CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE
SPECIALTY CROP BLOCK GRANT PROGRAM
FINAL PERFORMANCE REPORT

USDA Project No.:	Project Title:	
31	Best management practices for hybrid onion seed production to improve crop sustainability in California	
Grant Recipient: The Regents of the University of California, UC Cooperative Extension	**Grant Agreement No.:** SCB10031	**Date Submitted:** August 14, 2014
Recipient Contact: Rachael Long	**Telephone:** 530-681-7661	**Email:** rflong@ucdavis.edu

Grant Award Amount (A)	Amount Invoiced to Date (B)	Remaining Grant Balance (A-B)	Program Income	Committed Match/In-Kind Funds	Match/In-Kind Funds Spent to Date
$	$	$	$	$	$

Project Summary

- Provide a background for the initial purpose of the project, which includes the specific issue, problem, or need that was addressed by this project.
- Establish the motivation for this project by presenting the importance and timeliness of the project.
- If the project built on a previously funded SCBGP project, describe how this project complimented and enhanced previously completed work.

The purpose of our research was to develop best management practices for hybrid onion seed production to address the variable, unpredictable, and declining yields in California. Hybrid onion seed production in California is primarily in Colusa Co. and the Imperial Valley, on about 2000 acres, and valued at $12 million annually to growers and $40 million in retail sales to industry. While clearly a specialty, small acreage crop, onion seed production is important to these local economies with different varieties shipped worldwide. Although acreage harvested has increased by about 50% during the past 5 years, yields (lbs/ac) have declined by about 75% statewide, resulting in millions of dollars in losses (county crop report data, 2008-10). These declines have coincided with increased insecticide use to control onion thrips (*Thrips tabaci)*, which vectors iris yellow spot virus (ISVY, Long and Morandin 2011).

Onion seed production involves planting male and female parent onion lines in the same field, with honey bees relied on for cross-pollination during bloom. Research to date suggests that yield variations are due to a lack of adequate pollination. This may be a result of insecticide use targeting onion thrips, a vector of the iris yellow spot virus. Additional issues affecting pollination and yield may include irrigation management, and floral nectar production. UCCE research has developed best management practices for onion seed production in California with a focus on pollination ecology, iris yellow spot virus (newly introduced to California in 2002), and onion thrips control (Voss et al., 2013). Given growing concern about the maintenance of pollination services across many agricultural crops, our project addresses questions of timely concern to growers of many pollinator-dependent crops.

Project Approach

- Briefly summarize activities performed and tasks performed during the grant period. Whenever possible, describe the work accomplished in both quantitative and qualitative terms. Include the significant results, accomplishments, conclusions and recommendations. Include favorable or unusual developments.
- Present the significant contributions and role of project partners in the project.

Summary: To address whether insecticides effect honey bee activity and pollination service, we planted a large-scale 1.5 acre onion seed production trial, where we experimentally manipulated insecticide applications. We evaluated 8 insecticides with different

active ingredients and modes of action, 3 spray timings, and 3 levels of application number. All treatments were replicated five times within a randomized complete block design and were compared to an untreated control. We observed honey bee and native bee visitation and pollen viability relative to the different treatments and collected umbels to measure seed yield from each treated plot.

Results and conclusions: Select insecticides had negative impacts on pollinator attraction and pollen-stigma interactions, with certain products dramatically reducing pollen germination and pollen tube growth. Decreased pollen germination was not associated with reduced seed set; however, reduced pollinator attraction was associated with lower seed set and seed quality for one of the two female onion lines examined. Our results highlight the importance of pesticide effects on the pollination process. Over-use may lead to yield reductions through impacts on pollinator behavior and post-pollination processes. The results of this study are currently in press in the Journal of Economic Entomology. A draft of this manuscript is attached.

2. Field surveys 2012-2013

Summary - We surveyed onion seed fields during bloom in May and June (17 farms in 2012 and 12 farms in 2013). We quantified pollinator visitation, nectar production, pollen germination and pollen tube growth, soil moisture, insecticide use and seed set. In 2013 we also measured nectar sucrose concentration. We then examined how the effects of soil moisture (and thus irrigation practices), and insecticide use may affect ultimate seed set via indirect effects on the pollination process.

Results and conclusions - In 2012, we found that both excessively low and high soil moisture reduced nectar production, which in turn reduced honeybee visitation rates (Figure 2). Furthermore, high insecticide use also tended to reduce honeybee visitation. Honeybee visitation was strongly linked to seed set, indicating that by reducing visitation, field management can impact seed yields (Figure 3). Pollen tube data from 2012 was inconclusive, and data for 2013 is still being analyzed, as insecticide use data was not available until late July. However, 2013 patterns for irrigation and nectar production match those from 2012. Overall, results from our field surveys show that field management can have indirect effects on the pollination process. Under or over-irrigation reduces nectar rewards and honeybee attraction, while high insecticide use further reduces visitation.

3. Onion thrips surveys 2012-2013

Summary - We sought to determine when onion thrips numbers peaked during the winter and spring, to help farmers better target insecticide use for onion thrips and IYSV control. We surveyed onion thrips abundance at 14 onion seed fields in Yolo and Colusa counties. We used similar methods to previous studies on thrips in tomato fields, placing a yellow sticky card on each of the four corners of the field, just above the level of the vegetation. Cards were swapped out every two weeks, and estimated the total number of thrips and number of onion thrips caught.

Results and conclusions - Thrips did not appear in fields in significant numbers until early February. It was around mid February when the proportion of thrips that were *Thrips tabaci* peaked. While total thrips numbers continued to rise into April, the proportion of *T. tabaci* in each sample declined until bloom (Figure 1). Furthermore, *T. tabaci* numbers were highly variable among farms, and total thrips number was not always indicative of *T. tabaci* density. Our results suggest that insecticide use prior to mid-late February will not aid in *T. tabaci* control and IYSV management. Furthermore, surveys of general thrips abundance that do not involve species identification may overestimate *T. tabaci* abundance. Finally, while we have pinpointed the timing of *T. tabaci* presence in onion seed fields, we do not know yet what proportion of these thrips carry ISVY, and at what thrips density treatment is necessary. This will require further research.

4. Field surveys in Oregon

Summary - We travelled to the Willamette valley, in Oregon, where native pollinator visitation is much higher and seed yields are more consistent than in California. We measured native pollinator and honeybee abundance at 10 onion production fields using pan traps, net sampling and observations of visitation. We also measured pollen deposition, pollen tube growth and seed set per umbel. We compared Oregon visitation patterns, seed yield, and pollen deposition and field management practices to California to develop hypotheses regarding why yields are more reliable in Oregon.

Results and conclusions - Working in Oregon provided an interesting contrast to onion seed production in California (summarized in Table 1). In Oregon, insecticides are rarely used (none in our study sites). Native bee visitation rates were higher in Oregon, though they still represented a low proportion of pollinators. However, Oregon fields have similar visitation rates by honeybees compared to California, despite lower stocking rates. Furthermore, they have higher pollen tube germination on their stigmas. Finally, besides rarely spraying insecticides, overall disease pressure is lower in Oregon, leading to less field to field variation in seed set due to the impacts of fungal disease (especially by downy mildew and purple blotch, UC IPM).

5. ISVY Research

Summary:

Collaborators in Imperial County examined the efficacy of both organic and conventional pesticides in controlling thrips populations, and in reducing incidence of IYSV. They also examined patterns of abundance of onion thrips over time in production fields. Finally, they sampled 34 fields for IYSV via genetic tests using ELISA (Enzyme-Linked Immuno-Sorbent Assay), and compared yields to IYSV incidence.

*Results and conclusions: S*ome organic pesticides significantly suppressed thrips populations, as did conventional insecticides. In 2011 thrips suppression via pesticides did not reduce IYSV, however, in 2012, insecticides reduced the incidence of IYSV by 73%. Yields were not significantly changed in either 2011 or 2012 due to reduced ISVY incidence. Similar results were found in onion seed production fields in 2012, where 10 out of 34 fields tested positive for IYSV with no yield reduction. Four fields tested negative via ELISA, and 20 fields showed no visual symptoms of IYSV. Yields in these fields were variable with no apparent correlation with IYSV. Finally, thrips abundance was low throughout the winter, but by spring, about 50% of the thrips present were onion thrips, suggesting thrips control should not begin until early March, when onion thrips become more abundant in onions, to try to minimize the spread of IYSV within fields, just as we found for the Northern Sacramento Valley. Impacts of different insecticides on thrips control are currently being evaluated for 2013.

These data suggest that other factors besides IYSV play a more important role in onion seed production, including variety, irrigation management, weather, pollination, and pollinator services by honey bees and other pollinators, as we are currently evaluating. Both organic insecticides and conventional insecticides controlled onion thrips, and potentially IYSV. However, as with conventional insecticides, use should be minimized, because organically registered pesticides can negatively impact the pollination and pollinator activity. Finally, IYSV incidence did not correlate significantly with yields, thus minimizing insecticide use to reduce impacts on pollination should not negatively impact yields. However, more studies are needed to understand the epidemiology of IYSV in California, and in particular, an evaluation of weeds that harbor and vector this disease.

6. Outreach and dissemination of work

We have given extensive presentations on the results of our work, including twice at the annual meeting of the Entomological Society of America annual meeting, the Columbia Basin Vegetable Seed Association Annual Meeting and the California Garlic and Onion research advisory board meeting. Rachael Long also hosted a Pollination Symposium that touched on our research, and other issues in pollination in agriculture. We have featured our work in Rachael Long's grower newsletter and UCCE Yolo website (http://ceyolo.ucdavis.edu) and have revised the Onion Seed Production guidelines for California.

Present the significant contributions and role of project partners in the project.

Set up, design, and implementation of field research at UC Davis was conducted by co-Project Directors (PDs) and the Post doc. Data collection was conducted by the PDs, post doc and field assistants. Data organization and analysis was the planned by PDs and the Post doc, and conducted by the Post doc. Communication of results was conducted by PDs and the Postdoc

Goals and Outcomes Achieved

- Supply the activities that were completed in order to achieve the performance goals and measurable outcomes for the project.
- If outcome measures were long term, summarize the progress that has been made towards achievement.
- Provide a comparison of actual accomplishments with the goals established for the reporting period.
- Clearly convey completion of achieving outcomes by illustrating baseline data that has been gathered to date and showing the progress toward achieving set targets.

Activities completed

Project Activity	Status	Details
1. Establish research plots in hybrid onion production fields	Complete	In 2011, we conducted a replicated field trial UC Davis. In 2012 and 2013 we conducted field surveys in grower production fields.

2. Establish greenhouse onion bulb plantings (to screen insecticides for bee health and pollen viability)	Modified / complete	We used a combination of greenhouse plants, field trials, and data from our field surveys to look at pollen viability.
3. Data collection. Insecticides, onion thrips control, IYSV control, onion yields	Complete	Data on IYSV was conducted by PD's in Imperial County.
4. Data collection. Evaluate thrips insecticides on honey bee visitation to onion flowers.	Complete	Evaluated with 2011 experiment and 2012, 2013 field surveys
5. Data collection. Evaluate pollen viability on onion flowers treated with thrips insecticides	Complete	Evaluated with 2011 experiment.
6. Data collection. Quantify visitation by honey bees and other native pollinators on onion flowers relative to insecticide use, field size, hive number, and distance to hives, pollen incompatibility/viability	Complete	Evaluated with 2011 experiment and 2012, 2013 field surveys
7. Assess potential behavioral competition between honeybees at high densities.	Complete	Rachael Long's 2009 study showed no evidence of behavioral competition between honeybees at high densities- thus we consider this objective complete.
8. Data collection. Measure onion nectar quantity and quality relative to honey bee activity	Complete	Based on 2009 studies and others, nectar quantity, not quality drives honey bee foraging activity. We measured nectar production relative to soil moisture and temperature and examined sucrose concentration in 2013.
9. Data collection. Determine whether pollen transfer is limiting onion seed production	Complete	Rachael Long's 2009 study showed no evidence for pollen limitation.
10. Data collection. Quantify pollen use by honey bees positioned to pollinate onion to determine potential competing flower sources	Complete /modified	Rachael Long's 2009 study showed no evidence for pollen limitation.
11. Data collection. Assess health of honey bee hives in production fields	Dropped	Honey bee hives were active at all sites and always well managed by local bee keepers (frequently inspected and given nutrient supplements as needed).
12. Data collection. Determine the compatibility and viability of onion pollen used in specific hybrid crosses in field context	Complete	Evaluated with 2011 experiment and 2012/2013 field surveys
13. Data evaluation and management	Ongoing	Data from 2011 is being published. Data from 2012/2013 collected, analysis is in progress. This will be submitted as a journal article.
14. Project outreach. Results presentation at the California garlic and onion research advisory board and Professional Society Meetings	Complete	The post doc spoke at 5 professional meetings in 2011 and 2012, including the California Garlic and Onion research advisory board meeting and a grower pollination workshop.
15. Project outreach. Results presentation through grower newsletters, ANR peer publication, and UC website	Complete and ongoing	Information has been presented in 4 grower newsletters (Pest Control Notes, R.Long) and is available on the UC cooperative Extension website, Yolo County, http://ceyolo.ucdavis.edu, under Pest Management/Field Crops drop down menu. We also updated the UC ANR onion seed production guidelines (publication #8008).
16. Final report, CDFA Specialty Crop Grant	Complete	
17. Peer review journal publication on best management practices for hybrid onion seed production in California	Ongoing	One paper is in press (J. of Econ. Entomology) and several others are in preparation.

Comparison of accomplishments with goals, progress towards set targets

The focus of our project was to develop best management practices for hybrid onion seed production to address the problem of variable, unpredictable and declining yields in California. Our project focused on the causes for these yield declines and to develop grower and industry recommendations to bring onion seed yields back to economically stable levels. Our data document that the use of four or more insecticides in onion seed production for thrips and IYSV control will reduce honey bee activity and seed yields. We also documented that excessive dry or too moist soil conditions will reduce nectar production and honey bee visitation. As a result of our work, onion seed growers in the northern Sacramento Valley reduced the number of insecticides applied to onions from an average of 3 (range 1-7) in 2009 to 2.2 (range 0-6) in 2012. Yields are still variable, but have increased from a low of 50 lbs/ac in 2008 worth $1.2 million to 201 lbs/ac in 2012 worth $7.8 million on similar sized acreage (Colusa County Agricultural Crop Report).

Beneficiaries

- Provide a description of the groups and other operations that benefited from the completion of this project's accomplishments.
- Clearly state the quantitative data that concerns the beneficiaries affected by the project's accomplishments and/or the potential economic impact of the project.

Our research has directly benefited both seed companies and farmers by giving them better information on how pollination issues interact with crop management, production, and honeybee activity. This will help both parties understand potential issues that may occur during onion seed production. Growers were previously unaware that irrigation practices could impact pollinator attraction. Furthermore, pollen viability is a new factor that seed companies are considering in the development of new varieties. We have even trained some in our methodology.

Beneficiaries are most concerned with the negative effects of crop management on both pollinators and pollen germination. They are concerned with finding effective ways to reduce insecticide use, given our results showing negative effects on both pollinators and pollen germination. They further should be concerned with modifying irrigation practices to maintain optimal soil moisture for nectar production and pollinator attraction; that is, not over or under watering production fields.

Lessons Learned

- Offer insights into the lessons learned by the project staff as a result of completing this project. This section is meant to illustrate the positive and negative results and conclusions for the project.
- Provide unexpected outcomes or results that were an effect of implementing this project.
- If goals or outcome measures were not achieved, identify and share the lessons learned to help others expedite problem-solving.

Our research showed several surprising results. First, the negative impact of insecticides on pollen tube growth has not previously been documented. Second, both organic and conventional insecticides both negatively impacted pollination, suggesting that insecticide use of any type should be minimized. This implication is further supported by results showing that IYSV incidence is not a major correlate of seed yields in California as much as honey bee activity and pollination.

We also have several lessons to take away for future research. While our field experiment yielded clear results, work on pollen tubes was challenging in surveys of grower fields. It was difficult to reliably conduct crosses and account for varietal differences as well as impacts of insecticides. Further studies of pollen tubes would be best conducted experimentally in the lab or greenhouse. However, we also had challenges working with onion in the greenhouse – plants were highly susceptible to disease in this context, and likely require larger pots than we had space for. Such problems will have to be overcome for more mechanistic studies of pollen germination to be possible.

Finally, we found that there is lack of clear information in the incidence of IYSV in Yolo and Colusa counties, and it's actual economic impacts on yields. While we could document when onion thrips were abundant in fields (vectors of IYSV), the economically damaging threshold where disease transfer is likely is unknown. More studies on the epidemiology of IYSV in

California, and in particular, an evaluation of weeds that harbor and vector this disease, will help growers develop IPM based strategies for reduced-pesticide disease management to facilitate adequate pollination.

Remaining Grant Balance

- If there is a remaining balance, explain why the project did not utilize all awarded grant funds.

We had significant salary savings due the Post Doc's later start date on the grant (7 months of salary savings). We hired extra lab and field help, but still not could expend all funds.

Contact Information

Rachael Long, UCCE Farm Advisor/County Director
530-666-8734 (office), 530-666-8736 (FAX)
530-681-7661 (mobile)
rflong@ucdavis.edu

Additional Information

- Provide additional information available (i.e. publications, websites, photographs) that is not applicable to any of the prior sections.

References

Long RF and L Morandin. 2011. Low hybrid onion seed yields relate to honey bee visits and insecticide applications. J. of Cal. Agr. 65(3):155-58.

Long RF. Website information onion seed production (Pest Management/Field Crops drop down menu), http://ceyolo.ucdavis.edu

Gillespie S, RF Long, N Seitz, and NM Williams. In press. Insecticide use in hybrid onion seed production effects pre and post-pollination processes. J. of Econ. Ent..

Voss R, M Murray, K Bradford, K Mayberry, I Millar, R Long, S Gillespie. 2013. Onion Seed Production in California, UC ANR Publication 8008.

UC IPM Guidelines for garlic and onions, http://ipm.ucdavis.edu

Figures and Tables

Table 1: Summary of variables measured in Oregon and California (mean (min-max)).

Variable	Oregon (10 fields)	California (16 sites)
Hives/acre	4	10
Insecticides	0	2.2 (0-6)
HB visitation (visits/5 min period)	9.6(6-14)	7.5 (1-13)
% visits non-honeybees	12%	1.5%
Pollen tubes	15.61 (6-26)	2.6 (0.4-8.5)
Seeds/umbel	1115 (695-1850)	271 (17-695)

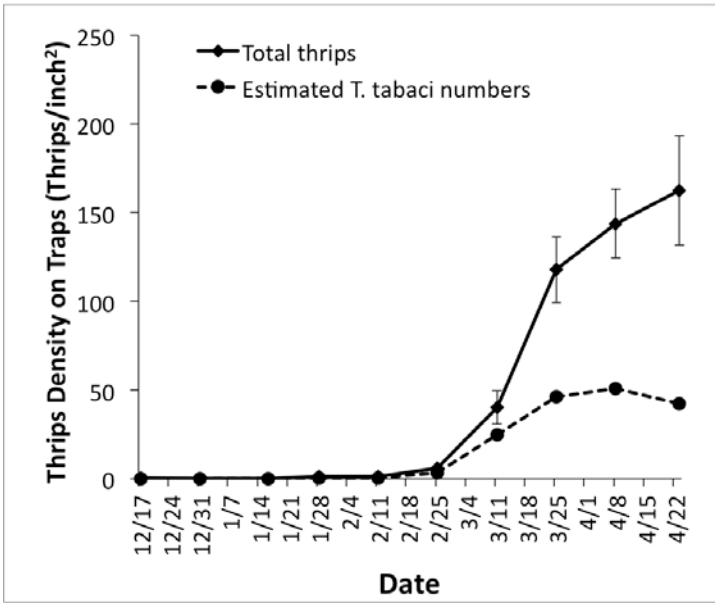

Figure 1: Thrips abundance on traps over time in 2013, showing total thrips numbers and onion thrips numbers as estimated by their proportion of total thrips present, Yolo and Colusa Counties.

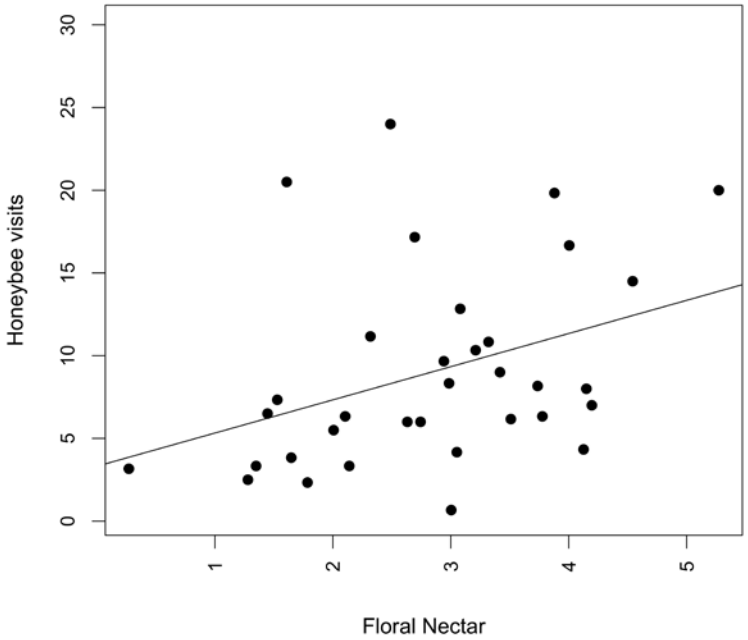

Figure 2: Relationship between honeybee visits and nectar production for field surveys in 2012

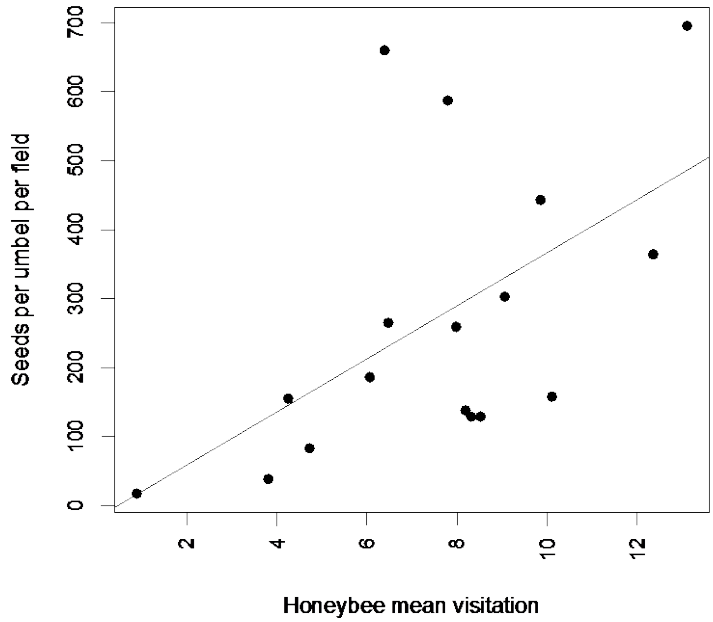

Figure 3: Relationship between honeybee visitation and seed yields for field surveys in 2012

Photo: PI Rachael Long monitoring honey bee activity in a commercial onion seed production field.