# Seasonal biology and behaviour of the predatory mirid *Hyaliodes vitripennis*, a beneficial insect of apple orchards in Quebec, Canada

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***Abstract***

***Hyaliodes vitripennis*** **(Say) is a predatory mirid that feeds on spider mites, aphids, and immature stages of various other insects. It is sparsely distributed in North America but in the apple orchards of Quebec, Canada, it can be one of the four most important biological control agents of aphids and mites, provided that selective insecticides and other integrated pest management practices are used. The objectives of this two-year study were to 1) quantify the population distribution of the insect in Quebec orchards, 2) pinpoint appearance dates of its different developmental stages in those orchards, 3) locate preferred micro-habitats and measure time spent in these various habitats, and 4) compare the suitability of various rearing conditions. The predator was found in 68-85% of visited orchards. First observations were recorded, on average, around the beginning of July, and first adults between the end of July and the beginning of August depending on the year. Populations peaked on average 0-1 weeks following the appearance of adults. Only one generation per year was observed. Adults were observed until the first week of September and they spent 95% of their time on the underside of leaves. Among prey tested (*Tetranychus urticae, Panonychus ulmi, Myzus persicae, Macrosiphum euphorbiae* and *Choristoneura rosaceana*), mirids fed with *T. urticae* had a higher survival rate and higher longevity. *P. ulmi* and *C. rosaceana* larvae were the least suitable preys and aphids were intermediate.**

**Keywords:** Miridae, Tetranychidae, biological control, integrated pest management, phytophagous mites, predatory mirids

## INTRODUCTION

*Hyaliodes vitripennis* (Say) (Hemiptera: Miridae) is one of three species in the genus *Hyaliodes* to be found in apple orchards of northeastern North America (Horsburgh, 1969; Braimah et al., 1982) and the most common in Quebec, Canada (Arnoldi et al., 1992; Firlej et al., 2003). Food sources for this species consist mostly of European red mites, *Panonychus ulmi* Koch (Acarina: Tetranychidae); two-spotted spider mites, *Tetranychus urticae* Koch (Acarina: Tetranychidae); aphids, *Aphis pomi* DeGeer *Aphis spiraecola* Patch (Hemiptera: Aphididae); leafhopper nymphs (Hemiptera: Cicadellidae); and lepidopteran larvae (Horsburgh, 1969). Arnoldi et al. (1992) describe *H. vitripennis* as more arboreal and specific to the apple tree than other hemipteran predators.

In Pennsylvania, USA, two generations develop each year (Horsburgh, 1969) whereas only one is observed in Nova Scotia, Canada (McMurtry et al., 1970). According to Horsburgh (1969), the bug overwinters as an egg and, shortly after hatching, nymphs remain near the oviposition site, in the centre of the canopy, before they eventually start looking for prey on the underside of leaves.

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In the first half of the 20th century, *H. vitripennis* was encountered frequently in apple orchards (Gilliatt, 1935; Lord, 1949; Chachoria, 1967). However, the insect gradually disappeared from orchards during the 40 years following the arrival of synthetic insecticides. Beginning in the early 1990s, the predator was observed once again in many Quebec apple orchards (Firlej et al., 2003; Chouinard et al., 2006). *Hyaliodes vitripennis* populations might have benefited from the implementation of integrated pest management practices, the reduction of broad-spectrum insecticide use, and the development of resistance to some pesticides.

Although many authors have reported the predatory habits of *H. vitripennis* (Lord, 1949, 1968; Sanford and Lord, 1962; Sanford, 1964; Chachoria, 1967; Horsburgh and Asquith, 1968), they did not provide quantitative evidence. An exception to this is the study from Arnoldi et al. (1992), who has shown in laboratory settings that this species was the most voracious of the 30 predaceous Hemiptera and Araneae species found in an insecticide-free apple orchard in Quebec. In commercial orchards, Chouinard et al. (2006) demonstrated that introductions of *H. vitripennis* can significantly decrease European red mite populations and Firlej et al. (2003) demonstrated that the predator can successfully establish itself following such introductions.

The purpose of this study was to increase our knowledge of *H. vitripennis* biology and behaviour in field and laboratory settings. We focused on 1) getting more information about the distribution of *H. vitripennis* and the relative importance of its populations in Quebec commercial orchards; 2) determining the average time frame of the different *H. vitripennis* stages in the same orchards; 3) determining the favoured micro-habitats used by the predator and measuring the amount of time spent foraging in orchards; and 4) specifying the conditions suitable to *H. vitripennis* feeding and breeding in a controlled environment. Information obtained from this last aspect of the project was aimed at complementing the small-scale conservation method described by Horsburgh and Asquith (1969) and possibly allowing the elaboration of a protocol for *H. vitripennis* rearing for commercial purposes.

## MATERIALS AND METHODS

### Seasonal activity

For two consecutive years, *H. vitripennis* individuals and their prey were counted in commercial orchards located in southern Quebec, Canada. In the year preceding the counts, *H. vitripennis* individuals had been observed in these orchards, which varied in dimensions, age, and cultivars. Surveys were carried out weekly from July until the beginning of October to determine the appearance date of the first nymphs, the emergence date of the first adults, and the population peak in apple orchards. Surveys were also carried out in orchards where the bug had not been observed the previous year. These orchards were surveyed at the end of July/beginning of August, and data from both sets of orchards were used to improve our knowledge of population levels during the estimated period of peak activity.

In each orchard, ten apple trees ('McIntosh') were chosen randomly and tagged. During each visit, the *H. vitripennis* population (nymphs and adults) was evaluated by observing each tree for a period of one minute (Firlej et al., 2003; Chouinard et al., 2006). Main prey populations were evaluated at the same time, by examining with a hand lens (16X) ten randomly chosen leaves from each selected tree. From each selected tree aphid populations were evaluated by quantifying the importance of colonies on five randomly chosen shoots (Chouinard et al., 2006).

### Behaviour in field conditions

*H. vitripennis* adults were observed 1-2 times a week in a commercial orchard located in Saint-Paul-d'Abbotsford, Quebec (45°24'N, 72°51'W) from 9 am-12 pm and from 2-5 pm, on six different days between the end of July and the end of August. Observers first located the adults in standard 'McIntosh' trees and kept track of their movements until they would, for example, fly away or disappear from the observer's sight. For each three-hour observation period, the following data were gathered; duration of adult movement, rest and flight periods, observed habitat (leaf side, petiole, branch, fruit, others), and apparent behaviour (resting, moving, feeding, others).

### Behaviour in laboratory conditions

*H. vitripennis* individuals were collected from two commercial orchards in Quebec, Canada. Year 1: Frelighsburg, 45°02’N, 72°47’W, and year 2: Saint-Alexandre-d’Iberville, 4515’N, 73°07’W. These orchards had not been treated with products that are toxic to the predator (Bostanian et al., 2000, 2001) for at least 30 days before collection days. Individuals were collected early in the morning (year 1: nymphs collected at the end of July and adults in mid-August; year 2: nymphs collected in mid-July) and placed individually with an apple leaf in 10 mL plastic containers (Solo P100) (Chouinard et al., 2006). Containers were then stored in a cooler to avoid excessive death that could have resulted from heat and transportation, and used for the following experiments upon arrival in the lab.

### 1. Prey suitability.

Three species are known as potential *H. vitripennis* prey (Horsburgh, 1969) and easy to rear in captivity were tested; the two-spotted spider mite, the potato aphid *Macrosiphum euphorbiae* (Thomas) (Hemiptera: Aphididae), and the green peach aphi *Myzus persicae* (Sulzer) (Hemiptera: Aphididae). For the second year of the study, the European red mite and the obliquebanded leafroller (OBLR) *Choristoneura rosaceana* (Harris) (Lepidoptera: Tortricidae) were tested along with the two-spotted spider mite. These prey are important apple pests in eastern North America, including Quebec (Agnello et al., 2015; Chouinard et al., 2001).

Collected *H. vitripennis* individuals (fifth instar nymphs the first year, third and fourth instar nymphs the second year) were transferred individually in 10 mL plastic containers (Solo P100) with Nytex (mesh size: 80 µm) windows to allow air circulation and avoid condensation inside the container. For each treatment, the predators were fed *ad libitum* with a mix of prey from different developmental stages, except for OBLR, for which only first instar larvae were used. Prey and predators were placed on an apple leaf. Prey and leaves were changed daily to maintain the quality of the environment. Containers and their contents were kept in rearing chambers set to constant conditions (year 1: 20°C, 75-80% RH, 16L:8D; year 2: 24°C, 75-80% RH, 16L:8D). Total longevity was noted as well as the number of individuals reaching the adult stage.

## RESULTS AND DISCUSSION

### Seasonal activity

The first field observation of *H. vitripennis* nymphs was recorded between the end of June and in mid-July (median date: July 7) depending on the orchard and year (Table 1). The predator was present in 68% of visited orchards the first year (which only comprised of orchards in which the predator was reportedly present the year before) and 83% of visited orchards the second year (Table 2). *H. vitripennis* individuals were found in at least one orchard from all communities where the selected orchards were located, but predator populations were more significant in Dunham, Frelighsburg, Saint-Alexandre, and Saint-Jean-Baptiste.

During the first year of the project, the first adults were observed around the end of July (median date: July 27) and populations peaked between the end of July and the beginning of August (median date: August 1). The last nymphs were observed around the end of July. In the second year, the first adults were observed a few days later (median date: July 30) and the populations peaked similarly a few days later (median date: August 4) It is important to note that the population peak is the result of combined activity and dispersal behaviours of adults and nymphs and that the availability of prey (see below) also plays a role in these behaviours. Spider mite populations also depend on weather and pesticide regimes, which make *H. vitripennis* peak population date a highly variable parameter.

Table 1. Observation dates for *Hyaliodes vitripennis* first nymphs, first adults, and population peak in selected commercial orchards (8 orchards in year 1, and 7 orchards in year 2) from southern Quebec.

| Region | Year | First nymph observation date | First adult observation date | Population peak date |
|---|---|---|---|---|
| Earliest date | 1 | 25/06 | 24/07 | 24/07 |
| Median date | 1 | 07/07 | 27/07 | 01/08 |
| Latest date | 1 | 19/07 | 02/08 | 02/08 |
| Earliest date | 2 | 03/07 | 25/07 | 01/08 |
| Median date | 2 | 07/07 | 30/07 | 04/08 |
| Latest date | 2 | 14/07 | 05/08 | 14/08 |

Table 2. *Hyaliodes vitripennis* mean population assessments in commercial orchards located in southern Quebec for two consecutive years. Observations (1-min counts) made at estimated population peak (in 19 orchards between end of July and 1st week of August in year 1, and in 13 orchards between first and 2nd week of August in year 2).

| Orchard | Year | Nymphs | Adults | Total |
|---|---|---|---|---|
| Lowest count | 1 | 0.00 | 0.00 | 0.00 |
| Highest count | 1 | 2.60 | 2.40 | 4.90 |
| Average count | 1 | 0.85 | 0.48 | 1.33 |
| Standard deviation | 1 | 0.99 | 0.66 | 1.49 |
| Lowest count | 2 | 0.00 | 0.00 | 0.00 |
| Highest count | 2 | 1.25 | 4.40 | 5.65 |
| Average count | 2 | 0.39 | 1.55 | 1.95 |
| Standard deviation | 2 | 0.43 | 1.28 | 1.58 |

*H. vitripennis* populations were always associated with the species' main prey: the European red mite. In the orchard with the largest *H. vitripennis* population, red mite populations decreased even though no acaricides were applied throughout the season. A similar situation was observed in year 2 in four of the seven similarly surveyed orchards. *H. vitripennis* populations seemed little or not affected by the application of the organophosphate phosalone (Zolone®) in both orchards, as shown for two orchards in Figure 1. This result is consistent with that of Bostanian et al. (2000), who labelled this product as the least toxic to the predator amongst other products tested in laboratory conditions. Phosalone was a commonly used compound in orchards where *H. vitripennis* was observed by scouts in years preceding the project (Y. Morin, pers. commun.). Tolerance to the compound might be caused by the selection of resistant individuals, although this hypothesis should be verified.

A single generation per season was observed during the two years of the project. After the nymph populations had decreased and the first adults had been observed in July, immature stages were never observed in the surveyed orchards. However, adults were found as late as the beginning of September in an orchard, three years after the end of the project (Y. Morin, pers. commun.).

**Behaviour in field conditions**

Adults spent most of their time (95%) on the lower leaf surface. However, this average pattern was influenced by temperature as more adult-movement occurred on the upper leaf surface under warmer conditions. *H. vitripennis* individuals spent 33-42% of our observation time walking and flight only occurred <5% of the time. Individuals remained in place (resting or feeding) 55-65% of our observation time. Such observations support the preference of Chouinard et al. (2006) for using localized observations under tree canopy as a reliable monitoring method for assessing *H. vitripennis* populations.

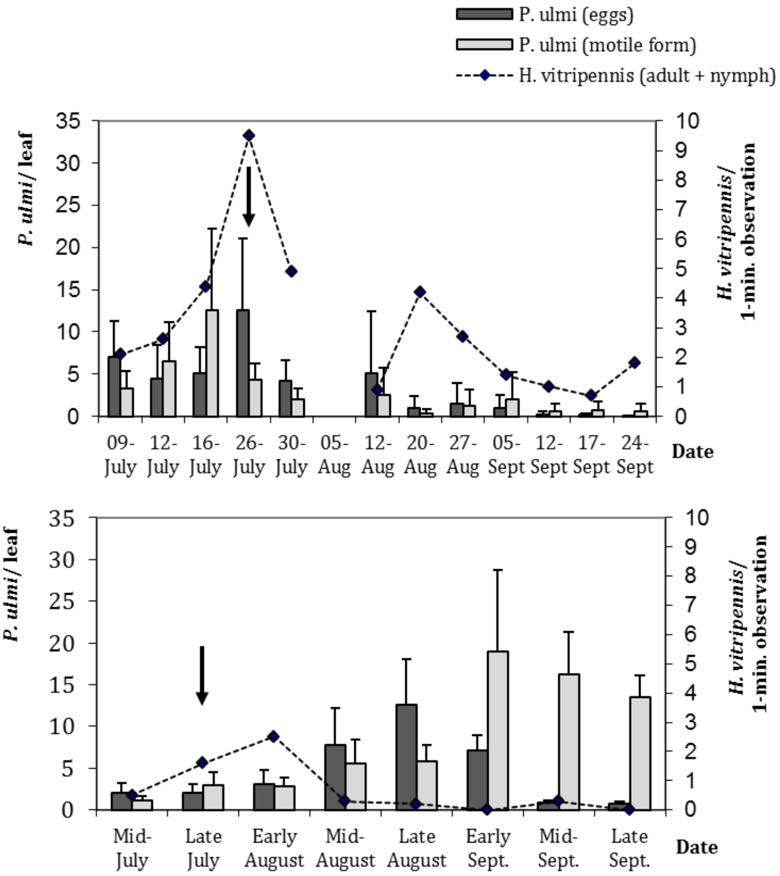


Figure 1. Seasonal evolution of *Panonychus ulmi* and *Hyaliodes vitripennis* populations in two orchards. The arrow (↓) indicates an application of the organophosphate insecticide phosalone (Zolone®).

According to Horsburgh (1969), soon after hatching, nymphs are mostly found around the centre of the tree, where the majority of eggs are laid. When they search for prey, nymphs visit the underside of leaves from non-fruiting leaf clusters, mostly along the midrib (Horsburgh, 1969), where mites are also frequently found. Our results suggest this behaviour also applies to adult *H. vitripennis* under our conditions.

**Behaviour in laboratory conditions – prey suitability**

Under laboratory conditions, the two-spotted spider mite was the most suitable prey for *H. vitripennis* development (Tables 3 and 4). However, the proportion of mite-fed individuals reaching the adult stage appeared to differ between years. In year 2, fewer of the earlier nymphal instars reached the adult stage than in the first year. Perhaps the two-spotted spider mite does not fulfill the nutrition needs of first *H. vitripennis* nymphal instars (as suggested by Firlej et al. 2006), perhaps other age-related mortality factors, or temperature, which was higher in year 2, were responsible. Molting could also be the cause; we observed many individuals dying during this process under laboratory conditions. Last-instar nymphs used in the first year had to molt only once to reach the adult stage, whereas nymphs collected the second year were younger and so had to undergo the molting process in the lab multiple times before reaching the adult stage, possibly further reducing their chances of survival.

Table 3. Proportion of *Hyaliodes vitripennis* nymphs reaching the adult stage, for two populations reared on various diets (population 1: 20°C, 75-80%, 16L:8D; population 2: 24°C, 75-80%, 16L:8D).

| Population 1 | *n* | % | Population 2 | *n* | % |
|---|---|---|---|---|---|
| *Tetranychus urticae* | 14 | 70 | *Tetranychus urticae* | 27 | 44 |
| *Macrosiphum euphorbiae* | 7 | 35 | *Panonychus ulmi* | 21 | 24 |
| *Myzus persicae* | 8 | 40 | *Choristoneura rosaceana* | 20 | 20 |

Table 4. *Hyaliodes vitripennis* longevity for two populations reared on various diets (population 1: 20°C, 75-80%, 16L:8D; population 2: 24°C, 75-80%, 16L:8D).

| Year 1 | n | Days±$s_x$ | Year 2 | n | Days±$s_x$ |
|---|---|---|---|---|---|
| *Tetranychus urticae* | 14 | 12±5.0 | *Tetranychus urticae* | 12 | 4.2±3.8 |
| *Macrosiphum euphorbiae* | 7 | 4.3±3.9 | *Panonychus ulmi* | 5 | 2.0±1.2 |
| *Myzus persicae* | 8 | 5.0±2.7 | *Choristorneura rosaceana* | 4 | 2.3±2.5 |

Except for predators that were fed two-spotted spider mites, few individuals reached the adult stage (Table 3). For both populations, *H. vitripennis* longevity seemed greater when bugs were fed two-spotted spider mites rather than any of the other four prey species (Table 4). However, longevity appeared to differ from one year to the other; the causes might be the same as those mentioned earlier, except for mortality due to molting, since it cannot apply to individuals having reached the adult stage. Firlej et al. (2006) reported much higher longevity for adults reared on a coccinellid diet than on two-spotted spider mite, but still with high mortality levels. Their suggested additions to the rearing diet included *P. ulmi* and plant materials.

## CONCLUSIONS

Population densities of *H. vitripennis* have varied widely in northeastern North America since its first mention in the early 1990s, most probably as a result of differential pesticide usage. In the current study, we studied its population biology following an important resurgence in Quebec orchards, which corresponded to the wide-scale implementation of IPM in the area, using selective insecticides which included phosalone, an organophosphate material to which local populations of *H. vitripennis* are relatively immune. The predator has an excellent fit as a biological control agent of mites: it appears in orchards in July, prior to usual mite outbreaks, it is relatively common in orchards provided that no material toxic to nymphs and/or adults are applied for the control of insect pests, and in these orchards it can avoid the need for application of summer miticides. However many orchards are free of *H. vitripennis* because they do not comply with one or many of these conditions, and in these orchards, inoculative or inundative releases could be considered to resume biological control. Inoculative releases have proven effective, but for inundative releases to be feasible, mass-rearing methods need to be developed. Such mass rearing methods will need to overcome the following difficulties (Firlej et al., 2006):

1. the predator is fragile and dies rapidly when the temperature or relative humidity regimes are too high or too low;
2. survival rates of individuals fed a prey diet are very low;
3. mating in laboratory conditions is complicated and either very few eggs are laid (Chouinard, unpublished data), or embryonic development and hatching of eggs are problematic;
4. due to cannibalism, only low *H. vitripennis* rearing densities are practicable, which is counter-productive from an economical perspective.

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