1. Project Summary

Provide a brief summary of your project—its purpose, what you were hoping to find out, and a short description of your main findings.

The purpose of the project was to investigate effects of adding floral diversity to the edge of an organic strawberry field in Florida. We anticipated that sweet alyssum and Spanish needles would: 1) increase the number of thrips predators and decrease thrips numbers and damage they cause to strawberries and 2) increase insect and pollinator abundance and improve strawberry pollination and quality. We found that adding these two plants did not affect chilli thrips, reduced flower thrips during the early part of the strawberry season, and had a minor positive impact on predatory insidious flower bug, a thrips predator. Small positive effects due to flowers on known and potential pollinators were evident, but reduction in thrips damage to strawberry or increased quality due to improved pollination were not evident. Future efforts are being made to refine and investigate an optimal arrangement and composition of plants for adding floral diversity and optimizing pest control and pollination ecosystem services provided.

2. Introduction to Topic

Provide an introduction to the organic farming issues being addressed by this project and what led to the development of this project.

Agricultural systems have been designed to maximize production and profitability, but there is an increasing recognition for agriculture to also conserve organisms providing ecosystem services, including pollinators and natural enemies (Fiedler et al. 2008). As part of conservation efforts, habitat can be managed to enhance beneficial organisms through provisioning limiting resources in farmed landscapes (Landis et al. 2000). In many cases resources are delivered through intentional use of plants and plant communities that provide pollen, nectar, shelter, oviposition sites or alternative hosts. Organic agriculture is well-suited for the use of flowering resources because of minimal or lack of disruptive practices, such as insecticide use (Zehnder et al. 2007). There is a tremendous need to explore the potentially positive effects of flowering plants on pollinators and natural enemy/pest interactions in southern USA horticultural systems.

Strawberry production is an important industry in Florida with 11,000 acres and a production value of over $300 million (USDA 2014). The majority of acreage is the Plant City area of Hillsborough County, where large fields are managed intensively and insecticides are relied on for pest control. Florida is the primary winter supplier of strawberries in the USA, yet lags behind other production regions in certified organic acreage. However, beginning this production season (November 2015 to March 2016), three new fields, totaling about 100 acres, were developed and certified under the National Organic Program. This presents an exciting and new opportunity to develop integrated pest and pollinator management strategies to support organic production.

Thrips are a pest of significant concern in many horticultural crops worldwide, including Florida strawberries. A species complex in strawberries often exists where native Florida flower thrips (*Frankliniella bispinosa*) (FFT) predominates and invasive Western flower thrips (*Frankliniella occidentalis*) (WFT) is often present at lower levels. Both species accumulate towards the end of the strawberry season. In addition, the invasive chilli thrips (*Scirtothrips dorsalis*) causes damage to foliage and fruit, but is more abundant early in the season when temperatures are typically warmer.

Insidious flower bugs (*Orius insidiosus* and *O. pumilio* in Florida) are efficient thrips predators, effectively suppressing thrips at a 1:180 ratio on pepper flowers (Funderburk et al. 2015). The population dynamics of *Orius* and thrips in Florida strawberries are not well-known but are currently being studied by the J. Funderburk laboratory. Initial observations in 2014-2015 showed low *Orius* abundance in many fields, likely due to lack of habitat and/or use of insecticides harmful to *Orius*.

As has been shown in other systems, intentional use of flowering plants are an effective method to increase *Orius*. In everbearing strawberries in the UK, alyssum, *Lobularia maritima*, was used to boost *Orius laevigatus* numbers, resulting in improved WFT suppression in adjacent strawberry flowers (Bennison et al. 2011). In Florida peppers, sunflower, *Helianthus annus*, resulted in FFT increases followed by *Orius* increases, with the number of *Orius* reaching levels sufficient to suppress less-numerous WFT (Tyler-Julian et al. 2014). In addition to being attractive to *Orius*, an appropriate flowering plant(s) in Florida strawberries will need to be frost tolerant, low-growing so as not to shade strawberries, quick to flower after planting or continuously flowering, easy to manage and sustain, and amenable to Florida moisture and humidity levels.

Flowering plants can benefit *Orius* populations for different reasons. In Florida, *Orius* were found in flowers of sunflower, clover, beggar ticks, creeping oxeye, crape myrtle, and Queen Anne's lace growing in agricultural landscapes likely because thrips were also present (Bottenberg et al. 1999, Funderburk et al. 2015, Shirk et al. 2012). Adult *Orius* also benefitted from floral and extrafloral resources in vegetationally diverse plots of row crops that included common weeds but also morning glory, chamomile, phacelia, buckwheat, alyssum, fava bean that were favorable for oviposition and nymphal development (Pumariño et al., 2012, Lundgren et al. 2009). During winter in central Florida a proportion of *Orius* are likely in reproductive diapause, but increasing daylength in late February/March when thrips are most problematic may trigger oviposition and thus affect flowering plant choice.

Many economically-important fruit crops are dependent on insect-mediated pollination for high yields (Delaplane and Mayer 2000). Most pollination is provided by managed honey bee colonies, but native bees and other managed bees can contribute substantially to specialty crop production. In recent years though, populations of managed and native bees have suffered declines that can be linked to agricultural intensification and the resulting loss of foraging and nesting habitat, among other factors. Recent studies have shown that this trend can be reversed and that native bees can also contribute to crop pollination where their habitat needs are met. Native pollinators, most importantly wild bees, provide valuable services and can potentially enhance productivity and profitability through increased yields and improved crop quality.

Strawberries are a specialty crop that can significantly benefit from biotic pollination despite having hermaphroditic and self-pollinating flowers. For the flower to develop into a perfect fruit, every pistil must be pollinated and insufficient pollination can result in malformations.

This means self-pollination and wind are generally insufficient to produce highest quality fruit, and that open pollination by insects will increase fruit set, yield and the overall crop economics. It is widely believed that creation of bee habitat in farmland, enhancement of existing bee habitat adjacent to farms, or supplementing bee floral resources, can allow greater bee survival, reproduction, and crop pollination. In many cases, such enhancements involve the planting of wildflowers or other blooming plants for forage within or adjacent to the target crop. Recent studies in Florida have demonstrated potential of different wildflower mixes or species to attract native pollinators and to support honey bees in agricultural landscapes (Williams et al. in press). Of more than 20 native Florida ecotypes and naturalized flowering plants tested, several including *Gaillardia pulchella, Coreopsis basalis, Coreopsis lanceolata*, and *Chamaecrista fasciculata*, were highly affordable, performed well in agricultural settings and attracted a high diversity of native bees and other pollinating insects.

3. Objectives Statement

State your original objectives as outlined in your project proposal. Were there any changes in your objectives as the project unfolded? Please describe any differences from the original proposal and why these changes were made. This is valuable information for others who are studying the same topic and essential for our evaluation of the project.

The primary objective of our project is to determine the effect and feasibility of flowering plants as resource subsidies for beneficial insects in organic strawberry production in Florida. Measurable outcomes include:

1. Enhance pollinator and natural enemy abundance and diversity
2. Reduce thrips numbers and thrips damage to strawberries
3. Improve berry quality and yield
4. Determine cost-effective and practical methods for establishment and maintenance of flowering plants

The extension objective of our project is to provide organic and conventional growers with knowledge about the importance of conserving pollinators and natural enemies, skills to identify these organisms, and practical tools and recommendations to implement conservation practices, such as using flowering plants. Demonstrating a novel tool that is effective in improving organic strawberry production and pest control, will provide impetus for increased acreage of organic strawberries in future years.

Our project objectives did not change considerably as the project unfolded.
For outcome 1 we focused on abundance of insidious flower bug (*Orius* spp.), a common and effective thrips predator, rather than overall natural enemy abundance and diversity.
For outcome 4 we also recorded growth parameters (height, size, flower number) of the flowering plants we used.

4. Materials and Methods

Describe your project methodologies and materials used. Where were the trials conducted and what is the certification status of these sites? How were treatments applied? What data were collected and how? What statistical analyses were conducted? Maps or drawings of the site *and/or any special apparatus used are very helpful (hand drawings are fine). Provide as much detail as possible in this section.*

Experiment set-up and design

The experiment was conducted on a 50+ acre organic strawberry field located south of Plant City, FL (27° 56' 19'' N; 82° 7' 58'' W). This field is owned and farmed by Astin Farms Inc. and certified since November 2015 under the USDA NOP by Quality Certification Services located in Gainesville, FL.

Flowering plants – sweet alyssum (*Lobularia maritima*, 'Snow Crystals') and Spanish needles (*Bidens alba*) were grown from purchased or saved seed planted in plug trays with growing media in the greenhouse about 1 month in advance of the transplant date. Plugs were transplanted into the strawberry field on October 12, 2016, the same day strawberries were transplanted. Flowering plants were placed along one edge of the strawberry field in three blocks. Half of each block was planted with flowering plants and the other half had strawberry transplants (Fig. 1). Sweet alyssum was planted into the strawberry bed, in place of strawberry plants, and Spanish needles were planted into the shoulder of the bed, making planting holes in the plastic every 15-16 inches.

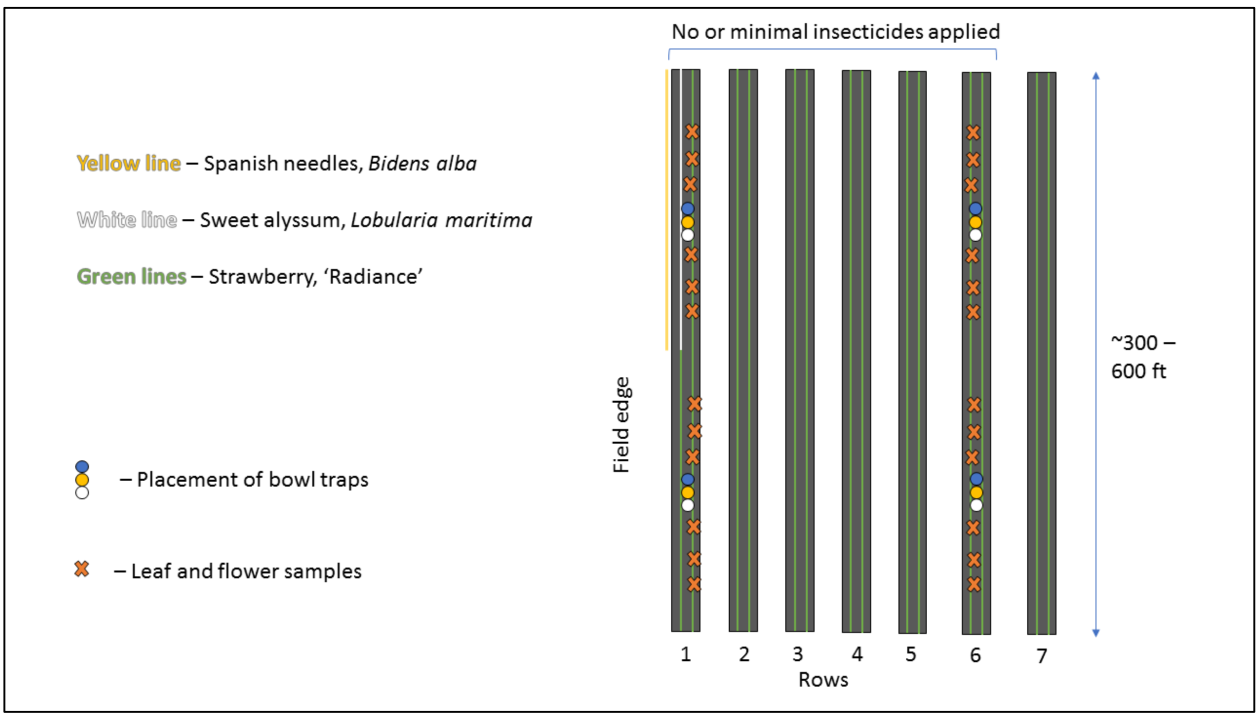

Figure 1. Flowering plant experimental design, showing placement of flowering plants and strawberries and sampling locations. One block (replication) shown.

Data collection

1. Sweet alyssum size was assessed by measuring the diameter and height of 10 randomly chosen plants per replicate about twice monthly (8 times total). Diameter and height was

used to calculate an estimated plant volume. Spanish needles height was measured twice monthly (8 times total) from 10 randomly selected plants per replicate. Spanish needles flower number was counted from 10 plants per replicate on the first two sampling dates (November). From December, once plant growth overlapped, flowers were counted in 10, 0.25 m^2 quadrats per replicate.

2. Chilli thrips were assessed by collecting 10 young strawberry trifoliates in Rows 1 and 6 of each plot (a plot is half of one block, either with or without flowering plants on edge) twice monthly from November to February. Leaves were washed in 70% ethanol to extract thrips and adults and larvae were counted under a stereomicroscope.
3. Flower thrips and insidious flower bugs were assessed by collecting 20 fully-open strawberry flowers in Rows 1 and 6 of each plot twice monthly from late November to late February. Flower thrips and insidious flower bugs were also assessed from 20 Spanish needles flower and 20 alyssum racemes. Flowers were placed into vials with 70% ethanol. Thrips and bugs were identified under a stereomicroscope.
4. Pollinators were assessed by placing bowl traps (plastic blue, yellow and white bowls) on the plastic mulch between strawberry plants in Rows 1 and 6 of each plot twice monthly in December and January. Bowls were partially filled with soapy water. After 48 h, water with drowned specimens was poured into jars (combining from all bowl colors) with 70% ethanol. Pollinators were pinned and identified.
5. Strawberry flower visitation rates were assessed once in December and twice in January and February by visually counting pollinators in open flowers in Rows 1 and 6 of each plot. The numbers of flowers observed was recorded as well as the "type" of pollinator (eg, hover fly, honey bee, other type of bee, wasp).
6. Strawberry yield, quality and damage was assessed by sorting, counting and weighing all strawberries harvested in Rows 1 and 6 per plot by Astin Farm pickers. Pickers placed unmarketable strawberries in separate containers instead of discarding them on the ground. Due to some miscommunication with farm managers, yield data was assessed only once, December 16.

Data analysis

Data was analyzed using mixed-model analysis of variance, comparing separately effects in Rows 1 and 6 between plots with and without flowers. Block was included as a random effect. Means across dates were statistically compared using Tukey's HSD test. Means within dates are also shown for most assessments.

5. Project Results

Present your project results. Quantitative results (numerical and/or statistical data) and qualitative results (descriptions of how well or poorly something worked) are both important. Tables, graphs and other figures representing your data are excellent ways to summarize data and present them in an accessible way.

1. Sweet alyssum grew well, increasing about 5X in size from early November to late January. Size declined slightly in February as flowers began to senesce (Fig. 2). Spanish needles produced flowers up to a maximum of about 25 per ¼ m^2 in mid-January (Fig. 2).

2. Chilli thrips were not significantly affected by presence of flowers in Row 1 or 6 ($p > 0.05$). However, on the first sample date, Nov 9, there were relatively few chilli thrips in strawberries next to flowers in Row 1, whereas on some sample dates, chilli thrips numbers were slightly greater in strawberries in Row 1 next to flowering plants (Fig. 3).
3. Flower thrips larvae were significantly affected by presence of flowering plants in Row 1 (flowers*date interaction, $p = 0.03$). There were fewer larvae in strawberry flowers next to flowering plants in December, and a significant decline in the number of thrips larvae during December (Fig. 4). There were no significant effects of flowering plants on thrips larvae in Row 6. Adult flower thrips were not significantly affected by flowering plants in Rows 1 or 6 ($p > 0.05$), although means were generally greater across dates from plots without flowering plants (Fig. 5). Predatory insidious flower bugs were not significantly affected by the presence of flowering plants ($p > 0.05$). Overall, numbers recovered tended to be low (1 per 20 flowers), but numbers increased somewhat in strawberry flowers next to flowering plants after thrips numbers peaked (Fig. 6).
   Flower thrips and predatory insidious flower bugs were found on sweet alyssum and Spanish needle flowers (Fig. 7). Numbers on Spanish needles tended to be higher than on sweet alyssum.
4. Total insects captured in bowl traps was significantly different between plots with or without flowering plants in Row 1 ($p < 0.05$) but not Row 6 ($p > 0.05$) (Fig. 8). Of the potential pollinators and pollinators, wasps were more abundant in Row 1 near flowering plants than in plots without flowering plants (Fig. 8). The distribution of bees, flies and wasps was 13% Apidae (honey bees), 13% Halictidae (sweat bees), 19% Syrphidae (hover flies), 44% Pompilidae (wasps) and about 10% other wasps and unknown specimens.
5. Flower visitation rates by all pollinators + potential pollinators were significantly different between plots with and without flowering plants in Row 6 ($p < 0.05$) but not in Row 1 ($p > 0.05$). The visitation rate in Row 6 for plots with flowering plants was about twice as high as in plots without flowering plants (Fig. 9). The distribution of flower visitors was 47% honey bees (*Apis* spp.), 13% other bees, 19% hover flies (Syrphidae), 13% other flies. No bumblebees were observed.
6. Strawberry quality – measured by the type of damage recorded on ripe fruit – was not different between plots with our without flowering plants for Rows 1 or 6 ($p > 0.05$). The percent of strawberries that were cracked and/or bronzed (likely due to thrips damage) was 10-20% and the percent misshapen (potentially due to poor pollination) was 5-10% (Fig. 10).

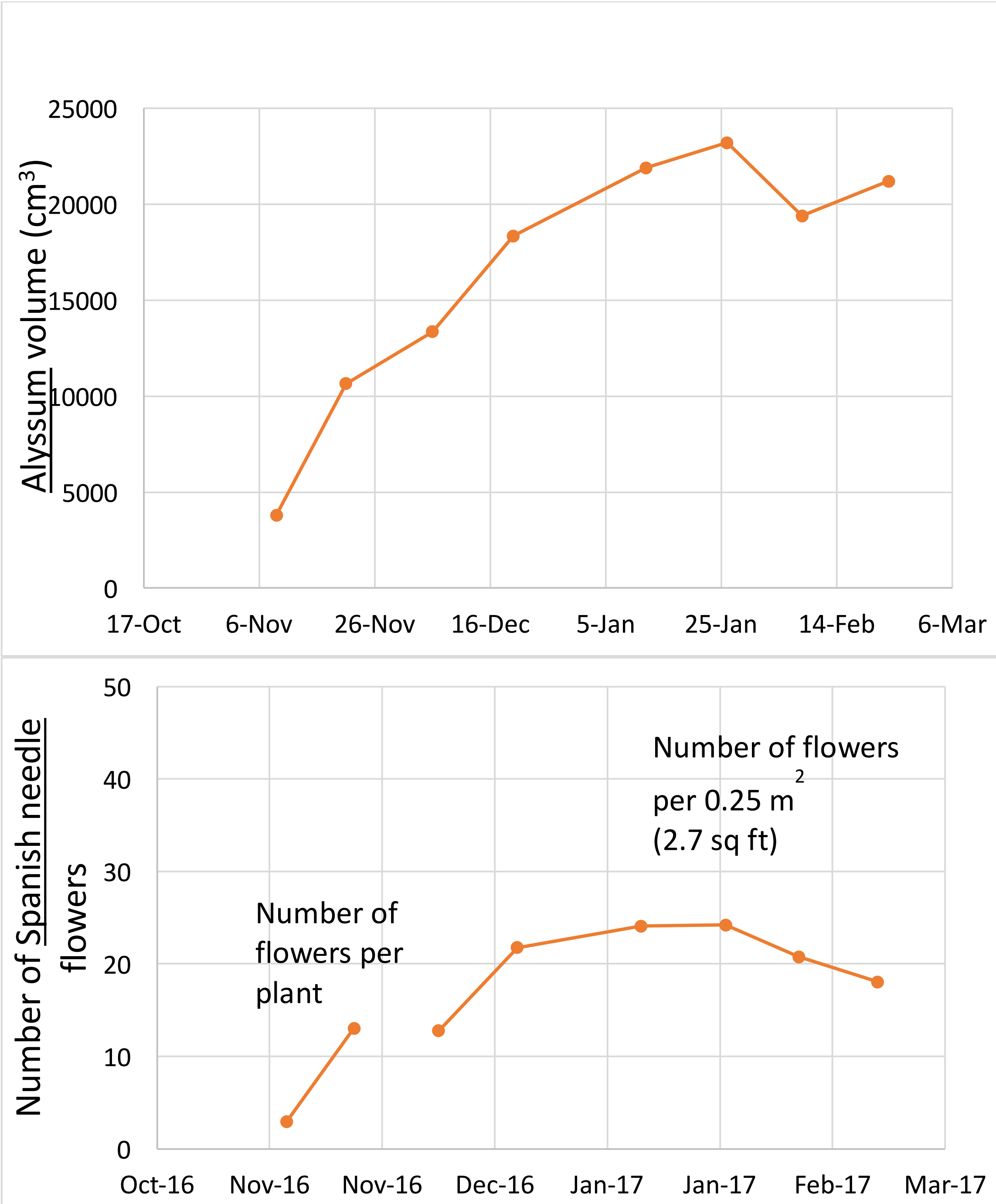

Figure 2. Flowering plant growth characteristics – sweet alyssum volume and numbers of Spanish needles flowers.

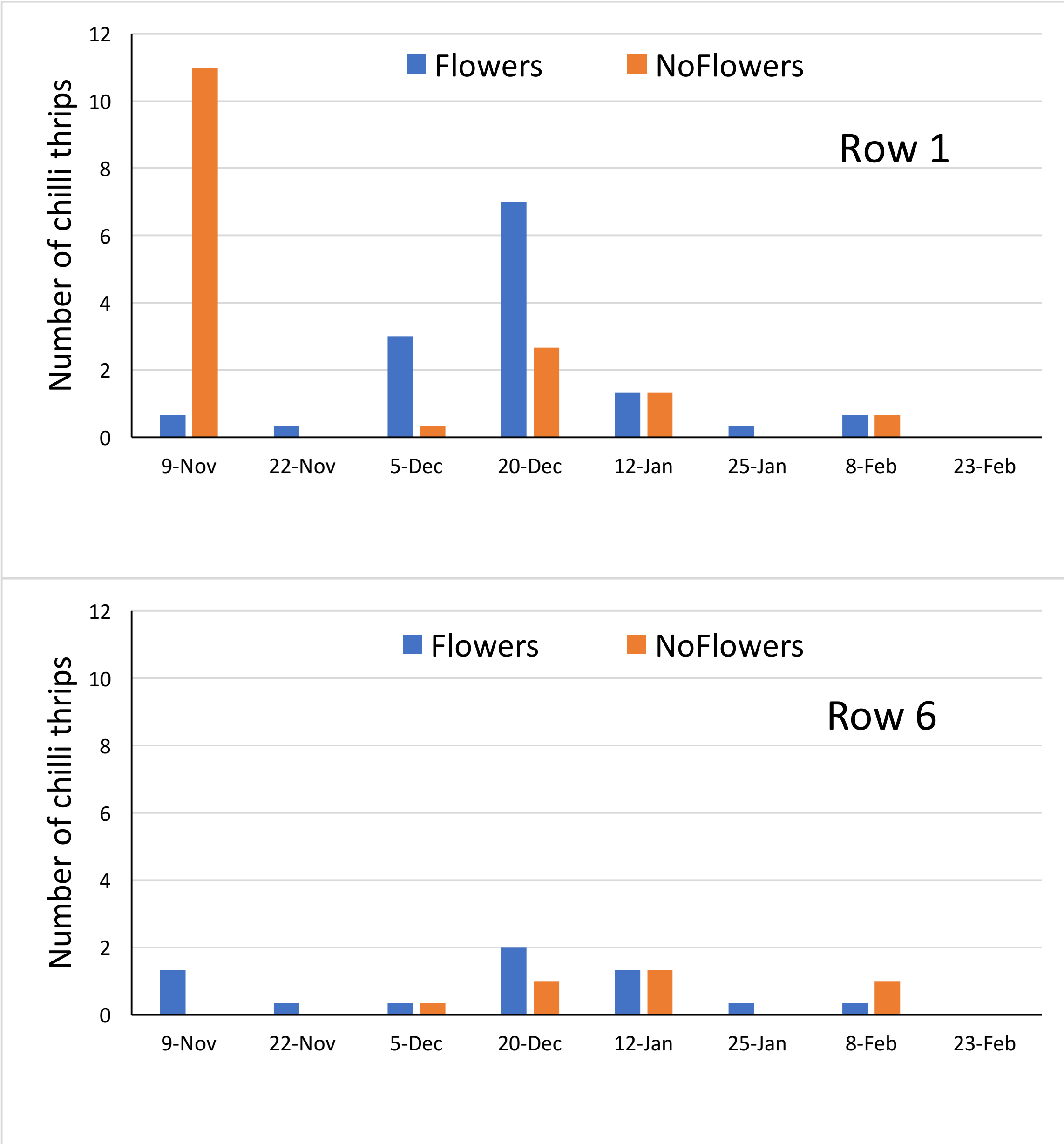

Figure 3. Chilli thrips recovered from 10 strawberry trifoliates, 2016-2017.

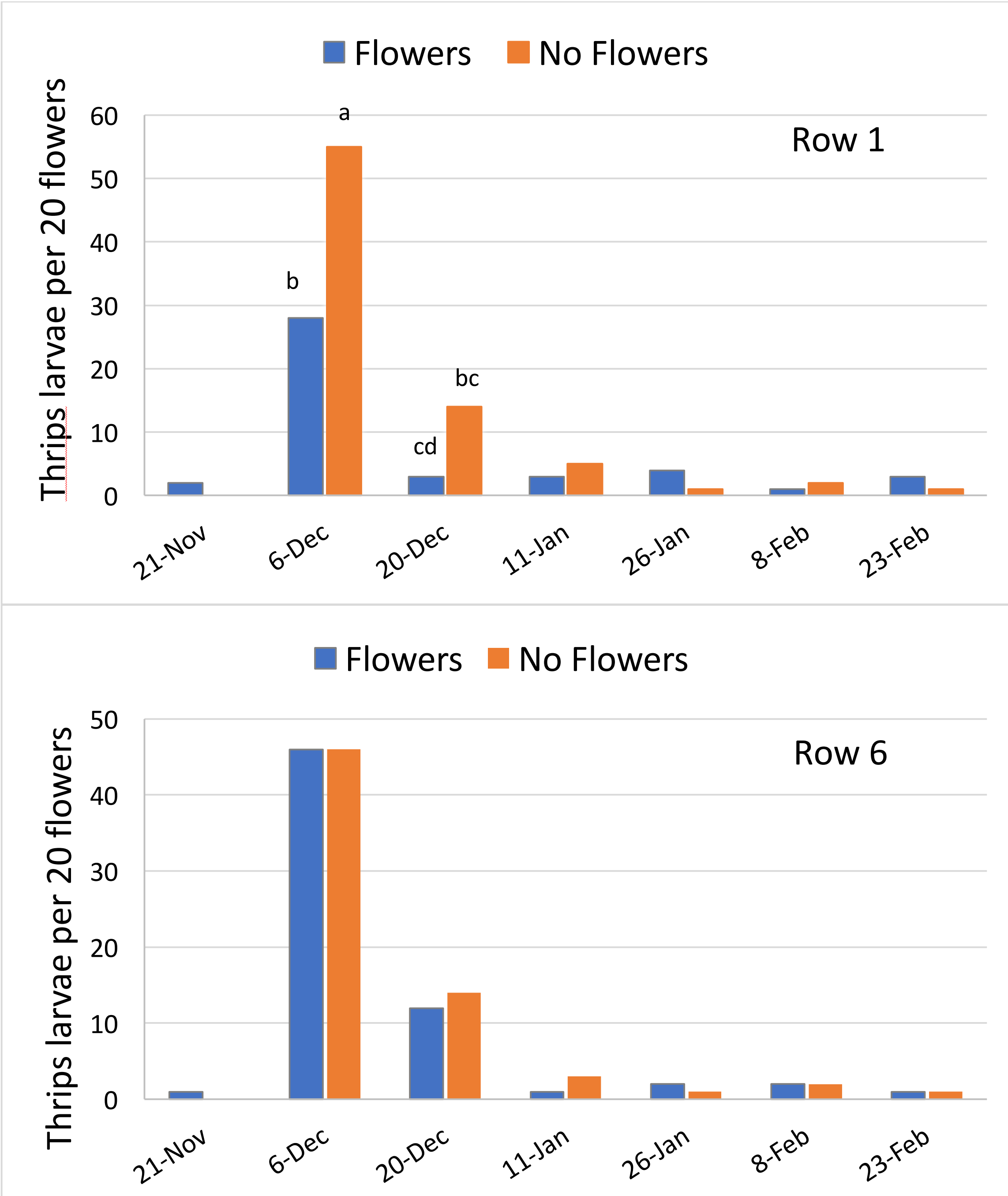

Figure 4. Flower thrips larvae recovered from 20 strawberry flowers, 2016-2017.

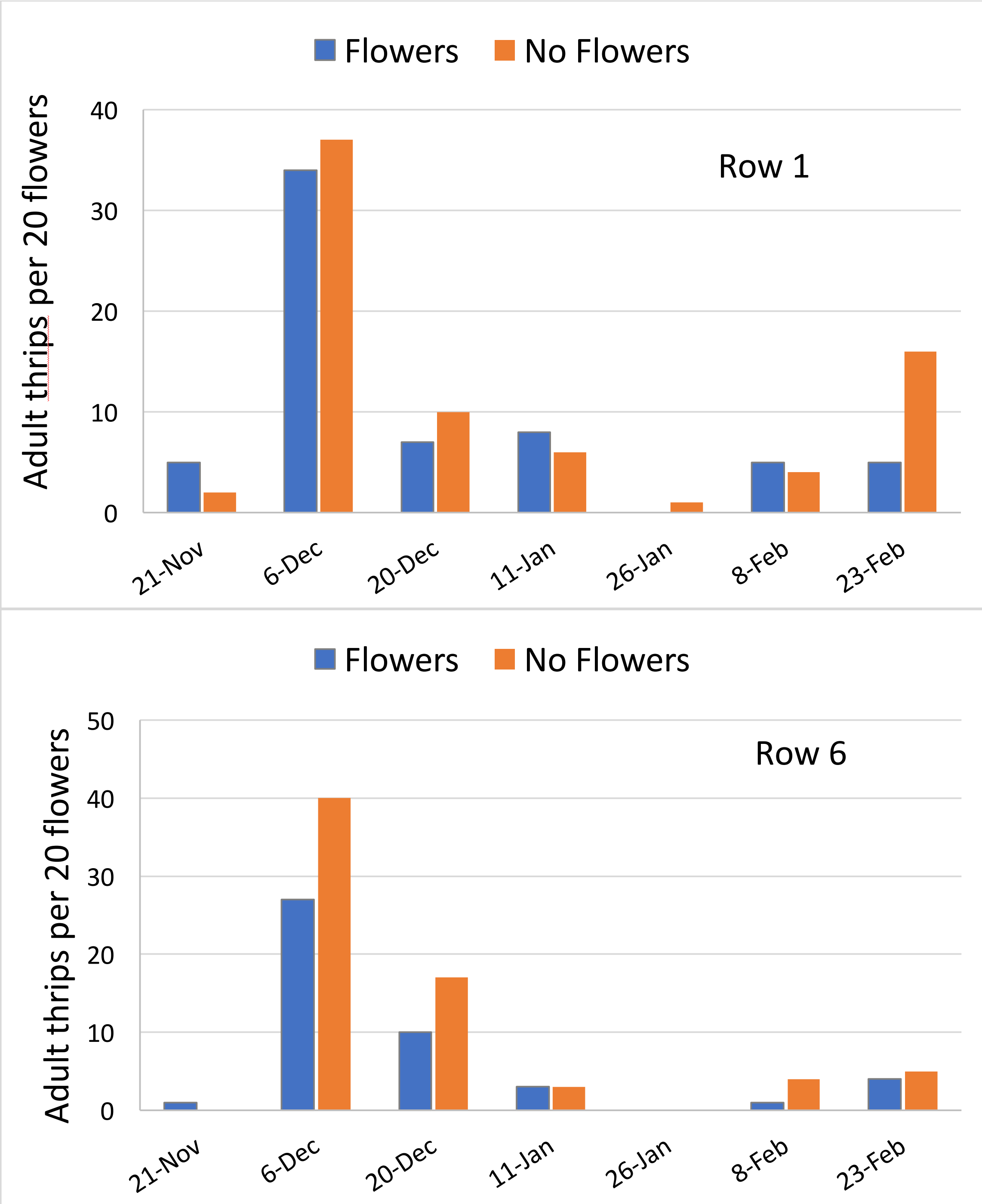

Figure 5. Flower thrips adults recovered from 20 strawberry flowers, 2016-2017.

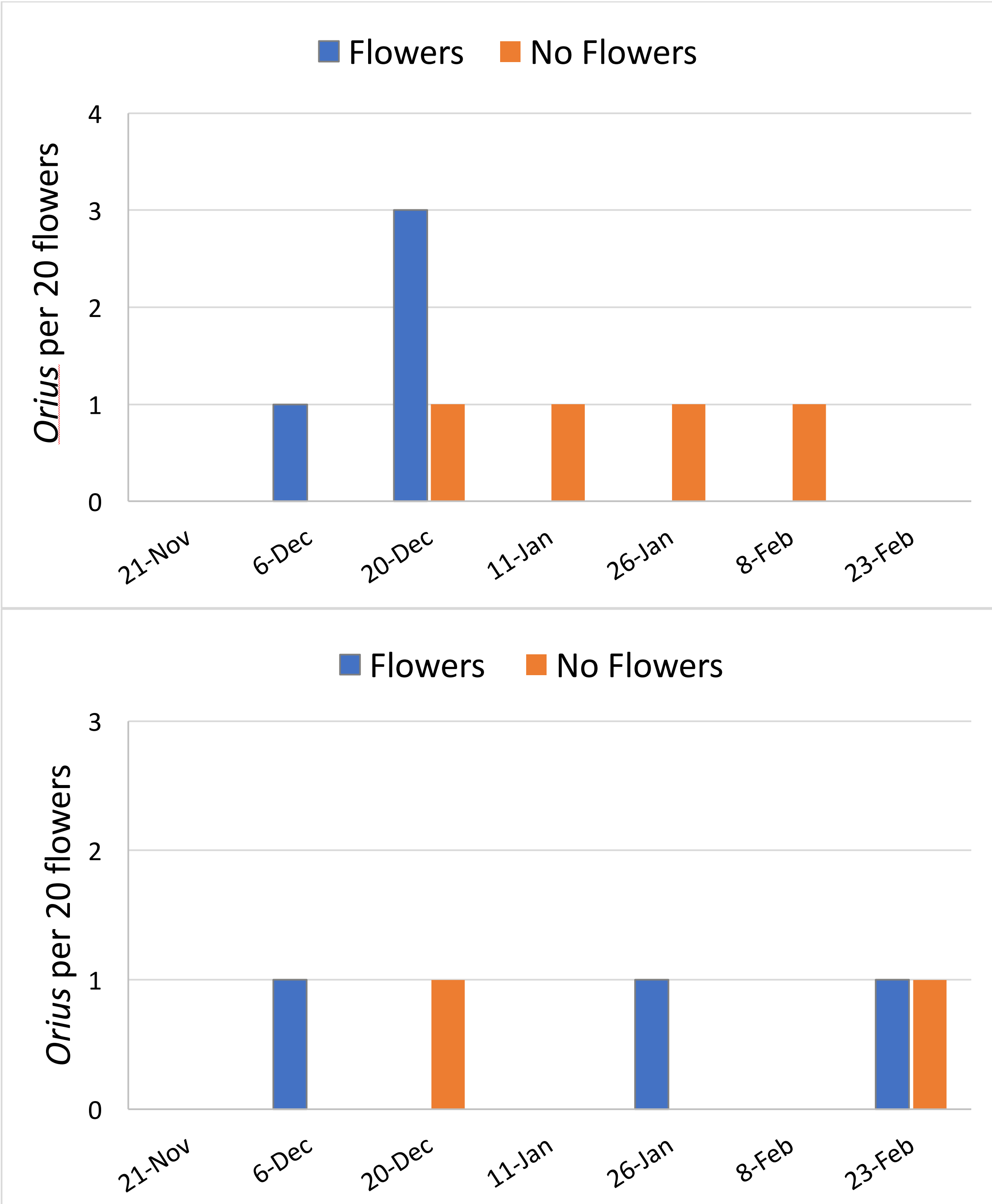

Figure 6. Insidious flower bugs (*Orius* spp.) recovered from 20 strawberry flowers, 2016-2017

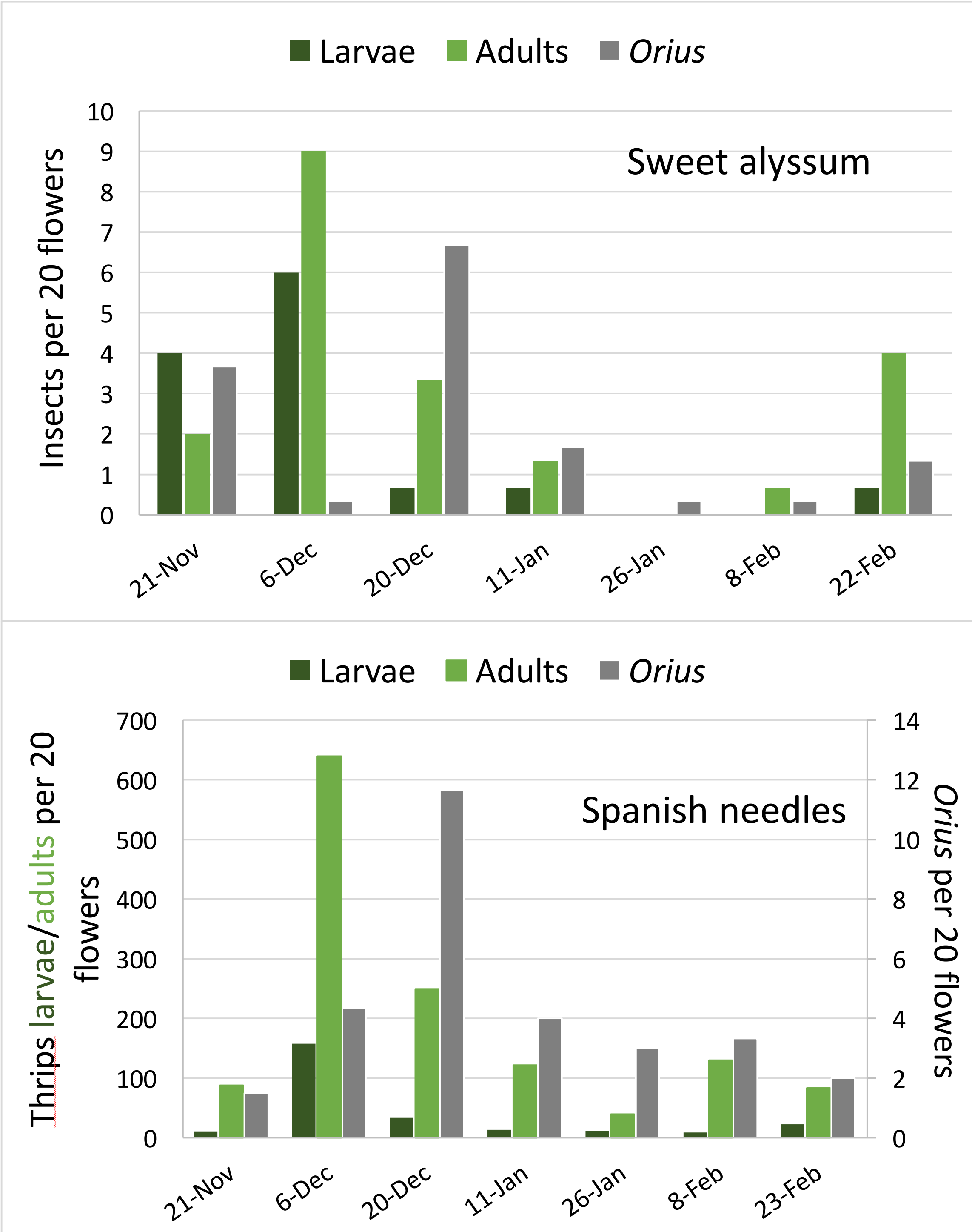

Figure 7. Flower thrips larvae and adults and insidious flower bugs (Orius spp.) on sweet alyssum and Spanish needles planted on a strawberry field edge, 2016-2017.

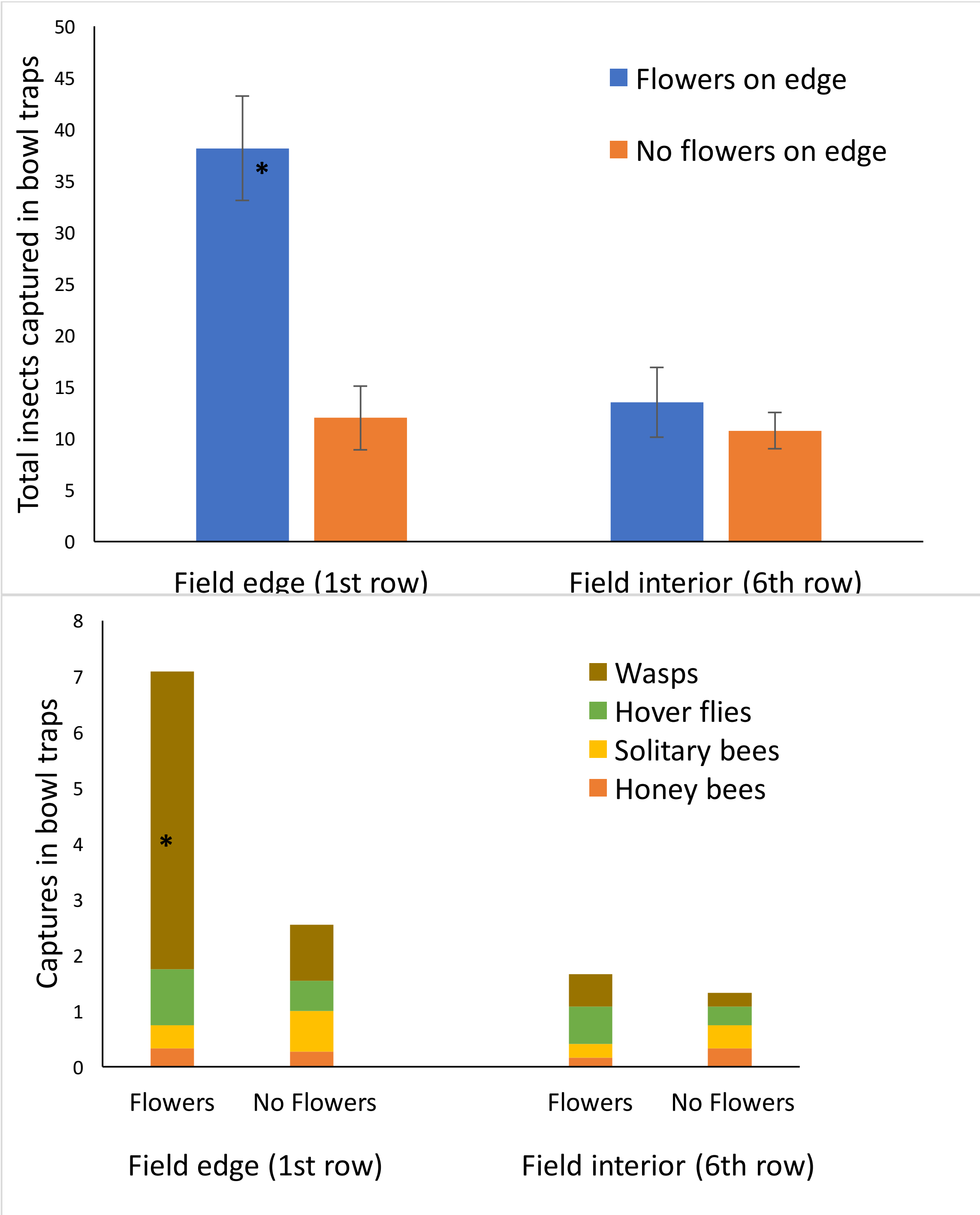

Figure 8. Results of bowl trap captures in organic strawberry. Data summed across trapping periods in Dec and Jan 2016-2017. Asterisks denote significantly different means.

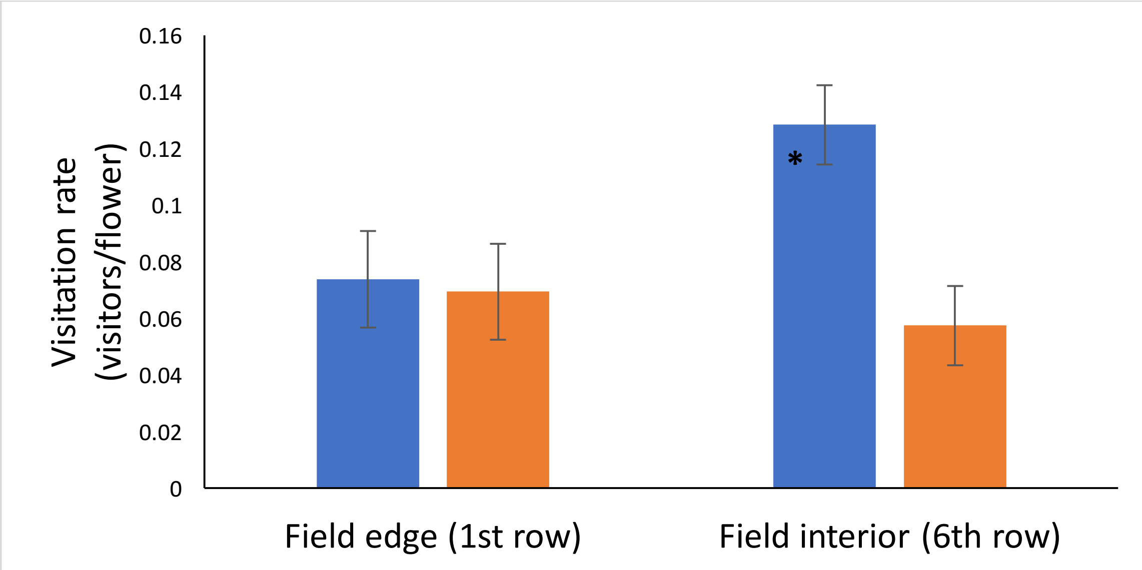

Figure 9. Insect flower visitors on strawberry, data combined from assessments 22 Dec, 12 and 26 Jan, 10 and 23 Feb, 2016-2017. Asterisk denotes significantly different mean.

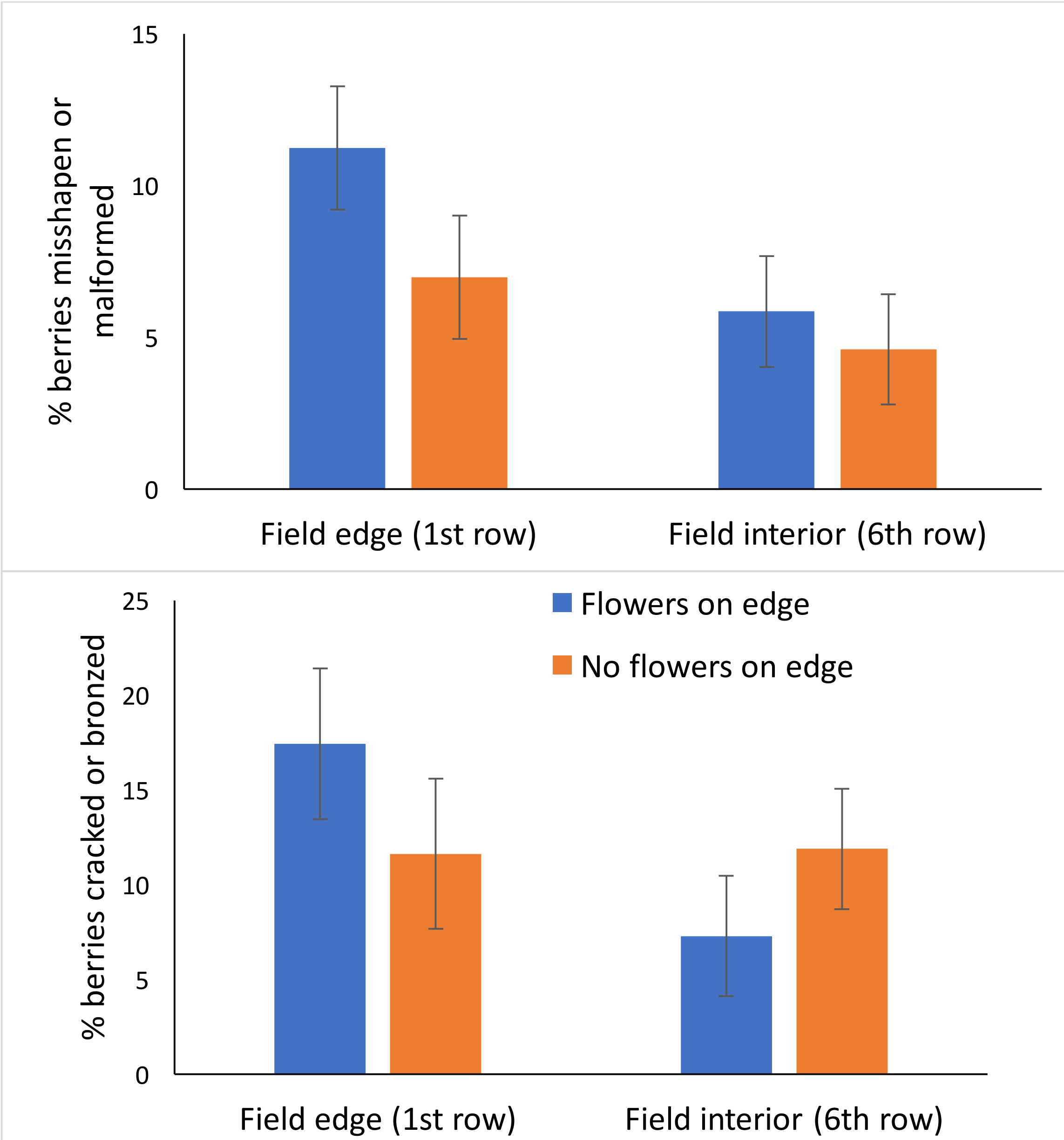

Figure 10. Strawberry quality determined by the type of damage recorded on 16 Dec 2016.

6. Conclusions and Discussion

Discuss the results of the project and what you found out. What do the results lead you to believe did, or did not, happen? In the end, how useful was this project to you and the farm operation? How useful do you feel the study and results will be to other organic farms? Did you encounter any problems during the project? What would you do differently if you did this project again? What are the farmer-ready applications of the research results? Based on what you've learned, what do you think should be studied next?

Our results illustrate that flowering plants – a combination of sweet alyssum and Spanish needles – on the edges of an organic strawberry field in Florida have mixed results on the pest and beneficial organisms studied in this project. Flower thrips numbers were lower next to flowering plants, but chilli thrips numbers were not consistently lower next to flowering plants. The predatory insidious flower bug benefitted from the flowering plants and was likely responsible for limiting flower thrips in the strawberries. Despite lower flower thrips, lower thrips-related damage on strawberries was not found. Pollinator and overall insect abundance were higher when flowering plants were used. However, even though greater visitation rates were recorded, improved strawberry pollination and quality was not evident.

The project was useful as it showed to the research and strawberry farming community that adding floral diversity can/has future potential to improve pest management and pollination in Florida strawberries. Results have been useful to the PI in securing on-going funding to continue the efforts begun by this project. As the organic acreage of strawberry in Florida is increasing annually, the results of this and the ongoing research will be highly valuable to support new, organic farmers.

We encountered several problems during the project. Miscommunication between the farmer and researchers meant that yield and damage data was collected just once. Shortly after the Spanish needles were planted, farmworkers mistakenly pulled them out of one replication, thinking they were weeds. The transplants were replanted, but the plants in that replication did not grow as large as in the other two replications. The experiment was conducted on the west side of the field adjacent to a small road and large live oak trees. This meant that the flowering plants did not receive full sun, limiting their growth and therefore potential to positively impact pest control and pollination.

We are planning to repeat different iterations of this experiment in future seasons. In addition to considering the amount of sun/shade due to field edge characteristics, we will also reconsider placing sweet alyssum in the same bed as strawberry plants. We noticed, but did not measure, that strawberry plants were smaller next to alyssum than in plots without alyssum (next to other strawberry plants). Alyssum is an aggressive plant and seems to out-compete strawberry plants. We will consider whether placing flowering plants outside of the field is a better option than mixing strawberries and flowering plants in a raised bed. In addition, we may consider using other flowering plants, such as blanketflower (*Gaillardia*) and borage (*Borago officinalis*), as we have had success with these in small-plot projects.

In the upcoming strawberry season, we plan to repeat this experiment on a conventional farm (see below about SSARE funding). We also plan to better measure and understand the interaction between growth of strawberry and flowering plants in the same bed (not only alyssum but also other plants). We also plan to consider whether a larger, more diverse planting of flowers, both annuals and perennials, outside a field is a better approach to habitat conservation than annuals in a strawberry field.

Overall, the exploratory nature of the research undertaken in this project has garnered interest with strawberry growers to continue efforts focused on refining methods for flowering plant use to reduce pests and boost pollinators. While we did not produce a ready-made application for growers, we increased their knowledge on biocontrol of thrips and pollinators in strawberry fields and ways to approach biodiversity conservation.

7. Outreach

Describe in detail the type of outreach that you did, or expect to do, including any publications, tours, or other presentations of your project to the public. Include the number and type of people (students, researchers, farmers, etc.) reached through outreach activities as part of this grant.

Our primary outreach activity was a half-day workshop/research presentations at the Gulf Coast Research and Education Center, University of Florida on June 7. The event was attended by about 15 strawberry growers from Hillsborough County/central Florida and 15-20 extension, industry and academic personnel. Strawberry growers were those currently growing organic, planning to grow organic and considering organic production. Joseph Funderburk presented general information on thrips identification and biological control, Josh Campbell (in place of Jaret Daniels) on pollination in strawberry and pollinator identification, and Justin Renkema and Iris Smith on this project's results. Attendees were enthusiastic about the presentations and asked many good questions.

After the OFRF project presentations, other faculty at GCREC presented results of their research trials on organic management of diseases, weeds and nematodes in Florida strawberry.

An article about the OFRF project outreach event was written by Jim Frankowiak for In the Field Magazine, a local Florida publication read by those in the agricultural industry. The article is on p. 48-49 of the July-August 2017 Hillsborough County edition, found at: http://inthefieldmagazine.com/view-back-issues/hillsborough-county-issues/current-issue/

8. Financial accounting

Please provide a list of the expenditures made to conduct this project. OFRF requests that any unspent funds be returned to OFRF.

Category	Budget	Spent	Details
Personnel - wages	$7,118.00	$1,854.87	Graduate assistantship (26%) to PhD student Babu Panthi working on the project
	$5,674.00	$10,801.80	Hourly wage (50%) to OPS Shashan Devkota working on the project
Personnel – fringe benefits	$947.00	$1,202.96	Benefits paid for personnel working on the project at University rates
Materials and Supplies	$950.00	$879.75	Seedling trays, alyssum seeds, plastic pots, potting soil, measuring wheel, fertilizer, plastic storage vials, ethanol, PVC piping, plastic bowls, plastic bags, batteries, bowl trap set-up accessories
Travel	$200.00	$143.27	Fuel costs for university vehicle to make field visits for data collection
TOTAL	$14,889.00	$14,882.65	

9. Leveraged resources

OFRF encourages grant recipients to acquire additional funding to continue projects initiated with OFRF funds. Please document any additional funding you have acquired to date to continue or expand the work.

Funding was secured from Southern Sustainable Agriculture Research and Education (SSARE; On-farm grant, $15,000, 2-years) to conduct a concurrent study in a conventional strawberry field using the same protocol as the OFRF project.

Funding was secured from the Specialty Crop Block Grant Program in Florida to develop management strategies for thrips in strawberry and blueberry. An objective of the project is to continue evaluating flowering plants for thrips control.

Funding was secured from a University of Florida – Institute of Food and Agricultural Sciences through an Early-Career Scientist Grant to Justin Renkema to evaluate trophic interactions among invertebrates in strawberry fields augmented with flowering plants.

10. References

Provide a list of references you used to help develop your project and/or that you referred to in the body of your report.

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11. Photos and other addenda

We require the submission of ***photos*** *of your project site, of the results of different treatments, and/or of project cooperators and field demonstrations. Additional materials, such as videos, articles about the project, scientific articles, Extension bulletins, theses, or related research reports, are welcome and appreciated.*

Picture showing the arrangement of Spanish needles and sweet alyssum on the edge of a Florida organic strawberry field, mid-November 2016. A flower thrips adults and predatory insidious flower bug adult depicted above.
Additional pictures of the same experiment, but at a conventional field (SSARE project), can be found at: https://jmrlab.wordpress.com/2016/12/06/flowering-plants-along-strawberry-field-edges/