109*, 1275–1281.
42. Rodríguez-Cruz, F.A.; Venzon, M.; Pinto, C.M.F. Performance of *Amblyseius herbicolus* on Broad Mites and on Castor Bean and Sunnhemp Pollen. *Exp. Appl. Acarol.* **2013**, *60*, 497–507. <https://doi.org/10.1007/S10493-013-9665-Y>.
43. Villanueva, R.; Childers, C. Phytoseiidae Increase with Pollen Deposition on Citrus Leaves. *Florida Entomol.* **2014**, *87*, 609–611.
44. Peixoto, M.L.; Fernandes, L.G.; Carvalho, M.A.C.; de Oliveira, M.L.; Putti, F.F.; Reis, A.R. Assessment of Mite Fauna in Different Coffee Cropping Systems in Brazil. *Biocontrol Sci. Technol.* **2017**, *27*, 424–432. <https://doi.org/10.1080/09583157.2017.1296931>.
45. Pallini, A. Acarofauna e Predação de Ácaros Fitófagos Por Ácaros Predadores Em Cafeeiro (*Coffea arabica* L.) No Sul de Minas Gerais. Level of Ph.D. thesis. Universidade Federal de Lavras, Lavras, MG, Brazil, 1991.
46. Reis, P.; Chiavegato, L.; Alves, E.; Sousa, E. Ácaros Da Família Phytoseiidae Associados Aos Citros No Município de Lavras, Sul de Minas Gerais. *An. Soc. Entomol. Bras.* **2000**, *29*, 95–104.
47. Marchetti, M.M. Ácaros Do Cafeeiro Em Minas Gerais Com Chave de Identificação. Level of Master's thesis., Universidade Federal de Viçosa, Viçosa, MG, Brazil, 2008.
48. De Carvalho Mineiro, J.L.; Sato, M.E.; Raga, A.; De Souza Filho, M.F.; Spongowski, S. Mite Fauna on Coffee Plants Cv. Catuaí Amarelo. *Bragantia* **2008**, *67*, 197–201. <https://doi.org/10.1590/S0006-87052008000100024>.
49. Silva, E.A.; Reis, P.R.; Zacarias, M.S.; Marafeli, P.P. Phytoseiids (Acari: Phytoseiidae) Associated to Coffee Plantations and Adjacent Forest Fragments. *Cienc. Agrotec.* **2010**, *34*, 1146–1153. <https://doi.org/10.1590/S1413-70542010000500010>.
50. Berton, L.H.C.; de Mineiro, J.L. C.; Sato, M.E.; de Joaquim, A.A.F.; Raga, A. Mite Fauna of a Coffee Agroecosystem (*Coffea arabica* L.) in the Municipality of Monte Alegre Do Sul, São Paulo State, Brazil. Part I. *Acarologia* **2019**, *59*, 542–550. <https://doi.org/10.24349/acarologia/20194352>.
51. Mineiro, J.; Sato, M.; Matioli, A.; Raga, A. Ácaros Plantícolas e Edáficos Em Agroecosistema Cafeeiro, Em Atibaia, Estado de São Paulo. In Proceedings of the Simpósio de Pesquisa dos Cafés do Brasil, Brasília, Brazil, January/June 2009. Available online: [http://www.biologico.agricultura.sp.gov.br/uploads/docs/bio/v70\\_1/mineiro.pdf](http://www.biologico.agricultura.sp.gov.br/uploads/docs/bio/v70_1/mineiro.pdf) (accessed on 20 January 2022).

52. Mineiro, J.; Sato, M.; Raga, A.; Arthur, V.; Cangani, K.; Barbosa, F. Diversidade de Ácaros (Arachnida: Acari) Em Cinco Cultivares de Duas Espécies de Cafeeiros (*Coffea* Spp.) Em Garça, Estado de São Paulo. *Arq. Inst. Biol.* **2006**, *73*, 333–341. <https://doi.org/10.1590/1808-1657v73p3332006>.
53. Reis, P.; Souza, J. Pragas Do Cafeeiro. In *Cultura do Cafeeiro: Fatores que Afetam a Produtividade*. Piracicaba: Associação Brasileira para Pesquisa da Potássio e do Fosfato; Piracicaba, Brazil, 1986; pp. 323–378.
54. Reis, P. Ácaro-Vermelho. In *Cultivar Grandes Culturas*; 2005; Volume 7, pp. 14–17.
55. Reis, P.; Zacarias, M. Ácaros Em Cafeeiro. *EPAMIG*, 2007; pp. 1–76. Available online: [http://www.sapc.embrapa.br/arquivos/consorcio/boletins\\_tecnicos/Acaros\\_em\\_cafeeiro.pdf](http://www.sapc.embrapa.br/arquivos/consorcio/boletins_tecnicos/Acaros_em_cafeeiro.pdf) (accessed on 10 July 2021).
56. Chagas, C. Associação Do Ácaro *Brevipalpus phoenicis* (Geijskes) à Mancha Anular Do Cafeeiro. *Biológico* **1973**, *39*, 229–232.
57. Navia, D.; Mendonça, R.S.; Ferragut, F.; Miranda, L.C.; Trincado, R.C.; Michaux, J.; Navajas, M. Cryptic Diversity in *Brevipalpus* Mites (Tenuipalpidae). *Zool. Scr.* **2013**, *42*, 406–426. <https://doi.org/10.1111/zsc.12013>.
58. Beard, J.; Ochoa, R.; Braswell, W.; Bauchan, G. *Brevipalpus phoenicis* (Geijskes) Species Complex (Acari: Tenuipalpidae)—A Closer Look. *Zootaxa* **2015**, *3944*, 1–67. <https://doi.org/10.11646/zootaxa.3944.1.1>.
59. Nunes, M.A.; de Carvalho Mineiro, J.L.; Rogerio, L.A.; Ferreira, L.M.; Tassi, A.; Novelli, V.M.; Kitajima, E.W.; Freitas-Astúa, J. First Report of *Brevipalpus papayensis* as Vector of Coffee Ringspot Virus and Citrus Leprosis Virus C. *Plant Dis.* **2018**, *102*, 1046–1046. <https://doi.org/10.1094/PDIS-07-17-1000-PDN>.
60. Mineiro, J.L.D.C.; Sato, M.E. Distribuição de *Brevipalpus papayensis* Baker e *Brevipalpus yothersi* Baker (Acari: Tenuipalpidae) Em Cafeeiros No Estado de São Paulo. In *X Simpósio de Pesquisa dos Cafés do Brasil*; Vitória, Brazil, 2019. Available online: <http://www.consorciopesquisacafe.com.br/ojs/index.php/SimposioCafe2019/article/view/321> (accessed on 11 May 2021).
61. Flechtmann, C.H. Os Ácaros Do Cafeeiro. *An. Esc. Super. Agric. Luiz Queiroz* **1967**, *24*, 91–95.
62. Pena, J.E.; Bullock, R.C. Effects of Feeding of Broad Mite (Acari: Tarsonemidae) on Vegetative Plant Growth. *Florida Entomol.* **1994**, *77*, 180–184. <https://doi.org/10.2307/3495885>.
63. Amaral, J. A Infestação de Ácaros Nos Cafezais. *Biológico* **1951**, *17*, 130.
64. Jeppson, L.; Keifer, H.; Baker, E. *Mites Injurious to Economic Plants*; University of California Press: Berkeley, CA, USA, 1975.
65. Matiello, J. Novas Condições de Ocorrência de Mancha Anular Do Cafeeiro. In Proceedings of the 14 Congresso Brasileiro de Pesquisas Cafeeiras, Rio de Janeiro, Brazil, 1987.
66. IBGE Estado de Minas Gerais Meso e Microrregiões Do IBGE. Available online: [https://www.mg.gov.br/sites/default/files/paginas/arquivos/2016/ligminas\\_10\\_2\\_04\\_listamesomicro.pdf](https://www.mg.gov.br/sites/default/files/paginas/arquivos/2016/ligminas_10_2_04_listamesomicro.pdf) (accessed on 27 July 2021).
67. Souza, J.C.; Reis, P.; de Rigitano, R.L.O. Bicho-Mineiro Do Cafe: Biologia, Dano e Manejo Integrado. *Bol. Técnico EPAMIG* **1998**, *1*–29. Available online: [http://www.sapc.embrapa.br/arquivos/consorcio/boletins\\_tecnicos/bt\\_bicho\\_mineiro.pdf](http://www.sapc.embrapa.br/arquivos/consorcio/boletins_tecnicos/bt_bicho_mineiro.pdf) (accessed on 02 July 2021).
68. Krantz, G.W.; Walter, D.E. *A Manual of Acarology*, 3rd ed.; Krantz, G.W., Walter, D.E., Eds.; Texas Tech University Press: Lubbock, TX, USA, 2009.
69. Andre, H. A Generic Revision of the Family Tydeidae (Acari: Actinedida). IV. Generic Descriptions, Keys and Conclusions. *Ann. Soc. R. Zool. Belgie* **1980**, *116*, 103–168.
70. Baker, E.; Tuttle, D. *A Guide to the Spider Mites (Tetranychidae) of the United States*; Indira Publishing House: West Bloomfield, MI, USA, 1994; ISBN 9780930.
71. Chant, D.; McMurtry, J. *Illustrated Keys and Diagnoses for the Genera and Subgenera of the Phytoseiidae of the World (Acari: Mesostigmata)*; Indira Publishing House: West Bloomfield, MI, USA, 2007; ISBN 0930337220.
72. Beard, J.J.; Ochoa, R.; Bauchan, G.R.; Trice, M.D.; Redford, A.J.; Walters, T.W.; Mitter, C. Lucid Key: *Brevipalpus* of the World. Available online: [https://idtools.org/id/mites/flatmites/key.php?key=genera\\_key](https://idtools.org/id/mites/flatmites/key.php?key=genera_key) (accessed on 3 October 2022).
73. Fan, Q.H.; Flechtmann, C.H.W.; De Moraes, G.J. Annotated Catalogue of Stigmaeidae (Acari: Prostigmata), with a Pictorial Key to Genera. *Zootaxa* **2016**, *4176*, 199. <https://doi.org/10.11646/ZOOTAXA.4176.1.1>.
74. Chant, D.; McMurtry, J. A Review of the Subfamilies Phytoseiinae and Typhlodrominae (Acari: Phytoseiidae). *Int. J. Acarol.* **1994**, *20*, 223–310. <https://doi.org/10.1080/01647959408684022>.
75. Paktinat-Saeij, S.; Bagheri, M.; Noronha, A.C.D.S. A New Species of *Agistemus* Summers (Acari: Trombidiformes: Stigmaeidae) from Brazil, with a Key to the American Species. *Syst. Appl. Acarol.* **2016**, *21*, 813–819. <https://doi.org/10.11158/saa.21.6.8>.
76. Beard, J.; Ochoa, R.; Bauchan, G.; Trice, M.; Redford, A.; Walters, T.; Mitter, C. Lucid Key: Flat Mite Genera of the World. Lucid Key: Flat Mite Genera of the World. Available online: <http://idtools.org/id/mites/flatmites/> (accessed on 18 November 2022).
77. Amrine, J.; Manson, D. Preparation, Mounting and Descriptive Study of Eriophyoid Mites. In *Eriophyoid Mites—Their Biology, Natural Enemies and Control*; Lindquist, E., Sabelis, M., Bruin, J., Eds.; Elsevier Science Publishers: Amsterdam, The Netherlands, 1996; pp. 383–396.
78. Bates, D.; Mächler, M.; Bolker, B.M.; Walker, S.C. Fitting Linear Mixed-Effects Models Using Lme4. *J. Stat. Softw.* **2014**, *67*, 1–48. <https://doi.org/10.18637/jss.v067.i01>.
79. Mazerolle, M.; Linden, D. AICcmodavg: Model Selection and Multimodel Inference Based on (Q) AIC (c)(2.2-2). 2019; pp. 1–223. Available online: <https://cran.r-project.org/web/packages/AICcmodavg/AICcmodavg.pdf> (accessed on 11 March 2021).
80. Burnham, K.; Anderson, D. *Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach*; Springer: Berlin/Heidelberg, Germany, 2002.

81. Nakagawa, S.; Schielzeth, H. A General and Simple Method for Obtaining R<sup>2</sup> from Generalized Linear Mixed-Effects Models. *Methods Ecol. Evol.* **2013**, *4*, 133–142. <https://doi.org/10.1111/J.2041-210X.2012.00261.X>.
82. Fox, J.; Weisberg, S. *An R Companion to Applied Regression*; Sage Publications: Thousands Oaks, CA, USA, 2018.
83. Lenth, R.V. Least-Squares Means: The R Package Lsmeans. *J. Stat. Softw.* **2016**, *69*, 1–33.
84. Legendre, P.; De Cáceres, M. Beta Diversity as the Variance of Community Data: Dissimilarity Coefficients and Partitioning. *Ecol. Lett.* **2013**, *16*, 951–963. <https://doi.org/10.1111/ELE.12141>.
85. Oksanen, J.; Blanchet, F.; Friendly, M.; Kindt, R.; Legendre, P.; Mcglinn, D.; Minchin, P.; Hara, R.; Simpson, G.; Solymos, P.; et al. *Community Ecology Package. R Package Version 2.5–6*; 2019. Available online: <http://cran.r-project.org/> (accessed on 12 March 2021).
86. Zhang, D. Rsq: R-Squared and Related Measures. R Package Version. 2018; Volume 1. Available online: <https://cran.r-project.org/web/packages/rsq/rsq.pdf> (accessed on 12 March 2021).
87. Oksanen, J. Vegan: Community Ecology Package. R Package Version 1.8-5. 2007. Available online: <https://cran.r-project.org/web/packages/vegan/vegan.pdf> (accessed on 12 March 2021).
88. Arbizu, M. *Pairwise Multilevel Comparison Using Adonis R Package Version 0.3*; 2019.
89. Team, R.C. R: A Language and Environment for Statistical Computing. 2013. Available online: <https://www.gbif.org/tool/81287/r-a-language-and-environment-for-statistical-computing> (accessed on 12 March 2021).
90. de Silva, V.C.; Perdoná, M.J.; Soratto, R.P.; Negrisoli, E. Ocorrência de Plantas Daninhas Em Cultivo Consorciado de Café e Nogueira-Macadâmia. *Pesqui. Agropecu. Trop.* **2013**, *43*, 441–449. <https://doi.org/10.1590/S1983-40632013000400013>.
91. Landis, D.A.; Wratten, S.D.; Gurr, G.M. Habitat Management to Conserve Natural Enemies of Arthropod Pests in Agriculture. *Annu. Rev. Entomol.* **2000**, *45*, 175–201. <https://doi.org/10.1146/annurev.ento.45.1.175>.
92. Hessein, N.A.; Perring, T.M. *Homeopronematus anconai* (Baker) (Acari: Tydeidae) Predation on Citrus Flat Mite, *Brevipalpus lewisi* McGregor (Acari: Tenuipalpidae). *Int. J. Acarol.* **1988**, *14*, 89–90. <https://doi.org/10.1080/01647958808683791>.
93. Thistlewood, H.M.A.; Clements, D.R.; Harmsen, R. Chapter 2.2 Stigmaeidae. *World Crop Pests* **1996**, *6*, 457–470. [https://doi.org/10.1016/S1572-4379\(96\)80028-5](https://doi.org/10.1016/S1572-4379(96)80028-5).
94. Abou-Awad, B.A.; El-Sawaf, B.M.; Kader, A.A.A. Life History and Life Table of *Pronematus ubiquitus* (McGregor) as a Predator of Eriophyoid Mites in Egypt (Acari: Tydeidae). *Acarologia* **1999**, *40*, 29–32.
95. Horn, T.B.; Johann, L.; Ferla, N.J. Ecological Interactions between Phytophagous and Predaceous Mites in Citrus Agroecosystems in Taquari Valley, Rio Grande Do Sul, Brazil. *Syst. Appl. Acarol.* **2011**, *16*, 133–144. <https://doi.org/10.11158/saa.16.2.2>.
96. Van De Velde, V.; Duarte, M.V.A.; Benavente, A.; Vangansbeke, D.; Wäckers, F.; De Clercq, P. Quest for the Allmitey: Potential of *Pronematus ubiquitus* (Acari: Iolinidae) as a Biocontrol Agent against *Tetranychus urticae* and *Tetranychus evansi* (Acari: Tetranychidae) on Tomato (*Solanum lycopersicum* L.). *bioRxiv* **2021**. <https://doi.org/10.1101/2021.04.08.438973>.
97. Gerson, U.; Smiley, R.; Ochoa, R. *Mites (Acari) for Pest Control*; Blackwell Science: Oxford, UK, 2008.
98. Reis, P.R.; Chiavegato, L.G.; Alves, E.B. Biologia de *Iphiseiodes zuluagai* Denmark & Muma (Acari: Phytoseiidae). *An. Soc. Entomol. Bras.* **1998**, *27*, 185–191. <https://doi.org/10.1590/S0301-80591998000200003>.
99. Reis, P.R.; Sousa, E.O.; Teodoro, A.V.; Pedro Neto, M. Effect of Prey Density on the Functional and Numerical Responses of Two Species of Predaceous Mites (Acari: Phytoseiidae). *Neotrop. Entomol.* **2003**, *32*, 461–467. <https://doi.org/10.1590/s1519-566x2003000300013>.
100. Yamamoto, P.T.; Gravena, S. Influência Da Temperatura e Fontes de Alimento No Desenvolvimento e Oviposição de *Iphiseiodes zuluagai* Denmark & Muma (Acari: Phytoseiidae). *An. Soc. Entomol. Bras.* **1996**, *25*, 109–115. <https://doi.org/10.37486/0301-8059.v25i1.1098>.
101. De Albuquerque, F.A.; De Moraes, G.J. Perspectivas Para a Criação Massal de *Iphiseiodes zuluagai* Denmark & Muma (Acari: Phytoseiidae). *Neotrop. Entomol.* **2008**, *37*, 328–333. <https://doi.org/10.1590/S1519-566X2008000300013>.
102. Andre, H.; Fan, A. Phylogeny, Ontogeny and Adaptive Radiation in the Superfamily Tydeoidea (Acari: Actinedida), with a Reappraisal of Morphological Characters. *Zool. J. Linn. Soc.* **2000**, *130*, 405–448. <https://doi.org/10.1111/J.1096-3642.2000.TB01636.X>.
103. White, N. Some Aspects of the Biology of the Predaceous Mite *Zetzellia mali* (Ewing) (Acarine: Stigmaeidae) Found in Southern Ontario Apple Orchards. Level of Master’s thesis, University of Guelph, Guelph, ON, Canada, 1976.
104. O’Dowd, D. Mite Association with the Leaf Domatia of Coffee (*Coffea arabica*) in North Queensland, Australia. *Bull. Entomol. Res.* **1994**, *84*, 361–366. <https://doi.org/10.1017/s000748530003248x>.
105. Franco, R.A.; Reis, P.R.; Zacarias, M.S.; Altoé, B.F.; Neto, M.P. Population Dynamics of *Oligonychus ilicis* (McGregor, 1917) (Acari: Tetranychidae) in Coffee Plants and of Their Associated Phytoseiids. *Coffee Sci.* **2008**, *3*, 38–46.
106. Landis, D.; Menalled, F.; Costamagna, A.C.; Wilkinson, T.K. Manipulating Plant Resources to Enhance Beneficial Arthropods in Agricultural Landscapes. *Weed Sci.* **2005**, *53*, 902–908. <https://doi.org/10.1614/WS-04-050R1.1>

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