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Mite species (Acari) on blackberry cultivars in organic and conventional farms in Florida and Georgia, USA

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Original research

ABSTRACT

This study was carried out to determine mite species on blackberry plants (*Rubus* spp. (Rosaceae)) in Florida and Georgia, USA, and differences in mite species between organic and conventional blackberry plantings in the area sampled. Surveys were conducted in organic and conventional commercial blackberry plantings from June to October 2016. Leaf samples were collected monthly from nine different blackberry cultivars including 'Arapaho', 'Choctaw', 'Freedom', 'Kiowa', 'Natchez', 'Navaho', 'Osage', 'Ouachita', and Von. Approximately 20 leaves per blackberry plant were taken. Twenty mite species (a total of 152 mite specimens) belonging to 7 families including Phytoseiidae (9 species), Ascidae (1), Cheyletidae (1), Erythraeidae (1), Stigmaeidae (1), Tetranychidae (4) and Tarsonemidae (3) were identified during the study. It was found that the abundance of predatory mites collected in organic farms was over 2-fold higher (105) than in conventional farms (47), which may be related to pesticide use on these commercial farms. Future surveys should provide a list of predatory species, which may hold potential for biological control of economically important pest mites.

Keywords blackberry; *Rubus* spp.; mite; pest; predatory mite groups

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Introduction

Blackberries (*Rubus* spp. (Rosaceae)) are a major small fruit crop that is grown throughout Europe and the United States (Strik 2007). Mexico is the leading producer of blackberries worldwide. In the US, the crop is valued at 50 million USD (USDA-NASS 2016) with 90% of its production in the northwest region (Oregon). Production is expanding in the southern United States (Arkansas to Florida) and several new cultivars are being developed that do not require the heat units for satisfactory production that is required of traditional cultivars.

Several mite species have been found in association with blackberry plants (Vincent *et al.* 2010) and most of these mites are agricultural pests that are known to cause economic damage. The broad mite, *Polyphagotarsonemus latus* (Banks) is one of two species in the family Tarsonemidae that cause extensive damage to crop plants (Liburd *et al.* 2020). *Polyphagotarsonemus latus* has been found in association with leaf-curling symptoms on primocane-fruiting blackberry (*Rubus* L. subgenus *Rubus* Watson) in Arkansas (Vincent *et al.* 2010), which negatively affect plant growth and development.

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Davies *et al.* (2001) examined microhabitats and aggregation patterns of the phytophagous mite, *Acalitus essigi* (Hassan) (Trombidiformes: Eriophyidae), on *Rubus fruticosus* L. (Rosaceae). They found that *A. essigi* was a refugee inhabiting species that resided in the buds and leaf axils on primocanes and fructocanes. Scott *et al.* (2008) collected the same species of eriophyid mites from the fruits of three species of the weedy blackberry (*R. anglocandicans* A. Newton, *R. laudatus* A. Berger and *R. ulmifolius* Schott) in south-west Australia. This was the first record for this species in Western Australia and these plants appear to be new host records for *A. essigi*. Similarly, Cetin *et al.* (2010) recorded *A. essigi* as a new pest in blackberry plantings in the Marmara region of Turkey in 2009.

Marchetti and Ferla (2011) determined the diversity and population fluctuation of mites on blackberry (*R. fruticosus*) in Rio Grande do Sul, Brazil. A total of 26 mite species belonging to 12 families were found. Most of the mites were phytophagous species belonging to the families Diptilomiopidae (80.9%) and Tetranychidae (13.9%). The most common families of predaceous mites were Stigmaeidae (2.1%) and Phytoseiidae (0.4%). Recently, Trinidad *et al.* (2019) evaluated the occurrence of phytophagous and predatory mites in different blackberry genotypes in the municipality of Pelotas, RS, Brazil. They recorded a total of 12 mite species belonging to the families Tetranychidae, Diptilomiopidae, Eriophyidae, Tarsonemidae, Tenuipalpidae, Stigmaeidae, Tydeidae, Phytoseiidae. The families Tydeidae, Diptilomiopidae, Tetranychidae, and Eriophyidae showed a higher representability.

Ozsisli and Cobanoglu (2019) determined predatory and harmful mite species on *R. fruticosus*, and *Rubus sanctus* Schreber in Turkey (Adana, Hatay, Kahramanmaraş provinces). *Phytoseius finitimus* Ribaga (Phytoseiidae), *Pronematus ubiquitus* (McGregor), *Tydeus californicus* (Banks) (Tydeidae), and *Zetzelia mali* (Ewing) (Stigmaeidae) were predatory mite species obtained in the study. The phytophagous mites were *Cenopalpus pulcher* (Canestrini & Fanzago), *C. spinosus* (Donnadieu) (Tenuipalpidae) and *Tetranychus urticae* Koch (Tetranychidae).

In a recent study, Akyazi and Liburd (2019) assessed the effectiveness of a commercially available predator, *Neoseiulus californicus* (McGregor) to reduce *T. urticae* populations in a commercial blackberry planting and recommended that an assessment of local phytoseiids and other predators should be considered before further releases of *N. californicus* are considered.

To our knowledge a survey of mite fauna associated with blackberries have not been conducted in Florida and Georgia despite an expanding blackberry industry in the region. This study was carried out to determine phytophagous and predatory mite species on nine commercially available blackberry cultivars in Florida and Georgia, USA in 2016.

Material and Methods

Sampled Areas

The survey was conducted in selected organic and conventional commercial blackberry farms in Florida and Georgia, USA (Figure 1). Geographical coordinates were recorded using a GPS mobile device.

Sampled Blackberry Cultivars

This study was carried out on nine blackberry cultivars including ‘Arapaho’, ‘Choctaw’, ‘Freedom’, ‘Kiowa’, ‘Natchez’, ‘Navaho’, ‘Osage’, ‘Ouachita’ and ‘Von’ (Table 1).

Sampling Method

The survey was conducted from June to October 2016. Leaf samples were collected monthly. The number of sampled plants per site was determined according to the total number of the plants in each planting (Table 2). On each sampling date, leaves were taken from different

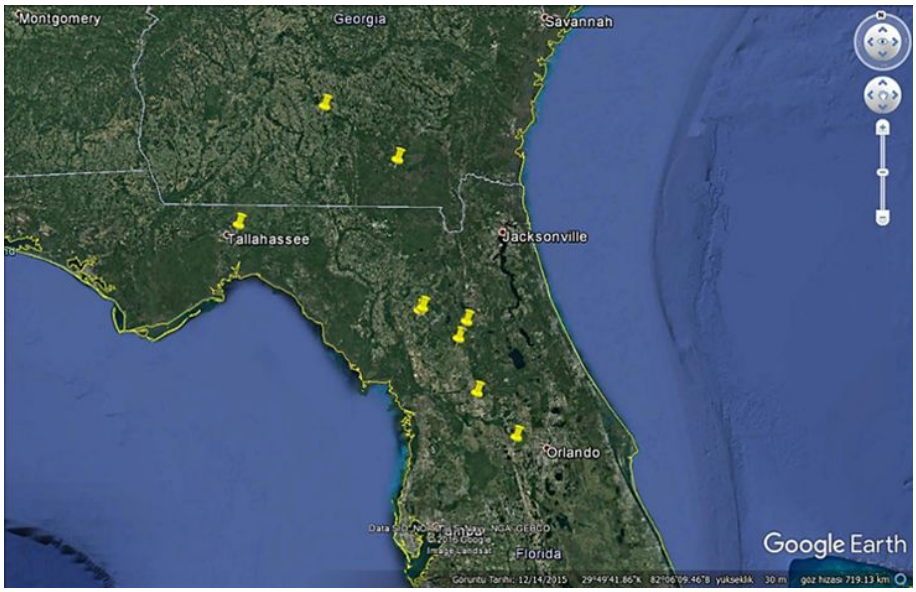


Figure 1 Sampled farms in Florida and Georgia, USA.

parts of the bush canopy, i.e. lower, middle, and upper canopy. Approximately 20 leaves per blackberry plant were collected. The samples were placed in paper bags and then later in Ziplock plastic bags, labeled and transferred to the University of Florida, Small Fruit and Vegetable IPM (UF-SFVIPM) laboratory.

Extraction, preparation, and identification of mite specimens

The mites were collected with a 0 or 00 paint brush under a stereomicroscope LEICA M205 C (Leica Microsystems Inc., Buffalo Grove, Illinois, USA) directly from the leaves. In this way, all mites were separated into families before examination using 40 x to 160 x magnification.

Table 1 Sampled blackberry cultivars with growth characteristics (Adapted from Fernandez *et al.* 2015).

Cultivar	Erect	Thorns	Season	Comments
Arapaho	Erect	No	Early	Lower yields; plant at higher density.
Choctaw	Erect	Yes	Early	High-yielding
Freedom	Erect	No	Floricane crop very early, Primocane crop from early September to first frost	Primocane-fruiting; soft berries for home garden or local market only
Kiowa	Erect	Yes	Mid	Low chilling; best for local sales and PYO (Pick your Own)
Natchez	Erect	No	Early (slightly before or with Arapaho)	Very large fruit; very high yield; tends to over produce so careful pruning is essential. Winter hardiness is poor in high elevations.
Navaho	Erect	No	Mid to late	Stores well; excellent flavor; average size. Quite susceptible to orange rust; long harvest season
Osage	Erect	No	Mid	New cultivar with superior flavor. It has excellent post-harvest quality with medium- high yields.
Ouachita	Erect	No	Early to mid	Excellent flavor; high yields, large fruit size, and good post-harvest quality.
Von	Erect	No	Mid to late	Holds up well in rain; high yields; average size. It has a good post-harvest quality and late season production

Table 2 According to the total number of plants in each planting, the number of sampled plants (Madanlar and Kısmalı 1991).

Total number of plants in each planting	The number of sampled plants
0- 50	All plants
51-200	50 plants
201-400	60 plants
More than 400	20% of the total number of plants

Specimens were preserved in vials containing 70% ethanol (according to cultivar and family). All mites were cleared in Lacto-phenol medium. Each mite was mounted in a drop of Hoyer's medium on microscope slides and dried in an oven at 50 °C for 5-7 days according to the method of Krantz and Walter (2009).

Species identifications were made in Division of Plant Industry, FSCA, Gainesville, USA by the second author. The mite specimens were deposited in the Mite Collection at the Division of Plant Industry, FSCA, Gainesville, USA.

Results and Discussion

During the surveys, a total of 20 mite species belonging to 7 families were identified (Table 3) as follows: nine species of Phytoseiidae, four Tetranychidae, three Tarsonemidae, one for each of Ascidae, Stigmaeidae, Cheyletidae and Erythraeidae.

Predatory mite species on nine different blackberry cultivars in selected organic and conventional commercial blackberry farms in Florida and Georgia, USA

Family Phytoseiidae

Galendromus (*Galendromus*) *floridanus* (Muma)

Typhlodromus floridanus (original designation) Muma
Galendromus floridanus Muma
Metaseiulus (*Galendromus*) *floridanus* Karg
Galendromus (*Galendromus*) *gratus* (Chant), synonymy according to Demite *et al.* (2020)
Galendromus (*Galendromus*) *helveolus* (Chant), synonymy according to Demite *et al.* (2020)

Material Examined (n = 8; 7 ♀♀, 1 ♂) — 1♀ (28°34′5.62″ N, 81°41′22.17″ W, 24 m, 2 August 2016, Osage, Organic Farm), 1♀ (30°26′18.19″ N, 84°11′55.83″ W, 39 m, 31 July 2016, Navaho, Organic Farm), 1♀ (29°24′30.77″ N, 82°10′16.13″ W, 19 m, 11 August 2016, Choctaw, Organic Farm), 1♀ (30°54′18.31″ N, 82°38′51.06″ W, 46 m, 18 August 2016, Choctaw, Conventional Farm), 1♂ (30°54′18.31″ N, 82°38′51.06″ W, 46 m, 18 August 2016, Choctaw, Conventional Farm), 1♀ (30°54′18.31″ N, 82°38′51.06″ W, 46 m, 18 August 2016, Ouachita, Conventional Farm), 1♀ (28°34′5.62″ N, 81°41′22.17″ W, 24 m, 25 August 2016, Osage, Organic Farm), 1♀ (29°24′30.77″ N, 82°10′16.13″ W, 19 m, 15 July 2016, Choctaw, Organic Farm).

Comments — *G.* (*G.*) *floridanus* was recorded in Costa Rica, Cuba, El Salvador, Jamaica, Mexico, Nicaragua, Colombia, Ecuador, Guadeloupe, Guatemala, Honduras, Martinique, Panama Venezuela, and USA- Florida. It was collected from *Citrus* sp. (Rutaceae) and *Thespesia populnea* L. (Malvaceae) (Demite *et al.* 2020). In the present study, *G. floridanus* was collected together with *P. latus*, *Tarsonemus* (*Tarsonemus*) *bilobatus* Suski, *Tarsonemus* (*Tarsonemus*) *confusus* Ewing (Trombidiformes: Tarsonemidae), *Eotetranychus carpini*

(Qudemansi), *Tetranychus schoenei* McGregor and *Tetranychus urticae* Koch (Trombidiformes: Tetranychidae).

Phytoseius chanti Denmark

Phytoseius (*Dubininellus*) *chanti* Denmark
Phytoseius (*Phytoseius*) *chanti* Muma & Denmark
Phytoseius chantii Chant & McMurtry

Material Examined (n = 4; 4 ♀♀) — 1♀ (22 August 2016, Kiowa); 2♀♀ (15 July 2016, Arapaho); 1♀ (15 July 2016, Choctaw); 29°24′30.77″ N, 82°10′16.13″ W, 19 m, Organic Farm.

Comments — *Phytoseius chanti* was detected in USA- Florida (Denmark 1966; Denmark and Evans 2011; Muma and Denmark 1970). It was found on *Quercus virginiana* Mill (Fagaceae) (Denmark 1966), *Calocarpum sapota* (Jacq.) Merr (Sapotaceae), *Cynadon dactylon*

Table 3 Mite species determined on blackberry plants in organic and conventional farms in Florida and Georgia, USA.

Family	Species	Organic			Conventional		Total
		♀	♂	L/N	♀	♂	
Phytoseiidae	*Galendromus* (*Galendromus*) *floridanus* (Muma)*	5	-	-	2	1	8
	Phytoseius chanti Denmark	4	-	-	-	-	4
	Proprioseius meridionalis Chant	2	-	-	2	-	4
	Typhlodromips dentilis (De Leon)	4	-	-	1	-	5
	Typhlodromalus peregrinus (Muma)	14	-	-	15	-	29
	Amblyseius sp.	1	2	-	-	-	3
	Phytoseius sp.1	4	-	-	1	-	5
	Phytoseius sp.2	6	-	-	-	-	6
	Proprioseiopsis sp.	3	1	-	-	-	4
Ascidae	*Asca* sp.	-	1	-	-	-	1
Cheyletidae	*Oudemanscheyla denmarki* (Yunker)	1	-	-	1	-	2
Erythraeidae	*Lasioerythraeus* sp.**	-	-	1L	-	-	1
Stigmaeidae	*Agistemus* sp.	-	-	8N	-	-	8
Predatory Mite Number		44	4	9	22	1	80
Total Predatory Mite Number (Organic/ Conventional/ Total)		**57**			**23**		**80**
Tarsonemidae	*Polyphagotarsonemus latus* (Banks)	3	2	-	2	3	10
	Tarsonemus (*Tarsonemus*) *bilobatus* Suski	1	-	-	-	-	1
	Tarsonemus (*Tarsonemus*) *confusus* Ewing	2	-	-	3	-	5
Tetranychidae	*Eotetranychus carpini* (Oudemans)	4	18	-	-	-	22
	Tetranychus schoenei McGregor	3	8	-	3	9	23
	Tetranychus urticae Koch	-	2	-	-	3	5
	Tetranychus sp.	-	5	-	-	1	6
Phytophagous Mite Number		13	35	0	8	16	72
Total Phytophagous Mite Number (Organic/ Conventional/ Total)		**48**			**24**		**72**
Total Mite Number		57	39	9	30	17	152
GENERAL TOTAL (Organic/ Conventional/ Total)		**105**			**47**		**152**

L: Larva; N: Nymph

* : It was followed what is mentioned in the Phytoseiidae catalogue by Demite et al. (2020) considering *Galendromus* (*Galendromus*) *gratus* (Chant) as a junior synonym of *Galendromus* (*Galendromus*) *floridanus* (Muma)

**: Erythraeid mites are ectoparasitic in their larval stage and predatory in their deutonymphal and adult stages (Goldarazena et al. 2000)

(L.) (Poaceae), *Diospyros* sp. (Ebenaceae), *Pisium* sp. (Fabaceae), *Quercus durandii* Buckley, *Quercus* sp. (Fagaceae), *Rhus copallinum* L. var. *leucantha* (Jacq.) (Anacardiaceae), *Styrax americana* Lam (Styracaceae) and *Vitis* sp. (Vitaceae) (Muma and Denmark 1970). During the present study, *P. chanti* was collected together with *P. latus*, *E. carpini*, *T. bilobatus*, *T. confusus*, *T. schoenei* and *T. urticae*.

Proprioseius meridionalis Chant

Amblyseius (*Proprioseius*) *meridionalis* Pritchard & Baker
Phytoseiulus (*Proprioseius*) *meridionalis* Wainstein
Amblyseius (*Amblyseius*) *meridionalis* Tseng
Proprioseius (*Proprioseius*) *meridionalis* Karg
Typhlodromus psychotriae Hirschmann (unjustified replacement name for *Proprioseius meridionalis*)

Material Examined (n=4; 4 ♀♀) — 1♀ (29°24′30.77″ N, 82°10′16.13″ W, 19 m, 22 August 2016, Arapaho, Organic Farm), 1♀ (29°39′15.95″ N, 82°31′25.49″ W, 32 m, 27 July 2016, Arapaho, Organic Farm), 2♀♀ (30°54′18.31″ N, 82°38′51.06″ W, 46 m, 18 August 2016, Choctaw, Conventional Farm).

Comments — *Proprioseius meridionalis* was recorded previously on wide range of host plants including blackberry, *Rubus* sp. in USA, Florida (Chant 1957; De Leon 1959; Denmark and Evans 2011; Denmark and Muma 1966; Muma and Denmark 1970; Walter and Denmark 1991) and New Jersey (Dyer and Swift 1979). In the current study, this species was collected with all phytophagous mite species, which were collected during the present study.

Typhlodromips dentilis (De Leon)

Amblyseius dentilis Athias-Henriot
Amblyseius (*Typhlodromopsis*) *dentilis* Muma

Material Examined (n=5; 5 ♀♀) — 1♀(29°32′35.80″ N, 82°5′7.34″ W, 28 m, 11 August 2016, Natchez, Organic Farm), 1♀ (28°34′5.62″ N, 81°41′22.17″ W, 24 m, 25 August 2016, Von, Organic Farm), 1♀ (29°32′35.80″ N, 82°5′7.34″ W, 28 m, 20 September 2016, Ouachita, Organic Farm), 1♀ (29°32′35.80″ N, 82°5′7.34″ W, 28 m, 28 June 2016, Arapaho, Organic Farm), 1♀ (28°57′13.97″ N, 82°1′49.14″ W, 30 m, 12 July 2016, Natchez, Conventional Farm).

Comments — *Typhlodromips dentilis* has been found on many different types of plants worldwide (Demite *et al.* 2020). In Florida, it was recorded for the first time on *Rhus copallina* in Miami, Florida, USA and subsequently in various localities in Florida (Denmark and Evans 2011; Muma 1964a b; Muma and Denmark 1970). During the present study, *T. dentilis* was found together with populations of *P. latus*, *T. schoenei*, *E. carpini* and *T. confusus*.

Typhlodromalus peregrinus (Muma)

Typhlodromalus evansi (Chant)
Typhlodromalus primulae (Chant)
Typhlodromalus robiniae (Chant) *Typhlodromalus sextus* (Garman)
Typhlodromalus aripo (De Leon)

Material Examined (n=29; 29 ♀♀) — 2♀ (29°32′35.80″ N, 82°5′7.34″ W, 28 m, 11 August 2016, Natchez, Organic Farm), 1♀ (29°24′30.77″ N, 82°10′16.13″ W, 19 m, Choctaw, Organic Farm), 2♀♀ (31°22′49.19″ N, 83°19′8.57″ W, 89 m, 18 August 2016, Natchez, Conventional Farm), 1♀ (29°24′30.77″ N, 82°10′16.13″ W, 19 m, 22 August 2016, Choctaw, Organic Farm), 2♀♀ (28°34′5.62″ N, 81°41′22.17″ W, 24 m, 25 August 2016, Von, Organic Farm), 1♀Natchez, 1♀Osage, 1♀ Ouachita (29°32′35.80″ N, 82°5′7.34″ W, 28 m, 20 September 2016, Organic Farm), 1♀Natchez, 2♀♀Osage, 2♀♀ Ouachita (28°34′5.62″ N, 81°41′22.17″ W, 24 m, 21 September 2016 Organic Farm), 1♀ (30°54′18.31″ N, 82°38′51.06″

W, 46 m, 22 September 2016, Ouachita, Conventional Farm), 8♀♀ Natchez, 1♀Osage, 3♀♀ Ouachita (31°22′49.19″ N, 83°19′8.57″ W, 89 m, 22 September 2016, Conventional Farm).

Comments — According to Demite *et al.* (2020), to date, *T. peregrinus* was reported from 18 countries including the US. In the USA, it was detected in Florida, Georgia, Massachusetts, Missouri, New, North Carolina, Oklahoma, Pennsylvania, South Carolina, Tennessee, Texas, and Virginia (Demite *et al.* 2020). It was generally found on citrus (Childers 1994; Fadamiro *et al.* 2008, 2009; Muma 1955a, 1967; Pena 1992; Villanueva and Childers 2004, 2005) and solanaceous plants (Fiaboe *et al.* 2007; McMurtry 1983; Silva *et al.* 2016). This species was also collected from ground cover vegetation (weeds) of Alabama (Fadamiro *et al.* 2008, 2009) and Florida (Childers and Denmark 2011) citrus orchards (Kreiter *et al.* 2018). Vieira de Souza *et al.* (2015) detected it on *Cocos nucifera* (L.) (Arecaceae), *Theobroma cacao* L. (Malvaceae), *Psidium guajava* L. (Myrtaceae), *Carica papaya* L. (Caricaceae). It was also found on *Alchornea triplinervea* (Spreng.) Müll.Arg. (Euphorbiaceae) by Zacarias and De Moreas (2001). Kreiter *et al.* (2018) collected this species from *Neonotonia wightii* (Wight and Arn.) *Pueraria phaseoloides* (Roxb.) *Macroptilium atropurpureum* (DC.) (Fabaceae) and *Paspalum notatum* Flügge cv. Pensacola (Poaceae). However, according to Demite *et al.* (2020), there is no known record on *Rubus* spp. This species was associated with many insect and mite species by different researchers. While Aleyrodidae, Coccidae and Tetranychidae were evaluated as optimal prey for this species by Muma (1971), Childers and Denmark (2011) indicated that this species is a predator of thrips. According to Muma (1955b, 1971), it is a facultative predator of *Chrysomphalum aonidum* (L) and *Lepidosaphes beckii* (Newn.) (Hemiptera: Diaspididae) (Pena *et al.*1989). It was also collected from miners of *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae) and whitefly exuvia, empty scale armour, clump, dead scale insects, sooty mold (Childers 1994; Muma 1967; Villanueva and Childers 2011). It was found associated with *Panonychus citri* (McGregor), *Eotetranychus sexmaculatus* (Riley) (Trombidiformes: Tetranychidae), *Parlatoria pergandii* Comstock (Hemiptera: Diaspididae) (Muma 1969), *Phyllocoptruta oleivora* (Ashmead) (Trombidiformes: Eriophyidae) (Pena, 1992; Kretier *et al.*, 2018). Silva *et al.* (2016) noted that this predator also was able to feed on all stages of *P. latus*. Immature stages of *P. citri*, all stages of *T. urticae*, and pollens of *Malephora crocea* (Jacq.) Schwant (Aizoaceae), *Quercus virginiana* Miller (Fagaceae), and *Typha latifolia* L. (Typhaceae) were evaluated as suitable diet in the laboratory by Fouly *et al.* (1995). In the present study, *T. peregrinus* was found together with populations of *P. latus*, *E. carpini*, *T. bilobatus*, *T. confusus*, *T. schoenei* and *T. urticae*.

Amblyseius sp.

Material Examined (n=3; 1 ♀, 2 ♂♂) — 1♂ (28°34′5.62″ N, 81°41′22.17″ W, 24 m, 25 August 2016, Ouachita, Organic Farm), 1♂ (29°40′37.56″ N, 82°29′32.73″ W, 32 m, 1 August 2016, Kiowa, Organic Farm), 1♀ (28°34′5.62″ N, 81°41′22.17″ W, 24 m, 21 September 2016, Natchez, Organic Farm).

Phytoseius sp. 1

Material Examined (n=5; 5 ♀♀) — 1♀ (30°54′18.31″ N, 82°38′51.06″ W, 46 m, 18 August 2016 Ouachita, Conventional Farm), 2♀♀ (22 August 2016, Arapaho, Organic Farm), 1♀ 22 August 2016, Kiowa, 1♀ 20 September 2016, Kiowa (29°24′30.77″ N, 82°10′16.13″ W, 19 m Organic Farm)

Phytoseius sp. 2

Material Examined (n=6; 6 ♀♀) — 1♀ (22 August 2016, Arapaho), 1♀ (22 August 2016, Choctaw), 1♀ (22 August 2016, Kiowa); 2♀♀ (20 September 2016, Kiowa); 1♀ (15 July 2016, Kiowa) (29°24′30.77″ N, 82°10′16.13″ W, 19 m Organic Farm)

***Proprioseiopsis* sp.**

Material Examined (n=4; 3 ♀♀, 1 ♂) — 1♀ 11 August 2016, Osage, 1♀ 15 July 2016, Ouachita (29°32′35.80″ N, 82°5′7.34″ W, 28 m, Organic Farm), 1♂ (29°24′30.77″ N, 82°10′16.13″ W, 19 m, 22 August 2016, Choctaw, Organic Farm), 1♀ (28°34′5.62″ N, 81°41′22.17″ W, 24 m, 2 August 2016, Ouachita, Organic Farm).

Family Cheyletidae

***Oudemanscheyla denmarki* (Yunker)**

Cheletomimus denmarki Yunker

Material Examined (n=2; 2 ♀♀) — 1♀ (28°34′5.62″ N, 81°41′22.17″ W, 24 m, 2 August 2016, Natchez, Organic Farm), 1♀ (31°22′49.19″ N, 83°19′8.57″ W, 89 m, 18 August 2016, Ouachita, Conventional Farm).

Comments — Yunker (1961) and Muma (1964c) recorded this species from Florida citrus. It was recorded from *Lantana camara* L. (Verbenaceae) leaves collected from native forests in southeastern Queensland, Australia by Walter (1999). Hagstrum (2013) detected this species on betel nut (*Areca catechu* L., Arecaceae) in Taiwan. It was observed feeding on tydeid mites in domatia on leaves of wild grapes by Walter and Denmark (1991). In the current study, it was collected together with *P. latus*, *T. confusus*, *E. carpini* and *T. schoenei* phytophagous mites.

Family Stigmaeidae

***Agistemus* sp.**

Material examined (n=8; 8 nymph) — 1N (28°34′5.62″ N, 81°41′22.17″ W, 24 m, 2 August 2016, Von, Organic Farm), 2N (29°32′35.80″ N, 82°5′7.34″ W, 28 m, 11 August 2016, Osage, Organic Farm), 3N Natchez, 2N Osage (29°32′35.80″ N, 82°5′7.34″ W, 28 m, 15 July 2016, Organic Farm).

Family Ascidae

***Asca* sp. (n=1; 1♂)**

Material examined — 1♂ (29°24′30.77″ N, 82°10′16.13″ W, 19 m, 11 August 2016, Arapaho, Organic Farm)

Family Erythraeidae

***Lasioerythraeus* sp.**

Material examined (n=1, 1 Larva) — 1L (29°24′30.77″ N, 82°10′16.13″ W, 19 m, 15 July 2016, Arapaho, Organic Farm)

Phytophagous mite species on nine different blackberry cultivars in selected organic and conventional commercial blackberry farms in Florida and Georgia, USA

Family Tarsonemidae

***Polyphagotarsonemus latus* (Banks)**

Acarus translucens Green
Polyphagotarsonemus latus (Banks)
Acarus translucens Green
Hemitarsonemus latus Banks
Tarsonemus translucens Green
Avrosita translucens Oudemans

Tarsonemus latus Banks
Tarsonemus phaseoli Bondar
Neotarsonemus latus Smiley

Material examined (n=10; 5 ♀♀, 5 ♂♂) — 1♀ Ouachita, 1♂ Osage (29°32′35.80″ N, 82°5′7.34″ W, 28 m, 11 August 2016, Organic Farm); 1♂ (29°32′35.80″ N, 82°5′7.34″ W, 28 m, 28 June 2016, Ouachita, Organic Farm); 1♂ (30°54′18.31″ N, 82°38′51.06″ W, 46 m, 18 August 2016, Ouachita, Conventional Farm); 1♀ Osage, 1♀ Von (28°34′5.62″ N, 81°41′22.17″ W24 m, 25 August 2016, Organic Farm); 1♂ (31°22′49.19″ N, 83°19′8.57″ W, 89 m, 22 September 2016, Ouachita, Conventional Farm), 1♀ (28°57′13.97″ N, 82°1′49.14″ W, 30 m, 12 July 2016, Ouachita, Conventional Farm); 1♂ (30°54′18.31″ N, 82°38′51.06″ W, 46 m, 21 July 2016, Osage, Conventional Farm). 1♀ (31°22′49.19″ N, 83°19′8.57″ W, 89 m, 21 July 2016, Natchez, Conventional Farm).

Comments — *Polyphagotarsonemus latus* is distributed worldwide and has a wide host range (Fasulo 2019; Azzazy and Alhewairini 2018; Gerson 1992; Johnson *et al.* 2016; Pena and Campel 2005). It was first described by Banks (1904) as *Tarsonemus latus* from the terminal buds of mango in a greenhouse in Washington, D.C., USA (Denmark 1980; Fasulo 2019). This mite was recently found in multiple states in the US causing yield reductions in blackberries (Johnson *et al.* 2016; Lefors *et al.* 2017). Vincent *et al.* (2010) reported it on blackberry in organic production in Arkansas. Rebek (2017) detected it in Oklahoma Blackberry orchards. Demchak and Johnson (2017) noticed that it has been problematic for blackberry growers in Pennsylvania. Rebek (2017) also found it on blackberries in Oklahoma. Finally, in 2017, this mite has been detected on blackberries in Arkansas, Illinois, Indiana, Maryland, North Carolina, South Carolina, Pennsylvania, Virginia, California, and Oklahoma (Rebek 2017). Renkema *et al.* (2017) recorded it from commercial strawberries in Florida. It is also considered a serious pest of *Pittosporum* spp. (Pittosporaceae) in Florida (Johnson and Lyon 1991). Pena *et al.* (2000) observed *P. latus* on citrus.

Tarsonemus (*Tarsonemus*) *bilobatus* Suski

Tarsonemus (*Tarsonemus*) *hungaricus* Schaarschmidt
Lupotarsonemus bilobatus Suski & Schaarschmidt

Material examined (n=1; 1 ♀) — 1♀ (29°24′30.77″ N, 82°10′16.13″ W, 19 m 11 August 2016 Arapaho Organic Farm)

Comments — *Tarsonemus bilobatus* has been reported on many plant species in Central America (Costa Rica), Europe (Byelorussia, Hungary, Italy, Poland, Ukraine), Asia (China, India Japan, Korea,), Africa (Egypt) (Lin and Zhang 2002; Zhang 2003) and South America (Brazil) (Lofego *et al.* 2005; Rezende *et al.* 2012). It was also collected from bacterial and fungal cultures, stored food products, litter and soil. It is primarily a fungivorus species (Zhang 2003).

Tarsonemus (*Tarsonemus*) *confusus* Ewing

Tarsonemus assimilis Banks
Tarsonemus confusus Ewing; Beer; Smiley; Kaliszewski

Material Examined (n=5; 5 ♀♀) — 1♀ (29°24′30.77″ N, 82°10′16.13″ W, 19 m, 11 August 2016, Arapaho, Organic Farm); 1♀ (31°22′49.19″ N, 83°19′8.57″ W, 89 m, 18 August 2016, Ouachita, Conventional Farm); 2♀♀ (30°54′18.31″ N, 82°38′51.06″ W, 46 m, 18 August 2016 Kiowa Conventional Farm); 1♀ (29°32′35.80″ N, 82°5′7.34″ W, 28 m, 28 June 2016, Ouachita, Organic Farm).

Comments — *Tarsonemus confusus* occurs on many types of plants in Canada, Byelorussia, Egypt, China, Ireland, Italy, Japan, Germany, Korea, Netherlands, Ukraine, Poland, Russia, Turkey (Lin and Zhang 2002), Hungary (Ripka *et al.* 2005) and Brazil (Lofego *et al.* 2005). It was also previously recorded from multiple states in the US on various plants including *Rubus* sp. (Lin and Zhang 2002).

Family Tetranychidae

Eotetranychus carpini (Oudemans)

Material Examined (n=22; 4 ♀♀, 18 ♂♂) — 1♂ (28°34′5.62″ N, 81°41′22.17″ W, 24 m, 2 August 2016, Osage, Organic Farm); 11♂♂ 2♀♀ (28°34′5.62″ N, 81°41′22.17″ W, 24 m, 21 September 2016, Von, Organic Farm); 1♂ Von, 1♂2♀♀ Ouachita, 28°34′5.62″ N, 81°41′22.17″ W24 m, 25 August 2016, Organic Farm; 1♂ (29°24′30.77″ N, 82°10′16.13″ W, 19 m, 15july 2016, Kiowa, Organic Farm), 2♂♂ (29°24′30.77″ N, 82°10′16.13″ W, 19 m, 22 August 2016, Arapaho, Organic Farm), 1♂ (29°32′35.80″ N, 82°5′7.34″ W, 28 m, 11 August 2016, Osage, Organic Farm)

Comments — *Eotetranychus carpini* has been widely reported in Europe (Migeon *et al.* 2007; Malagnini *et al.*, 2012)) . It is also found in Mexico (Beer and Lang 1958) and USA (McGregor 1917). To date, it was reported from 30 countries in two major regions of Nearctic and Palearctic (Migeon and Dorkeld 2020). This species also exploits a wide range of host plants and have been reported on 54 host plants including *Rubus idaeus* (Migeon and Dorkeld 2020) and *Rubus* sp. (Bolland *et al.* 1998).

Tetranychus schoenei McGregor

Septanychus schoenei McGregor
Tetranychus schoenei Pritchard & Baker
Tetranychus (*Polynychus*) *schoenei* Flechtmann & Hunter

Material Examined (n=23; 6 ♀♀, 17 ♂♂) — 1♀ Osage, 1♀ Ouachita (31°22′49.19″ N, 83°19′8.57″ W, 89 m, 18 August 2016, Conventional Farm); 1♀ (30°54′18.31″ N, 82°38′51.06″ W, 46 m, 18 August 2016, Ouachita, Conventional Farm); 1♀ Kiowa, 1♂ Arapaho, 1♂ Choctaw (29°24′30.77″ N, 82°10′16.13″ W, 19 m, 22 August 2016, Organic Farm), 1♀ (28°34′5.62″ N, 81°41′22.17″ W, 24 m, 25 August 2016, Osage, Organic Farm); 2♂♂ Natchez, 2♂♂ Osage (29°32′35.80″ N, 82°5′7.34″ W, 28 m, 20 September 2016, Organic Farm); 1♂ (29°32′35.80″ N, 82°5′7.34″ W, 28 m, 28 June 2016, Ouachita, Organic Farm); 1♀ (28°34′5.62″ N, 81°41′22.17″ W, 24 m, 21 September 2016, Von, Organic Farm); 3♂♂ (30°54′18.31″ N, 82°38′51.06″ W, 46 m, 22 September 2016, Ouachita, Conventional Farm); 1♂ (29°32′35.80″ N, 82°5′7.34″ W, 28 m, 15 July 2016, Osage, Organic Farm); 1♂ Osage, 4 ♂♂ Ouachita (30°54′18.31″ N, 82°38′51.06″ W, 46 m, 21 July 2016, Conventional Farm); 1♂ Osage (31°22′49.19″ N, 83°19′8.57″ W, 89 m, 21 July 2016, Conventional Farm).

Comments — *Tetranychus schoenei* is widely distributed over the eastern and southwestern United States. Previous distribution records included Georgia (Flechtmann and Hunter 1971). It is also found in Iran (Beyzavi *et al.* 2013). According to Migeon and Dorkeld (2020), to date, it was reported from 2 countries and on 52 host plants including *Rubus allegheniensis*, *R. idaeus*, *R. occidentalis* (Reeves 1963), *Rubus* sp. (Reeves 1963; Seeman and Beard 2011).

Tetranychus urticae Koch

Fifty species names have been synonymized with *T. urticae* in spider Mites Web (Migeon and Dorkeld 2020).

Material Examined (n=5; 5 ♂♂) — 1♂ (31°22′49.19″ N, 83°19′8.57″ W, 89 m, 18 August 2016, Osage, Conventional Farm); 1♂ (29°24′30.77″ N, 82°10′16.13″ W, 19 m, 22 August 2016, Choctaw, Organic Farm); 2♂♂ (31°22′49.19″ N, 83°19′8.57″ W, 89 m, 21 July 2016, Osage, Conventional Farm); 1♂ (29°39′15.95″ N, 82°31′25.49″ W, 32 m, 27 July 2016, Navaho, Organic Farm).

Comments — *Tetranychus urticae* has an almost cosmopolitan distribution. It is also a highly polyphagous species. To date, it is reported on 1169 host plants including many *Rubus* spp. from 124 countries (Migeon and Dorkeld 2020).

***Tetranychus* sp.**

Material Examined (n=6; 6 ♂) — 1♂ Osage 1♂ Von (28°34′5.62″ N, 81°41′22.17″ W, 24 m, 2 August 2016, Organic Farm); 1♂ (28°34′5.62″ N, 81°41′22.17″ W, 24 m, 25 August 2016, Von, Organic Farm); 1♂ Navaho, 1♂ Ouachita (29°39′15.95″ N, 82°31′25.49″ W, 32 m, 27 July 2016, Organic Farm); 1♂ (30°54′18.31″ N, 82°38′51.06″ W, 46 m, 21 July 2016, Ouachita, Conventional Farm).

Conclusion

In conclusion, the total number of mites collected in organic farms (105) was over 2-fold higher than in conventional farms (47). Moreover, while all of the twenty mite species identified during the study could be collected from organic farms, just nine could be obtained from conventional farms. The total number of beneficial mites collected in the organic farm was 57. In contrast, 23 beneficial mites were collected from conventional farms (Table 3). These results may be related to pesticide use on the conventional farms and are similar to that previously reported for mites (Incekulak and Ecevit 2002; Yanar and Ecevit 2008; Akyazı *et al.* 2016; Fathipour and Maleknia 2016; Soysal and Akyazı 2018).

Among the nine sampled cultivars, Quachita had 35 mites and 12 mite species, Osage had 27 mites, 9 species, Natchez had 26 mites, 9 species, Von had 22 mites, 7 species, Arapaho had 15 mites, 11 species, Choctaw had 13 mites, 8 species and Kiowa had 12 mites, 7 species. In contrast, no mite was found on the leaf samples taken from the Freedom cultivar, and

Table 4 Mite numbers according to blackberry cultivars (Arapaho, Choctaw, Freedom, Kiowa, Natchez, Navaho., Osage, Ouachita, Von.)

Mite Species	Mite Numbers								
	Arapaho	Choctaw	Freedom	Kiowa	Natchez	Navaho	Osage	Ouachita	Von
Galendromus (*G.*) *floridanus*	-	4	-	-	-	1	2	1	-
Phytoseius chanti	2	1	-	1	-	-	-	-	-
Proprioseius meridionalis	2	2	-	-	-	-	-	-	-
Typhlodromips dentilis	1	-	-	-	2	-	-	1	1
Typhlodromalus peregrinus	-	2	-	-	14	-	4	7	2
Amblyseius sp.	-	-	-	1	1	-	-	1	-
Phytoseius sp.1	2	-	-	2	-	-	-	1	-
Phytoseius sp.2	1	1	-	4	-	-	-	-	-
Proprioseiopsis sp.	-	1	-	-	-	-	1	2	-
Asca sp.	1	-	-	-	-	-	-	-	-
(*Oudemanscheyla*) *denmarki*	-	-	-	-	1	-	-	1	-
Lasioerythraeus sp.	**1**	-	-	-	-	-	-	-	-
Agistemus sp.	-	-	-	-	3	-	4	-	1
Polyphagotarsonemus latus	-	-	-	-	1	-	**3**	**5**	**1**
Tarsonemus (*T.*) *bilobatus*	**1**	-	-	-	-	-	-	-	-
Tarsonemus (*T.*) *confusus*	**1**	-	-	**2**	-	-	-	**1**	-
Eotetranychus carpini	**2**	-	-	**1**	-	-	**2**	**3**	**14**
Tetranychus schoenei	**1**	**1**	-	**1**	**2**	-	**7**	**10**	**1**
Tetranychus urticae	-	**1**	-	-	**1**	-	**3**	-	-
Tetranychus sp.	-	-	-	-	**1**	-	**1**	**2**	**2**
TOTAL	**15**	**13**	**0**	**12**	**26**	**1**	**27**	**35**	**22**

just one mite was collected from Navaho (Table 4). We hypothesize that differences in mite numbers and diversity may be caused by different phytochemical components, morphological and histological leaf structure of blackberry cultivars as stated by Camporese and Duso (1996), Krips *et al.* (1999), Kretier *et al.* (2002), Kabicek (2008), Khan *et al.* (2008) and Ali *et al.* (2015) for different plants. It should be noted that a single factor is not responsible for the abundance and diversity of mites but a combination of factors. Since the effect of cultivars on the mite population is time-consuming, such results can only be observed in the long term. As far as we know, no previous research has investigated the effect of blackberry cultivars on the mite population. And, future investigations are necessary to validate the kinds of conclusions that can be drawn from this study.

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