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Pollen increases fitness and abundance of *Orius insidiosus* Say (Heteroptera: Anthocoridae) on banker plants

Sarah K. Wong, Steven D. Frank *

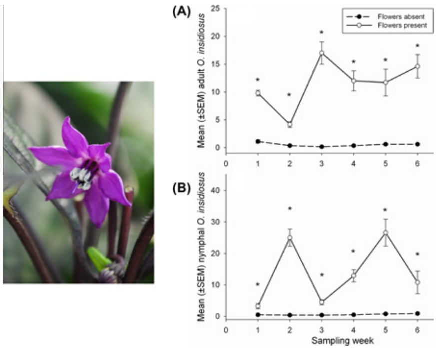
North Carolina State University, Department of Entomology, Campus Box 7613, Raleigh, NC 27695, USA

HIGHLIGHTS

- ‘Black Pearl’ pepper pollen increased *Orius insidiosus* longevity and adult size.
- Pollen also reduced *O. insidiosus* development time compared to prey only diet.
- Combined these effects increased *O. insidiosus* abundance on flowering plants.

GRAPHICAL ABSTRACT

The presence of flowers on Black Pearl pepper plants reduces *Orius insidiosus* Say (Heteroptera: Anthocoridae) development time and increases survival, longevity, and size resulting in greater *O. insidiosus* abundance when flowers are present.



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ABSTRACT

Banker plants are intended to enhance biological control by sustaining populations of natural enemies. Banker plants do this by providing alternative sources of food for natural enemies, such as pollen for omnivorous predators, thus decreasing the likelihood of their starvation and emigration from a cropping system when pest populations are low or absent. A banker plant system consisting of the Black Pearl pepper, *Capsicum annuum* ‘Black Pearl’, and the omnivorous minute pirate bug, *Orius insidiosus* Say (Hemiptera: Anthocoridae) has recently been proposed to improve biological control of thrips. Therefore, we studied how pollen from the Black Pearl pepper plant affects *O. insidiosus* fitness and abundance through a series of laboratory and greenhouse experiments. We found that a mixed diet of pollen and thrips increased *O. insidiosus* female longevity, decreased nymphal development time, and yielded larger females compared to a diet of thrips alone. Furthermore, *O. insidiosus* abundance was greater on flowering pepper plants than non-flowering pepper plants. From these results, we suggest that pollen from Black Pearl pepper banker plants could increase adult *O. insidiosus* abundance for the purpose of biological control in two ways: (1) reduce starvation and increase longevity of *O. insidiosus* when prey is absent; (2) enhance *O. insidiosus* fitness and fecundity when prey is present by mixing plant and prey diets. These results encourage future studies with the Black Pearl pepper as a banker plant for improving biological control of thrips in commercial greenhouses.

* Corresponding author.
E-mail addresses: skwong@ncsu.edu (S.K. Wong), sdfrank@ncsu.edu (S.D. Frank).

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1. Introduction

Banker plant systems are intended to improve fitness, abundance, and efficacy of biological control agents in greenhouses (Frank, 2010; Huang et al., 2011). Banker plant systems consist of non-crop plants that provide alternative hosts for parasitoids, prey for predators, or plant-based resources such as nectar and pollen for omnivores (Frank, 2010). Therefore, banker plant systems are intended to decouple natural enemy-pest population dynamics in order to sustain natural enemy survival and reproduction within a growing system when pest populations are low or absent (Frank, 2010). Interest in banker plant systems is increasing among researchers and growers due to their potential to improve biological control by sustaining populations of natural enemies (Huang et al., 2011; Frank, 2010; Rodda, 2011; Valentin, 2011). However, some banker plant systems require further research to demonstrate and improve the efficacy of this biological control strategy.

Recently, the Black Pearl pepper (*Capsicum annuum* 'Black pearl') has been proposed as a possible banker plant for biological control of thrips (Valentin, 2011). Growers use the ornamental Black Pearl pepper as a banker plant instead of other peppers because they grow and flower indeterminately thus producing pollen continuously. A typical Black Pearl pepper banker plant system consists of placing pepper plants throughout a greenhouse and releasing omnivorous Minute Pirate Bugs, *Orius insidiosus* Say (Hemiptera: Anthocoridae) with the goal of preventing a thrips outbreak.

The first proposed benefit of this system is that *O. insidiosus* can avoid starvation by feeding on pollen provided by Black Pearl pepper flowers if thrips populations are low or absent. This is especially important in crops without suitable pollen sources. The second proposed benefit of this system is to enhance *O. insidiosus* fitness and fecundity traits when prey is present by mixing plant and prey diets. Despite growers' present use of this system and claims that it works as part of a biological control program, there is no published research documenting how or if Black Pearl pepper pollen benefits *O. insidiosus* fitness for the purpose of suppressing thrips populations in commercial greenhouses.

Omnivores often benefit from or even require pollen as part of their diet (Coll and Guershon, 2002). Availability of pollen as an alternative source of food can enhance survival, decrease development time, and improve fecundity of omnivorous predators (Abdallah et al., 2001; De Clercq et al., 2005; Vanderkerkhove and De Clercq, 2010) but pollen from different plant species differ in nutritional value (Lundgren, 2009). *O. insidiosus* is an omnivore that feeds on a variety of small, soft bodied arthropods including thrips, mites and aphids but also feeds on pollen (McCaffrey and Horsburgh, 1986; Corey et al., 1998). The effect of pollen on *Orius* fitness and development is the subject of conflicting reports. For example, longevity of *O. insidiosus* adult females is significantly increased when corn pollen is added to a diet of green beans and/or *Ephestia kuehniella* eggs compared to either diet alone or in combination (Richards and Schmidt, 1996). In contrast, *Orius sauteri* adult female survival is not significantly increased when a diet of aphids, *Aphis gossypii*, is supplemented with corn pollen (Funao and Yoshiyasu, 1995). Likewise, *O. insidiosus* nymphs have been reported to develop solely on pollen from Common mullein, *Verbascum thapsus* L. (McCaffrey and Horsburgh, 1986) and honeybee pollen (Kiman and Yeargan, 1985). However, *O. insidiosus* nymphs fed corn pollen are not able to complete development (Richards and Schmidt, 1996). Black Pearl pepper banker plants could conserve or increase abundance of *O. insidiosus* populations in the absence of prey if pollen alone improves *O. insidiosus* survival and development.

In the presence of prey, Black Pearl pepper banker plants could increase *O. insidiosus* abundance if its pollen supports *O. insidiosus* fitness more than prey or if a mixed diet of pollen and prey increases *O. insidious* fitness more than prey alone. Alternatively, if pollen reduces predation on thrips or increases thrips abundance the banker plants could disrupt biological control. Based on a preliminary greenhouse experiment, our hypothesis is that Black Pearl pepper pollen will increase *O. insidiosus* abundance through the benefits of diet mixing (Wong and Frank, 2011). We test this hypothesis and the underlying mechanisms with a series of factorial greenhouse and laboratory experiments designed to determine how pollen from Black Pearl pepper plants affects *O. insidiosus* survival and development time, female size, and abundance on individual banker plants. Results from this study will provide a foundation of information as to how Black Pearl pepper pollen affects *O. insidiosus* fitness and abundance and whether the pepper plants merit further investigation as banker plants for improving biological control of thrips in commercial greenhouses.

2. Methods

2.1. Study organisms

All *O. insidiosus* were purchased from Koppert Biologicals (Howell, MI), and used for experiments within 1 week of arrival. When not being used, *O. insidiosus* were kept in a refrigerator. Black Pearl pepper plants (128 plugs/flat; plant <7 cm in height) were supplied by Van Wingerden International (Mills River, NC) and C. Raker and Sons Inc. (Litchfield, MI). Plants were transplanted to 10.2 cm pots and allowed to grow for 8 weeks until they were transplanted to 11.36 liter pots. Fafard 2 light weight soil mix was used for all plants with 473 ml of Osmocote/soil bag (14-14-14; 2.8 cu ft or 0.85 cu meters). Western flower thrips, *Frankliniella occidentalis* Pergande, were obtained from a colony started from field collected adults and maintained in the laboratory on green beans and cabbage.

2.2. Effect of flowers and thrips on female O. insidiosus longevity

To determine if Black Pearl pollen, thrips prey, or a mixed diet of both increase *O. insidiosus* adult longevity, we conducted a 2×2 factorial laboratory experiment that crossed two pollen treatments (absent or present) with two thrips treatments (absent or present). The experiment was conducted in arenas made from plastic 50 mL Corning vials (Corning, Corning, NY). One hole (2 cm diameter) was made in the top and side of each vial for ventilation. Holes were covered with thrips screen and secured with hot glue to prevent escape of experimental organisms. A third smaller hole (0.7 cm diameter) was made through the bottom tip of the vial (Fig. 1).

Black Pearl pepper stems were collected from greenhouse pepper plants. Each stem was 6–8 cm in length and had three leaves. All buds and flowers were picked from 'flower absent' treatment stems. Buds and 1–2 open flowers were left on stems in 'flower present' treatments. The bottom-half of each stem was wrapped in cotton then pulled through the small hole in the bottom of vials so that the stem fit snugly in the hole. The cut end was inserted into a #55 (12.7 cm, 10 ml) floral-pick (Syndicate Sales Inc., Kokomo, Indiana) filled with tap water. Floral-picks were stuck into a Styrofoam board and a wire-grid was made from craft wire in order to support the experimental vials in an up-right position (Fig. 1). To establish 'thrips present' and 'thrips absent' treatments, 20–30 adult thrips were added to 'thrips present' treatment vials. Then one female *O. insidiosus* was added to each vial. Ten replicates of each treatment were conducted simultaneously. Adult *O. insidiosus* in this experiment were purchased from Koppert Biologicals (Howell, MI) and used within 1 day of arrival. The experiment was repeated over time to obtain 20 replicates of each treatment.

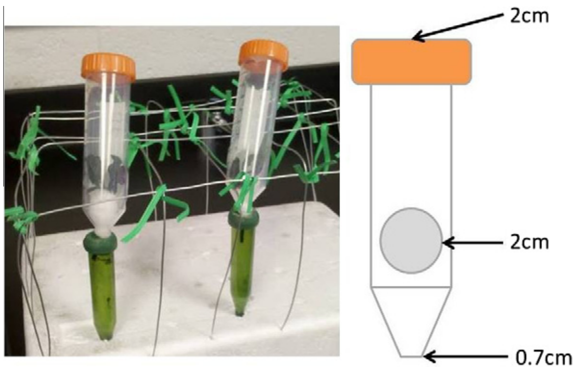

Fig. 1. Experimental arenas made from 50 ml corning vial held up by a wire grid with Black Pearl pepper stems in water picks (left), and schematic of vial with hole sizes (right).

O. insidiosus survival was determined daily by gently tapping and turning each vial until the female was found alive or dead. Living females were transferred to a new vial, set up as described, twice a week so *O. insidiosus* would have fresh plant and insect material for refuge and food. Vials were placed in an incubator at 27–28 °C and 55–60% RH for the entirety of the experiment.

Statistical analysis. We compared adult survival distribution functions using the LIFETEST procedure in SAS (SAS, 2008). The total number of days female *O. insidiosus* survived was compared with Kruskal–Wallis tests in the NPAR1WAY procedure of SAS (SAS, 2008).

2.3. Effect of pollen and thrips on development of O. insidious nymphs

To determine how pollen and thrips prey affect development of *O. insidiosus* nymphs, we conducted a factorial laboratory experiment that crossed two pollen levels (absent or present) with two thrips levels (absent or present). Experiments were conducted using *O. insidiosus* nymphs within 24 h of hatching. *O. insidiosus* nymphs were reared similarly to Kiman and Yeargan (1985) procedures. To obtain eggs, adult *O. insidiosus* were placed in a plastic container with two moist cotton balls for water, *Heliothis subflexa* Guenée (Lepidoptera: Noctuidae) eggs (obtained from NCSU colony) for food, and pole beans or green beans as an oviposition substrate. The adult colony container was placed in an incubator at 27–28 °C and 55–60% RH so adult *O. insidiosus* could lay eggs. Every 2–3 days, beans were inspected under a stereo dissecting scope for eggs. Sections of bean that contained eggs were removed and placed on filter paper in 5 cm petri dishes and placed back in the incubator. Petri dishes were inspected for newly emerged nymphs daily.

New nymphs were placed into an experimental arena. Experimental arenas were 5 cm petri dishes that contained a piece of filter paper moistened with 1–2 drops of tap water. A disc of Black Pearl pepper leaf was cut out using a 2 cm cork borer, soaked in tap-water to regain turgidity, and placed on the filter paper. To establish ‘thrips present’ treatments, 10 second instar thrips were placed in each petri dish. To establish ‘pollen present’ treatments, eight anthers from Black Pearl pepper flowers were added to each petri dish. Anthers were obtained by picking open Black Pearl pepper flowers that had pollen producing anthers and cutting the anthers out with dissecting scissors. This was done once a week or as needed and anthers were stored in a sealed plastic container in a refrigerator. As a precaution, the plastic container was filled with CO_2 and sealed for 20 min in order to kill any small arthropods, such as mites, in or on the anthers. Depending on the treatment, dishes were replenished with 4–5 anthers and 5–10 thrips (depending on how many were still alive from the previous day) so nymphs did not run out of food. Every 2–3 days nymphs were placed in new arenas with a new leaf disc and filter paper. Since nymphs were emerging daily, a few nymphs at a time were assigned to each treatment until a minimum total of 20 nymphs had been assigned to each treatment. All petri dishes were placed in an incubator at 27–28 °C and 55–60% RH for the entirety of the experiment. Arenas were inspected daily with a dissecting scope to record nymphal survival. Observation of nymphal development lasted until all nymphs had died or matured into adults.

Statistical analysis. We used logistic regression with Firth correction for sparse data in the LOGISTIC procedure of SAS (SAS, 2008) to compare the total number of *O. insidiosus* that completed development among the treatments. The total number of days required to develop from egg to adult was compared with a Kruskal–Wallis test in the NPAR1WAY procedure of SAS (SAS, 2008).

2.4. Effect of pollen and thrips on O. insidiosus adult size

To determine the effect of pollen and thrips on adult *O. insidiosus* size we conducted a laboratory experiment with two treatments: ‘thrips’ and ‘thrips + pollen’. These were the only treatments that enabled *O. insidiosus* to complete development in the previous experiment. *O. insidiosus* was reared from first instar to adult according to the procedures described in Section 2.3. Once nymphs had matured into adults, the hind tibia length was measured on 10 females from the ‘thrips’ treatment and 17 from the ‘thrips + pollen’ treatment.

Statistical analysis. T-tests were used to compare the length of adult female tibias between treatments (SAS, 2008).

2.5. Effect of flowers and thrips on O. insidiosus abundance

To determine how flowers affect *O. insidiosus* abundance on Black Pearl pepper banker plants, we conducted a greenhouse experiment with individually bagged peppers as experimental units. Two treatments were created by allowing plants to flower versus continuously picking buds and flowers from other plants. There were a total of 40 plants, or 20 replicates per treatment.

Plants were dipped in insecticidal soap (Safer Brand, Lititz, PA) every 2 days for 1 week to remove thrips and other arthropods prior to establishing either ‘flower present’ or ‘flower absent’ treatments. One week before the experiment began, individual plants were placed in a bag made from organdy fabric (Jo-Anns Fabric, Raleigh, NC; 60 cm wide × 121.9 cm tall). Two 91.4 cm bamboo stakes were inserted on the outer edge of the pot to support the bag. The top of the bag was sealed by twisting the fabric and securing it with a large binder clip. Plants remained in bags for the entirety of the experiment.

Plants in the ‘flower present’ treatment were encouraged to flower by picking all peppers and dying flowers from each plant. To establish ‘flower absent’ treatment plants, open flowers and buds were removed from each plant. This procedure was repeated the day before the experiment began and twice per week for the duration of the experiment to maintain the ‘flower present’ and ‘flower absent’ treatments. After both flower treatments were established, 20 adult thrips were also added to each plant so that thrips could lay eggs on the plants and build populations in the absence of predators. Plant material removed before the experiment began was discarded. On week zero, 1 week after treatments were established and thrips were added to plants, 20 adult *O. insidiosus* (male:female ratio of 1:1) were added to each plant.

Plants were sampled for arthropods once a week. Each plant was beaten a total of four times for four seconds each time into a 33 × 40.5 cm white tray. *O. insidiosus* adults and nymphs, and thrips were counted and collected using an aspirator. Plants were then visually inspected to count open flowers from 'flowers present' treatment plants and remove buds or open flowers from 'flowers absent' treatment plants. All trapping materials on the beat tray, picked peppers, flowers, buds, and aspirated insects were placed back on their respective plant. This was done so that any insects that were not aspirated, or eggs that had been laid on foliage, would be put back onto plants. This experiment ran for a total of 6 weeks from 6 June 2011 to 19 July 2011.

Statistical analysis. A repeated measures ANOVA was used to test the effect of flowering and non-flowering plants on *O. insidiosus* adult and nymphal abundance and thrips abundance over a course of 6 weeks. Data for both nymphs and thrips was $\log(x + 1)$ transformed to correct for non-normal distribution (SAS, 2008).

3. Results

3.1. Effect of flowers and thrips on female O. insidiosus longevity

There was no significant difference in the survival distribution functions of *O. insidiosus* in the four experimental treatments ($X^2{}_3 = 3.53$; $P = 0.317$; Fig. 2). There was a significant different in the number of days *O. insidiosus* survived among treatments ($X^2{}_3 = 12.23$; $P = 0.007$) wherein adults survived more days (mean ± SEM) with thrips (8 ± 1), flowers (6 ± 1), or both (8 ± 1) than with only leaves (3 ± 0).

3.2. Effect of pollen and thrips on development of O. insidious nymphs

Logistic regression found a significant difference among the four treatments ($X^2{}_3 = 56.3$; $P < 0.0001$) in number of nymphs that completed development. The frequency of nymphs completing development in either of the 'thrips absent' treatments was 0% regardless of the presence of pollen. Contrast statements found that significantly more nymphs in the 'thrips present' treatments completed development in the presence of thrips and pollen (74%) compared to thrips only (42%) ($X^2{}_1 = 4.93$; $P = 0.026$). There was no significant difference in the distribution functions calculated for *O. insidiosus* development time ($X^2{}_1 = 2.21$; $P = 0.136$). The number of days (mean ± SEM) required to complete development was less for *O. insidiosus* fed flowers and thrips (7 ± 0) than for those fed thrips only (8 ± 0; $X^2{}_1 = 17.80$; $P < 0.001$).

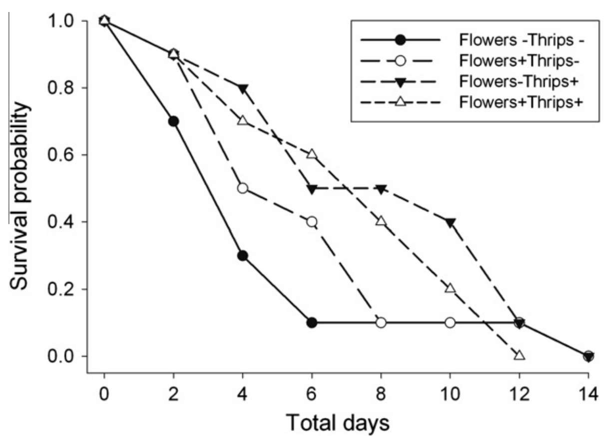

Fig. 2. Survival distribution functions of adult female *O. insidiosus* survived when fed diets of Black Pearl pepper flowers (Flower+Thrips−), *F. occidentalis* (Flower−Thrips+), both (Flower+Thrips+), or neither (Flower−Thrips−). All experimental arenas contained a Black Pearl pepper leaf disk and moist filter paper.

3.3. Effect of pollen and thrips on O. insidiosus adult size

Females fed a mixed diet of thrips and pollen had longer hind tibias (0.451 ± 0.01 mm) than females fed only thrips (0.435 ± 0.01 mm; $t = 2.17$; df = 25; $P = 0.0398$).

3.4. Effect of flowers and thrips on O. insidiosus abundance

Although some flowers were able to open in the 'flowers absent' treatment, the overall mean abundance of flowers was significantly greater on 'flowers present' plants (15.23 ± 0.99) than 'flowers absent' plants (2.07 ± 0.57) ($F = 408.12$; df = 1, 215; $P = <0.0001$). For abundance of *O. insidiosus* adults, there was a significant interaction of sampling date and treatment ($F = 6.98$; df = 5, 224; $P = <0.0001$; Fig. 3) as demonstrated by oscillating adult abundance due to population cycles. Similarly, there was a significant interaction of sampling date and treatment for abundance of *O. insidiosus* nymphs ($F = 12.53$; df = 5, 223; $P = <0.0001$; Fig. 3) due to population cycles where nymphal abundance was decreased after nymphs had matured to adults. Adult and nymphal abundance was greater in the presence of flowers ($F = 251.57$; df = 1, 224; $P = <0.0001$ and $F = 446.64$; df = 1, 223; $P < 0.0001$, respectively). Abundance for adults and nymphs changed significantly by sampling date ($F = 6.53$; df = 5, 224; $P = <0.0001$ and $F = 14.65$; df = 5, 223; $P < 0.0001$), respectively. During observation, nymphs could be seen in and around Black Pearl pepper flowers probing for pollen.

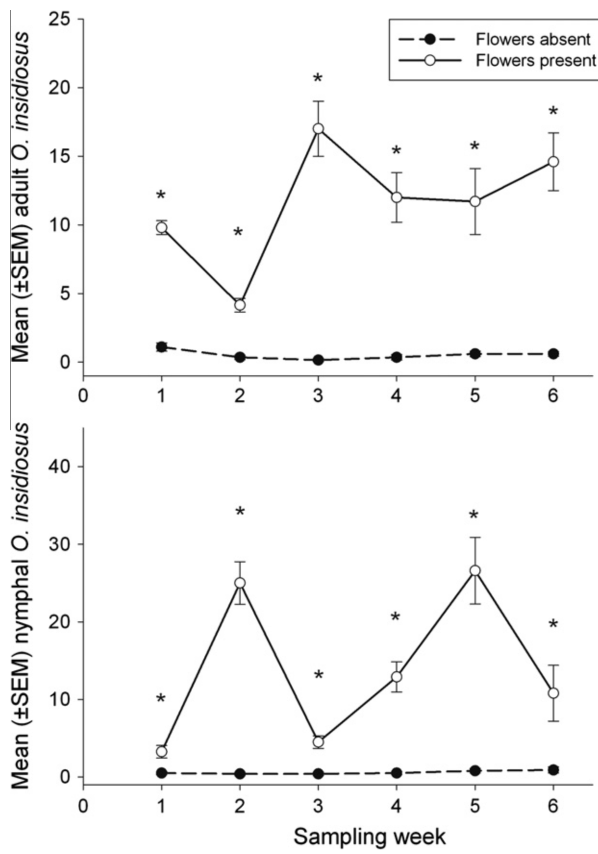

Fig. 3. Weekly mean (±SEM) abundance of *O. insidiosus* adults (top) and nymphs (bottom) found in beat samples of caged Black Pearl pepper plants with and without flowers. Overall mean abundance for adults was 11.54 ± 1.80/plant and 0.51 ± 0.13/plant for flowers present and absent, respectively. Overall treatment mean abundance for nymphs was 13.83 ± 4.06/plant and 0.58 ± 0.09/plant for flowers present and absent, respectively. *Indicates significant difference between treatments ($P < 0.05$).

Total thrips (adults + nymphs) abundance also showed a significant interaction of sampling date and treatment as *O. insidiosus* adults and nymphs ($F = 16.64$; df = 5, 223; $P < 0.0001$). Thrips abundance was greater when flowers were absent ($F = 8.49$; df = 1, 223; $P = 0.0039$; Fig. 4), and there was a significant difference in thrips abundance among sampling dates ($F = 4.7$; df = 5, 223; $P = 0.0004$).

4. Discussion

The goal of banker plant systems is to improve biological control by supporting populations of natural enemies when pest populations are low or absent (Frank, 2010). This study found that Black Pearl pepper pollen can benefit *O. insidiosus* fitness and development resulting in larger populations of the natural enemy on Black Pearl pepper plants when flowers are present. This is the first evidence that Black Pearl pepper banker plants can increase *O. insidiosus* longevity when thrips prey are absent and reduce development time and increase likelihood of survival to adult when prey are present. These results are a valuable step in validating the benefit of Black Pearl pepper banker plant systems that growers are already implementing.

The first goal of Black Pearl pepper banker plants is to reduce starvation and increase longevity of *O. insidiosus* when prey is absent by providing pollen, which allows them to survive long enough to reproduce and consume incoming or growing pest populations. Providing plant resources can improve biological control by sustaining populations of omnivorous natural enemies rather than letting them starve or emigrate from the cropping system in search of food (Landis et al., 2000; Coll and Guershon, 2002; Griffiths et al., 2008). Sometimes providing pollen in the total absence of prey is enough to sustain omnivores for a period of time (Beckman and Hurd, 2003; Carrillo et al., 2010). This study found that *O. insidiosus* females survived just as long on Black Pearl pepper flowers as on thrips or both. These results are consistent with other studies in which *O. insidiosus* have similar if not increased longevity when pollen (e.g. corn or *Acer* spp.) is present regardless of prey availability (Kiman and Yeargan, 1985; Richards and Schmidt, 1996).

Secondly, this banker plant may provide nutrition that is lacking in prey and as a result, enhance *O. insidiosus* fitness and fecundity traits when prey is present by mixing plant and prey diets. A mixed diet of pollen and thrips allowed nymphs to complete development in significantly less time than nymphs fed only thrips. These results are similar to other studies supporting the fact that mixed diets of prey and plant food can enhance various life history traits including decreasing development time (Patt et al., 2003; De Clercq et al., 2005; Lundgren, 2009). This study also found that a mixed diet of thrips and pollen as opposed to a prey only diet yielded significantly larger females. This may have positive consequences and increase female fecundity as demonstrated by other insect taxa such as Coleoptera and Hemiptera (Kajita and Evans, 2010; Moya-Raygoza and Garcia-Medina, 2010) and the generalized theory that larger individuals are more fecund (Honek, 1993). Furthermore, mixed diets of plant and prey food may provide benefits not covered in the present study, for example female ladybird beetles fed a mixed diet of pollen and *E. kuehniella* eggs had shorter pre-oviposition periods than females fed a prey-only diet (Berkvens et al., 2008).

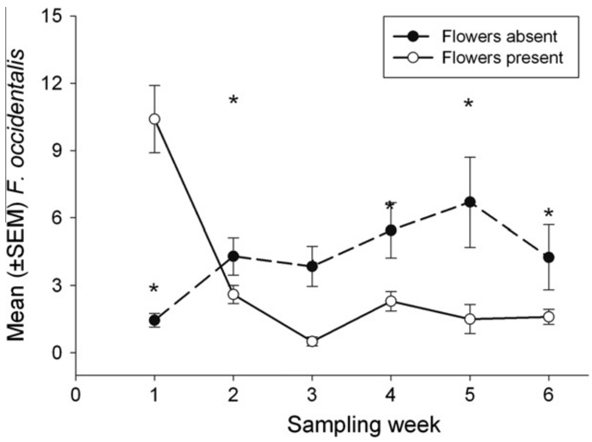

Fig. 4. Weekly mean (±SEM) abundance of thrips found in beat samples. Overall treatment mean abundance for thrips was 3.14 ± 1.47/plant and 4.33 ± 0.72/plant for flowers present and absent, respectively. *Indicates significant difference between treatments ($P < 0.05$).

In the greenhouse experiment, *O. insidiosus* abundance was significantly higher on flowering plants than non-flowering plants, which is consistent with laboratory results from this study that demonstrated that pollen increases female longevity. Survival is the first benefit of banker plants in which the goal is to increase the likelihood that adults will survive long enough to reproduce. On the first sampling date, less than five adults survived per non-flowering plant, whereas flowering plants had more than twice as many adults per plant. Thus nymphal abundance on flowering plants increased between week one and two. The lack of nymphs on non-flowering plants indicates adults that survived on these plants did not reproduce, perhaps due to decreased fecundity or increased nymphal mortality on non-flowering plants. Although not tested directly, nymphal mortality could have increased if nymphs had difficulty finding food. In addition, alternative plant resources can reduce cannibalism among juvenile insects (Frank et al., 2010).

There seem to be some compounding factors affecting *O. insidiosus* abundance on flowering plants, as there was an extreme difference in abundance between the two treatments. Few of the initial 20 adult *O. insidiosus* survived from week zero to week one on non-flowering plants, whereas nearly half survived on flowering plants. Adult populations continued to decrease from week one to week two in flowering treatments, which was not surprising as female longevity was less than 2 weeks according to our laboratory results and there were only a handful of potential adults (nymphs) found in samples on week one. However, nymphal abundance increased from week one to week two, and translated into increased adult abundance on week three, which is consistent with our laboratory results in which nymphs fed a mixed diet of prey and pollen completed development in about a week. In the absence of pollen, not only were there fewer adults to reproduce and lay eggs after the first week, it is likely that fewer nymphs completed development, and did so more slowly than nymphs on flowering plants. This same trend was seen in our laboratory results when significantly fewer nymphs completed development and developed slower on a prey only diet compared to a mixed diet of thrips and pollen. Overall, the greenhouse abundance experiment was consistent with our laboratory experiments in adult longevity and nymphal survival and development time, which, in combination, led to a dramatic difference in *O. insidiosus* abundance between flowering and non flowering plants.

In the greenhouse experiment thrips abundance was significantly lower on flowering plants compared to plants without flowers. This is inconsistent with studies demonstrating that pollen increases thrips abundance (Nondillo et al., 2009; Riley et al., 2010). However, this result provides useful insight into this system. First, the presence of flowers did not cause a significant increase in thrips abundance. In a related experiment we found that the presence of flowers did not reduce predation of thrips by *O. insidiosus* (Wong and Frank, 2012). These findings help to address important concerns growers may have about this banker plant system. Second, flowering Black Pearl pepper banker plants may be providing small sentinel populations of thrips, which would help sustain populations of *O. insidiosus*.

This study found that Black Pearl pepper pollen can enhance life-history traits of *O. insidiosus* in a number of ways: increase female longevity, decrease nymphal development time, increase female size, and increase predator abundance on flowering peppers. These results indicate that pollen from the Black Pearl pepper banker plant could be valuable tool for increasing *O. insidiosus* abundance in greenhouses. Further research is required to determine the impact of Black Pearl pepper banker plants on biological control efficacy.

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