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Drosophila suzukii in Michigan vineyards, and the first report of *Zaprionus indianus* from this region

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Abstract

Drosophila suzukii is a new invasive pest that in recent years has become established in the Great Lakes region of the United States. Understanding the level of infestation in potentially susceptible crops is an important first step for planning appropriate management responses. This study was conducted in 2010–2012 to determine the infestation potential of this pest in native *Vitis labrusca*, French hybrid and *V. vinifera* grape cultivars grown in Michigan vineyards. *Drosophila suzukii* adults were reared out of collected grape samples in all 3 years, comprising a low proportion of all emerged drosophilids in each of the years. This trend was also found in vacuum sampling, conducted in 2011, with the majority of flies collected being non-*D. suzukii* drosophilids. Another recently introduced invasive fly species, *Zaprionus indianus*, was also reared out of grape samples collected in 2012. While the results of this study indicate no immediate threats to commercial grape production from *D. suzukii*, further research is needed to elucidate possible secondary effects that this species may have on vineyards, such as the introduction of diseases to the fruit.

Introduction

Over the past several years, the spotted wing Drosophila, *Drosophila suzukii* Matsumura, has expanded its range around the globe (Hauser 2011; Calabria et al. 2012; Cini et al. 2012). As it moved into new regions, fruit crops have been adversely affected causing significant commercial losses (Goodhue et al. 2011; Walsh et al. 2011). For some crops such as raspberries and cherries, *D. suzukii* has become the key pest driving insecticide programmes through the season (Bolda et al. 2010; Beers et al. 2011). In other crops, such as grapes and peaches, the fly has not become a key pest, but its economic impact in vineyards remains unknown (Pfeiffer et al. 2012). Initial fruit susceptibility studies by Lee et al. (2011) showed that *D. suzukii* adults reproduced poorly when presented with wine grapes in a laboratory setting. Additional work by Bellamy et al. (2013) found table grapes have the lowest potential as a host for *D. suzukii* of the fruits tested. However, early research in Japan indicated *D. suzukii* would infest grapes (Kanzawa 1939; Walsh et al. 2011). *Drosophila suzukii* adults also have been found in wine grape vineyards (Rouzes et al. 2012) and have been reared out of wine grapes collected from vineyards in Quebec (Saguez et al. 2013). Grapes are one of the most valuable fruit crops worldwide (FAO 2011), with almost 5 billion dollars of grapes produced in the United States in 2012 (USDA-NASS 2013). Given the high value of this crop, it is crucial to understand the potential for *D. suzukii* to affect its production.

Drosophila suzukii was first detected in Michigan, USA, in 2010 and has since become a pest in blueberries and raspberries in this region (Isaacs 2011; Van Timmeren and Isaacs 2013). While this species has also been trapped in the region's vineyards (R. Isaacs, unpublished data), there has been no indication that it has yet reached pest status in the 5000 ha of grapevines grown in Michigan. Another potentially invasive drosophilid, *Zaprionus indianus* Gupta (van der Linde 2010), has been discovered in southern regions of North America (van der Linde et al. 2006), but its recent detection in more northern regions (Virginia) in 2012 (D. Pfeiffer, personal communication) led to greater awareness of the potential for spread to new regions of the continent. Adaptation of *Z. indianus* to cooler climates has been documented previously (da Mata et al. 2010; Ramniwas et al. 2012), indicating plasticity in tolerance to environmental conditions and potential ability to survive in the temperate regions of North America.

The first objective of this study was to determine whether *D. suzukii* was present in commercial and non-commercial vineyards in Michigan. The second objective was to determine the prevalence of *D. suzukii* in grapes as a percentage of the broader Drosophila community. This research also provided an opportunity to sample for *Z. indianus* to determine its status within the same geographic region.

Table 1 Drosophilids reared out from grapes collected weekly from commercial and non-commercial vineyards in Michigan during 2010

		Week of:		
Cultivar	Type[1]	Oct 10	Oct 17	Oct 31
Commercial				
Cabernet franc	H, R	1.6 (0)		
Chambourcin	H, R	11.6 (0)		
Vignoles 1	H, W	8.7 (0)		
Vignoles 2	H, W	3.4 (0)		
Average		6.3 (0)		
Non-commercial				
Chancellor	H, R	87.7 (0)		
Concord 1	L, R	19.3 (0.3)	60.2 (0)	
Concord 2	L, R	74.8 (0)	89.8 (0)	
Niagara 1	L, W		70.8 (0.3)	39.4 (0)
Niagara 2	L, W	137.6 (0)		
Pinot gris	V, W	0.8 (0)		
Average		64.0 (0.06)	67.0 (0.07)	

Values presented are average total number of adult Drosophila (number that are *D. suzukii*) per litre of grape.

[1]Type of grape cultivar: V (*Vitis vinifera*), H (hybrid), L (*Vitis labrusca*); R (red grape), W (white grape).

Material and Methods

Fruit sampling for Drosophila

Grape clusters were collected in the fall of 2010, 2011 and 2012 in south-west Michigan from commercial vineyards (five locations, a total of 19 vineyard blocks) that received insecticide and fungicide sprays and non-commercial vineyards (four locations, a total of 18 vineyard blocks) that were left unsprayed. Most of these non-commercial sites were vineyards at research stations, while one was a vineyard that received no inputs due to spring frost damage that removed over 90% of the fruit. Specific cultivars collected are listed in Tables 1–5. Few collections were made in 2010 due to the fact that the initial detection of *D. suzukii* in Michigan did not occur until the end of September, near the end of grape harvest. Weekly collections in 2011 and 2012 began 2–3 weeks after veraison and continued for several weeks until harvest took place (commercial) or for several weeks after harvest (non-commercial). At each vineyard, a random selection of clusters was collected from vines at the border, adjacent to woods whenever possible. At sites where different cultivars were grown close together, sampling was spread through the area of each cultivar. A volume of 3.78 l of fruit (approximately 10 clusters) was collected at each sampling time. Clusters collected in 2010 and 2011 were placed in 3.78-l plastic containers (Meijer Company, Grand Rapids, MI) covered with fine white mesh bags (150 μm, The Cary Company, Addison, IL) and sealed with hot glue. Clusters collected in 2012 were weighed, and a cellulose sponge (3M™ Natural Yellow Cellulose Sponge, St. Paul, MN) was placed in the bottom of the plastic container to minimize larval drowning before the container was covered and sealed. Any adult flies present in the clusters at the time of collection were removed from the container before the final seal was applied. Adult flies emerging from the fruit were collected once a week for 1 month using suction provided by a modified Black & Decker Dust-Buster™ (Bioquip Products®; Rancho, Dominguez, CA). Emerged flies were placed in 70% ethanol and identified as *D. suzukii*, *Z. indianus* or other *Drosophila* spp. using the keys of van der Linde (2010) and Vlach (2010). To reduce the potential for contamination by flies that could develop as a second generation within the containers, flies that emerged within the first 14 days were included in the analyses. If a container had no flies emerged at that point, for the next 2 weeks, the first specimen of each species or group to emerge (*D. suzukii*, *Z. indianus* or other *Drosophila* spp.) was also counted and included. For all samples collected at commercial and non-commercial sites, the average percentage of reared flies that were *D. suzukii* was arcsine-transformed before analysis using a two-sample *t*-test.

Cultivar comparisons

In addition to weekly sampling of vineyards, grape cultivars were sampled in non-commercial plantings at the Northwest Michigan Horticultural Research Center near Traverse City, Michigan, in 2011 (October

Table 2 Drosophilids reared out of grapes collected weekly from the border of commercial vineyards in Michigan during 2011. Results are given as average total number of adult Drosophila (number that are *D. suzukii*) per litre of grape

		Week of:						
Cultivar	Type[1]	September 4	September 11	September 18	October 2	October 9	October 16	October 23
Cabernet franc	H, R			0.5 (0)	0.0 (0)			
Chambourcin 1	H, R			1.3 (0.8)	1.1 (0)			
Chambourcin 2	H, R			7.9 (2.9)	1.1 (0.6)	0.5 (0)		
Chambourcin 3	H, R			0.5 (0.3)	1.1 (0)	3.2 (0)	0.8 (0)	
Chancellor	H, R			6.6 (5.5)	15.3 (0.3)	11.1 (0)	1.6 (0)	0.8 (0)
Chardonel 1	H, W			0.0 (0)	1.1 (0)	2.1 (0)	4.8 (0)	
Chardonel 2	H, W			0.0 (0)	0.0 (0)	0.5 (0)	2.4 (0)	
Chardonnay	V, W			0.0 (0)	2.6 (0)			
Concord 1	L, R			1.3 (0)				
Concord 2	L, R			0.5 (0)		30.4 (0.5)		
Concord 3	L, R			0.3 (0.3)		12.9 (0)		
Foch	H, R			1.8 (0.8)	12.7 (0.3)[2]	54.2 (0)[2]	11.9 (0)[2]	12.7 (1.3)[2]
Gewürztraminer	V, W			1.1 (0.3)	0.3 (0)			
Jupiter Seedless	H, R	10.8 (0.5)						
Merlot	V, R			0.8 (0.3)	0.8 (0.3)			
Niagara	L, W		0.5 (0)					
Pinot gris 1	V, W				4.0 (0)			
Pinot gris 2	V, W				39.1 (0)	61.3 (0)	23.3 (0)	31.2 (0)
Pinot noir	V, R				4.0 (0)			
Riesling	V, W			0.0 (0)	0.0 (0)	0.0 (0)	0.3 (0)	
Sauvignon blanc	V, W			5.5 (0.8)				
Seyval blanc	V, W			0.0 (0)	0.0 (0)	11.1 (0)		
Traminette	H, W			1.3 (0)	0.0 (0)	7.7 (0)		
Vignoles 1	H, W			31.4 (1.3)	60.5 (0)	47.6 (0)	30.1 (0)	
Vignoles 2	H, W			35.6 (0)	5.5 (0)	20.6 (0)	10.8 (0)	
Vignoles 3	H, W			18.0 (0)				
Average				5.0 (0.6)	7.8 (0.07)	17.0 (0.05)	8.6 (0)	11.4 (0.3)

[1]Type of grape cultivar: V (*Vitis vinifera*), H (hybrid), L (*Vitis labrusca*); R (red grape), W (white grape).
[2]Samples collected from a small section of unharvested grapes within the harvested vineyard.

15, 16) and 2012 (September 15, 16). Cultivars sampled in 2011 included NY62.122, NY65.403.1, NY76.0044, NY81.0315, NY73.136.17, Albariño, Cabernet franc, Chambourcin, Chardonel, Chardonnay, Cinsault, Corot noir, Dornfelder, Gewürztraminer, Gruner veltliner, Lagrein, Moscato giallo, Muscat ottonel, Noiret, Pinot blanc, Pinot meunier, Pinot noir, Riesling, Rkatsiteli, Semillon, Seyval blanc, Syrah, Teroldego, Traminette, Vidal blanc, Vignoles and Viognier. Samples taken in 2012 were the same as those collected in 2011 with the addition of Frontenac. In 2011, the vineyards received regular fungicide sprays but no insecticide sprays during the season, while in 2012 the vineyards again received regular fungicide sprays and also received four insecticide applications from late May through late August (May 3: phosmet, Imidan 70WP; June 22: imidacloprid, Macho 2F; August 14: phosmet, Imidan 70WP; August 27 spinetoram, Delegate WG). A non-commercial planting was also sampled at the Southwest Michigan Research and Extension Center in Benton Harbor, Michigan, in 2012 (September 9). Cultivars sampled are listed in Table 5 with collection vineyards all receiving minimal fungicide and insecticide applications during the 2012 growing season. All grape samples were collected in 3.78-l containers using the methods described above.

Berry versus cluster sampling

In 2012, grape samples were taken between August 19 and September 2 to compare collections of individual berries that had no obvious signs of insect infestation with whole cluster collections that included rotting and damaged berries. An average of 10.1 ± 0.4 clusters with 49.8 ± 2.5 berries per cluster were collected. Individual berries were collected from the same locations where the cluster samples were collected, with 118.3 ml of berries placed in a 0.95-l container (Gordon Food Service®, Wyoming, MI) on

Table 3 Drosophilids reared out from grapes collected weekly from the border of commercial vineyards in Michigan during 2012

		Week of:								
Cultivar	Type[1]	August 12	August 19	August 26	September 2	September 9	September 16	September 23	September 30	October 7
Cabernet franc	H, R		0.0 (0)		0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	1.3 (0.03)	0.5 (0.01)
Chambourcin 1	H, R		0.0 (0)		0.0 (0)	0.0 (0)	0.0 (0)	22.7 (9.0)		
Chambourcin 2	H, R		0.0 (0)		1.3 (0)	0.0 (0)	0.0 (0)	0.0 (0)	6.3 (0.6)	
Chambourcin 3	H, R		0.0 (0)		0.0 (0)	0.0 (0)	0.0 (0)	7.4 (0.3)	12.7 (0.5)	0.0 (0)
Chancellor	H, R		1.6 (1.6)		32.2 (0.3)	20.9 (0)	0.0 (0)			
Chardonel	H, R		0.0 (0)		6.1 (0)	10.0 (0.5)				
Chardonnay	V, R	0.0 (0)	0.0 (0)		0.3 (0)	4.8 (0)				
Concord	L, R	0.0 (0)	0.0 (0)		0.8 (0.3)	21.9 (0)				
Foch	H, R		47.0 (0)	265.8 (0)	226.1 (0)					
Gewürztraminer	V, W		0.0 (0)		8.2 (0)	10.6 (0.5)	14.5 (0)			
Merlot	V, R		0.5 (0.5)		0.0 (0)	12.4 (0.8)	0.0 (0)			
Niagara	L, W	0.0 (0)	0.5 (0.5)		7.9 (0)					
Pinot gris	V, W		16.6 (0)		7.9 (0)	58.9 (0.5)				
Pinot noir	V, R		1.6 (0)	40.4 (0)	21.9 (0)					
Riesling	V, W		0.0 (0)		0.0 (0)	0.0 (0)	0.0 (0)	2.9 (0.3)		
Sauvignon blanc	V, W		0.0 (0)	0.0 (0)	0.0 (0)					
Seyval blanc	V, W		0.0 (0)		0.0 (0)	34.1 (0.3)				
Traminette	H, W		0.0 (0)		0.0 (0)	17.2 (0)	5.0 (0)	0.3 (0)		
Vignoles 1	H, W		7.9 (3.2)		11.6 (0)					
Vignoles 2	H, W		0.5 (0)		0.8 (0)					
Vignoles 3	H, W	0.5 (0)			84.5 (0)					
Average		0.1 (0)	3.6 (0.3)	102.1 (0)	21.6 (0.1)	11.2 (0.2)	2.2 (0)	5.5 (1.0)	6.8 (1.4)	0.3 (0)

Results are given as average total number of adult Drosophila (number that are *D. suzukii*) per litre of grape.
[1]Type of grape cultivar: V (*Vitis vinifera*), H (hybrid), L (*Vitis labrusca*); R (red grape), W (white grape).

top of a piece of yellow cellulose sponge (L × W × H: 5.08 × 5.08 × 3.81 cm; 3M™ Company, St. Paul, MN, USA) and held in place by a small hardware cloth basket (6.35 mm diameter, Tractor Supply Company, Brentwood, TN). Emerging flies were collected from containers by trapping them on a yellow sticky insert (7.6 × 8.9 cm; Great Lakes IPM, Inc., Vestaburg, MI) placed in the container. Flies were collected once or twice weekly and were identified as *D. suzukii*, *Z. indianus* or non-*D. suzukii* drosophilids. All samples were weighed prior to placing them in containers to compare the number of emerging Drosophila flies per gram of fruit between the berry and cluster samples. The average number of *D. suzukii* and non-*D. suzukii* drosophilids reared out per gram of fruit were log $(X + 1)$-transformed before analysis using a Mann–Whitney U-test to compare between intact berries and whole cluster samples.

Vacuum sampling

During the four sampling dates in October 2011, vacuum sampling was conducted to test for the presence of adult Drosophila flies on vines. Grapevines were sampled using a modified reverse-flow leaf blower (BG 56 C-E; Stihl, Waiblingen, Germany) with a fine white mesh bag (150 μm; The Cary Company) secured over the intake to capture flies (Tuell et al. 2008). At each location, vines were vacuum-sampled immediately before fruit samples were collected. Twenty vines along the vineyard border were sampled in the fruiting zone for 30 s, and samples were placed in the freezer for later sorting into *D. suzukii* and non-*D. suzukii* drosophilids. The average number of these two types of flies collected in each sample were log $(X + 1)$-transformed before being compared using a Mann–Whitney U-test.

Results

Weekly sampling for *Drosophila*

Drosophila adults were reared out of 83.1% of the grape samples collected over the 3 years of this study, in both commercial and non-commercial vineyards (Tables 1–4). *Drosophila suzukii* flies were reared out of 26.0% of the grape samples, with detections in all 3 years sampled. The remainder of the flies emerging from the grapes were primarily the native species, *D. melanogaster* and *D. simulans*. Only a few *D. suzukii* specimens were reared out of samples in 2010, with two of 14 samples positive for *D. suzukii* (Table 1). In 2011 and 2012, when more extensive sampling took place, most cultivars had at least one sample that was positive for *D. suzukii* in at least one of the 2 years, and 26 of 88 (2011) and 32 of 134 (2012) samples were positive for *D. suzukii* (Tables 2–5). However, the prevalence of *D. suzukii* in the samples remained low, both in commercial (2011: 1.02 ± 0.37%, 2012: 1.22 ± 0.53%) and in non-commercial vineyards (2011: 2.54 ± 1.57%, 2012: 2.34 ± 1.0%). There were no significant differences between commercial and non-commercial sites when comparing the average percentage of flies that were *D. suzukii* in either 2011 ($t = -1.4$, d.f. = 28, P = 0.16) or 2012 ($t = -1.3$, d.f. = 24, P = 0.2). Grape samples where many Drosophila adults were reared out were all dominated by non-*D. suzukii* drosophilids.

Collections over 2 years at a non-commercial research station site revealed *D. suzukii* emerging from grapes during mid- to late September in 2011 and early to mid-September in the warmer 2012 growing season (Table 4). The overall proportion of the flies that were *D. suzukii* declined after late September in 2011, and after mid-September in 2012. In both years, these peaks of the species composition being *D. suzukii* were coincident with harvest timing for the cultivars at this planting.

In addition to *D. suzukii*, a new fly species invasive to Michigan, *Z. indianus*, was reared out of some grape samples collected in 2012. *Zaprionus indianus* adults were reared out of a cluster sample collected from a non-commercial Niagara vineyard that had been damaged in the spring by frost (one fly, fruit collected on 14 September), a cluster sample collected from a commercial Chambourcin vineyard (five flies, fruit collected on 5 October) and a berry sample collected from a non-commercial Chancellor vineyard at a research station (one fly, fruit collected on 5 October).

Cultivar comparisons

No *D. suzukii* emerged from clusters collected on cultivars grown in north-west Michigan, either in 2011 or in 2012. In 2011, there were non-*D. suzukii* drosophilids that emerged, including from NY62.122 (19.3 Drosophila per litre of fruit collected), Chardonnay (1.1), Lagrein (0.3), Muscat ottonel (6.3), Pinot meunier (1.8), Syrah (0.3), Riesling (0.3) and Rkatsiteli (9.5). No Drosophila adults emerged from any of the cultivar samples collected from north-west Michigan in 2012, and no *Z. inidianus* were detected at this location.

All of the samples collected from south-west Michigan in 2012 had Drosophila adults emerge from grapes; Cabernet franc, Merlot, Regent, Mars, Noiret and Traminette had the fewest adults emerge, and Concord and Pinot gris had the most flies emerge (Table 5). Five of the 16 cultivars had *D. suzukii* adults that emerged from the grapes (Chardonnay, Concord, Mars, Noiret and Vanessa), constituting 0.6–33.3% of emerging adults per sample.

Berry versus cluster sampling

There were no significant differences in the average number of *D. suzukii* adults reared out of berry samples (0.2 ± 0.2 flies/gram) as compared to cluster samples (0.6 ± 0.4 flies/gram; $U = 0.8$, d.f. = 75, P = 0.38). While there was a lower average number of non-*D. suzukii* drosophilids reared out of berry samples (3.8 ± 1.7 flies/gram) as compared to cluster samples (69.5 ± 35.0 flies/gram), this difference was not significant ($U = 0.8$, d.f. = 75, P = 0.36).

Vacuum sampling

On average, there were significantly fewer *D. suzukii* adults caught in vacuum samples in grape vineyards in 2011 than non-*D. suzukii* drosophilids. This was true for samples from commercial vineyards (*D. suzukii*: 0.4 ± 0.3; non-*D. suzukii* drosophilids: 24.9 ± 10.9; $U = 18.6$, d.f. = 26, P < 0.0001) as well as for samples collected from non-commercial vineyards (*D. suzukii*: 1.4 ± 0.9; non-*D. suzukii* drosophilids: 134.1 ± 45.1; $U = 5.4$, d.f. = 6, P = 0.02). There were no significant differences in the number of *D. suzukii* adults caught in commercial and non-commercial vineyards ($U = 1.5$ d.f. = 16, P = 0.2; fig. 1); however, there were significantly more non-*D. suzukii* drosophilids caught in non-commercial vineyards than in commercial vineyards ($U = 6.0$, d.f. = 16, P = 0.02; fig. 1).

Discussion

Drosophila suzukii adults were reared out of grapes collected in each of the 3 years of this study. The number of Drosophila flies reared out of grapes in 2010 was very small compared with the following 2 years. While this may be evidence that *D. suzukii* was establishing in Michigan, it also may be due to the lower number of samples collected in 2010. Although *D. suzukii* adults were reared out of grapes in all

Table 4 Drosophilids reared out of grapes collected weekly from non-commercial research station sites in Michigan during 2011 and 2012

			Week of:						
Year	Cultivar	Type[1]	September 11	September 18	September 25	October 2	October 9	October 16	October 23
2011	Aurore	H, R		84.3 (0)		17.7 (0)	17.7 (0)		
	Concord 1	L, R	32.8 (6.6)		6.1 (3.2)	30.6 (0)	43.3 (0)	16.6 (0)	20.3 (0)
	Concord 2	L, R		9.8 (3.7)	11.9 (1.63)	10.0 (3.4)	19.8 (1.8)	3.4 (0)	3.2 (0.3)
	Niagara	L, W	6.9 (0.5)			39.4 (4.2)	107.0 (0)	27.7 (0)	23.5 (0)
	Average		19.8 (3.6)	47.0 (1.8)	9.0 (2.4)	24.4 (1.9)	47.0 (0.5)	15.9 (0)	15.7 (0.09)

Year	Cultivar	Type[1]	August 19	August 26	September 2	September 9	September 16	September 23	September 30	October 7
2012	Concord 1	L, R	0	0	6.3 (1.6)	6.9 (3.7)	2.6 (2.6)	35.7 (0.8)	0.0 (0)	15.3 (0)
	Concord 2	L, R	0	0	0.5 (0)		0.0 (0)	11.6 (2.1)	0.0 (0)	18.2 (0)
	Niagara 1	L, W			0.3 (0)	7.4 (2.4)	18.8 (0.3)	7.4 (0)	0.0 (0)	23.8 (0)
	Niagara 2	L, W	0	0	4.8 (1.1)	5.8 (1.8)	19.6 (0)	32.5 (0)	27.5 (0)	0.0 (0)
	Pinot gris	V, W	0	1.6 (0)	0.8 (0)	30.6 (0)	0.0 (0)	82.2 (0)	170.4 (0)	
	Average		0 (0)	0.4 (0)	2.5 (0.5)	12.7 (2.0)	8.2 (0.6)	33.9 (0.6)	39.6 (0)	14.3 (0)

Results are given as average total number of adult Drosophila (number that are *D. suzukii*) per litre of grape.
[1]Type of grape cultivar: V (*Vitis vinifera*), H (hybrid), L (*Vitis labrusca*); R (red grape), W (white grape).

Table 5 Drosophilids reared out from grapes collected at non-commercial vineyards at the Southwest Michigan Research and Extension Center on 9 September 2012

Cultivar	Type[1]	Average no. of Drosophila (no. *D. suzukii*)
Cabernet franc	H, R	2.6 (0)
Chardonnay	V, W	37.3 (0.3)
Concord	L, R	134.7 (0.8)
Marquette	H, R	46.8 (0)
Marquis	H, R	21.1 (0)
Mars	H, R	0.8 (0.3)
Merlot	V, R	0.8 (0)
Niagara	L, W	16.6 (0)
Noiret	H, R	1.1 (0.3)
Pinot gris	V, W	437.5 (0)
Pinot noir	V, R	46.8 (0)
Regent	H, R	1.8 (0)
Seyval blanc	V, W	37.8 (0)
Traminette	H, W	8.5 (0)
Vanessa	H, R	42.0 (0.8)
Zweilgelt	V, R	84.8 (0)
Average		57.4 (0.2)

Results are given as average total number of adult Drosophila (number *D. suzukii*) per litre of grape.

[1]Type of grape cultivar: V (*Vitis vinifera*), H (hybrid), L (*Vitis labrusca*); R (red grape), W (white grape).

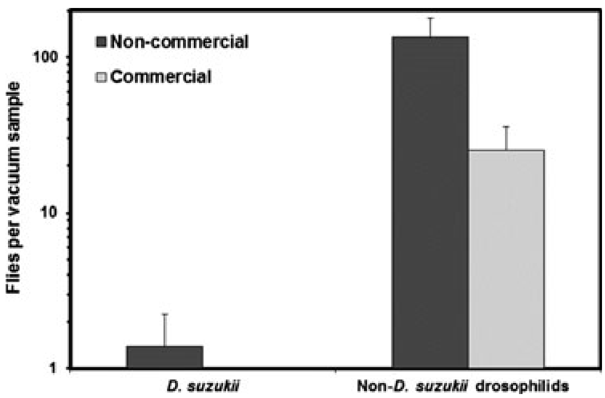

Fig. 1 Average number (±SEM) of *Drosophila suzukii* adults and non-*D. suzukii* drosophilids captured in vacuum sampling of vines in commercial and non-commercial vineyards during October 2011. The total number of other Drosophila flies captured at commercial and non-commercial vineyards was significantly different (P = 0.001), but there was no significant difference for *D. suzukii* (P = 0.09). For cultivars sampled, see Tables 2 and 4.

3 years, they were consistently the minority, even in unsprayed vineyards where ample ripe fruits were available. Regional variation was observed in the number of *D. suzukii* reared out of grapes, as shown by the presence of *D. suzukii* in grapes collected from south-west Michigan and the absence of any in grapes collected from north-west Michigan. This may be due to *D. suzukii* being more established in the south part of the state than the north, but more work is needed to determine specific causes for this trend. This contrasts with blueberry fruit samples collected from fields within a few kilometres of the grape vineyards, where *D. suzukii* increased rapidly over a similar time period (Isaacs et al. in review). In addition, *Phytolacca americana* L. (American pokeweed) berries that were collected from plants along the wooded borders directly adjacent to the collection vineyards in 2011 were heavily infested with *D. suzukii* (J. Lee, A. Dreves, H. Burrack, A. Cave, S. Kawai, R. Isaacs, J. Miller, S. V. Timmeren, and D. Bruck, in preparation), while *Vitis riparia* (riverbank grape) berries collected at the same time and location remained free of *D. suzukii*. Preference for red grape cultivars has been reported recently (Saguez et al. 2013); however, in controlled choice tests by Lee et al. (2011), there was no significant preference. Our data presented here indicate the capacity of *D. suzukii* to lay eggs and develop in both red and white cultivars, and further controlled comparisons among cultivars relevant to different production regions will be required to assess relative risk of different cultivars to this pest. Our vacuum sampling from grape vines indicates that of the Drosophilids present on the vines, very few were *D. suzukii*. In addition, more flies were present in non-commercial vineyards, suggesting that the presence of adult flies in the vineyards may have been affected by insecticide applications. These results suggest that there are host berries with greater suitability or susceptibility to *D. suzukii* in this ecosystem and that *Vitis* spp. are not likely to be primary hosts of this species. This supports the results of recent studies, which indicated that grapes are not a preferred host (Lee et al. 2011; Bellamy et al. 2013).

Even though grapes are not a preferred host for *D. suzukii*, this does not mean that there is zero risk for commercially relevant levels of damage to take place. While Drosophila flies are ubiquitous in vineyards as the grapes ripen, *D. suzukii* is the first species found in this region that can lay eggs in the maturing fruit (Lee et al. 2011). This may provide an opportunity for facilitation wherein otherwise excluded insects such as drosophilids without the well-developed ovipositor morphology are able to exploit grape berries that they would otherwise be excluded. Of greater potential concern than facilitating access by insects is the potential for facilitation of pathogens. Drosophila have been shown to be associated with the bacteria that causes sour rot and its spread (Bisiach et al. 1986; Barata et al. 2012). If *D. suzukii* is able to injure otherwise healthy grapes during its oviposition attempts, other *Drosophila* may be able to take advantage of these injury points and allow bacteria to be introduced to vineyards earlier and in greater amounts. Future studies should also include assessment of oviposition potential to further understand the risk of this pathogen transfer among different grape cultivars. Also, while it is clear that *D. suzukii* does not prefer grapes as a host, it is able to develop in them to a certain extent. Given the late harvest of many grape cultivars, *D. suzukii* adults may choose to oviposit in grapes due to the lack of other available host options at that late point in the season. So, while the growers involved in this study did not report any excess or unusual damage to their grapes over the 3 years of observation, further research is needed to elucidate how much of a risk, if any, *D. suzukii* poses to commercial grapes.

Zaprionus indianus was first detected in Michigan in the fall of 2012. Flies were discovered in *D. suzukii* traps located in cherry orchards (L. Gut, unpublished data). *Zaprionus indianus* adults were successfully reared out of grape samples only in 2012, at the same time as the initial detection. This finding is interesting as it appears to be confirmation of niche adaptation of this historically tropical species (da Mata et al. 2010; Ramniwas et al. 2012). When the fly was introduced to Brazil (Vilela 1999), it became a pest of figs by taking advantage of cracks that form near the petiole of maturing fruit (Raga 2002). It is unclear whether *Z. indianus* will become a significant pest of grapes in the temperate regions of North America by taking advantage of damaged fruit, or if it will just be added to the list of Drosophilids that already take advantage of damaged and rotting grapes in vineyards.

This study highlights the need for greater knowledge of the Drosophilid community in vineyards, which is currently quite lacking. The ecology of some specific species has been investigated, such as the work of McKenzie (1974) and McKenzie and McKechnie (1979) on the distribution and behaviour of *D. simulans* and *D. melanogaster*. However, in general, there is limited knowledge of the typical species composition in vineyards, and this would be valuable baseline information to enable detection of species composition shifts as new invasive *Drosophila* spp. are detected. With the recent detection of two new species in our regions' vineyards, we expect additional species introductions in the future, given the increasing frequency of international trade in fresh fruits and vegetables (Huang 2010). Early detection of exotic species is an important part of invasive species management, particularly if those species have the potential to cause economic damage. This is more difficult with small, cryptic species (Mehta et al. 2007) and is particularly challenging with insects such as *Drosophila* spp. that may be present as small eggs or larvae in fresh fruit. Widespread monitoring for both of the *Drosophila* spp. detected in this study is underway in North America, and the economic impact of *D. suzukii* and *Z. indianus* in vineyards will depend on their ability to colonize grapes, as well as their competitive interactions and associations with pathogens that may be spread during the pre-harvest period.

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