2012-2013 research report

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Project title: Best management practices for hybrid onion seed production to improve crop sustainability in California

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Introduction

The purpose of our study was to develop best management practices for hybrid onion seed production to address and mitigate the significant variable, unpredictable, and declining onion seed yields in California.

Hybrid onion seed production involves planting distinct male and female onion lines in the same field with honey bees primarily relied on for pollination. Trials conducted in 2009 suggested that increased insecticide use to control the onion thrips, vectors of iris yellow spot virus (IYSV), might impact crop pollination. Furthermore, results of a manipulative field experiment conducted in 2011 showed that certain insecticides may have impacts on pollen germination and ovule fertilization. We also found preliminary evidence that soil moisture affected nectar production, which could reduce honey bee visitation.

Pollination is a step-wise process, thus our study aimed to determine how management practices, such as irrigation or insecticide use, interfere with seed set via impacts on (1) nectar production, (2) honey bee behavior, both directly, and indirectly through changes in nectar amount, and (3) pollen germination and pollen tube growth.

Methods

We surveyed 17 commercial fields in 2012, and 12 fields in 2013 in the Sacramento Valley, managed by a range of growers for different seed companies during bloom in May and June.

To measure pollinator activity, we flagged six 1 by 1 meter plots in the male and female row in 2012, and four in 2013. We visited farms between two and four times throughout bloom, and counted pollinator visitors to male and female umbels in each plot for 5-minute periods. We counted honey bees and all other insect visitors entering our plot within this time, and the number of blooming umbels. We also measured the air temperature during each observation. We calculated the number of floral visitors and the number of honey bee visitors per open umbel per plot per observation period.

To quantify per umbel nectar production, we bagged six male and six female umbels per field for 24-hours and measured nectar from 10 randomly selected florets per each umbel. We repeated this two to three times for each field. We then calculated nectar volume per floret.

On each pollinator survey date, we took four 1-foot deep soil core samples within the sampled fields. Two cores were taken in the middle plot of each transect, one from the male row and one from the female row. On days when we collected nectar data, we also took soil cores directly below bagged female and male umbels. All cores were weighed "wet" (level found in freshly sampled core), then dried in an oven and re-weighed. Percent soil moisture was calculated for each core as an estimate of soil moisture.

To quantify the impacts of insecticide use on pollen tube growth, we conducted controlled crosses within each site. We bagged 15 female umbels per site with mesh bags to prevent pollen deposition on stigmas. In 2012, we pollinated 1 stigma on each umbel with pollen from the same site. In 2013, to improve our sample size, we pollinated 3 stigmas from each umbel. All stigmas were fixed in ethanol, stained in decolorized aniline blue and the numbers of pollen tubes germinating at the tip of the stigma and reaching the base of the style counted using a fluorescence microscope. (Kho & Baer, 1968).

We collected post-hoc data on insecticide use from County Agricultural Commissioner records. Insecticide use was quantified as the number of insecticides applied from January 1st through bloom. If a tank mix used two different insecticides on one day, we counted this as two applications. In our analyses we focused on conventional insecticides, which are expected to have the strongest effect on visitation, but it should be noted that several growers applied organic products as well.

Results

Nectar

Nectar responded non-linearly to soil moisture and sampling date, regardless of floral gender. Nectar peaked mid-bloom, and at mid-range soil moisture (Figure 1). Males flowers produced more nectar overall than females.

Visitation

Visitation was not directly affected by insecticide use, but there was an insecticide use by date interaction, such that lower spray sites (0-2) showed steady or declining visitation over time, whereas higher spray sites (3-4) showed increasing visitation over time (Figure 2). Visitation in high spray fields also started at an overall lower level, then increased to match low-spray fields. Visitation increased with nectar, soil moisture and temperature, and was higher for female umbels than for males.

Pollen tubes

For pollen germination at the stigmatic tip there was a significant year effect on the number of germinating grains. There was also a significant year by time since last spray interaction. For pollen tubes to the base, there was also a significant year effect and a significant year by timing interaction. Overall pollen germination and pollen tube growth were higher in 2012 than in 2013. In 2013, but not 2012, sprays near to bloom time led to overall lower pollen germination and pollen tube growth.

Seed set

Seed set was not significantly affected by insecticide use, soil moisture, or nectar production, but increased with visitation (Figure 3).

Implications

Our results show that management decisions such as irrigation regime and insecticide use can have negative effects on seed yield mediated by the pollination process. For example, our results suggest that low irrigation negatively impacts nectar production, leading to reduced honey bee visitation. Low honey bee visitation was related to lower seed yield. We also saw a reduction in

nectar production at extremely high soil moisture. Over-irrigation may lead to suffocation of the roots, and thus negatively impact nectar.

Pesticide use affected both pollinator attraction and pollen-stigma interactions. We saw an effect of spray rates on the temporal pattern of visitation, where high spray sites began bloom with overall lower visitation, but saw an increase in visitation over time, whereas visitation to lower-spray sites was steady. This likely indicates the degradation of insecticide residues that repel pollinators. Furthermore, fields that were sprayed close to bloom had lower pollen germination and lower pollen tube growth than fields that were sprayed at earlier dates.

Both these results represent a reduced impact of insecticides on pollinator visitation and pollen tubes relative to previous research, which showed direct reductions in overall visitation at high spray rates. Indeed, we find that grower insecticide use has greatly declined since the publication of Long and Morandin's previous study, where growers averaged 3 sprays (range 1-7) in 2009, compared to an average of two sprays in our study (range 0-4). Similar to previous work, this suggests that pronounced effects of insecticides on pollinator behavior and seed set are more likely at rates of 3 sprays per year or higher; however, even at reduced insecticide use, we still see the potential for subtle effects on both the pattern of visitation over time, and pollen-stigma interactions.

Our results highlight the importance of considering the indirect effects of management on the pollination process. Low irrigation and high insecticide use may both interfere with pollination via their impacts on the pollination process. In hybrid onion, we continue to advise moderation in insecticide use, and recommend that growers consider impacts on nectar production when planning irrigation during bloom.

Figures

Figure 1: Non-linear effect of soil moisture on the log-transformed average nectar per umbel. Points are site averages across both 2012 and 2013 sampling dates. The line represents a local regression smoother, and the dashed lines are the standard error.

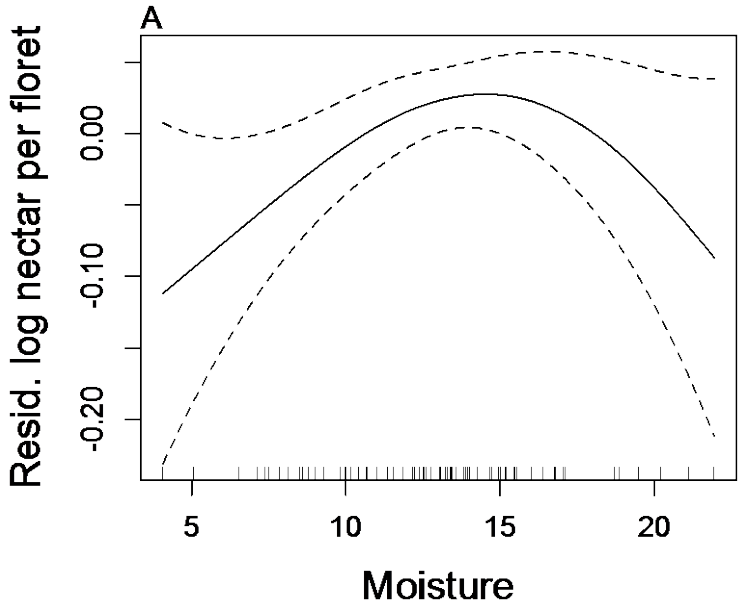

Figure 2: Patterns in visitation rates over time differed among sites with different spray rates. Sites with low spray rates saw constant visitation, whereas sites with high spray rates saw increases in visitation over time.

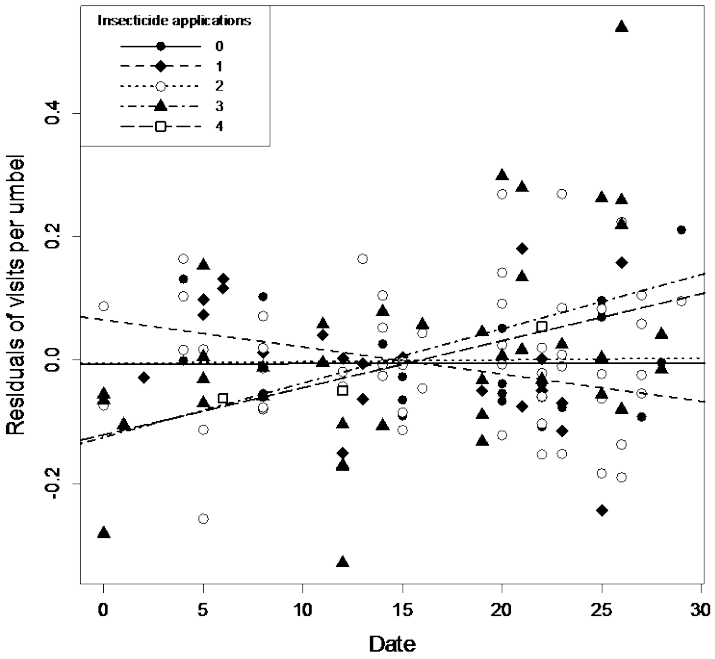

Figure 3: The average number of seeds per umbel per field was positively related to honey bee visitation/