UNIVERSITY OF CALIFORNIA SAN DIEGO

Cucurbit specialist, *Peponapis pruinosa*, is a more effective pollinator than generalist, *Apis mellifera* for cultivated squash

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by Maria Izabel Martinez

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The Thesis of Maria Izabel Martinez is approved, and it is acceptable in quality and form for publication on microfilm and electronically:

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

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ABSTRACT OF THE THESIS

Cucurbit specialist, *Peponapis pruinosa*, is a more effective pollinator than generalist, *Apis mellifera* for cultivated squash

by

Maria Izabel Martinez

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Professor David Holway, Chair

The western honey bee (*Apis mellifera*) is a super-generalist in terms of floral visitation, but its effectiveness as a pollinator varies greatly. This variation has called attention to the importance of native insects as pollinators in agricultural systems and has raised concerns that floral visitation by honey bees can adversely impact some plant species. To clarify what factors underlie this variation, we use multiple approaches to compare the effectiveness of specialist (*Peponapis pruinosa*) and generalist (honey bees) pollinators of cultivated squash (*Cucurbita pepo*). Previous studies report conflicting results on the effectiveness of *P. pruinosa* and *A.*

mellifera as pollinators of *C. pepo* but have not typically considered how specific foraging behaviors (e.g., degree of contact with the stigma or anthers) influence their effectiveness. To resolve this uncertainty, I conducted single and multiple visit trials on *C. pepo* plants at the UC San Diego Biology Field Station to examine how visitation and behavior of these two bee species affect pollinator effectiveness. Visitation by female squash bees was found to have a greater positive effect on pollen removal, pollen deposition, fruit set, and seed set (i.e. seed number) compared to honey bee visitation. These findings were consistent with the behavior of the pollinator species. Cumulative duration of stigmatic and anther contact by female squash bees had a greater effect on pollen deposition and pollen removal compared to the same behaviors in honey bees. Previous studies on cultivated squash conducted in agricultural settings have found that the effectiveness of honey bees and squash bees appears more similar than what we report here. These contrasting results could be explained by differences in resource availability in large scale agricultural versus small scale plots. At our study sites, for example, honey bees primarily collected nectar from cucurbits and foraged for pollen on other plant species in the immediate environment.

Introduction

Pollination by insects and other animals represents an important ecosystem service in both natural and agricultural systems (Losey and Vaughan 2006, Ollerton et al. 2011). For instance, 70% of global food production results from pollination by animals (Klein et al. 2007), and the economic benefits provided by pollinators have been estimated to be $235 - $577 billion annually (Lautenbach et al. 2012, Potts et al. 2016). For these reasons, it has become increasingly important to learn more how pollination services are affected by different aspects of environmental change. Non-native pollinator species, for example, may differ in their effectiveness compared to native pollinators and could affect pollination services if they became abundant. Effective pollinators collect and transfer the most pollen, relative to other pollinators, thereby increasing reproductive success of a plant (i.e. fruit set and seed set) (Herrera 1987, Ne'eman et al. 2010, Williams and Thomson 2003). The western honey bee (*Apis mellifera*) is a globally distributed super-generalist pollinator that collects pollen and nectar from a wide variety of plant species and exhibits substantial variation in its effectiveness as a pollinator (Hung et al. 2018). To clarify what factors underlie this variation, we compare the effectiveness of specialist (native squash bees) and generalist (non-native honey bees) pollinators of cultivated squash (*Cucurbita pepo*).

We focus on *Cucurbita pepo* for the following reasons. This species is monoecious with separate female (pistillate) and male (staminate) flowers. Cultivated squash does not self-pollinate and therefore requires pollinators to transfer pollen from staminate flowers to pistillate flowers (Hurd et al. 1971). Squash flowers are large and short-lived, opening before sunrise and then wilting and becoming unreceptive by midday (Hurd et al. 1971, Tepedino 1981, Willis and

Kevan 1995). Important pollinators of cultivated squash include the western honey bee (*Apis mellifera*) and the eastern cucurbit bee (*Peponapis pruinosa*) (Hurd et al. 1974). As a specialist pollinator, *P. pruinosa* (hereafter referred to as the squash bee) requires cucurbit pollen to reproduce but can visit other plants to obtain nectar. Behavioral and physiological differences between honey bees and squash bees may also influence their effectiveness as pollinators. Honey bee workers forage throughout the day for pollen and nectar, whereas squash bees mainly forage during the morning and decrease their activity later in the day (Hurd et al. 1974). Squash bees also can collect resources with little to no light which makes foraging before sunrise a possibility (Hurd et al. 1974). Moreover, this observed activity coincides with early flowering times of squash plants. To further emphasize the specialist relationship between squash bees and squash plants, Hurd et al. (1974) demonstrated that annual nest emergence and construction occurs during the flowering period of squash plants. Squash bees have a physiological advantage in terms of collecting and transferring pollen because squash bees fly faster and begin to forage much earlier compared to honey bees. Additionally, female squash bees are larger and have hairier bodies than honey bees which results in pollen being collected passively. A caveat, however, is that squash bees have an advantage only when their population is well-established. This brings up the question of how effective squash bees are as pollinators if they are not as abundant.

Tepedino (1981) further explained how effective honey bees and squash bees were at pollinating by looking at how single and double visits from either honey bees or squash bees compared regarding fruit set and pollen deposition. He found that there were no significant differences between fruit set or pollen deposition by squash bees and honey bees during single and double flower visits from each species. Therefore, both pollinators were equally effective

which further supported Hurd's (1974) claim that in areas with well-established squash bee populations, honey bees are not necessary (i.e., to provide pollination services in agriculture). However, Tepedino's result diverges from the findings of recent studies showing that squash bees deposit significantly more pollen during a single visit (Canto-Aguilar et al. 2000), and that honey bees do not remove pollen readily during a single visit (Williams and Thomson 2003). Therefore, it is still unclear if squash bees are more efficient than honey bees or if honey bees are equally as effective during a single visit to a squash flower.

The results of studies that rely on single-visit trials to compare the effectiveness of honey bees and squash bees as pollinators may be influenced by environmental context and do not consider differential visitation(Ne'eman et al. 2010). Controlled multiple visitation experiments can be used to better understand how increasing visits from different pollinators affects a plant's reproductive success. Vidal et al. (2010), for example, showed that pistillate squash flowers required twelve honey bee visits to be successfully pollinated; after twelve visits there was no longer an increase in reproductive success. Therefore, this study suggests that a pollinators effectiveness when collecting and transferring pollen may differ with the number of visits (visitation) a flower receives and thereby affect reproductive success of squash plants differently.

In this study, I aim to determine the pollinator effectiveness of honey bees and squash bees (female and male) on cultivated squash. To do this I looked at (i) how increasing visitation (number of visits) from these bee species affected the amount of pollen deposited on stigmas of pistillate squash flowers and on removal of pollen from staminate squash flowers, (ii) how visitation affected squash reproductive success, and (iii) how behavioral differences between these species influenced their effectiveness as pollinators. Measuring the effects of multiple visitation builds on the results of studies that consider smaller numbers of visits (Artz and Nault

(2011) and Tepedino (1981)). Furthermore, behavioral differences, which have scarcely been quantitatively compared, can reveal the mechanisms underlying different degrees of pollinator effectiveness by honey bees and squash bees.

Methods

Study site

I grew *Cucurbita pepo* at the UC San Diego Biology Field Station (32°53'08.8"N, 117°13'47.2"W) from June through early September 2019. Individual plants (n = 142) were germinated and grown in a 19 x 13 m plot with each plant occupying its own 1.2 x 1.2 m section. Seeds were planted in mid-June, and individual plot sections were reseeded if there was no sign of germination five days after the initial seeding. After germination, plants were monitored daily by recording the emergence of cotyledons, number of true leaves, approximate amount of herbivory (if any), and presence of fungal pathogens (if any). A dripline system was used to irrigate plants daily. Individual 1.2 x 1.2 m sections were each traversed by two 0.64 cm drip lines in which equal-sized and evenly spaced holes were punctured such that all plants received similar amounts of water during scheduled hourly morning irrigation. To ensure that all plants received comparable levels of irrigation, a Field Scout TDR 100 soil moisture meter was used to measure the volumetric water content (VWC%) of the soil underneath each plant. After germination, soil moisture was measured one hour after watering in the morning, three times per week; the mean soil moisture throughout the summer was 33.4% VWC (SD = 5.9, n = 4503 measurements) (Appendix 1).

Pollinator visitation

Each plant was randomly assigned to an experimental pollinator visitation category that set the number of pollinator visits that every flower (of either sex) on that plant would receive. These categories included: 0 visits, 1 visit, 3 - 6 visits, 9 - 12 visits, or open pollinated. To determine which flower buds would open in a given morning, daily surveys were conducted on

the previous afternoon in which Seedburo S27 wax treated pollination bags were placed on each of the flower buds that appeared ready to open the next day. Pollination bags placed over floral buds prevented insect visitors from entering flowers. For these flowers, visitation trials began at sunrise on the following day (at which time pollination bags were removed); trials lasted approximately two hours. Before beginning visitation trials, pollination bags were removed from a portion of staminate flowers from the plot (mean = 0.41, SD = 0.09, n = 43 days) (Appendix 2) in order to supply enough pollen for deposition on female stigmas. For staminate flowers in the 0-visit experimental group, flowers were removed from the plant but left inside the pollination bag to be measured later that day. For pistillate flowers in the 0-visit experimental group, each pollination bag was replaced with a Paper Mart standard gold organza 15 x 23 cm mesh bag, which excluded visitors while simultaneously permitting similar environmental conditions as open flowers (Kearns and Inouye 1999). Mesh bags were used to replace pollination bags since placing female squash flowers back into pollination bags may result in damaging the stigma or fruit bulb of the flower. Also, mesh bags contained draw strings which allowed for the bag to be secured onto the flower.

For flowers visited by pollinators, each open flower was observed until the designated number of visits (or range of visits) for that plant had occurred. The duration of an individual visit was defined as the total time spent inside the cup of the flower (from entry to exit). For pistillate flowers, once the designated number of visits had occurred, mesh bags were used to prevent additional visitors from entering the flower. After the designated number of visits had occurred for staminate flowers, these flowers were removed from the plant and placed in pollination bags so that remaining pollen could be weighed. On some trial days, the abundance of honey bees made it difficult to obtain an even balance of squash bees versus honey bees. For

this reason, an aspirator was used to blow puffs of air at arriving honey bees (i.e., prior to them entering the flower) to prevent individuals of this species from monopolizing visitation on plants in the 3 - 6 and 9 - 12 visit groups. Application of this method discouraged honey bees from landing in the flowers and did not seem to affect other visitors (Nabors et al. 2018).

In addition to visual observation of flowers, all trials were videotaped except those in the 0-visit group. A Victure Action 4K Wi-Fi video camera was positioned on a tripod approximately 20 - 40 cm away from each focal flower. Camera distance was close enough to each flower so that the entire corolla was within the frame of the video but far enough away such that bee visitation did not seem to be affected. Videos began after pollination bags were removed and were directly compared to visual observations of visitation for each flower. In all videos, the number of visits by honey bees and by male and female squash bees was recorded. For each bee visit to pistillate flowers, the time spent drinking nectar and contacting the stigma were estimated. For each bee visit to staminate flowers, the time spent drinking nectar, the time spent contacting the anthers, and the time spent collecting pollen were estimated (Appendix 3). Flowers in the open pollinator group were videotaped but received no observation. Cameras set up for open-pollinated flowers began recording after pollination bags were removed and were left running for two hours.

Pollen deposition and pollen removal

Approximately 24 hours after the conclusion of visitation trials, a single-edged razor blade was used to separate stigmas from the fruit bulb of each pistillate flower. This span of time allowed for pollen grains to germinate and fertilize ovules in the pistillate flower without affecting fruit or seed set (*personal observation*). Each stigma was placed in a 50 mL centrifuge

tube filled with 100% ethanol. To estimate pollen deposition on each stigma, I added 4 drops of basic fuchsin dye solution to each tube to make pollen grains visible. Pollen deposition was counted at least one week after the addition of basic fuchsin dye. Pollen deposition on each stigma (including pollen grains in the ethanol dye solution) were counted using a dissecting microscope at 4x magnification.

To estimate how much pollen was removed from staminate flowers by bees, I conducted the following measurements. Staminate flowers that were not visited by any insect were collected from each plant. Using a small spatula (0.64 cm wide × 19 cm long) pollen was removed from the anthers and weighed on a scale. The mass of the pollen was then averaged across unvisited staminate flowers within each plant. The average pollen mass was used as a proxy measurement of an individual plant's per flower pollen production. To estimate the amount of pollen removed from staminate flowers that received visits, the amount of pollen remaining after the visits occurred was first weighed. The remaining pollen mass after bee visitation was then subtracted from the average pollen mass for a given plant.

Fruit and seed set

Fruit bulbs of pollinated pistillate flowers were checked daily for evidence of fruit set. Of those that did set fruit, I let each fruit grow for 50 days following pollination and at that time separated them from the plant by cutting the stem 3 cm above where it met the top portion of the fruit. After harvesting, fruit volume was measured by submerging each fruit in a 2000 mL graduated pitcher filled with 1000 mL of water and measuring the displaced volume of water. Seeds were removed after the volumetric measurements of each fruit, counted, and placed in

mesh bags to dry for 14 days in the laboratory. Dried seeds were then weighed collectively for each fruit.

Statistical analysis

I used R (R Core Team, 2019) to analyze all data, and I prepared all figures using the package ggplot2 (Wickham, 2009). To determine how visitation (number of visits) from different bee species affected the reproductive success of squash plants, I used (i) multiple logistic regression with fruit set as a response variable, and (ii) multiple regression with mean seed mass (per fruit) and seed number (per fruit) as response variables. Seed number was log transformed to meet model assumptions. Predictor variables for the logistic regression analyses included visitation by honey bees, female squash bees, and male squash bees as well as pollination date (i.e. day of year). Predictor variables for the multiple regression analyses included pollination date, linear and quadratic visitation terms (for honey bees, female squash bees, and male squash bees), and interaction terms. The simplest best fit model was derived by first creating a full model that included all linear and quadratic terms as well as interaction terms. I performed model selection by successively removing non-significant terms from the full model and using Akaike Information Criterion (AIC) to identify the best supported model among all possible models (Crawley 2013). I report the full model and the simplest model with the lowest AIC value (see *Results*). This model selection approach was also used in analyses with pollen deposition (on the stigmas of pistillate flowers) and pollen removal (from the anthers of staminate flowers) as response variables. Pollen deposition was log-transformed to improve normality. Furthermore, to determine if partial regression coefficients were significantly different (within an individual analysis), I used a Wald-test based comparison.

To determine how the behavior of different bee species influenced plant reproductive performance, I again used multiple regression analyses with the cumulative time spent on floral stigmas by each bee species as the predictor variables and the following response variables: fruit set (logistic regression), seed set (multiple regression), and pollen deposition (multiple regression). Number of seeds was log-transformed to better meet regression model assumptions. I also used multiple regression to test the relationship between the cumulative time spent on floral anthers by each bee species and the amount of pollen removed. Time spent on anthers was log transformed to better meet regression model assumptions. For all regression analyses, I tested the assumptions for multiple regression models by plotting residuals to test for linearity and equal variances and inspecting q-q plots to determine if normality assumptions were met. Note that for each analysis I only used data from one flower per plant.

To determine if individual bee visits influenced subsequent visits, I used two-sample *t*-tests to compare the duration of stigmatic contact of the second visitor (honey bee or female squash bee) to a pistillate flower when the first visitor was either a honey bee or a female squash bee. Similarly, I compared the duration of anther contact of the second visitor to a staminate flower, when the first visitor was either a honey bee or when the first visitor was a female squash bee. For these analyses, the duration of stigmatic contact and anther contact were log-transformed to improve normality.

Results

Fruit set, pollen deposition, and seed set

The likelihood of fruit set increased with visitation and the cumulative duration of stigmatic contact for both female squash bees and honey bees (Tables 1-2, Figure 1A). However, the effect of female squash bee visitation on fruit set was significantly greater than the effect of honey bee visitation (Figure 1A; $\chi^2 = 4.65$, df = 1, p = 0.031). Fruit set was independent of visitation by male squash bees. In an analysis that was restricted to flowers visited only by honey bees, the likelihood of fruit set increased with visitation (Table 3) but not with the cumulative duration of stigmatic contact (Table 4).

For flowers that set fruit, pollen deposition by female squash bees linearly increased both with visitation (Table 1, Figure 1B) and with the cumulative duration of stigmatic contact (Table 2). Pollen deposition by honey bees quadratically increased with visitation (Table 1), but the parameter coefficient for this relationship was small, and the significance of the relationship between pollen deposition and honey bee visitation disappeared in an analysis that was restricted to flowers visited only by honey bees (Table 3). Moreover, the amount of pollen deposited by honey bees was independent of the cumulative duration of stigmatic contact (Table 2).

The number of seeds produced by squash fruit linearly increased with visitation by female squash bees, and linearly decreased with visitation by male squash bees (Table 1). Honey bee visitation affected seed number only in terms of its interaction with male squash bee visitation (Table 1), and the relationship between honey bee visitation and seed number were no longer significant in an analysis that was restricted to flowers visited only by honey bees (Table 3). The cumulative duration of stigmatic contact did not affect seed number for any type of

visitor (Table 2). In contrast to seed number, mean seed mass was independent of visitation by both squash bees and honey bees (Table 1).

Pollen removal

The amount of pollen removed from staminate flowers increased with visitation by both female squash bees and honey bees (Table 5). For each female squash bee visit, however, seven-fold more pollen was removed compared to the amount removed by a honey bee visit (Fig 1C; $F = 18.08$, $df = 1$, $p < 0.001$). The significant and negative quadratic term for female squash bee visitation (Table 5) indicates that pollen removal did not continue to increase with increasing visitation (i.e., likely because of pollen depletion). Pollen removal by honey bees also depended on visitation by male squash bees (Table 5) with the latter tending to depress pollen removal by the former. In an analysis that was restricted to flowers visited only by honey bees, visitation increased pollen removal by this species alone (Table 3). Pollen removal was positively related to the cumulative duration of anther contact for both female squash bees and honey bees (Table 4 and 5).

First visit effect on second visit

The stigmatic time of the second visitor, honey bee, was not significantly different when the first visit was either a female squash bee or honey bee (Fig 2A). Similarly, the stigmatic time of female squash bees did not significantly differ when the first visitor was either a female squash bee or a honey bee (Fig 2A). Furthermore, in staminate flowers duration of anther contact of the second visitor (honey bee or female squash bees) was not significantly different when the first visitor was either a female squash bee or a honey bee (Fig 2B).

Discussion

Effective pollinators collect and transfer pollen more proficiently relative to other pollinators, thereby positively affecting the reproductive success of the plants that they pollinate. Comparisons of different aspects of pollinator effectiveness in the present study revealed that female squash bees are more effective compared to honey bees in terms of the likelihood of fruit set, pollen deposition, seed set (seed number), and pollen removal. Behavioral differences when foraging help to explain differences in pollinator effectiveness. The time that female squash bees spent on the anthers of staminate flowers increased the amount of pollen removed, and the time spent on the stigma of pistillate flowers increased the amount of pollen deposited. These relationships held for honey bees, but the relationships were weaker compared to those of female squash bees. Male squash bees, however, did not appear to be as effective as female squash bees or honey bees. Additionally, it did not appear that the first visit to a squash flower affected the behavior of the second visitor; this indicates that visitation by squash bees is not influenced by visitation honey bees and vice versa.

Previous studies have shown that specialist pollinators can be more effective pollinators compared to generalist pollinators (Cane et al. 2011, Hurd et al. 1974, Larsson 2005, Tepedino et al. 2016). Specialists collect and transfer pollen more successfully than do generalists (Larsson 2005, Tepedino et al. 2016). As with Canto-Aguilar et al. (2000), I found that squash bees deposit more pollen during a single visit than do honey bees, and honey bee visitation did not significantly affect pollen deposition for flowers visited only by honey bees. In this system, I typically observed that honey bees landed on the edge of a flower's corolla and then crawled to the base of the flower to collect nectar (Artz and Nault 2011). Therefore, during a visit it was possible that honey bees would not make any contact with the stigma. In contrast, female squash

bees tended to land on the stigma and remain on the stigma while drinking nectar. The constant contact during a female squash bee visit may explain the significant positive effect female squash bee cumulative stigmatic contact had on the amount of pollen deposited. It remains unclear whether these behavioral differences apply to other systems. Artz and Nault (2011), for example, found that squash bees and honey bees do not differ from one another with respect to single-visit, stigmatic pollen deposition. However, Artz and Nault (2011) pooled male and female squash bees in their analyses, and the disparity in the results of their study and the results of my study may stem from this difference in how squash bees were treated, perhaps especially if the number of male squash bees visits was higher than that of female squash bee visits within a treatment group (Cane et al. 2011).

Previous studies have reported no difference between honey bees and squash bees in terms of their effect on fruit set (Tepedino 1981, Artz and Nault 2011). My results, however, suggest that visitation by female squash bees causes a higher frequency of fruit set than visitation by honey bees than does honey bee visitation. The disparity in results of this and previous studies again may result in site-to-site variation in the extent to which honey bees collect squash pollen, and in the case of Artz and Nault (2011) the pooling together of male and female squash bees in their analyses. Although I did not see a significant effect of male squash bee visitation on fruit set as demonstrated by Cane et al. (2011), this result may be due to relatively low male squash bee visitation to pistillate flowers in my study. Cane et al. (2011) found that five or more visits by male squash bees resulted in a successfully pollinated flower with seed set comparable to that of an open pollinated flower. In my study, most of the flowers received one to three visits by male squash bees. Furthermore, male squash bees are typically active earlier in the season (mid-

June to early July) while female squash bees tend to be more active near the end of August (Tepedino 1981, this study).

Visitation by female squash bees positively affected the number of seeds produced by individual fruits, whereas honey bee visitation did not show this effect. Similarly, in flowers that only received honey bee visits, visitation did not affect the number of seeds. This finding contrasts Artz and Nault' s (2011) findings that showed that flowers with higher honey bee visits resulted in more seeds per fruit and that squash bee visitation had no effect on the number of seeds. However, previous studies have shown that with increasing pollen deposition, number of seeds also increases (Walters and Taylor 2006, Winsor and Stephenson 1987). Given the positive relationship between female squash bee visits and pollen deposition, the results of my study are consistent with studies that have found that visitors that effectively deposit greater amounts of pollen will ensure a higher number of seeds per fruit.

In terms of pollen removal, previous studies have reported that honey bees vary in the extent to which they remove pollen from squash flowers. Tepedino (1981), Artz & Nault (2011), and McGrady et al. (2019), for example, have all found that honey bees visit male squash flowers less often compared to pistillate flowers, whereas the opposite pattern holds for squash bees. Vidal et al. (2010), however, found that honey bees often collected pollen from squash flowers and could remove up to two-thirds of the pollen available from squash flowers within two visits. Site-to-site variation in the extent to which honey bees remove pollen from squash flowers may depend on the availability of other sources of pollen in the environment. As with Canto-Aguilar (2011), I found that female squash bees were the most effective in removing pollen. Additionally, Hurd et al. (1974) suggested that squash bees may have an advantage since they are larger and fly faster than honey bees, thereby visiting more staminate flowers and

possibly removing more pollen during a visit compared to other bee species. Behavioral foraging patterns of female squash bees may affect pollen removal. Female squash bees will generally land on the anthers of the flower and move around the anthers as they drink nectar. The constant movement on the anthers and hairier bodies results in passive collection of pollen during a visit, even in cases where no active pollen collection takes place.

Overall, female squash bees appear to be more effective pollinators compared to honey bees for cultivated squash. Davids (2018) showed that single visitation by female squash bees resulted in higher fruit set and pollen deposition than for single visits by honey bees. My study further revealed that increasing visitation and time spent on the flower's stigma increased reproductive success of squash plants. A possible explanation for why my results differs from previous studies, most of which were conducted in agricultural areas, could be due in part to the study site, which was a small plot of squash surrounded by a heterogeneous patchwork of natural and ornamental vegetation. At this study site, honey bees likely have access to a variety of pollen sources and may not be as motivated to collect squash pollen. Furthermore, Williams and Thomson (2003) proposed that even if pollinators had low pollen deposition and pollen removal rates but had high visitation rates than effectiveness per visit would not be an applicable measurement for pollinators. Therefore, to better understand the importance of honey bees and squash bees, determining how overall pollinator visitation and pollen deposition to a flower affect reproductive success may be considered (Sahli and Conner 2007). Additionally, in order to have a better understanding of the pollinator effectiveness of male squash bees, earlier nest emergence by male squash bees should be considered. In this study, flowering began at the end of July, however, previous studies have shown that male squash bees begin to emerge from their

nests as early as mid-June (Tepedino 1981). For this reason, earlier seeding of squash plants should be studied to determine if seasonality has an effect on pollinator effectiveness.

References

Artz, D. R., Hsu, C. L., & Nault, B. A. (2011a, October). Influence of honey bee, Apis mellifera, hives and field size on foraging activity of native bee species in pumpkin fields. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/22251726

Artz, D. R.,& Nault, B. A. (2011b). Performance of Apis mellifera, Bombus impatiens, and Peponapis pruinosa (Hymenoptera: Apidae) as Pollinators of Pumpkin. *Journal of Economic Entomology*, 104(4), 1153–1161. https://doi.org/10.1603/EC10431

Cane, J. H., Sampson, B. J., & Miller, S. A. (2011). Pollination Value of Male Bees: The Specialist Bee Peponapis pruinosa (Apidae) at Summer Squash (Cucurbita pepo). Environmental Entomology, 40(3), 614–620. https://doi.org/10.1603/EN10084

Canto-Aguilar, M.A., Parra-Tabla, V. Importance of Conserving Alternative Pollinators: Assessing the Pollination Efficiency of the Squash Bee, Peponapis limitaris in Cucurbita moschata (Cucurbitaceae). *Journal of Insect Conservation* 4, 201–208 (2000). https://doi.org/10.1023/A:1009685422587

Crawley, M. J. (2013). *The R book*. Chichester, West Sussex, United Kingdom: Wiley.

Garibaldi, L.A., Steffan-Dewenter, I., Winfree, R., Aizen, M.A., Bommarco, R., Cunningham, S.A., Kremen, C., Carvalheiro, L.G., Harder, L.D., Afik, O., Bartomeus, I., Benjamin, F., Boreux, V., Cariveau, D., Chacoff, N.P., Dudenhoffer, J.H., Freitas, B.M., Ghazoul, J., Greenleaf, S., Hipolito, J., Holzschuh, A., Howlett, B., Isaacs, R., Javorek, S.K., Kennedy, C.M., Krewenka, K.M., Krishnan, S., Mandelik, Y., Mayfield, M.M., Motzke, I., Munyuli, T., Nault, B.A., Otieno, M., Petersen, J., Pisanty, G., Potts, S.G., Rader, R., Ricketts, T.H., Rundlof, M., Seymour, C.L., Schuepp, C., Szentgyorgyi, H., Taki, H., Tscharntke, T., Vergara, C.H., Viana, B.F., Wanger, T.C., Westphal, C., Williams, N., Klein, A.M. (2013). Wild Pollinators Enhance Fruit Set of Crops Regardless of Honey Bee Abundance. *Science*, *339*(6127), 1608-1611. doi:10.1126/science.1230200.

Greenleaf, S. S., & Kremen, C. (2006). Wild bees enhance honey bees pollination of hybrid sunflower. *Proceedings of the National Academy of Sciences*, *103*(37), 13890–13895. doi: 10.1073/pnas.0600929103

Gould, J., & Gould, C. (1988). *The honey bee* (Scientific american library series, no. 25). New York: Scientific American Library.

Herrera, C. M. (1987). Components of pollinator "quality": comparative analysis of a diverse insect assemblage. *Oikos* **50**: 79– 90

Hung, K.-L. J., Kingston, J. M., Albrecht, M., Holway, D. A., & Kohn, J. R. (2018). The worldwide importance of honey bees as pollinators in natural habitats. *Proceedings of the Royal Society B: Biological Sciences*, *285*(1870), 20172140. doi: 10.1098/rspb.2017.2140.

Hurd, P. D., Linsley, E. G., & Whitaker, T. W. (1971). Squash and Gourd Bees (Peponapis, Xenoglossa) and the Origin of the Cultivated Cucurbita. *Evolution*, *25*(1), 218. Doi: 10.2307/2406514

Hurd, P. D., Linsley, E. G., & Michelbacher, A. E. (1974). Ecology of the squash and gourd bee, Peponapis pruinosa, on cultivated cucurbits in California (Hymenoptera: Apoidea). *Smithsonian Contributions to Zoology*, (168), 1 – 17. https://doi.org/10.5479/si.00810282.168

Kearns, C. A., & Inouye, D. W. (1999). *Techniques for pollination biologists*. Boulder, CO: NetLibrary, Inc.

Klein, A.-M., Vaissière, B. E., Cane, J. H., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C., & Tscharntke, T. (2006). Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society B: Biological Sciences*, *274*(1608), 303–313. doi: 10.1098/rspb.2006.3721

Larsson, M. (2005). Higher pollinator effectiveness by specialist than generalist flower-visitors of unspecialized Knautia arvensis (Dipsacaceae). *Oecologia*, *146*(3), 394–403. doi: 10.1007/s00442-005-0217-y

Lautenbach, S., Seppelt, R., Liebscher, J., & Dormann, C. F. (2012). Spatial and Temporal Trends of Global Pollination Benefit. *PLoS ONE*, *7*(4). doi: 10.1371/journal.pone.0035954

Losey, J. E., & Vaughan, M. (2006). The Economic Value of Ecological Services Provided by Insects. *BioScience*, *56*(4), 311. doi: 10.1641/0006-3568(2006)56[311:tevoes]2.0.co;2

Ne'eman, G., Jürgens, A., Newstrom-Lloyd, L., Potts, S. G., & Dafni, A. (2010). A framework for comparing pollinator performance: Effectiveness and efficiency. Biological Reviews. https://doi.org/10.1111/j.1469-185X.2009.00108.x

Nabors, A., Cen, H., Hung, K. L. J., Kohn, J. R., Holway, D. A. (2018). The effect of removing numerically dominant, non-native honey bees on seed set of a native plant. Oecologia 186(1), 281–289. doi.org/10.1007/s00442-017-4009-y

Ollerton, J., Winfree, R., and Tarrant, S. (2011). How many flowering plants are pollinated by animals? Oikos, 120,321-326. doi: 10.1111/j.1600-0706.2010.18644.x

Petersen, J. D., Reiners, S., & Nault, B. A. (2013). Pollination Services Provided by Bees in Pumpkin Fields Supplemented with Either Apis mellifera or Bombus impatiens or Not Supplemented. *PLoS ONE*, *8*(7). doi: 10.1371/journal.pone.0069819

Potts, S.G., Imperatriz-Fonseca, V., Ngo, H.T., Aizen, M.A., Biesmeijer, J.C., Breeze, T.D., Dicks, L.V., Garibaldi, L.A., Hill, R., Settele, J., Vanbergen, A.J. (2016). Safeguarding pollinators and their values to human well-being. *Nature*, *540*(7632), 220-229. doi:10.1038/nature20588.

Sahli, H. F., & Conner, J. K. (2007). Visitation, effectiveness, and efficiency of 15 genera of visitors to wild radish, *Raphanus raphanistrum* (Brassicaceae). *American Journal of Botany*, *94*(2), 203–209. doi: 10.3732/ajb.94.2.203

Smith, K. M., Loh, E. H., Rostal, M. K., Zambrana-Torrelio, C. M., Mendiola, L., & Daszak, P. (2013). Pathogens, pests, and economics: drivers of honey bee colony declines and losses. Ecohealth, 10(4), 434-445. doi:10.1007/s10393-013-0870-2

Tepedino, J. (1981). The Pollination Efficiency of the Squash Bee (Peponapis pruinosa) and the Honey Bee (Apis mellifera) on Summer Squash (Cucurbita pepo) Author (s): Vincent J. Tepedino Source: *Journal of the Kansas Entomological Society*, Vol. 54, No. 2 (Apr. Journal of the Kansas Entomological Society, 54(2), 359–377.

Tepedino, V., Horn, L. A., & Durham, S. (2016). Pollen removal and deposition by pollen- and nectar-collecting specialist and generalist bee visitors to Iliamna bakeri (Malvaceae). *Journal of Pollination Ecology*, *19*, 50–56. doi: 10.26786/1920-7603(2016)2

Vidal, Maria das Graças, Jong, David de, Wien, Hans Chris, & Morse, Roger A. (2010). Pollination and fruit set in pumpkin (Cucurbita pepo) by honey bees. *Brazilian Journal of Botany*, *33*(1), 106-113. https://dx.doi.org/10.1590/S0100-84042010000100010

Walters, S. A., & Taylor, B. H. (2006). Effects of Honey Bee Pollination on Pumpkin Fruit and Seed Yield. *HortScience*, *41*(2), 370–373. doi: 10.21273/hortsci.41.2.370

Willis, D. S., & Kevan, P. G. (1995). Foraging Dynamics Of Peponapis Pruinosa (Hymenoptera: Anthophoridae) On Pumpkin (Cucurbita Pepo) In Southern Ontario. *The Canadian Entomologist*, *127*(2), 167–175. doi: 10.4039/ent127167-2

Williams, N.M., & Thomson, J.D. (2003) Comparing pollinator quality of honey bees (Hymenoptera: Apoidea) and native bees using pollen removal and deposition measures. In: Say T (ed) Publications in entomology. Entomological Society of America, Lanham

Winfree, R., Gross, B. J., & Kremen, C. (2011). Valuing pollination services to agriculture. *Ecological Economics*, *71*, 80–88. doi: 10.1016/j.ecolecon.2011.08.001

Winsor, J. A., Davis, L. E., & Stephenson, A. G. (1987). The Relationship between Pollen Load and Fruit Maturation and the Effect of Pollen Load on Offspring Vigor in Cucurbita pepo. *The American Naturalist*, *129*(5), 643–656. doi: 10.1086/284664

Xie, Z., Pan, D., Teichroew, J., & An, J. (2016). The Potential Influence of Bumble Bee Visitation on Foraging Behaviors and Assemblages of Honey Bees on Squash Flowers in Highland Agricultural Ecosystems. *Plos One*, *11*(1). doi: 10.1371/journal.pone.0144590

Tables

Table 1. Results of (i) multiple logistic regression analysis of visitation frequency on fruit set, and (ii) multiple regression analyses of visitation frequency on mean seed mass, number of seeds per fruit, pollen deposition, and pollen removed. Independent variables in these analyses consider pollination date and visitation by *A. mellifera*, *P. pruinosa* (♀), and *P. pruinosa* (♂). For each analysis the full model is provided under 'A' and the model with the lowest AIC value is provided under 'B.'

	Model 1A			Model 1B		
N = 103	AIC	χ^2	*P*	AIC	χ^2	*P*
	116	36.9	< 0.001	110	36.8	< 0.001
Response variable	Coefficients					
Fruit set	β ± 1SE	Wald (χ^2)	*P*	β ± 1SE	Wald (χ^2)	*P*
A. mellifera	0.278 ± 0.094	8.69	0.003202	0.275 ± 0.094	8.65	0.003264
P. pruinosa (♀)	0.674 ± 0.167	16.2	< 0.001	0.666 ± 0.164	16.5	< 0.001
P. pruinosa (♂)	-0.075 ± 0.269	0.077	0.78			
Pollination date (day of year)	-0.066 ± 0.028	5.59	0.018105	-0.065 ± 0.028	5.51	0.018884

	Model 2A				Model 2B			
N = 40	AIC	Adjusted R^2	F	*P*	AIC	Adjusted R^2	F	*P*
	335	0.173	3.04	0.02981	330	0.217	11.8	0.00145
Response Variable	Coefficients							
Mean seed mass	β ± 1SE		t-value	*P*	β ± 1SE		t-value	*P*
A. mellifera	0.191 ± 0.844		0.226	0.8223				
P. pruinosa (♀)	-1.03 ± 1.16		-0.886	0.3816				
P. pruinosa (♂)	0.049 ± 2.13		0.023	0.9818				
Pollination date (day of year)	-0.465 ± 0.246		-1.89	0.0672	-0.607 ± 0.177		-3.43	0.00146

	Model 3A				Model 3B			
N = 40	AIC	Adjusted R^2	F	*P*	AIC	Adjusted R^2	F	*P*
	78.2	0.144	2.10	0.08018	74.4	0.190	3.29	0.02181
Response variable	Coefficients							
log(Number of seeds)	β ± 1SE		t-value	*P*	β ± 1SE		t-value	*P*
A. mellifera	0.013 ± 0.035		0.36	0.71845				
P. pruinosa (♀)	0.072 ± 0.047		1.53	0.13563	0.071 ± 0.034		2.07	0.04638
P. pruinosa (♂)	-1.14 ± 0.378		-3.01	0.00504	-1.17 ± 0.358		-3.26	0.00249
(*P. pruinosa* (♂))^2	0.086 ± 0.047		1.93	0.06194	0.088 ± 0.043		2.03	0.05035
A. mellifera * *P. pruinosa* (♂)	0.210 ± 0.072		2.92	0.00631	0.218 ± 0.067		3.26	0.00249
Pollination date (day of year)	0.0001047 ± 0.0098		0.011	0.99159				

Table 1. Continued.

	Model 4A				Model 4B			
N = 41	AIC	Adjusted R^2	F	*P*	AIC	Adjusted R^2	F	*P*
	91.2	0.267	3.91	0.006414	88.4	0.287	6.36	0.00138
Response variable	Coefficients							
log(Pollen deposition)	β ± 1SE		t-value	*P*	β ± 1SE		t-value	*P*
A. mellifera	-0.224 ± 0.128		-1.75	0.08910	-0.188 ± 0.121		-1.56	0.12768
P. pruinosa (♀)	0.169 ± 0.055		3.09	0.00392	0.142 ± 0.00077		3.67	0.00077
P. pruinosa (♂)	0.068 ± 0.101		0.669	0.50757				
(*A. mellifera*)^2	0.037 ± 0.015		2.49	0.01754	0.032 ± 0.014		2.33	0.02546
Pollination date (day of year)	- 0.008 ± 0.011		-0.682	0.49990				

Table 2. Results of (i) multiple logistic regression analysis of cumulative duration of stigmatic contact on fruit set, and (ii) multiple regression analyses of duration of stigmatic contact on mean seed mass, number of seeds per fruit, and pollen deposition. Independent variables in these analyses consider pollination date and visitation by *A. mellifera*, *P. pruinosa* (♀), and *P. pruinosa* (♂). For each analysis the full model is provided under 'A' and the model with the lowest AIC value is provided under 'B.'

	Model 1A			Model 1B		
N = 101	AIC	χ^2	*P*	AIC	χ^2	*P*
	119	27.5	< 0.001	117	27.5	< 0.001
Response variable	Coefficients					
Fruit set	β ± 1SE	Wald (χ^2)	*P*	β ± 1SE	Wald (χ^2)	*P*
A. mellifera stigma time	0.018 ± 0.008	5.68	0.017193	0.018 ± 0.008	5.67	0.0172863
P. pruinosa (♀) stigma time	0.015 ± 0.004	17.0	< 0.001	0.015 ± 0.004	17.0	< 0.001
P. pruinosa (♂) stigma time	0.000632 ± 0.007	0.009	0.923943			
(*P. pruinosa* (♀) stigma time)^2	-0.0000139 ± 0.00000401	12.0	0.000531	-0.0000139 ± 0.00000272	12.0	< 0.001
Pollination date (day of year)	-0.057 ± 0.027	4.41	0.035767	-0.057 ± 0.027	4.50	0.0339558

	Model 2A				Model 2B			
N = 38	AIC	Adjusted R^2	F	*P*	AIC	Adjusted R^2	F	*P*
	315	0.329	3.60	0.006283	313	0.349	4.30	0.002884
Response Variable	Coefficients							
Mean seed mass	β ± 1SE		t-value	*P*	β ± 1SE		t-value	*P*
A. mellifera stigma time	-0.020 ± 0.062		-0.330	0.74390				
P. pruinosa (♀) stigma time	-0.018 ± 0.013		-1.342	0.18967	-0.017 ± 0.013		-1.32	0.19550
P. pruinosa (♂) stigma time	-0.911 ± 0.323		-2.818	0.00848	-0.900 ± 0.317		-2.84	0.00790
(*P. pruinosa* (♂) stigma time)^2	0.008 ± 0.003		2.779	0.00931	0.008 ± 0.003		2.81	0.00847
A. mellifera stigma time * *P. pruinosa* (♀) stigma time	-0.032 ± 0.017		-1.940	0.06183	-0.032 ± 0.002		-1.98	0.05683
P. pruinosa (♀) stigma time **P. pruinosa* (♂) stigma time	0.001 ± 0.001		1.890	0.06847	0.001 ± 0.001		1.91	0.06560
Pollination date (day of year)	-0.539 ± 0.235		-2.289	0.02930	-0.552 ± 0..228		-2.42	0.02168

Table 2. Continued.

	Model 3A			
N = 38	AIC	Adjusted R^2	F	*P*
	80.9	- 0.106	0.114	0.9766
Response Variable	Coefficients			
log(Number of seeds)	β ± 1SE		t-value	*P*
A. mellifera stigma time	- 0.0002769 ± 0.002921		- 0.095	0.925
P. pruinosa (♀) stigma time	0.0003285 ± 0.0006262		0.525	0.603
P. pruinosa (♂) stigma time	-0.000669 ± 0.00262		-0.064	0.950
Pollination date (day of year)	-0.0006465 ± 0.01091		-0.059	0.953

	Model 4A				Model 4B			
N = 39	AIC	Adjusted R^2	F	*P*	AIC	Adjusted R^2	F	*P*
	573	0.122	2.31	0.077	569	0.149	7.66	0.00876
Response variable	Coefficients							
Pollen deposition	β ± 1SE		t-value	*P*	β ± 1SE		t-value	*P*
A. mellifera stigma time	0.730 ± 1.56		0.469	0.64202				
P. pruinosa (♀) stigma time	0.954 ± 0.333		2.87	0.00704	0.670 ± 0.242		2.77	0.00876
P. pruinosa (♂) stigma time	- 0.508 ± 1.40		- 0.364	0.71785				
Pollination date(day of year)	- 7.50 ± 5.81		-1.29	0.20593				

Table 3. Results of logistic regression analysis (model 1) and linear regression analyses (model 2 – 5) on the effect of visitation frequency by *A. mellifera* on fruit set, seed set, pollen deposition and pollen removal for squash flowers that were only visited by *A. mellifera*. Akaike information criterion (AIC) was used to estimate best fit model. The number of visits for model 5 was log transformed to reduce variance.

			Coefficient summary			Model summary			
Model		Response variable	β ± 1SE	Wald (χ^2)	*P*	AIC	χ^2		*P*
1	N = 58	Fruit set	0.205 ± 0.086	5.65	0.01749	66.2	6.15		0.01315
			β ± 1SE	t-value	*P*	AIC	Adjusted R^2	F-value	*P*
2	N = 16	Mean seed mass (mg)	1.024 ± 1.912	0.535	0.601	153	-0.050	0.287	0.6007
3	N = 16	Number of seeds	1.38 ± 3.91	0.352	0.7302	176	-0.062	0.124	0.7302
4	N = 16	log(Pollen deposition)	0.067 ± 0.046	1.46	0.166	33.1	0.070	2.131	0.1664
5	N = 38	Pollen removed (mg)	4.50 ± 1.95	2.31	0.027	271	0.104	5.31	0.02703

Table 4. Results of logistic regression analysis (model 1) and linear regression analyses (model 2 – 5) on the effect of *A. mellifera* behavior (i.e. total stigma and total anther time) on fruit set, seed set, pollen deposition and pollen removal for squash flowers that were only visited by *A. mellifera*. Total stigma time and anther time were log transformed to better meet regression analysis assumptions.

			Coefficient summary			Model summary			
Model		Response variable	β ± 1SE	Wald (χ^2)	*P*	AIC	χ^2		*P*
1	N = 58	Fruit set	0.466 ± 0.271	2.94	0.08624	69.1	3.19		0.7395
			β ± 1SE	t-value	*P*	AIC	Adjusted R^2	F-value	*P*
2	N = 16	Mean seed mass (mg)	1.08 ± 6.63	0.163	0.872609	153	-0.069	0.027	0.872
3	N = 16	Number of seeds	14.4 ± 13.0	1.11	0.286	174	0.015	1.23	0.2856
4	N = 16	log(Pollen deposition)	0.391 ± 0.132	2.96	0.0104	27.7	0.340	8.74	0.01043
5	N = 38	Pollen removed (mg)	2.68 ± 0.921	2.91	0.00613	268	0.168	8.48	0.006126

Table 5. Results of multiple regression analyses on the effect of visitation frequency and the total time species spent on the anthers by each species on pollen removed. Independent variables in these analyses consider pollination date, visitation and cumulative time spent on anthers by *A. mellifera*, *P. pruinosa* (♀), and *P. pruinosa* (♂). For each analysis the full model is provided under 'A' and the model with the lowest AIC value is provided under 'B.'

	Model 1A				Model 1B			
N = 102	AIC	Adjusted R^2	F	*P*	AIC	Adjusted R^2	F	*P*
	739	0.294	6.26	< 0.001	736	0.298	8.15	< 0.001
Response variable	Coefficients							
Pollen removed	β ± 1SE		t-value	*P*	β ± 1SE		t-value	*P*
A. mellifera	1.16 ± 0.429		2.70	0.00830	1.13 ± 0.406		2.78	0.006524
P. pruinosa (♀)	8.24 ± 1.80		4.58	< 0.001	7.96 ± 1.68		4.73	< 0.001
P. pruinosa (♂)	-1.24 ± 3.94		-0.316	0.75282				
(*P. pruinosa* (♀))^2	-0.709 ± 0.194		-3.65	< 0.001	-0.705 ± 0.186		-3.79	0.000268
(*P. pruinosa* (♂))^2	3.00 ± 1.80		1.67	0.09818	2.36 ± 0.980		2.41	0.017901
A. mellifera * *P. pruinosa* (♀)	-0.415 ± 0.230		-1.81	0.07411	-0.427 ± 0.221		-1.93	0.05628
A. mellifera * *P. pruinosa* (♂)	-1.37 ± 0.531		-2.58	0.01148	-1.368 ± 0.496		-2.76	0.006931
Pollination date (day of year)	- 0.101 ± 0.086		-1.78	0.24206				

	Model 2A				Model 2B			
N = 101	AIC	Adjusted R^2	F	*P*	AIC	Adjusted R^2	F	*P*
	711	0.417	12.9	< 0.001	708	0.423	19.3	< 0.001
Response variable	Coefficients							
Pollen removed	β ± 1SE		t-value	*P*	β ± 1SE		t-value	*P*
log *A. mellifera* anther time	1.17 ± 2.33		0.506	0.6141				
log *P. pruinosa* (♀) anther time	3.40 ± 0.469		7.25	< 0.001	3.19 ± 0.411		2.46	< 0.001
log *P. pruinosa* (♂) anther time	1.11 ± 0.588		1.88	0.0630	1.01 ± 0.574		7.77	0.0805
(log *A. mellifera* anther time)^2	0.926 ± 0.650		1.42	0.1573	1.21 ± 0.281		1.77	< 0.001
log *A. mellifera* anther time * log *P. pruinosa* (♀) anther time	-0.621 ± 0.280		-2.21	0.0293	-0.576 ± 0.251		4.32	0.0241
Pollination date (day of year)	-0.064 ± 0.073		-0.867	0.3881				

Figures

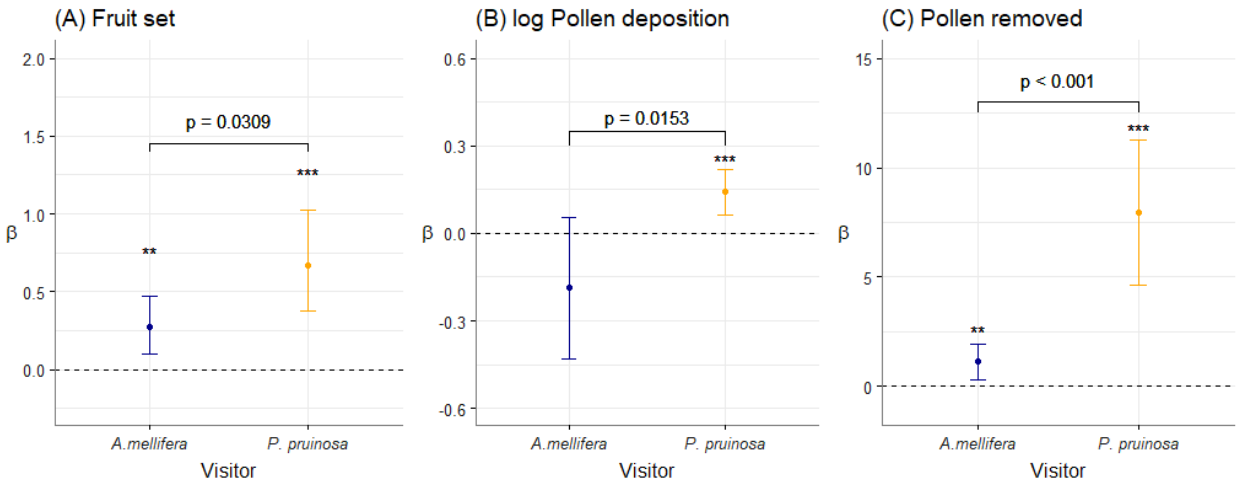

Figure 1. Partial regression coefficients (β ± 95% CI) from Model 1B, 4B, and 5B (Table 1) for the effect of visitation frequency of *A. mellifera* and *P. pruinosa* (♀) on (A) fruit set, (B) pollen grains deposited onto stigmas, and (C) the amount of pollen removed from anthers. Brackets indicate significant difference between regression coefficients. Asterisks refer to significance of coefficients within a model (*** < 0.001 ; ** < 0. 01; * < 0.05)

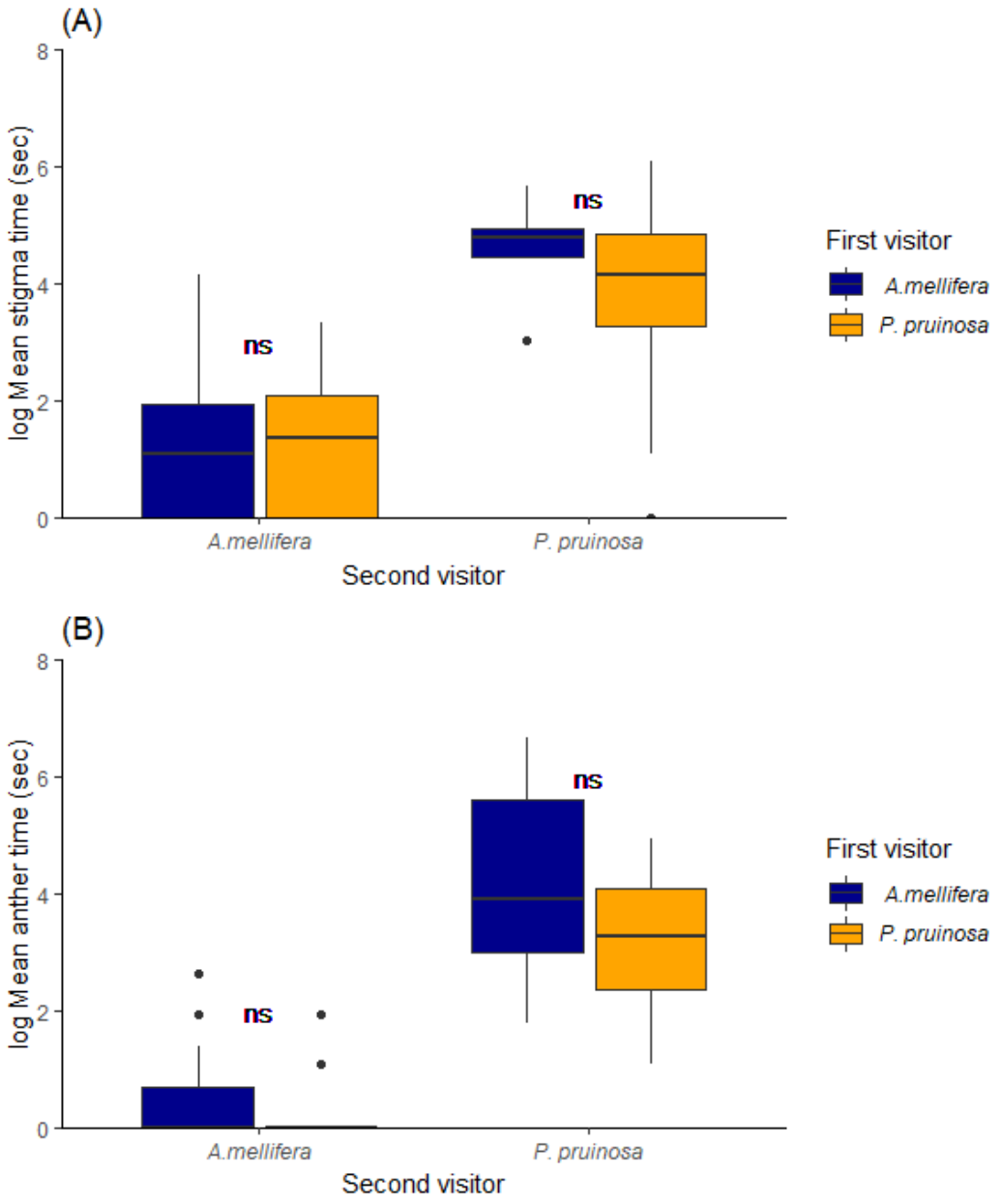

Figure 2. Mean time spent on stigma or anthers by second visitor. Mean stigma times of second visitors (*A. mellifera* or *P. pruinosa* (♀)) showed no significant difference in (A) pistillate flowers when the first visitor was either *A. mellifera* (blue) or *P. pruinosa* (♀) (orange). Likewise, there was no significant difference in mean anther times in (B) staminate flowers. ns: not significant.

Appendices

Appendix 1. Soil Moisture Reading Data. This table summarizes the mean soil moisture readings for each plant per date. Soil moisture readings were collected three times a week from July 8th to September 6th. Each plant received four soil moisture readings per date, one hour after watering ended. The mean of all soil moisture readings throughout the project are listed under Over Entire Season.

Plant #	8-Jul Mean VWC (%)	15-Jul Mean VWC (%)	22-Jul Mean VWC (%)	29-Jul Mean VWC (%)	5-Aug Mean VWC (%)	12-Aug Mean VWC (%)	19-Aug Mean VWC (%)	26-Aug Mean VWC (%)	2-Sep Mean VWC (%)	Over Entire Season Mean VWC (%)	StDev
1	41.8	36.2	31.9	29.7	23.4	21.8	28.7	24.8	33.0	30.1	6.4
4	34.6	32.4	30.3	33.0	25.2	30.1	39.7	29.4	29.3	31.5	4.1
6	28.3	31.9	26.1	28.0	24.0	30.3	24.2	13.1	29.2	26.1	5.5
9	29.4	38.8	27.2	29.1	25.1	26.6	27.5	26.7	29.8	28.9	4.0
11	29.9	37.7	29.5	25.5	25.3	28.5	26.8	27.5	28.3	28.7	3.7
14	31.2	40.9	29.3	29.9	24.5	31.5	30.9	28.4	36.2	31.4	4.7
17	30.1	40.9	30.2	26.0	26.1	30.4	30.0	18.3	40.2	30.2	7.0
20	33.3	46.5	33.1	25.2	23.8	35.1	26.0	23.2	34.5	31.2	7.5
23	30.8	44.7	31.4	25.6	25.1	31.7	28.7	27.6	35.9	31.3	6.0
27	29.7	36.4	29.1	23.6	27.3	32.4	36.8	23.9	35.0	30.5	5.0
30	29.4	41.5	31.7	28.3	30.8	34.3	33.5	35.6	37.9	33.6	4.2
33	32.1	43.5	30.6	24.5	25.8	25.4	22.9	22.0	17.2	27.1	7.6
37	31.3	41.8	27.1	24.4	22.3	16.2	21.8	19.2	16.4	24.5	8.1
40	33.3	48.2	36.5	35.7	32.6	32.1	32.6	30.2	36.8	35.3	5.3
43	34.8	49.1	36.3	33.7	37.3	36.9	38.5	35.1	42.3	38.2	4.8
46	34.1	44.9	37.9	29.8	35.2	31.1	41.5	38.2	32.6	36.1	4.9
49	30.1	39.8	32.4	18.4	25.8	20.4	40.5	30.3	32.4	30.0	7.6
51	30.6	37.3	34.2	21.3	22.8	23.6	23.9	22.4	19.5	26.2	6.3
54	30.5	37.3	33.7	20.5	33.9	29.2	28.6	24.2	29.6	29.7	5.1
56	46.0	61.9	34.9	25.0	34.3	35.7	59.3	35.0	40.4	41.4	12.2
59	45.6	40.0	38.1	30.9	34.6	33.7	34.9	36.4	37.5	36.8	4.2
62	25.5	39.3	36.7	22.9	35.0	32.3	30.5	34.6	36.1	32.5	5.4
65	25.8	42.5	32.2	26.2	28.4	28.4	31.8	34.0	27.1	30.7	5.3
68	21.7	39.3	31.6	27.8	32.4	38.0	42.2	36.8	38.6	34.3	6.5
72	23.2	38.8	35.0	25.9	34.4	37.0	44.5	45.2	39.4	35.9	7.5
75	27.4	42.9	37.6	25.2	38.8	38.3	38.6	36.4	41.5	36.3	6.0
78	23.3	41.5	36.1	26.8	36.7	32.9	47.4	36.4	42.0	35.9	7.5
82	20.8	41.1	39.3	25.9	31.1	36.1	42.2	34.1	38.3	34.3	7.2
85	23.5	31.0	39.9	24.1	26.7	34.6	33.8	28.6	24.7	29.6	5.6
88	23.2	39.1	38.7	30.5	29.8	33.2	38.5	41.0	37.4	34.6	5.8
91	31.3	38.6	37.4	23.0	21.9	22.8	32.3	23.2	17.1	27.5	7.6
94	20.1	32.2	37.0	26.9	29.4	26.6	40.6	38.1	36.5	31.9	6.7
96	22.7	36.2	35.6	25.1	25.9	28.1	39.2	35.5	35.4	31.5	6.0
99	20.4	40.9	38.8	26.7	23.9	26.4	37.0	31.3	34.5	31.1	7.2
101	19.4	36.2	33.7	27.8	27.5	30.8	38.9	38.1	31.2	31.5	6.1
104	19.6	38.9	36.3	18.7	23.0	30.2	35.3	29.5	33.7	29.5	7.5
107	21.5	37.0	38.5	26.4	23.0	35.9	42.2	39.1	35.3	33.2	7.6
110	19.4	45.1	36.9	24.4	24.4	31.3	30.0	31.9	26.5	30.0	7.7

Plant #	8-Jul Mean VWC (%)	15-Jul Mean VWC (%)	22-Jul Mean VWC (%)	29-Jul Mean VWC (%)	5-Aug Mean VWC (%)	12-Aug Mean VWC (%)	19-Aug Mean VWC (%)	26-Aug Mean VWC (%)	2-Sep Mean VWC (%)	Over Entire Season Mean VWC (%)	StDev
113	22.0	35.9	38.8	23.7	28.6	30.5	38.8	25.6	34.1	30.9	6.4
117	23.7	40.2	35.6	26.2	25.6	30.7	33.4	33.6	26.8	30.6	5.5
120	20.9	38.1	38.6	26.6	25.5	26.7	42.2	38.9	25.1	31.4	7.9
123	19.6	33.0	35.8	21.4	30.2	33.4	40.1	27.5	42.7	31.5	7.8
127	23.3	41.5	41.6	28.9	28.0	35.1	40.4	41.1	40.0	35.5	7.1
130	20.4	38.6	37.0	26.9	27.6	34.7	44.6	31.4	30.4	32.4	7.2
133	20.2	36.0	35.2	25.4	29.0	33.7	42.9	29.3	34.7	31.8	6.7
136	27.0	44.5	41.6	29.2	31.4	26.7	43.0	43.1	33.4	35.5	7.4
139	20.1	36.2	36.8	29.9	27.0	33.5	40.5	36.8	36.4	33.0	6.3
141	23.8	35.7	35.3	25.6	31.5	36.0	45.4	49.7	45.4	36.5	8.9
144	21.7	40.1	38.0	27.7	30.1	33.2	43.1	41.7	38.5	34.9	7.2
146	23.6	38.6	36.1	26.3	25.7	29.8	47.4	46.5	33.4	34.2	8.8
149	22.2	44.6	41.6	31.4	33.4	35.5	46.5	43.8	41.1	37.8	7.8
150	21.2	39.8	38.6	27.3	32.7	33.2	39.0	46.2	35.8	34.8	7.4

Plant #	10-Jul Mean VWC (%)	17-Jul Mean VWC (%)	24-Jul Mean VWC (%)	31-Jul Mean VWC (%)	7-Aug Mean VWC (%)	14-Aug Mean VWC (%)	21-Aug Mean VWC (%)	28-Aug Mean VWC (%)	4-Sep Mean VWC (%)	Over Entire Season Mean VWC (%)	StDev
3	31.9	29.6	26.6	24.3	17.1	20.5	17.5	25.5	24.4	24.1	5.1
7	28.5	28.3	26.0	22.7	16.0	N/A	19.9	17.4	14.3	21.6	5.6
10	29.6	29.5	27.8	23.0	22.7	19.7	14.9	25.5	16.2	23.2	5.4
13	30.1	29.7	27.0	21.9	23.5	N/A	16.4	23.8	19.3	23.9	4.8
16	32.6	36.6	30.8	44.3	36.3	N/A	N/A	37.8	26.1	34.9	5.8
19	30.8	38.7	23.9	41.7	28.0	31.8	18.6	43.3	25.8	31.4	8.4
21	33.9	36.1	27.5	31.6	31.1	25.7	29.7	29.9	23.3	29.9	4.0
24	33.5	36.1	29.2	39.3	38.8	33.2	25.8	40.8	24.1	33.4	6.0
26	31.7	38.2	28.9	37.0	32.7	21.0	23.7	30.9	26.6	30.1	5.7
29	51.2	59.2	37.9	61.6	57.1	33.3	42.1	49.6	21.5	45.9	13.3
32	37.7	39.7	31.7	34.1	28.5	23.8	29.3	35.6	24.3	31.6	5.6
35	37.7	39.1	37.9	40.1	31.9	29.3	37.5	33.7	30.4	35.3	4.0
38	30.5	33.7	27.0	36.1	22.2	24.6	30.8	32.1	21.4	28.7	5.2
45	45.3	40.6	29.2	42.0	44.7	33.6	41.5	35.0	26.9	37.6	6.7
48	37.1	42.7	31.5	41.1	35.0	28.2	36.0	35.1	38.8	36.2	4.5
52	38.2	46.0	31.0	37.1	35.9	26.4	37.8	26.9	28.2	34.1	6.5
55	43.3	50.5	32.0	39.7	45.0	27.9	42.6	32.2	29.9	38.1	7.9

58	39.5	41.3	36.4	54.8	53.9	35.8	58.7	49.8	42.2	45.8	8.6
61	38.9	41.1	27.9	34.2	30.7	28.5	40.1	36.5	33.0	34.5	4.9
64	34.1	41.5	28.1	37.5	31.1	27.4	35.2	34.1	33.2	33.6	4.4

	10-Jul	17-Jul	24-Jul	31-Jul	7-Aug	14-Aug	21-Aug	28-Aug	4-Sep	Over Entire Season	
	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	
Plant	VWC	VWC	VWC	VWC	VWC	VWC	VWC	VWC	VWC	VWC	
#	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	StDev
66	44.5	37.7	27.2	32.1	23.7	17.1	26.4	25.7	26.7	29.0	8.1
69	40.0	45.8	25.1	39.2	24.2	30.8	35.7	28.6	31.7	33.4	7.3
71	39.0	41.6	30.9	40.8	31.0	28.0	42.8	32.5	31.1	35.3	5.7
74	40.8	45.3	30.6	29.2	10.7	14.6	29.4	37.5	29.7	29.7	11.3
77	40.0	43.6	30.5	40.6	29.6	30.8	36.0	35.6	32.0	35.4	5.1
80	38.6	34.4	29.5	37.8	11.6	14.3	30.9	26.5	30.2	28.2	9.5
83	41.5	37.7	28.1	46.4	50.6	34.7	29.6	36.9	28.0	37.0	8.0
87	36.4	44.9	26.8	39.6	25.7	22.1	33.3	26.6	23.4	31.0	7.9
90	39.5	40.9	33.7	37.6	32.9	28.2	39.4	35.5	37.0	36.1	4.0
93	41.8	39.5	27.6	38.5	30.2	32.7	42.2	34.1	29.1	35.1	5.6
97	41.5	39.7	30.5	40.8	40.3	37.3	46.3	37.4	37.8	39.0	4.2
100	33.7	40.6	28.6	41.2	27.4	31.6	39.6	37.8	37.2	35.3	5.2
103	37.8	40.0	30.3	37.8	26.1	31.4	34.2	24.0	35.8	33.0	5.5
106	40.2	42.4	30.9	39.0	39.5	28.9	44.7	37.7	39.1	38.0	5.1
109	39.8	40.9	26.2	31.1	25.3	24.3	32.8	19.7	24.0	29.3	7.3
111	38.1	46.2	29.3	36.9	29.4	30.6	48.4	40.8	29.4	36.6	7.5
114	35.3	39.3	29.4	34.4	33.6	24.7	32.0	33.3	39.9	33.5	4.7
115	44.6	42.7	31.4	38.2	37.9	24.8	37.7	35.7	30.5	35.9	6.2
116	35.7	42.0	29.4	40.7	25.4	30.6	46.3	33.4	35.2	35.4	6.7
118	33.9	38.2	28.2	31.6	29.8	28.8	26.0	34.1	28.3	31.0	3.8
119	32.5	48.0	35.0	40.4	35.7	30.6	43.5	40.9	32.1	37.6	5.9
122	26.4	38.4	30.7	34.8	26.6	18.6	35.7	32.8	31.0	30.5	6.0
128	32.8	43.4	31.3	32.5	37.0	42.2	23.5	39.3	37.8	35.5	6.2
135	27.9	35.9	34.2	39.7	35.0	33.3	34.9	28.6	29.7	33.2	3.8
138	N/A	42.6	30.1	33.9	27.6	30.2	32.7	34.6	29.8	32.7	4.6
145	33.7	38.2	34.0	36.1	36.7	35.8	30.3	40.0	28.3	34.8	3.7
148	N/A	50.5	36.5	44.0	35.4	35.4	37.4	47.5	40.0	40.8	5.8

	19-Jul	26-Jul	2-Aug	9-Aug	16-Aug	23-Aug	30-Aug	6-Sep	Over Entire Season	
	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	
Plant	VWC	VWC	VWC	VWC	VWC	VWC	VWC	VWC	VWC	
#	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	StDev
2	34.2	31.3	42.9	34.4	39.5	36.8	35.6	42.4	37.1	4.1
5	29.4	25.8	39.0	33.3	34.1	34.8	33.9	39.9	33.8	4.6
8	30.6	30.4	25.7	20.7	31.5	35.2	28.8	35.6	29.8	4.9

15	28.8	27.4	34.3	25.6	31.6	35.7	30.4	36.2	31.3	3.9
18	29.9	26.2	30.7	21.2	29.3	32.3	29.2	39.2	29.7	5.1
22	26.7	26.7	31.3	18.5	30.0	18.0	23.7	24.7	24.9	4.8
25	25.8	22.9	32.2	25.9	31.5	34.7	24.5	30.1	28.4	4.2

	19-Jul	26-Jul	2-Aug	9-Aug	16-Aug	23-Aug	30-Aug	6-Sep	Over Entire Season	
Plant #	Mean VWC (%)	Mean VWC (%)	Mean VWC (%)	Mean VWC (%)	Mean VWC (%)	Mean VWC (%)	Mean VWC (%)	Mean VWC (%)	Mean VWC (%)	StDev
28	31.2	30.2	29.2	21.9	31.5	38.4	27.8	36.8	30.8	5.1
31	36.6	25.8	30.5	29.8	28.7	34.1	26.4	47.1	32.4	7.0
34	31.4	29.6	25.8	25.8	16.7	28.8	23.5	25.4	25.9	4.5
36	31.9	23.7	35.0	29.9	25.5	27.9	29.6	34.9	29.8	4.1
39	34.9	30.2	35.4	27.1	28.2	38.7	30.5	48.3	34.2	7.0
41	36.0	51.3	52.4	41.7	N/A	58.0	56.9	53.5	50.0	8.1
44	35.3	65.8	46.8	44.5	N/A	49.1	55.9	50.1	49.6	9.5
47	33.2	36.5	36.1	39.0	26.6	38.3	41.5	41.2	36.5	4.9
50	29.7	39.5	33.2	31.8	13.3	34.6	35.6	37.3	31.8	8.1
53	31.7	39.4	32.9	28.4	24.4	34.3	35.0	38.2	33.0	4.9
57	32.7	43.8	40.7	37.2	32.3	49.1	45.7	43.9	40.7	6.1
60	34.1	46.0	36.9	34.1	28.9	39.5	41.5	43.1	38.0	5.6
63	33.7	41.0	35.4	38.3	31.7	39.3	36.4	41.3	37.1	3.4
67	35.5	41.6	38.9	32.8	35.5	30.8	35.4	40.6	36.4	3.7
70	31.9	39.3	39.0	40.0	41.4	36.6	42.5	43.7	39.3	3.7
73	35.0	42.2	37.4	40.4	39.7	34.1	40.7	41.9	38.9	3.1
76	31.4	35.5	30.8	35.3	34.8	37.1	27.8	37.9	33.8	3.5
79	29.6	40.5	33.3	38.1	36.5	38.0	41.4	44.5	37.7	4.7
81	29.9	38.1	36.2	37.0	37.1	37.2	35.4	42.4	36.7	3.5
84	33.9	39.7	28.7	19.9	29.4	26.6	19.7	33.1	28.8	6.9
86	33.5	38.4	40.1	39.8	36.1	35.7	36.4	39.0	37.3	2.3
89	33.0	39.5	35.1	39.7	34.4	39.1	35.7	41.8	37.3	3.1
92	31.9	37.8	17.9	28.5	24.3	25.8	28.8	33.7	28.6	6.1
95	35.3	46.1	31.3	24.6	22.2	31.9	29.7	32.0	31.6	7.2
98	29.3	40.3	31.8	32.4	21.9	22.8	30.8	35.5	30.6	6.1
102	31.6	39.5	26.7	36.7	25.6	32.7	34.7	36.6	33.0	4.9
105	30.3	37.8	29.9	29.7	24.6	30.9	34.1	31.0	31.0	3.8
108	31.4	39.0	25.7	27.4	27.0	31.9	31.7	33.0	30.9	4.2
112	33.7	33.8	26.9	27.9	27.3	29.6	38.7	30.6	31.0	4.1
121	25.2	34.6	29.4	31.5	30.7	33.1	31.2	36.1	31.5	3.3
124	29.7	32.3	32.7	30.3	31.6	37.2	35.0	35.7	33.0	2.7
126	30.4	35.0	35.8	27.6	32.8	36.8	31.1	49.5	34.9	6.7
129	25.9	32.2	31.2	28.8	31.9	39.6	34.8	39.6	33.0	4.8
131	24.7	33.5	33.0	32.2	32.6	32.8	37.6	32.1	32.3	3.6

137	29.2	38.2	37.6	33.8	39.9	31.8	41.7	43.2	36.9	4.9
140	30.1	48.6	37.8	34.8	40.6	33.6	40.4	44.3	38.8	6.0
143	31.4	43.4	42.8	39.7	36.3	29.0	37.7	38.2	37.3	5.0
147	28.8	44.0	40.1	28.9	37.6	38.2	35.8	40.7	36.7	5.4

Appendix 2. Staminate flowers open to bees daily. Pollination bags were removed from a portion of staminate flowers before visitation trials began to supply visitors with enough pollen for deposition on pistillate flowers.

Flowering date (day of year)	Number of Flowers opening that day	Number of staminate flowers open to bees	Proportion of open staminate flowers
208	22	16	0.73
209	54	21	0.39
210	95	51	0.54
211	135	51	0.38
212	141	62	0.44
213	134	43	0.32
214	164	49	0.30
215	168	47	0.28
216	168	50	0.30
217	134	48	0.36
218	166	57	0.34
219	167	56	0.34
220	175	58	0.33
221	188	59	0.31
222	156	54	0.35
223	145	60	0.41
224	182	57	0.31
225	171	57	0.33
226	166	58	0.35
227	175	54	0.31
228	174	56	0.32
229	201	67	0.33
230	170	59	0.35
231	187	76	0.41
232	226	86	0.38
233	215	84	0.39
234	242	94	0.39
235	213	106	0.50
236	216	117	0.54
237	217	72	0.33
238	219	100	0.46
239	188	99	0.53
240	248	118	0.48
241	229	112	0.49
242	211	106	0.50
243	194	86	0.44
244	205	94	0.46

245	184	87	0.47
246	174	81	0.47
247	150	78	0.52
248	141	76	0.54
249	178	88	0.49
250	111	56	0.50
AVERAGE	172.07	69.91	0.41
SD	45.10	24.04	0.09

N = 43

Appendix 3. Protocols for behavior analysis of single visit and multiple visits (3- 6 visits and 9 to 12) to pistillate and staminate flowers

Single visits to pistillate flowers

A visit was defined as beginning when the bee entered the cup of the flower or touched the stigma of the pistillate flower and ended when the bee had left the cup of the flower completely. A spreadsheet was created for each video to quantify stigma behaviors and nectar behaviors. For a behavior to be noted, the behavior had to be at least one second since behaviors were analyzed in one second increments. For stigma behaviors, analysts recorded the duration the bee spent touching the stigma, the duration the bee was moving while on the stigma, and the number of stigma lobes the bee touched throughout its visit. Movement on the stigma was defined as any time the bee was moving its legs while on the stigma, swaying was not counted as movement. For nectar behaviors, analysts recorded the duration the bee spent drinking nectar. Nectar behaviors were recorded when the bee's head or tongue was visibly in the nectary. If the bee did not exhibit either of these during its visit then its behavior was defined as entered flower cup. After all behaviors were recorded, stigma and nectar behaviors were then added respectively to calculate total times for each behavior and proportion of behavior over total time bee spent in flower.

Single visits to staminate flowers

A visit was defined as beginning when the bee entered the cup of the flower or touched the anthers of the staminate flower and ended when the bee had left the cup of the flower completely. A spreadsheet was created for each video to quantify pollen, anther, and nectar behaviors. For pollen behaviors, analysts recorded the duration the bee spent collecting pollen either directly from the anthers or from the base of the flower cup. Honey bees typically collect

pollen with their front legs and then place pollen into pollen baskets on their back legs. Squash bees generally sit on the anthers and will collect pollen using their back legs. For anther behavior, analysts recorded the duration the bee spent touching the anthers and the amount of time they spent moving on the anthers. Like single visits to pistillate flowers, duration of nectar behavior was recorded when the bees head or tongue was visibly in the nectary. If bee did not exhibit any of these behaviors the bee's behavior was defined as entered flower cup. Once all behaviors were recorded, pollen, anther, and nectar time were added respectively to calculate total times for each behavior and proportion of behavior over total time the bee spent in the flower.

Multiple visits to pistillate and staminate flowers

Protocols for single visit pistillate and staminate flowers were adapted to for multiple visit videos to pistillate and staminate flowers. Definition of a visit was kept the same, however, a bee could visit multiple times. This meant that if a bee left and re-entered the flower cup, this would count as a new visit. Stigma and nectar behavior were recorded for each bee that visited the female flower as well as visitors that only entered the flower cup but did not exhibit stigma or nectar behavior. For staminate flowers duration for pollen, anther, and nectar behaviors were also recorded. The species of bee and the visitor number were also noted for each behavior. After all visits occurred total times for behaviors were recorded for each bee species that visited the flower. Any aggressive behavior or mating between bees was taken note of but not quantified. As stated above for a behavior to be recorded the behavior needed to last at least one second. However, an exception was made for bees that entered the flower cup and left the flower cup in less than one second since a visit was defined as entering the cup of a flower.

Appendix 4. Fruit set data of pistillate flowers visited by 1 visitor (SA = single *A. mellifera*, SPF = single *P. pruinosa* (♀), or SPM = single *P. pruinosa* (♂)), 3 – 6 visitors, and 9 – 12 visitors.

Plant	Pollination Date (day of year)	Pollination treatment	Number of visits			Fruit Set (Y/N)
			A. mellifera	*P. pruinosa* (♀)	*P. pruinosa* (♂)	
2	219	SPM	0	0	1	N
3	236	3 to 6	0	3	0	N
4	209	9 to 12	7	1	2	Y
5	213	3 to 6	1	2	0	N
6	209	SA	1	0	0	Y
7	237	9 to 12	4	6	0	Y
8	220	SA	1	0	0	N
9	211	SPF	0	1	0	Y
10	214	3 to 6	2	1	0	Y
11	210	SPM	0	0	1	N
13	219	SPF	0	1	0	N
14	242	3 to 6	1	5	0	Y
15	215	SA	1	0	0	N
16	222	SPF	0	1	0	N
18	242	9 to 12	4	5	3	Y
21	239	3 to 6	1	3	0	Y
22	219	SPM	0	0	1	N
24	217	SPM	0	0	1	N
25	220	SPF	0	1	0	Y
26	235	9 to 12	5	4	2	N
27	212	SA	1	0	0	N
28	249	9 to 12	3	5	2	N
29	218	SA	1	0	0	N
30	213	SPF	0	1	0	Y
32	222	9 to 12	4	5	0	Y
34	224	SA	1	0	0	N
35	220	3 to 6	1	1	2	N
36	224	SA	1	0	0	N
37	230	3 to 6	3	2	1	Y
38	230	9 to 12	3	6	1	Y
39	213	3 to 6	4	0	0	Y
40	224	9 to 12	7	4	0	Y
41	228	SPF	0	1	0	N
44	246	3 to 6	3	2	0	N
47	219	9 to 12	3	5	1	Y
48	222	3 to 6	3	2	0	N
49	241	9 to 12	8	1	0	Y
51	245	SPF	0	1	0	N

Appendix 4. Fruit set data, Continued

Plant	Pollination Date (day of year)	Pollination treatment	Number of visits			Fruit Set (Y/N)
			A. mellifera	*P. pruinosa* (♀)	*P. pruinosa* (♂)	
52	232	3 to 6	2	2	1	Y
53	236	SPF	0	1	0	Y
54	208	SPM	0	0	1	N
56	209	3 to 6	2	0	1	Y
59	234	9 to 12	1	8	0	Y
61	218	9 to 12	6	4	0	Y
64	218	SPF	0	1	0	N
66	246	9 to 12	1	7	1	Y
68	228	SA	1	0	0	N
69	221	3 to 6	1	3	0	N
70	221	9 to 12	7	2	0	Y
71	216	SA	1	0	0	N
72	214	SPF	0	1	0	Y
73	241	9 to 12	9	3	0	Y
75	215	SPM	0	0	1	N
76	217	3 to 6	2	2	0	N
77	250	9 to 12	0	10	0	Y
78	233	3 to 6	2	2	0	Y
79	219	9 to 12	3	2	6	Y
82	239	9 to 12	6	5	0	Y
83	227	SPF	0	1	0	N
85	220	SPM	0	0	1	N
86	245	3 to 6	0	5	0	N
87	243	9 to 12	8	3	0	Y
89	220	3 to 6	2	1	1	N
90	219	SA	1	0	0	N
92	246	3 to 6	0	3	1	N
94	230	9 to 12	6	4	1	N
95	244	3 to 6	3	2	0	N
96	214	SA	1	0	0	N
97	235	3 to 6	2	3	0	Y
99	213	SPF	0	1	0	N
101	208	3 to 6	6	0	0	Y
102	221	SPF	0	1	0	N
103	243	SPF	0	1	0	N
104	214	SA	1	0	0	N
105	238	3 to 6	3	2	1	N
106	213	SA	1	0	0	N
107	220	9 to 12	7	2	1	N
109	224	SPF	0	1	0	N

Appendix 4. Fruit set data, Continued

Plant	Pollination Date (day of year)	Pollination treatment	Number of visits			Fruit Set (Y/N)
			A. mellifera	*P. pruinosa* (♀)	*P. pruinosa* (♂)	
112	232	9 to 12	12	0	0	N
113	241	3 to 6	2	3	0	N
114	223	3 to 6	3	3	0	N
115	245	9 to 12	5	7	0	Y
117	245	9 to 12	1	8	0	Y
118	227	SA	1	0	0	N
120	219	SPF	0	1	0	Y
121	226	9 to 12	10	0	0	Y
123	208	SA	1	0	0	N
126	247	SPF	0	1	0	N
129	245	SPF	0	1	0	N
130	244	3 to 6	2	2	0	Y
131	222	SA	1	0	0	N
133	242	3 to 6	0	6	0	N
135	238	9 to 12	5	4	1	N
136	210	3 to 6	4	0	0	N
137	244	9 to 12	2	7	0	Y
138	224	SPF	0	1	0	N
139	235	9 to 12	0	9	1	Y
140	224	SA	1	0	0	N
141	215	3 to 6	3	2	0	Y
143	245	3 to 6	6	0	0	N
146	244	SPF	0	1	0	N
149	223	SA	1	0	0	N

Appendix 5. Pollen deposition data for pistillate flowers that set fruit. Pollination treatments: 1 visitor (SA = single *A. mellifera*, SPF = single *P. pruinosa* (♀), or SPM = single *P. pruinosa* (♂)), 3 – 6 visitors, and 9 – 12 visitors.

Plant	Pollination date (day of year)	Pollination treatment	Number of visits			First count	Second count	Mean pollen count (grains)
			A. mellifera	*P. pruinosa* (♀)	*P. pruinosa* (♂)			
4	209	9 to 12	7	1	2	896	815	856
6	209	SA	1	0	0	82	70	76
7	237	9 to 12	4	6	0	1406	1343	1375
9	211	SPF	0	1	0	874	864	869
10	214	3 to 6	2	1	0	252	235	244
14	242	3 to 6	1	5	0	494	489	492
18	242	9 to 12	4	5	3	743	760	752
21	239	3 to 6	1	3	0	293	308	301
25	220	SPF	0	1	0	199	203	201
30	213	SPF	0	1	0	1236	1235	1236
32	222	9 to 12	4	5	0	521	514	518
37	230	3 to 6	3	2	1	279	271	275
38	230	9 to 12	3	6	1	205	222	214
39	213	3 to 6	4	0	0	370	334	352
40	224	9 to 12	7	4	0	1020	1003	1012
47	219	9 to 12	3	5	1	980	954	967
49	241	9 to 12	8	1	0	181	181	181
52	232	3 to 6	2	2	1	112	99	106
53	236	SPF	0	1	0	409	418	414
56	209	3 to 6	2	0	1	215	179	197
59	234	9 to 12	1	8	0	577	541	559
61	218	9 to 12	6	4	0	311	306	309
66	246	9 to 12	1	7	1	1066	1070	1068
70	221	9 to 12	7	2	0	678	679	679
72	214	SPF	0	1	0	1217	1114	1166
73	241	9 to 12	9	3	0	717	698	708
77	250	9 to 12	0	10	0	674	676	675
78	233	3 to 6	2	2	0	189	181	185
79	219	9 to 12	3	2	6	392	400	396
82	239	9 to 12	6	5	0	765	789	777
87	243	9 to 12	8	3	0	2392	2338	2365
97	235	3 to 6	2	3	0	299	285	292
101	208	3 to 6	6	0	0	272	266	269
115	245	9 to 12	5	7	0	654	697	676
117	245	9 to 12	1	8	0	722	644	683
120	219	SPF	0	1	0	160	157	159
121	226	9 to 12	10	0	0	1075	1011	1043

Appendix 5. Pollination deposition data, Continued

Plant	Pollination date (day of year)	Pollination treatment	Number of visits			First count	Second count	Mean pollen count (grains)
			A. mellifera	*P. pruinosa* (♀)	*P. pruinosa* (♂)			
4	209	9 to 12	7	1	2	896	815	856
130	244	3 to 6	2	2	0	766	723	745
137	244	9 to 12	2	7	0	557	595	576
139	235	9 to 12	0	9	1	1640	1567	1604
141	215	3 to 6	3	2	0	221	213	217

Appendix 6. Fruit data. Fruits resulted from single *A. mellifera* (SA) visit, single *P. pruinosa* (♀) (SPF) visit, 3 – 6 visits by *A. mellifera* and *P. pruinosa* (♀ and ♂), and 9 – 12 visits by *A. mellifera* and *P. pruinosa* (♀ and ♂).

Plant	Pollination date (day of year)	Pollination treatment	Harvest date (day of year)	Process date (day of year)	Fruit weight (g)	Fruit height (cm)	Fruit diameter (cm)	Fruit volume (mL)	Fruit brix (°Bx)	Number of seeds per fruit	Total seed mass (mg)	Mean seed mass (mg)
4	209	9 to 12	259	259	693	109.19	116.78	740	11.5	156	18166	116.4
6	209	SA	259	259	202	76.23	71.58	193	11.5	18	1430	79.4
7	237	9 to 12	287	287	349	95.39	81.67	360	12.5	73	7182	98.4
9	211	SPF	261	261	704	109.15	114.33	720	11	194	23541	121.3
10	214	3 to 6	264	264	496	97.02	99.79	542	9.5	66	9277	140.6
14	242	3 to 6	292	292	388	88.51	94.55	400	10.5	73	7204	98.7
18	242	9 to 12	292	292	394	87.88	96.71	407	12	112	9426	84.2
21	239	3 to 6	289	289	242	79.56	79.14	240	12.5	32	2766	86.4
25	220	SPF	270	270	307	87.01	84.26	320	9.5	76	8713	114.6
30	213	SPF	263	263	550	98.65	105.01	597	10	201	19050	94.8
32	222	9 to 12	272	272	598	111.04	103.26	637	12	156	18546	118.9
37	230	3 to 6	280	280	406	93.67	92.46	410	11.5	101	10236	101.3
38	230	9 to 12	280	280	291	88.71	80.84	300	11	63	6577	104.4
39	213	3 to 6	263	263	311	85.82	83.13	300	9.5	29	768	26.5
40	224	9 to 12	274	274	296	95.18	78.53	300	11	79	7928	100.4
47	219	9 to 12	269	269	268	87.2	77.83	280	11.5	76	5928	78.0
49	241	9 to 12	291	291	297	85.34	81.62	307	11.5	38	3870	101.8
52	232	3 to 6	282	282	262	88.42	75.97	270	13	28	3024	108.0
53	236	SPF	286	286	331	87.57	84.07	340	11	69	7330	106.2
56	209	3 to 6	259	259	278	80.77	83.77	307	10	22	1890	85.9
59	234	9 to 12	284	285	473	91.03	96.59	480	11.5	185	18518	100.1
61	218	9 to 12	268	268	242	73.05	75.66	240	11	43	4301	100.0
66	246	9 to 12	296	296	212	75.88	71.55	220	14.5	29	1906	65.7
70	221	9 to 12	271	271	371	106.91	85.74	390	10	79	8176	103.5
72	214	SPF	264	264	258	85.65	76.59	263	10.5	47	4345	92.4
73	241	9 to 12	291	291	333	94.24	85.94	353	12.5	84	6664	79.3
77	250	9 to 12	300	300	469	95.11	96	473	12	172	15779	91.7
78	233	3 to 6	283	283	307	91.34	75.32	307	11	61	6887	112.9

Plant	Pollination date (day of year)	Pollination treatment	Harvest date (day of year)	Process date (day of year)	Fruit weight (g)	Fruit height (cm)	Fruit diameter (cm)	Fruit volume (mL)	Fruit brix (°Bx)	Number of seeds per fruit	Total seed mass (mg)	Mean seed mass (mg)
79	219	9 to 12	269	269	380	97.21	89.47	400	11	77	9050	117.5
82	239	9 to 12	289	289	250	95.85	67.68	250	13.5	44	3746	85.1
87	243	9 to 12	293	293	481	90.95	98.42	500	11.5	253	24805	98.0
97	235	3 to 6	285	285	348	90.01	84.89	340	12	126	12561	99.7
101	208	3 to 6	258	258	349	81.79	92.56	413	10	86	11461	133.3
115	245	9 to 12	295	295	419	93.74	94.7	440	12.5	122	11012	90.3
117	245	9 to 12	295	295	525	99.89	104.71	540	12.5	102	10491	102.9
120	219	SPF	269	269	326	94.18	87.39	340	11	51	5945	116.6
121	226	9 to 12	276	276	346	92.82	84.48	360	10.5	124	13035	105.1
130	244	3 to 6	294	294	404	92.07	90.93	417	12	134	11312	84.4
137	244	9 to 12	294	294	247	86.45	75.1	260	13	58	3915	67.5
139	235	9 to 12	285	285	273	88.6	76.45	270	11	49	4252	86.8
141	215	3 to 6	265	265	352	85.02	87.7	397	10	66	6798	103.0

Appendix 7. Behavioral analysis of videos data for *A. mellifera* visits to pistillate flowers that also received *P. pruinosa* (♀ or ♂) visits. Where Video label = (Plant number. Flower number. Pollination treatment [apis = single *A. mellifera*, pf = single *P. pruinosa* (♀), or pm = single *P. pruinosa* (♂), 3to6 = 3 – 6 visitors, and 9to12 = 9 – 12 visitors]. Pollination date). See appendix 7 and 8 for behavioral analysis of videos for *P. pruinosa* (♀ and ♂) respectively.

Plant	Video label	Video start time	Video end time	Number of visits	Total nectar duration (sec)	Total stigma duration (sec)	Total stigma movement duration (sec)	Total lobes touched
2	2.F1.PM.7August2019	8:08:00	8:08:53	0	0	0	0	0
3	3.F1.3to6.24August2019	7:59:27	8:24:50	0	0	0	0	0
4	4.F1.9to12.28July2019	6:36:58	6:55:24	7	417	41	40	24
5	5.F1.3to6.1August2019	6:45:10	6:49:14	1	80	2	2	3
6	6.F1(S).Apis.28July2019	6:52:54	6:54:19	1	79	3	3	2
7	7.F1.9to12.25August2019	6:38:07	7:44:45	4	149	11	11	19
8	8.F1.Apis.8August2019	7:40:35	7:42:06	1	87	2	2	4
9	9.F1.PF.30July2019	7:19:50	7:22:40	0	0	0	0	0
10	10.F1.3to6.2August2019	6:29:39	6:33:08	2	42	5	5	5
11	11.F1.PM.29July2019	8:05:52	8:05:59	0	0	0	0	0
13	13.F1.PF.7August2019	7:08:45	7:09:27	0	0	0	0	0
14	14.F1.3to6.30August2019	6:50:53	7:15:03	1	0	0	0	0
15	15.F1.Apis.3August2019	7:41:35	7:43:31	1	103	92	9	4
16	16.F1.PF.10August2019	12:08:30	12:09:28	0	0	0	0	0
18	18.F1.9to12.30August2019	7:41:44	8:28:24	4	1432	13	13	19
21	21.F1.3to6.27August2019	6:37:18	6:54:28	1	0	0	0	0
22	22.F1.PM.7August2019	12:37:13	12:39:45	0	0	0	0	0
24	24.F1.PM.5August2019	6:37:47	6:38:58	0	0	0	0	0
25	25.F1.PF.8August2019	7:05:20	7:08:20	0	0	0	0	0
26	26.F1.9to12.23August2019	7:50:14	8:21:06	5	681	34	31	23
27	27.F1.Apis.31July2019	6:54:15	6:55:08	1	50	3	3	8
28	28.F1.9to12.6September2019	7:44:49	8:09:42	3	150	5	5	11
29	29.F1.Apis.6August2019	7:28:01	7:29:19	1	70	27	7	6
30	30.F1.PF.1August2019	6:35:24	6:38:21	0	0	0	0	0
32	32.F1.9to12.10August2019	7:24:37	7:39:44	4	266	19	18	19
34	34.F1.Apis.12August2019	7:58:44	8:01:44	1	171	4	4	4
35	35.F1.3to6.8August2019	7:29:47	7:32:18	1	0	4	4	8
36	36.F1.Apis.12August2019	8:24:38	8:26:22	1	89	12	12	6
37	37.F1.3to6.18August2019	7:08:25	7:14:38	3	99	67	18	8
38	38.F1.9to12.18August2019	7:22:23	8:01:30	3	134	2	2	3
39	39.F1.3to6.1August2019	8:25:16	8:32:49	4	274	10	10	12
40	40.F1.9to12.12August2019	6:45:37	7:46:29	7	611	25	25	17
41	41.F1.PF.16August2019	8:16:53	8:18:58	0	0	0	0	0
44	44.F1.3to6.3September2019	7:24:20	7:33:45	3	0	7	7	7
47	47.F1.9to12.7August2019	12:02:48	12:09:03	3	134	11	11	11

48	48.F1.3to6.10August2019	6:54:42	7:01:42	3	177	10	10	8
49	49.F1.9to12.29August2019	6:54:38	7:08:01	8	196	118	85	18
51	51.F1.PF.2September2019	8:44:04	8:46:06	0	0	0	0	0
52	52.F1.3to6.20August2019	8:33:57	8:44:31	2	122	64	62	6
53	53.F1.PF.24August2019	7:51:16	7:52:19	0	0	0	0	0
54	54.F1.PM.27July2019	7:25:27	7:25:45	0	0	0	0	0
56	56.F1.3to6.28July2019	7:03:23	7:08:54	2	189	4	4	4
58	58.F1.Apis.7August2019	12:46:31	12:48:15	1	100	4	4	6
59	59.F1.9to12.22August2019	7:37:03	8:04:54	1	106	28	18	3
61	61.F1.9to12.6August2019	7:09:32	7:23:08	6	380	36	29	22
64	64.F1.PF.6August2019	12:27:59	12:31:33	0	0	0	0	0
66	66.F1.9to12.3September2019	6:39:46	7:12:47	1	26	6	6	5
68	68.F1.Apis.16August2019	8:44:35	8:45:54	1	72	1	1	3
69	69.F1.3to6.9August2019	7:37:32	7:55:47	1	99	4	4	5
70	70.F1.9to12.9August2019	8:07:22	8:39:56	7	563	148	40	47
71	71.F1.Apis.4August2019	8:09:55	8:11:05	1	54	0	0	0
72	72.F1.PForXF.2August2019	6:42:15	6:46:12	0	0	0	0	0
73	73.F1.9to12.29August2019	7:26:14	8:38:50	9	667	82	64	25
75	75.F1.PM.3August2019	7:31:42	7:32:38	0	0	0	0	0
76	76.F1.3to6.5August2019	7:48:08	7:52:22	2	237	4	4	2
77	77.F1.9to12.7September2019	6:28:38	6:59:36	0	0	0	0	0
78	78.F1.3to6.21August2019	7:08:40	7:26:46	2	400	2	2	3
79	79.F1.9to12.7August2019	12:52:22	13:18:46	3	160	28	14	14
82	82.F1.9to12.27August2019	6:45:52	8:32:04	6	2193	65	55	36
83	83.F1.PF.15August2019	7:09:53	7:12:50	0	0	0	0	0
85	85.F1.PM.8August2019	8:21:01	8:21:43	0	0	0	0	0
86	86.F1.3to6.2September2019	7:06:19	7:34:20	0	0	0	0	0
87	87.F1.9to12.31August2019	7:57:24	9:49:52	8	240	16	16	18
89	89.F1.3to6.8August2019	7:49:04	7:55:27	2	163	6	4	1
90	90.F1.Apis.7August2019	7:57:04	7:58:40	1	90	9	9	6
92	92.F1.3to6.3September2019	7:26:20	7:42:25	0	0	0	0	0
94	94.F1.9to12.18August2019	8:08:53	8:35:40	6	386	17	16	11
95	95.F1.3to6.1September2019	7:34:26	8:32:40	3	2340	50	48	19
96	96.F1.Apis.2August2019	7:22:17	7:22:24	1	0	7	7	7
97	97.F1.3to6.23August2019	6:33:35	6:53:37	2	50	8	8	6
99	99.F1.PF.1August2019	7:46:59	7:48:05	0	0	0	0	0
101	101.F1(SE).3to6.27July2019	6:34:11	6:56:23	6	98	5	5	8
102	102.F1.PF.9August2019	7:30:15	7:31:20	0	0	0	0	0
103	103.F1.PF.31August2019	7:23:10	7:24:59	0	0	0	0	0
104	104.F1.Apis.2August2019	8:03:08	8:04:12	1	43	15	15	9
105	105.F1.3to6.26August2019	7:30:37	7:48:12	3	111	3	3	6
106	106.F1.Apis.1August2019	7:47:00	7:48:17	1	69	2	2	3
107	107.F1.9to12.8August2019	11:57:12	12:31:57	7	307	15	15	20
109	109.F1.PF.12August2019	8:12:52	8:13:46	0	0	0	0	0

112	112.F1.9to12.20August2019	7:46:46	8:17:31	12	1056	70	63	38
113	113.F1.3to6.29August2019	6:38:29	7:01:20	2	64	6	6	2
114	114.F1.3to6.11August2019	7:45:44	7:59:13	3	360	14	13	14
115	115.F1.9to12.2September2019	6:42:31	6:53:55	5	465	18	18	14
117	117.F1.9to12.2September2019	6:35:22	6:55:57	1	22	0	0	0
118	118.F1.Apis.15August2019	6:57:48	6:59:32	1	89	2	2	2
120	120.F1.PF.7August2019	6:59:45	7:01:49	0	0	0	0	0
121	121.F1.9to12.14August2019	8:00:32	8:27:44	10	448	105	89	24
123	123.F1.Apis.27July2019	6:54:15	6:54:17	1	0	2	1	4
126	126.F1.PF.4September2019	7:19:47	7:20:20	0	0	0	0	0
129	129.F1.PF.2September2019	7:34:20	7:35:04	0	0	0	0	0
130	130.F1.3to6.1September2019	6:37:57	6:46:36	2	49	0	0	0
131	131.F1.Apis.10August2019	8:22:28	8:24:21	1	93	9	9	8
133	133.F1.3to6.30August2019	6:55:41	7:14:15	0	0	0	0	0
135	135.F1.9to12.26August2019	6:39:24	7:18:57	5	412	39	38	17
136	136.F1.3to6.29July2019	8:14:36	8:25:43	4	262	2	2	3
137	137.F1.9to12.1September2019	6:32:40	7:27:11	2	173	35	33	14
138	138.F1.PF.12August2019	8:04:16	8:04:27	0	0	0	0	0
139	139.F1.9to12.23August2019	6:33:40	7:14:07	0	0	0	0	0
140	140.F1.Apis.12August2019	7:38:56	7:40:51	1	107	4	4	5
141	141.F1.3to6.3August2019	6:23:17	6:50:53	3	0	1	1	4
143	143.F1.3to6.2September2019	8:23:23	8:30:48	6	213	193	52	24
146	146.F1.PF.1September2019	7:36:04	7:38:54	0	0	0	0	0
149	149.F1.Apis.11August2019	6:47:48	6:50:17	1	128	9	9	8

Appendix 8. Behavioral analysis of videos data for *P. pruinosa* (♀) visits to pistillate flowers that also received *A. mellifera* or *P. pruinosa* (♂) visits. Where Video label = (Plant number. Flower number. Pollination treatment [apis = single *A. mellifera*, pf = single *P. pruinosa* (♀), or pm = single *P. pruinosa* (♂), 3to6 = 3 – 6 visitors, and 9to12 = 9 – 12 visitors]. Pollination date). See appendix 6 and 8 for behavioral analysis of videos for *A. mellifera* and *P. pruinosa* (♂) respectively.

Plant	Video label	Video start time	Video end time	Number of visits	Total nectar duration (sec)	Total stigma duration (sec)	Total stigma movement duration (sec)	Total lobes touched
2	2.F1.PM.7August2019	8:08:00	8:08:53	0	0	0	0	0
3	3.F1.3to6.24August2019	7:59:27	8:24:50	3	391	481	277	21
4	4.F1.9to12.28July2019	6:36:58	6:55:24	1	143	193	43	8
5	5.F1.3to6.1August2019	6:45:10	6:49:14	2	18	20	2	2
6	6.F1(S).Apis.28July2019	6:52:54	6:54:19	0	0	0	0	0
7	7.F1.9to12.25August2019	6:38:07	7:44:45	6	3102	3163	670	40
8	8.F1.Apis.8August2019	7:40:35	7:42:06	0	0	0	0	0
9	9.F1.PF.30July2019	7:19:50	7:22:40	1	159	170	117	7
10	10.F1.3to6.2August2019	6:29:39	6:33:08	1	166	128	11	1
11	11.F1.PM.29July2019	8:05:52	8:05:59	0	0	0	0	0
13	13.F1.PF.7August2019	7:08:45	7:09:27	1	30	42	16	5
14	14.F1.3to6.30August2019	6:50:53	7:15:03	5	325	338	223	29
15	15.F1.Apis.3August2019	7:41:35	7:43:31	0	0	0	0	0
16	16.F1.PF.10August2019	12:08:30	12:09:28	1	27	58	45	8
18	18.F1.9to12.30August2019	7:41:44	8:28:24	5	452	495	172	31
21	21.F1.3to6.27August2019	6:37:18	6:54:28	3	292	310	183	17
22	22.F1.PM.7August2019	12:37:13	12:39:45	0	0	0	0	0
24	24.F1.PM.5August2019	6:37:47	6:38:58	0	0	0	0	0
25	25.F1.PF.8August2019	7:05:20	7:08:20	1	142	180	46	8
26	26.F1.9to12.23August2019	7:50:14	8:21:06	4	470	541	195	25
27	27.F1.Apis.31July2019	6:54:15	6:55:08	0	0	0	0	0
28	28.F1.9to12.6September2019	7:44:49	8:09:42	5	687	719	337	27
29	29.F1.Apis.6August2019	7:28:01	7:29:19	0	0	0	0	0
30	30.F1.PF.1August2019	6:35:24	6:38:21	1	174	177	88	8
32	32.F1.9to12.10August2019	7:24:37	7:39:44	5	84	96	90	30
34	34.F1.Apis.12August2019	7:58:44	8:01:44	0	0	0	0	0
35	35.F1.3to6.8August2019	7:29:47	7:32:18	1	79	106	30	6
36	36.F1.Apis.12August2019	8:24:38	8:26:22	0	0	0	0	0
37	37.F1.3to6.18August2019	7:08:25	7:14:38	2	106	110	100	9
38	38.F1.9to12.18August2019	7:22:23	8:01:30	6	244	262	217	35
39	39.F1.3to6.1August2019	8:25:16	8:32:49	0	0	0	0	0
40	40.F1.9to12.12August2019	6:45:37	7:46:29	4	119	200	200	18
41	41.F1.PF.16August2019	8:16:53	8:18:58	1	87	125	60	6
44	44.F1.3to6.3September2019	7:24:20	7:33:45	2	103	116	27	6

47	47.F1.9to12.7August2019	12:02:48	12:09:03	5	186	192	138	18
48	48.F1.3to6.10August2019	6:54:42	7:01:42	2	129	134	32	7
49	49.F1.9to12.29August2019	6:54:38	7:08:01	1	120	146	35	6
51	51.F1.PF.2September2019	8:44:04	8:46:06	1	111	121	7	2
52	52.F1.3to6.20August2019	8:33:57	8:44:31	2	81	121	34	11
53	53.F1.PF.24August2019	7:51:16	7:52:19	1	60	63	63	5
54	54.F1.PM.27July2019	7:25:27	7:25:45	0	0	0	0	0
56	56.F1.3to6.28July2019	7:03:23	7:08:54	0	0	0	0	0
58	58.F1.Apis.7August2019	12:46:31	12:48:15	0	0	0	0	0
59	59.F1.9to12.22August2019	7:37:03	8:04:54	8	409	504	426	48
61	61.F1.9to12.6August2019	7:09:32	7:23:08	4	245	286	184	17
64	64.F1.PF.6August2019	12:27:59	12:31:33	1	180	214	91	9
66	66.F1.9to12.3September2019	6:39:46	7:12:47	7	550	586	351	36
68	68.F1.Apis.16August2019	8:44:35	8:45:54	0	0	0	0	0
69	69.F1.3to6.9August2019	7:37:32	7:55:47	3	69	158	132	18
70	70.F1.9to12.9August2019	8:07:22	8:39:56	2	107	184	133	14
71	71.F1.Apis.4August2019	8:09:55	8:11:05	0	0	0	0	0
72	72.F1.PForXF.2August2019	6:42:15	6:46:12	1	235	237	17	7
73	73.F1.9to12.29August2019	7:26:14	8:38:50	3	471	621	205	14
75	75.F1.PM.3August2019	7:31:42	7:32:38	0	0	0	0	0
76	76.F1.3to6.5August2019	7:48:08	7:52:22	2	104	133	59	9
77	77.F1.9to12.7September2019	6:28:38	6:59:36	10	884	916	818	56
78	78.F1.3to6.21August2019	7:08:40	7:26:46	2	171	202	138	12
79	79.F1.9to12.7August2019	12:52:22	13:18:46	2	101	105	89	12
82	82.F1.9to12.27August2019	6:45:52	8:32:04	5	617	647	525	28
83	83.F1.PF.15August2019	7:09:53	7:12:50	1	128	166	73	8
85	85.F1.PM.8August2019	8:21:01	8:21:43	0	0	0	0	0
86	86.F1.3to6.2September2019	7:06:19	7:34:20	5	468	517	240	29
87	87.F1.9to12.31August2019	7:57:24	9:49:52	3	5617	6011	1209	24
89	89.F1.3to6.8August2019	7:49:04	7:55:27	1	114	116	28	6
90	90.F1.Apis.7August2019	7:57:04	7:58:40	0	0	0	0	0
92	92.F1.3to6.3September2019	7:26:20	7:42:25	3	267	390	144	16
94	94.F1.9to12.18August2019	8:08:53	8:35:40	4	810	952	139	23
95	95.F1.3to6.1September2019	7:34:26	8:32:40	2	171	180	88	12
96	96.F1.Apis.2August2019	7:22:17	7:22:24	0	0	0	0	0
97	97.F1.3to6.23August2019	6:33:35	6:53:37	3	244	250	127	19
99	99.F1.PF.1August2019	7:46:59	7:48:05	1	54	66	18	6
101	101.F1(SE).3to6.27July2019	6:34:11	6:56:23	0	0	0	0	0
102	102.F1.PF.9August2019	7:30:15	7:31:20	1	53	65	18	5
103	103.F1.PF.31August2019	7:23:10	7:24:59	1	95	109	7	5
104	104.F1.Apis.2August2019	8:03:08	8:04:12	0	0	0	0	0
105	105.F1.3to6.26August2019	7:30:37	7:48:12	2	894	949	340	12
106	106.F1.Apis.1August2019	7:47:00	7:48:17	0	0	0	0	0
107	107.F1.9to12.8August2019	11:57:12	12:31:57	2	463	466	406	14

109	109.F1.PF.12August2019	8:12:52	8:13:46	1	41	54	17	3
112	112.F1.9to12.20August2019	7:46:46	8:17:31	0	0	0	0	0
113	113.F1.3to6.29August2019	6:38:29	7:01:20	3	225	248	98	16
114	114.F1.3to6.11August2019	7:45:44	7:59:13	3	104	125	102	14
115	115.F1.9to12.2September2019	6:42:31	6:53:55	7	120	145	99	30
117	117.F1.9to12.2September2019	6:35:22	6:55:57	8	669	698	339	42
118	118.F1.Apis.15August2019	6:57:48	6:59:32	0	0	0	0	0
120	120.F1.PF.7August2019	6:59:45	7:01:49	1	119	124	124	6
121	121.F1.9to12.14August2019	8:00:32	8:27:44	0	0	0	0	0
123	123.F1.Apis.27July2019	6:54:15	6:54:17	0	0	0	0	0
126	126.F1.PF.4September2019	7:19:47	7:20:20	1	32	33	30	4
129	129.F1.PF.2September2019	7:34:20	7:35:04	1	42	44	3	6
130	130.F1.3to6.1September2019	6:37:57	6:46:36	2	178	185	122	10
131	131.F1.Apis.10August2019	8:22:28	8:24:21	0	0	0	0	0
133	133.F1.3to6.30August2019	6:55:41	7:14:15	6	468	527	377	32
135	135.F1.9to12.26August2019	6:39:24	7:18:57	4	254	280	135	14
136	136.F1.3to6.29July2019	8:14:36	8:25:43	0	0	0	0	0
137	137.F1.9to12.1September2019	6:32:40	7:27:11	7	448	458	300	35
138	138.F1.PF.12August2019	8:04:16	8:04:27	1	6	11	11	9
139	139.F1.9to12.23August2019	6:33:40	7:14:07	9	653	699	530	60
140	140.F1.Apis.12August2019	7:38:56	7:40:51	0	0	0	0	0
141	141.F1.3to6.3August2019	6:23:17	6:50:53	2	203	208	117	11
143	143.F1.3to6.2September2019	8:23:23	8:30:48	0	0	0	0	0
146	146.F1.PF.1September2019	7:36:04	7:38:54	1	145	170	27	3
149	149.F1.Apis.11August2019	6:47:48	6:50:17	0	0	0	0	0

Appendix 9. Behavioral analysis of videos data for *P. pruinosa* (♂) visits to pistillate flowers that also received *A. mellifera* or *P. pruinosa* (♀) visits. Where Video label = (Plant number. Flower number. Pollination treatment [apis = single *A. mellifera*, pf = single *P. pruinosa* (♀), or pm = single *P. pruinosa* (♂), 3to6 = 3 – 6 visitors, and 9to12 = 9 – 12 visitors]. Pollination date). See appendix 6 and 7 for behavioral analysis of videos for *A. mellifera* and *P. pruinosa* (♀) respectively.

Plant	Video label	Video start time	Video end time	Number of visits	Total nectar duration (sec)	Total stigma duration (sec)	Total stigma movement duration (sec)	Total lobes touched
2	2.F1.PM.7August2019	8:08:00	8:08:53	1	38	53	16	2
3	3.F1.3to6.24August2019	7:59:27	8:24:50	0	0	0	0	0
4	4.F1.9to12.28July2019	6:36:58	6:55:24	2	0	1	1	2
5	5.F1.3to6.1August2019	6:45:10	6:49:14	0	0	0	0	0
6	6.F1(S).Apis.28July2019	6:52:54	6:54:19	0	0	0	0	0
7	7.F1.9to12.25August2019	6:38:07	7:44:45	0	0	0	0	0
8	8.F1.Apis.8August2019	7:40:35	7:42:06	0	0	0	0	0
9	9.F1.PF.30July2019	7:19:50	7:22:40	0	0	0	0	0
10	10.F1.3to6.2August2019	6:29:39	6:33:08	0	0	0	0	0
11	11.F1.PM.29July2019	8:05:52	8:05:59	1	6	7	1	3
13	13.F1.PF.7August2019	7:08:45	7:09:27	0	0	0	0	0
14	14.F1.3to6.30August2019	6:50:53	7:15:03	0	0	0	0	0
15	15.F1.Apis.3August2019	7:41:35	7:43:31	0	0	0	0	0
16	16.F1.PF.10August2019	12:08:30	12:09:28	0	0	0	0	0
18	18.F1.9to12.30August2019	7:41:44	8:28:24	3	52	87	40	8
21	21.F1.3to6.27August2019	6:37:18	6:54:28	0	0	0	0	0
22	22.F1.PM.7August2019	12:37:13	12:39:45	1	115	152	51	4
24	24.F1.PM.5August2019	6:37:47	6:38:58	1	68	71	5	3
25	25.F1.PF.8August2019	7:05:20	7:08:20	0	0	0	0	0
26	26.F1.9to12.23August2019	7:50:14	8:21:06	2	64	67	40	6
27	27.F1.Apis.31July2019	6:54:15	6:55:08	0	0	0	0	0
28	28.F1.9to12.6September2019	7:44:49	8:09:42	2	0	0	0	0
29	29.F1.Apis.6August2019	7:28:01	7:29:19	0	0	0	0	0
30	30.F1.PF.1August2019	6:35:24	6:38:21	0	0	0	0	0
32	32.F1.9to12.10August2019	7:24:37	7:39:44	0	0	0	0	0
34	34.F1.Apis.12August2019	7:58:44	8:01:44	0	0	0	0	0
35	35.F1.3to6.8August2019	7:29:47	7:32:18	2	96	121	28	7
36	36.F1.Apis.12August2019	8:24:38	8:26:22	0	0	0	0	0
37	37.F1.3to6.18August2019	7:08:25	7:14:38	1	0	0	0	0
38	38.F1.9to12.18August2019	7:22:23	8:01:30	1	87	90	11	4
39	39.F1.3to6.1August2019	8:25:16	8:32:49	0	0	0	0	0
40	40.F1.9to12.12August2019	6:45:37	7:46:29	0	0	0	0	0
41	41.F1.PF.16August2019	8:16:53	8:18:58	0	0	0	0	0
44	44.F1.3to6.3September2019	7:24:20	7:33:45	0	0	0	0	0

47	47.F1.9to12.7August2019	12:02:48	12:09:03	1	44	45	9	5
48	48.F1.3to6.10August2019	6:54:42	7:01:42	0	0	0	0	0
49	49.F1.9to12.29August2019	6:54:38	7:08:01	0	0	0	0	0
51	51.F1.PF.2September2019	8:44:04	8:46:06	0	0	0	0	0
52	52.F1.3to6.20August2019	8:33:57	8:44:31	1	0	0	0	0
53	53.F1.PF.24August2019	7:51:16	7:52:19	0	0	0	0	0
54	54.F1.PM.27July2019	7:25:27	7:25:45	1	13	18	8	4
56	56.F1.3to6.28July2019	7:03:23	7:08:54	1	34	42	13	5
58	58.F1.Apis.7August2019	12:46:31	12:48:15	0	0	0	0	0
59	59.F1.9to12.22August2019	7:37:03	8:04:54	0	0	0	0	0
61	61.F1.9to12.6August2019	7:09:32	7:23:08	0	0	0	0	0
64	64.F1.PF.6August2019	12:27:59	12:31:33	0	0	0	0	0
66	66.F1.9to12.3September2019	6:39:46	7:12:47	1	0	4	4	4
68	68.F1.Apis.16August2019	8:44:35	8:45:54	0	0	0	0	0
69	69.F1.3to6.9August2019	7:37:32	7:55:47	0	0	0	0	0
70	70.F1.9to12.9August2019	8:07:22	8:39:56	0	0	0	0	0
71	71.F1.Apis.4August2019	8:09:55	8:11:05	0	0	0	0	0
72	72.F1.PForXF.2August2019	6:42:15	6:46:12	0	0	0	0	0
73	73.F1.9to12.29August2019	7:26:14	8:38:50	0	0	0	0	0
75	75.F1.PM.3August2019	7:31:42	7:32:38	1	46	56	12	3
76	76.F1.3to6.5August2019	7:48:08	7:52:22	0	0	0	0	0
77	77.F1.9to12.7September2019	6:28:38	6:59:36	0	0	0	0	0
78	78.F1.3to6.21August2019	7:08:40	7:26:46	0	0	0	0	0
79	79.F1.9to12.7August2019	12:52:22	13:18:46	6	95	219	91	27
82	82.F1.9to12.27August2019	6:45:52	8:32:04	0	0	0	0	0
83	83.F1.PF.15August2019	7:09:53	7:12:50	0	0	0	0	0
85	85.F1.PM.8August2019	8:21:01	8:21:43	1	36	42	6	4
86	86.F1.3to6.2September2019	7:06:19	7:34:20	0	0	0	0	0
87	87.F1.9to12.31August2019	7:57:24	9:49:52	0	0	0	0	0
89	89.F1.3to6.8August2019	7:49:04	7:55:27	1	36	49	13	4
90	90.F1.Apis.7August2019	7:57:04	7:58:40	0	0	0	0	0
92	92.F1.3to6.3September2019	7:26:20	7:42:25	1	0	0	0	0
94	94.F1.9to12.18August2019	8:08:53	8:35:40	1	16	19	4	4
95	95.F1.3to6.1September2019	7:34:26	8:32:40	0	0	0	0	0
96	96.F1.Apis.2August2019	7:22:17	7:22:24	0	0	0	0	0
97	97.F1.3to6.23August2019	6:33:35	6:53:37	0	0	0	0	0
99	99.F1.PF.1August2019	7:46:59	7:48:05	0	0	0	0	0
101	101.F1(SE).3to6.27July2019	6:34:11	6:56:23	0	0	0	0	0
102	102.F1.PF.9August2019	7:30:15	7:31:20	0	0	0	0	0
103	103.F1.PF.31August2019	7:23:10	7:24:59	0	0	0	0	0
104	104.F1.Apis.2August2019	8:03:08	8:04:12	0	0	0	0	0
105	105.F1.3to6.26August2019	7:30:37	7:48:12	1	73	75	64	4
106	106.F1.Apis.1August2019	7:47:00	7:48:17	0	0	0	0	0
107	107.F1.9to12.8August2019	11:57:12	12:31:57	1	0	0	0	0

109	109.F1.PF.12August2019	8:12:52	8:13:46	0	0	0	0	0
112	112.F1.9to12.20August2019	7:46:46	8:17:31	0	0	0	0	0
113	113.F1.3to6.29August2019	6:38:29	7:01:20	0	0	0	0	0
114	114.F1.3to6.11August2019	7:45:44	7:59:13	0	0	0	0	0
115	115.F1.9to12.2September2019	6:42:31	6:53:55	0	0	0	0	0
117	117.F1.9to12.2September2019	6:35:22	6:55:57	0	0	0	0	0
118	118.F1.Apis.15August2019	6:57:48	6:59:32	0	0	0	0	0
120	120.F1.PF.7August2019	6:59:45	7:01:49	0	0	0	0	0
121	121.F1.9to12.14August2019	8:00:32	8:27:44	0	0	0	0	0
123	123.F1.Apis.27July2019	6:54:15	6:54:17	0	0	0	0	0
126	126.F1.PF.4September2019	7:19:47	7:20:20	0	0	0	0	0
129	129.F1.PF.2September2019	7:34:20	7:35:04	0	0	0	0	0
130	130.F1.3to6.1September2019	6:37:57	6:46:36	0	0	0	0	0
131	131.F1.Apis.10August2019	8:22:28	8:24:21	0	0	0	0	0
133	133.F1.3to6.30August2019	6:55:41	7:14:15	0	0	0	0	0
135	135.F1.9to12.26August2019	6:39:24	7:18:57	1	0	24	20	4
136	136.F1.3to6.29July2019	8:14:36	8:25:43	0	0	0	0	0
137	137.F1.9to12.1September2019	6:32:40	7:27:11	0	0	0	0	0
138	138.F1.PF.12August2019	8:04:16	8:04:27	0	0	0	0	0
139	139.F1.9to12.23August2019	6:33:40	7:14:07	1	0	0	0	0
140	140.F1.Apis.12August2019	7:38:56	7:40:51	0	0	0	0	0
141	141.F1.3to6.3August2019	6:23:17	6:50:53	0	0	0	0	0
143	143.F1.3to6.2September2019	8:23:23	8:30:48	0	0	0	0	0
146	146.F1.PF.1September2019	7:36:04	7:38:54	0	0	0	0	0
149	149.F1.Apis.11August2019	6:47:48	6:50:17	0	0	0	0	0

Appendix 10. Pollen removal data for staminate flowers. Pollination treatments: 1 visitor (SA = single *A. mellifera*, SPF = single *P. pruinosa* (♀), or SPM = single *P. pruinosa* (♂)), 3 – 6 visitors, and 9 – 12 visitors. Pollen removal was calculated by subtracting pollen remaining from mean pollen available.

Plant	Flowering date (day of year)	Pollination treatment	*A. mellifera*	*P. pruinosa* (♀)	*P. pruinosa* (♂)	Pollen remaining (mg)	Mean pollen available (mg)	Calculated pollen removed (mg)
2	217	SPM	0	0	1	12	32.0	20.0
3	236	3 to 6	4	2	0	7	21.5	14.5
4	243	9 to 12	7	4	0	2	16.5	14.5
5	218	3 to 6	0	2	1	6	28.5	22.5
6	214	SA	1	0	0	23	11.5	0.0
7	232	9 to 12	6	1	2	1	20.0	19.0
8	243	SA	1	0	0	15	15.0	0.0
9	235	SPF	0	1	0	9	16.5	7.5
10	250	3 to 6	0	1	2	3	34.0	31.0
11	208	SPM	0	0	1	9	23.5	14.5
13	218	SPF	0	1	0	5	14.0	9.0
14	213	3 to 6	2	0	1	13	23.0	10.0
15	217	SA	1	0	0	14	20.7	6.7
16	227	SPF	0	1	0	16	22.3	6.3
18	220	9 to 12	6	3	1	9	20.0	11.0
19	217	SPM	0	0	1	26	16.0	0.0
21	244	3 to 6	1	2	0	3	23.5	20.5
22	220	SPM	0	0	1	19	16.5	0.0
25	220	SPF	0	1	0	8	28.5	20.5
26	241	9 to 12	0	9	0	1	22.0	21.0
27	227	SA	1	0	0	27	22.7	0.0
28	245	9 to 12	2	8	1	0	23.8	23.8
29	233	SA	1	0	0	18	22.5	4.5
30	228	SPF	0	1	0	17	19.0	2.0
32	249	9 to 12	7	3	0	1	22.8	21.8
33	243	SPM	0	0	1	14	20.5	6.5
34	219	SA	1	0	0	30	24.7	0.0
35	243	3 to 6	1	2	0	3	24.5	21.5
36	234	SA	1	0	0	28	29.0	1.0
37	209	3 to 6	5	0	0	11	26.5	15.5
38	213	9 to 12	8	1	0	1	27.0	26.0
39	220	3 to 6	2	1	0	2	37.0	35.0
40	234	9 to 12	8	1	0	3	20.0	17.0
41	221	SPF	0	1	0	1	27.5	26.5
44	214	3 to 6	3	0	1	20	25.5	5.5
47	221	9 to 12	9	3	0	1	34.0	33.0

48	216	3 to 6	2	0	1	36	22.0	0.0
49	216	9 to 12	8	0	2	12	17.3	5.3
51	219	SPF	0	1	0	9	37.0	28.0
52	241	3 to 6	6	0	0	4	27.0	23.0
53	229	SPF	0	1	0	7	19.0	12.0
54	215	SPM	0	0	1	21	20.7	0.0
56	235	3 to 6	0	4	0	8	25.0	17.0
58	250	SA	1	0	0	11	23.0	12.0
59	246	9 to 12	2	8	0	0	20.0	20.0
61	247	9 to 12	6	3	0	0	20.0	20.0
64	234	SPF	0	1	0	17	23.0	6.0
66	247	9 to 12	7	2	0	0	24.5	24.5
68	214	SA	1	0	0	10	31.7	21.7
69	230	3 to 6	1	3	0	0	27.0	27.0
70	250	9 to 12	0	9	0	2	32.5	30.5
72	226	SPF	0	1	0	21	20.0	0.0
73	250	9 to 12	5	2	2	1	10.0	9.0
75	212	SPM	0	0	1	11	29.0	18.0
76	222	3 to 6	4	0	0	6	35.0	29.0
77	235	9 to 12	4	5	1	1	32.0	31.0
78	211	3 to 6	4	0	0	13	29.0	16.0
79	245	9 to 12	10	0	1	12	17.0	5.0
82	243	9 to 12	2	7	0	2	9.0	7.0
83	232	SPF	0	1	0	3	24.5	21.5
85	234	SPM	0	0	1	20	25.0	5.0
86	228	3 to 6	2	2	0	3	29.0	26.0
87	246	9 to 12	7	2	0	2	32.0	30.0
89	232	3 to 6	4	1	0	4	25.0	21.0
90	225	SA	1	0	0	16	25.0	9.0
91	233	SPM	0	0	1	9	14.0	5.0
92	223	3 to 6	3	0	0	5	33.0	28.0
94	230	9 to 12	5	4	0	8	31.7	23.7
95	229	3 to 6	2	2	0	5	13.0	8.0
96	236	SA	1	0	0	24	21.0	0.0
99	214	SPF	0	1	0	5	26.5	21.5
101	239	3 to 6	2	3	0	0	35.0	35.0
102	234	SPF	0	1	0	9	21.5	12.5
103	224	SPF	0	1	0	16	16.5	0.5
104	215	SA	1	0	0	40	34.0	0.0
105	226	3 to 6	3	2	0	15	27.0	12.0
106	222	SA	1	0	0	22	12.0	0.0
107	248	9 to 12	0	8	0	1	19.0	18.0
109	231	SPF	0	1	0	12	26.5	14.5
112	229	9 to 12	9	0	0	5	7.0	2.0

114	228	3 to 6	3	3	0	1	21.0	20.0
115	248	9 to 12	5	6	0	1	29.0	28.0
117	240	9 to 12	8	1	0	5	12.0	7.0
118	210	SA	1	0	0	12	22.5	10.5
120	209	SPF	0	1	0	1	29.0	28.0
121	223	9 to 12	12	0	0	11	32.0	21.0
122	246	SPM	0	0	1	16	22.0	6.0
123	222	SA	1	0	0	29	26.0	0.0
126	226	SPF	0	1	0	11	29.7	18.7
129	224	SPF	0	1	0	3	31.0	28.0
130	208	3 to 6	2	1	0	15	23.0	8.0
131	225	SA	1	0	0	32	26.7	0.0
133	232	3 to 6	2	0	3	4	24.8	20.8
135	229	9 to 12	8	2	0	1	19.5	18.5
136	215	3 to 6	3	0	2	16	20.0	4.0
137	227	9 to 12	7	3	0	2	18.0	16.0
138	223	SPF	0	1	0	3	10.5	7.5
139	227	9 to 12	10	0	0	12	23.0	11.0
141	237	3 to 6	1	3	0	1	16.0	15.0
143	244	3 to 6	4	1	0	3	31.0	28.0
146	223	SPF	0	1	0	4	33.0	29.0
149	226	SA	1	0	0	21	29.0	8.0

Appendix 11. Behavioral analysis of videos data for *A. mellifera* visits to staminate flowers that also received *P. pruinosa* (♀ or ♂) visits. Where Video label = (Plant number. Flower number. Pollination treatment [apis = single *A. mellifera*, pf = single *P. pruinosa* (♀), or pm = single *P. pruinosa* (♂), 3to6 = 3 – 6 visitors, and 9to12 = 9 – 12 visitors]. Pollination date). See appendix 11 and 12 for behavioral analysis of videos for *P. pruinosa* (♀ and ♂) respectively

Plant	Video label	Video start time	Video end time	Number of visits	Total pollen duration (sec)	Total anther duration (sec)	Total anther movement duration (sec)	Total nectar duration (sec)
2	2.M1.PM.5August2019	7:35:04	7:35:48	0	0	0	0	0
3	3.M1.3to6.24August2019	6:37:32	6:51:57	4	0	0	0	7
4	4.M1.9to12.31August2019	7:33:29	8:12:12	7	0	7	7	9
5	5.M1.3to6.6August2019	7:30:30	7:35:22	0	0	0	0	0
6	6.M1.Apis.2August2019	7:13:05	7:13:28	1	0	1	1	9
7	7.M1.9to12.20August2019	7:20:44	7:35:11	6	30	12	12	16
8	8.M1.Apis.31August2019	8:27:01	8:27:40	1	0	0	0	35
9	9.M1.PF.23August2019	6:56:05	6:59:24	0	0	0	0	0
10	10.M1.3to6.7September2019	7:27:29	7:35:31	0	0	0	0	0
11	11.M1.PM.27July2019	7:07:22	7:08:12	0	0	0	0	0
13	13.M1.PF.6August2019	6:58:15	6:58:59	0	0	0	0	0
14	14.M1.3to6.1August2019	7:02:12	7:09:24	2	3	3	3	44
15	15.M1.Apis.5August2019	8:24:51	8:25:05	1	0	4	4	0
16	16.M1.PF.15August2019	8:20:22	8:20:55	0	0	0	0	0
18	18.M1.9to12.8August2019	8:07:38	8:13:49	6	0	0	0	91
19	19.M1.PM.5August2019	7:35:16	7:36:29	0	0	0	0	0
21	21.M1.3to6.1September2019	6:52:53	7:06:21	1	0	0	0	32
22	22.M1.PM.8August2019	12:56:39	12:57:09	0	0	0	0	0
25	25.M1.PF.8August2019	8:13:27	8:14:54	0	0	0	0	0
26	26.M1.9to12.29August2019	7:14:11	7:52:58	0	0	0	0	0
27	27.M1.Apis.15August2019	7:02:52	7:03:24	1	0	0	0	27
28	28.M1.9to12.2September2019	6:39:26	7:16:42	2	0	0	0	20
29	29.M1.Apis.21August2019	6:52:42	6:52:46	1	0	0	0	0
30	30.M1.PF.16August2019	7:48:32	7:48:42	0	0	0	0	0
32	32.M1.9to12.6September2019	7:02:03	7:11:53	7	0	1	249	248
33	33.M1.PM.31August2019	8:26:08	8:27:18	0	0	0	0	0
34	34.M1.Apis.7August2019	7:44:27	7:44:33	1	0	1	1	0
35	35.M1.3to6.31August2019	7:25:34	7:32:13	1	0	0	0	61
36	36.M1.Apis.22August2019	6:52:37	6:52:45	1	0	0	0	6
37	37.M1.3to6.28July2019	6:35:04	6:41:31	5	0	0	0	207
38	38.M1.9to12.1August2019	8:21:31	8:41:41	8	31	47	47	66
39	39.M1.3to6.8August2019	8:30:27	8:37:14	2	0	0	0	254
40	40.M1.9to12.22August2019	7:45:14	8:11:05	8	7	8	8	10
41	41.M1.PF.9August2019	12:52:34	12:53:14	0	0	0	0	0
44	44.M1.3to6.2August2019	7:27:24	7:33:08	3	0	2	2	0
47	47.M2.9to12.9August2019	12:34:01	12:42:03	9	0	0	0	37

48	48.M1.3to6.4August2019	8:03:35	8:13:35	2	0	6	6	17
49	49.M1.9to12.4August2019	7:50:57	7:54:12	8	14	2	2	184
51	51.M1.PF.7August2019	13:43:01	13:46:20	0	0	0	0	0
52	52.M1.3to6.29August2019	8:24:21	8:39:14	6	15	39	38	162
53	53.M1.PF.17August2019	8:24:15	8:26:51	0	0	0	0	0
54	54.M1.PM.3August2019	7:14:41	7:15:07	0	0	0	0	0
56	56.M1.3to6.23August2019	7:21:59	7:42:20	0	0	0	0	0
58	58.M1.Apis.7September2019	8:05:58	8:07:46	1	0	2	2	100
59	59.M1.9to12.3September2019	6:40:19	7:48:11	2	0	5	5	95
61	61.M1.9to12.4September2019	6:33:49	6:57:18	6	0	38	38	202
64	64.M1.PF.22August2019	7:06:28	7:06:45	0	0	0	0	0
66	66.M1.9to12.4September2019	7:27:22	8:02:16	7	0	16	16	157
68	68.M1.Apis.2August2019	8:00:02	8:02:54	1	0	2	2	123
69	69.M1.3to6.18August2019	8:09:04	8:19:38	1	0	0	0	0
70	70.M1.9to12.7September2019	6:32:40	7:20:38	0	0	0	0	0
72	72.M1.PF.14August2019	7:57:52	7:59:26	0	0	0	0	0
73	73.M1.9to12.7September2019	7:39:53	8:06:11	5	0	0	0	47
75	75.M1.PM.31July2019	8:01:10	8:03:18	0	0	0	0	0
76	76.M1.3to6.10August2019	7:45:30	7:47:32	4	0	15	15	13
77	77.M1.9to12.23August2019	7:03:41	7:35:34	4	11	28	28	20
78	78.M1.3to6.30July2019	7:13:52	7:15:50	4	18	6	6	10
79	79.M1.9to12.2September2019	7:41:18	7:56:26	10	0	0	0	199
82	82.M1.9to12.31August2019	6:37:48	6:48:49	2	0	6	6	21
83	83.M1.PF.20August2019	6:45:52	6:47:05	0	0	0	0	0
85	85.M1.PM.22August2019	8:13:37	8:13:40	0	0	0	0	0
86	86.M1.3to6.16August2019	6:42:23	6:51:39	2	0	0	0	0
87	87.M1.9to12.3September2019	8:05:48	8:28:39	7	31	4	4	9
89	89.M1.3to6.20August2019	6:44:33	6:55:17	4	4	0	0	13
90	90.M1.Apis.13August2019	8:30:05	8:30:16	1	0	0	0	2
91	91.M1.PM.21August2019	8:38:10	8:38:29	0	0	0	0	0
92	92.M1.3to6.11August2019	8:19:25	8:21:43	3	9	66	66	82
94	94.M1.9to12.18August2019	6:33:22	7:03:20	5	0	0	0	2
95	95.M1.3to6.17August2019	7:11:59	7:25:05	2	0	0	0	0
96	96.M1.Apis.24August2019	8:36:43	8:36:55	1	0	7	7	6
99	99.M1.PForXF.2August2019	6:54:54	6:55:13	0	0	0	0	0
101	101.M1.3to6.27August2019	7:15:34	7:27:35	2	1	2	2	40
102	102.M1.PF.22August2019	7:27:51	7:30:31	0	0	0	0	0
103	103.M1.PF.12August2019	8:28:14	8:28:36	0	0	0	0	0
104	104.M1.Apis.3August2019	7:40:48	7:42:27	1	0	0	0	94
105	105.M1.3to6.14August2019	8:07:44	8:13:04	3	0	0	0	0
106	106.M1.Apis.10August2019	12:54:22	12:54:28	1	0	0	0	2
107	107.M1.9to12.5September2019	6:30:16	7:11:55	0	0	0	0	0
109	109.M1.PF.19August2019	6:47:39	6:47:58	0	0	0	0	0
112	112.M1.9to12.17August2019	7:43:44	8:01:26	9	2	9	9	126

114	114.M1.3to6.16August2019	7:31:24	7:51:50	3	0	6	36	30
115	115.M1.9to12.5September2019	6:33:11	6:45:59	5	0	0	0	3
117	117.M1.9to12.28August2019	7:24:15	8:24:39	8	4	5	5	63
118	118.M1(S).Apis.29July2019	7:48:52	7:49:00	1	0	1	1	0
120	120.M1(S).PF.28July2019	8:25:33	8:30:28	0	0	0	0	0
121	121.M1.9to12.11August2019	8:14:20	8:30:15	12	21	36	36	98
122	122.M1.PM.3September2019	7:59:59	8:00:09	0	0	0	0	0
123	123.M1.Apis.10August2019	8:10:07	8:10:08	1	0	1	1	0
126	126.M1.PF.14August2019	7:42:40	7:43:51	0	0	0	0	0
129	129.M1.PF.12August2019	7:24:54	7:28:28	0	0	0	0	0
130	130.M1.3to6.27July2019	7:02:40	7:17:33	2	0	0	0	0
131	131.M1.Apis.13August2019	7:49:17	7:49:49	1	0	12	12	11
133	133.M1.3to6.20August2019	7:37:12	8:12:45	2	6	2	2	223
135	135.M1.9to12.17August2019	6:31:13	6:59:37	8	1	5	5	0
136	136.M1.3to6.3August2019	6:50:08	7:09:04	3	0	0	0	18
137	137.M1.9to12.15August2019	8:32:04	8:45:44	7	0	4	4	29
138	138.M1.PF.11August2019	8:23:39	8:24:12	0	0	0	0	0
139	139.M1.9to12.15August2019	7:42:08	7:56:40	10	16	23	23	60
141	141.M1.3to6.25August2019	6:40:31	6:49:04	1	0	0	0	0
143	143.M1.3to6.1September2019	8:05:38	8:17:23	4	0	10	10	92
146	146.M1.PF.11August2019	7:21:57	7:23:58	0	0	0	0	0
149	149.M1.Apis.14August2019	7:18:52	7:18:58	1	5	5	5	0

Appendix 12. Behavioral analysis of videos data for *P. pruinosa* (♀) visits to staminate flowers that also received *A. mellifera* or *P. pruinosa* (♂) visits. Where Video label = (Plant number. Flower number. Pollination treatment [apis = single *A. mellifera*, pf = single *P. pruinosa* (♀), or pm = single *P. pruinosa* (♂), 3to6 = 3 – 6 visitors, and 9to12 = 9 – 12 visitors]. Pollination date). See appendix 10 and 12 for behavioral analysis of videos for *A. mellifera* and *P. pruinosa* (♂) respectively

Plant	Video label	Video start time	Video end time	Number of visits	Total pollen duration (sec)	Total anther duration (sec)	Total anther movement duration (sec)	Total nectar duration (sec)
2	2.M1.PM.5August2019	7:35:04	7:35:48	0	0	0	0	0
3	3.M1.3to6.24August2019	6:37:32	6:51:57	2	0	29	29	39
4	4.M1.9to12.31August2019	7:33:29	8:12:12	4	37	137	133	61
5	5.M1.3to6.6August2019	7:30:30	7:35:22	2	74	34	33	36
6	6.M1.Apis.2August2019	7:13:05	7:13:28	0	0	0	0	0
7	7.M1.9to12.20August2019	7:20:44	7:35:11	1	0	5	5	5
8	8.M1.Apis.31August2019	8:27:01	8:27:40	0	0	0	0	0
9	9.M1.PF.23August2019	6:56:05	6:59:24	1	99	99	19	95
10	10.M1.3to6.7September2019	7:27:29	7:35:31	1	221	221	221	87
11	11.M1.PM.27July2019	7:07:22	7:08:12	0	0	0	0	0
13	13.M1.PF.6August2019	6:58:15	6:58:59	1	10	44	44	16
14	14.M1.3to6.1August2019	7:02:12	7:09:24	0	0	0	0	0
15	15.M1.Apis.5August2019	8:24:51	8:25:05	0	0	0	0	0
16	16.M1.PF.15August2019	8:20:22	8:20:55	1	15	31	31	17
18	18.M1.9to12.8August2019	8:07:38	8:13:49	3	90	156	145	95
19	19.M1.PM.5August2019	7:35:16	7:36:29	0	0	0	0	0
21	21.M1.3to6.1September2019	6:52:53	7:06:21	2	64	121	121	55
22	22.M1.PM.8August2019	12:56:39	12:57:09	0	0	0	0	0
25	25.M1.PF.8August2019	8:13:27	8:14:54	1	0	69	69	80
26	26.M1.9to12.29August2019	7:14:11	7:52:58	9	149	687	448	1545
27	27.M1.Apis.15August2019	7:02:52	7:03:24	0	0	0	0	0
28	28.M1.9to12.2September2019	6:39:26	7:16:42	8	88	272	246	177
29	29.M1.Apis.21August2019	6:52:42	6:52:46	0	0	0	0	0
30	30.M1.PF.16August2019	7:48:32	7:48:42	1	0	10	10	9
32	32.M1.9to12.6September2019	7:02:03	7:11:53	3	52	130	116	83
33	33.M1.PM.31August2019	8:26:08	8:27:18	0	0	0	0	0
34	34.M1.Apis.7August2019	7:44:27	7:44:33	0	0	0	0	0
35	35.M1.3to6.31August2019	7:25:34	7:32:13	2	11	57	31	50
36	36.M1.Apis.22August2019	6:52:37	6:52:45	0	0	0	0	0
37	37.M1.3to6.28July2019	6:35:04	6:41:31	0	0	0	0	0
38	38.M1.9to12.1August2019	8:21:31	8:41:41	1	0	141	121	25
39	39.M1.3to6.8August2019	8:30:27	8:37:14	1	23	43	43	0
40	40.M1.9to12.22August2019	7:45:14	8:11:05	1	84	84	84	0
41	41.M1.PF.9August2019	12:52:34	12:53:14	1	33	40	40	0
44	44.M1.3to6.2August2019	7:27:24	7:33:08	0	0	0	0	0

47	47.M2.9to12.9August2019	12:34:01	12:42:03	3	232	292	261	209
48	48.M1.3to6.4August2019	8:03:35	8:13:35	0	0	0	0	0
49	49.M1.9to12.4August2019	7:50:57	7:54:12	0	0	0	0	0
51	51.M1.PF.7August2019	13:43:01	13:46:20	1	0	199	100	107
52	52.M1.3to6.29August2019	8:24:21	8:39:14	0	0	0	0	0
53	53.M1.PF.17August2019	8:24:15	8:26:51	1	111	156	118	132
54	54.M1.PM.3August2019	7:14:41	7:15:07	0	0	0	0	0
56	56.M1.3to6.23August2019	7:21:59	7:42:20	4	23	272	267	139
58	58.M1.Apis.7September2019	8:05:58	8:07:46	0	0	0	0	0
59	59.M1.9to12.3September2019	6:40:19	7:48:11	8	67	364	364	104
61	61.M1.9to12.4September2019	6:33:49	6:57:18	3	206	484	277	392
64	64.M1.PF.22August2019	7:06:28	7:06:45	1	17	17	17	17
66	66.M1.9to12.4September2019	7:27:22	8:02:16	2	96	183	178	129
68	68.M1.Apis.2August2019	8:00:02	8:02:54	0	0	0	0	0
69	69.M1.3to6.18August2019	8:09:04	8:19:38	3	24	138	134	89
70	70.M1.9to12.7September2019	6:32:40	7:20:38	9	26	573	372	365
72	72.M1.PF.14August2019	7:57:52	7:59:26	1	94	94	23	90
73	73.M1.9to12.7September2019	7:39:53	8:06:11	2	0	172	127	147
75	75.M1.PM.31July2019	8:01:10	8:03:18	0	0	0	0	0
76	76.M1.3to6.10August2019	7:45:30	7:47:32	0	0	0	0	0
77	77.M1.9to12.23August2019	7:03:41	7:35:34	5	89	153	153	59
78	78.M1.3to6.30July2019	7:13:52	7:15:50	0	0	0	0	0
79	79.M1.9to12.2September2019	7:41:18	7:56:26	0	0	0	0	0
82	82.M1.9to12.31August2019	6:37:48	6:48:49	7	187	225	225	197
83	83.M1.PF.20August2019	6:45:52	6:47:05	1	0	73	20	61
85	85.M1.PM.22August2019	8:13:37	8:13:40	0	0	0	0	0
86	86.M1.3to6.16August2019	6:42:23	6:51:39	2	46	49	84	34
87	87.M1.9to12.3September2019	8:05:48	8:28:39	2	159	567	567	200
89	89.M1.3to6.20August2019	6:44:33	6:55:17	1	47	55	55	25
90	90.M1.Apis.13August2019	8:30:05	8:30:16	0	0	0	0	0
91	91.M1.PM.21August2019	8:38:10	8:38:29	0	0	0	0	0
92	92.M1.3to6.11August2019	8:19:25	8:21:43	0	0	0	0	0
94	94.M1.9to12.18August2019	6:33:22	7:03:20	4	0	72	72	60
95	95.M1.3to6.17August2019	7:11:59	7:25:05	2	46	73	73	52
96	96.M1.Apis.24August2019	8:36:43	8:36:55	0	0	0	0	0
99	99.M1.PForXF.2August2019	6:54:54	6:55:13	1	4	19	19	11
101	101.M1.3to6.27August2019	7:15:34	7:27:35	3	121	226	226	248
102	102.M1.PF.22August2019	7:27:51	7:30:31	1	160	160	119	124
103	103.M1.PF.12August2019	8:28:14	8:28:36	1	22	22	22	20
104	104.M1.Apis.3August2019	7:40:48	7:42:27	0	0	0	0	0
105	105.M1.3to6.14August2019	8:07:44	8:13:04	2	6	313	283	163
106	106.M1.Apis.10August2019	12:54:22	12:54:28	0	0	0	0	0
107	107.M1.9to12.5September2019	6:30:16	7:11:55	8	21	139	139	91
109	109.M1.PF.19August2019	6:47:39	6:47:58	1	0	19	19	18

112	112.M1.9to12.17August2019	7:43:44	8:01:26	0	0	0	0	0
114	114.M1.3to6.16August2019	7:31:24	7:51:50	3	39	198	198	189
115	115.M1.9to12.5September2019	6:33:11	6:45:59	6	64	67	67	531
117	117.M1.9to12.28August2019	7:24:15	8:24:39	1	9	1766	932	861
118	118.M1(S).Apis.29July2019	7:48:52	7:49:00	0	0	0	0	0
120	120.M1(S).PF.28July2019	8:25:33	8:30:28	1	101	204	204	87
121	121.M1.9to12.11August2019	8:14:20	8:30:15	0	0	0	0	0
122	122.M1.PM.3September2019	7:59:59	8:00:09	0	0	0	0	0
123	123.M1.Apis.10August2019	8:10:07	8:10:08	0	0	0	0	0
126	126.M1.PF.14August2019	7:42:40	7:43:51	1	71	71	71	71
129	129.M1.PF.12August2019	7:24:54	7:28:28	1	214	214	161	76
130	130.M1.3to6.27July2019	7:02:40	7:17:33	1	0	49	49	52
131	131.M1.Apis.13August2019	7:49:17	7:49:49	0	0	0	0	0
133	133.M1.3to6.20August2019	7:37:12	8:12:45	0	0	0	0	0
135	135.M1.9to12.17August2019	6:31:13	6:59:37	2	11	166	141	154
136	136.M1.3to6.3August2019	6:50:08	7:09:04	0	0	0	0	0
137	137.M1.9to12.15August2019	8:32:04	8:45:44	3	99	192	192	143
138	138.M1.PF.11August2019	8:23:39	8:24:12	1	33	33	33	17
139	139.M1.9to12.15August2019	7:42:08	7:56:40	0	0	0	0	0
141	141.M1.3to6.25August2019	6:40:31	6:49:04	3	213	272	206	248
143	143.M1.3to6.1September2019	8:05:38	8:17:23	1	0	110	224	114
146	146.M1.PF.11August2019	7:21:57	7:23:58	1	121	121	121	101
149	149.M1.Apis.14August2019	7:18:52	7:18:58	0	0	0	0	0

Appendix 13. Behavioral analysis of videos data for *P. pruinosa* (♂) visits to staminate flowers that also received *A. mellifera* or *P. pruinosa* (♀) visits. Where Video label = (Plant number. Flower number. Pollination treatment [apis = single *A. mellifera*, pf = single *P. pruinosa* (♀), or pm = single *P. pruinosa* (♂), 3to6 = 3 – 6 visitors, and 9to12 = 9 – 12 visitors]. Pollination date). See appendix 10 and 11 for behavioral analysis of videos for *A. mellifera* and *P. pruinosa* (♀) respectively.

Plant	Video label	Video start time	Video end time	Number of visits	Total pollen duration (sec)	Total anther duration (sec)	Total anther movement duration (sec)	Total nectar duration (sec)
2	2.M1.PM.5August2019	7:35:04	7:35:48	1	0	41	41	37
3	3.M1.3to6.24August2019	6:37:32	6:51:57	0	0	0	0	0
4	4.M1.9to12.31August2019	7:33:29	8:12:12	0	0	0	0	0
5	5.M1.3to6.6August2019	7:30:30	7:35:22	1	0	13	13	13
6	6.M1.Apis.2August2019	7:13:05	7:13:28	0	0	0	0	0
7	7.M1.9to12.20August2019	7:20:44	7:35:11	2	0	90	90	82
8	8.M1.Apis.31August2019	8:27:01	8:27:40	0	0	0	0	0
9	9.M1.PF.23August2019	6:56:05	6:59:24	0	0	0	0	0
10	10.M1.3to6.7September2019	7:27:29	7:35:31	2	14	23	23	23
11	11.M1.PM.27July2019	7:07:22	7:08:12	1	0	50	7	49
13	13.M1.PF.6August2019	6:58:15	6:58:59	0	0	0	0	0
14	14.M1.3to6.1August2019	7:02:12	7:09:24	1	0	8	8	8
15	15.M1.Apis.5August2019	8:24:51	8:25:05	0	0	0	0	0
16	16.M1.PF.15August2019	8:20:22	8:20:55	0	0	0	0	0
18	18.M1.9to12.8August2019	8:07:38	8:13:49	1	0	0	0	0
19	19.M1.PM.5August2019	7:35:16	7:36:29	1	0	66	25	70
21	21.M1.3to6.1September2019	6:52:53	7:06:21	0	0	0	0	0
22	22.M1.PM.8August2019	12:56:39	12:57:09	1	0	30	30	29
25	25.M1.PF.8August2019	8:13:27	8:14:54	0	0	0	0	0
26	26.M1.9to12.29August2019	7:14:11	7:52:58	0	0	0	0	0
27	27.M1.Apis.15August2019	7:02:52	7:03:24	0	0	0	0	0
28	28.M1.9to12.2September2019	6:39:26	7:16:42	1	0	6	6	6
29	29.M1.Apis.21August2019	6:52:42	6:52:46	0	0	0	0	0
30	30.M1.PF.16August2019	7:48:32	7:48:42	0	0	0	0	0
32	32.M1.9to12.6September2019	7:02:03	7:11:53	0	0	0	0	0
33	33.M1.PM.31August2019	8:26:08	8:27:18	1	0	67	23	59
34	34.M1.Apis.7August2019	7:44:27	7:44:33	0	0	0	0	0
35	35.M1.3to6.31August2019	7:25:34	7:32:13	0	0	0	0	0
36	36.M1.Apis.22August2019	6:52:37	6:52:45	0	0	0	0	0
37	37.M1.3to6.28July2019	6:35:04	6:41:31	0	0	0	0	0
38	38.M1.9to12.1August2019	8:21:31	8:41:41	0	0	0	0	0
39	39.M1.3to6.8August2019	8:30:27	8:37:14	0	0	0	0	0
40	40.M1.9to12.22August2019	7:45:14	8:11:05	0	0	0	0	0
41	41.M1.PF.9August2019	12:52:34	12:53:14	0	0	0	0	0
44	44.M1.3to6.2August2019	7:27:24	7:33:08	1	0	34	34	5

47	47.M2.9to12.9August2019	12:34:01	12:42:03	0	0	0	0	0
48	48.M1.3to6.4August2019	8:03:35	8:13:35	1	0	4	4	4
49	49.M1.9to12.4August2019	7:50:57	7:54:12	2	0	0	0	11
51	51.M1.PF.7August2019	13:43:01	13:46:20	0	0	0	0	0
52	52.M1.3to6.29August2019	8:24:21	8:39:14	0	0	0	0	0
53	53.M1.PF.17August2019	8:24:15	8:26:51	0	0	0	0	0
54	54.M1.PM.3August2019	7:14:41	7:15:07	1	0	15	15	19
56	56.M1.3to6.23August2019	7:21:59	7:42:20	0	0	0	0	0
58	58.M1.Apis.7September2019	8:05:58	8:07:46	0	0	0	0	0
59	59.M1.9to12.3September2019	6:40:19	7:48:11	0	0	0	0	0
61	61.M1.9to12.4September2019	6:33:49	6:57:18	0	0	0	0	0
64	64.M1.PF.22August2019	7:06:28	7:06:45	0	0	0	0	0
66	66.M1.9to12.4September2019	7:27:22	8:02:16	0	0	0	0	0
68	68.M1.Apis.2August2019	8:00:02	8:02:54	0	0	0	0	0
69	69.M1.3to6.18August2019	8:09:04	8:19:38	0	0	0	0	0
70	70.M1.9to12.7September2019	6:32:40	7:20:38	0	0	0	0	0
72	72.M1.PF.14August2019	7:57:52	7:59:26	0	0	0	0	0
73	73.M1.9to12.7September2019	7:39:53	8:06:11	2	0	164	119	141
75	75.M1.PM.31July2019	8:01:10	8:03:18	1	48	128	116	58
76	76.M1.3to6.10August2019	7:45:30	7:47:32	0	0	0	0	0
77	77.M1.9to12.23August2019	7:03:41	7:35:34	1	0	26	26	22
78	78.M1.3to6.30July2019	7:13:52	7:15:50	0	0	0	0	0
79	79.M1.9to12.2September2019	7:41:18	7:56:26	1	0	9	7	8
82	82.M1.9to12.31August2019	6:37:48	6:48:49	0	0	0	0	0
83	83.M1.PF.20August2019	6:45:52	6:47:05	0	0	0	0	0
85	85.M1.PM.22August2019	8:13:37	8:13:40	1	0	3	3	3
86	86.M1.3to6.16August2019	6:42:23	6:51:39	0	0	0	0	0
87	87.M1.9to12.3September2019	8:05:48	8:28:39	0	0	0	0	0
89	89.M1.3to6.20August2019	6:44:33	6:55:17	0	0	0	0	0
90	90.M1.Apis.13August2019	8:30:05	8:30:16	0	0	0	0	0
91	91.M1.PM.21August2019	8:38:10	8:38:29	1	0	19	19	18
92	92.M1.3to6.11August2019	8:19:25	8:21:43	0	0	0	0	0
94	94.M1.9to12.18August2019	6:33:22	7:03:20	0	0	0	0	0
95	95.M1.3to6.17August2019	7:11:59	7:25:05	0	0	0	0	0
96	96.M1.Apis.24August2019	8:36:43	8:36:55	0	0	0	0	0
99	99.M1.PForXF.2August2019	6:54:54	6:55:13	0	0	0	0	0
101	101.M1.3to6.27August2019	7:15:34	7:27:35	0	0	0	0	0
102	102.M1.PF.22August2019	7:27:51	7:30:31	0	0	0	0	0
103	103.M1.PF.12August2019	8:28:14	8:28:36	0	0	0	0	0
104	104.M1.Apis.3August2019	7:40:48	7:42:27	0	0	0	0	0
105	105.M1.3to6.14August2019	8:07:44	8:13:04	0	0	0	0	0
106	106.M1.Apis.10August2019	12:54:22	12:54:28	0	0	0	0	0
107	107.M1.9to12.5September2019	6:30:16	7:11:55	0	0	0	0	0
109	109.M1.PF.19August2019	6:47:39	6:47:58	0	0	0	0	0

112	112.M1.9to12.17August2019	7:43:44	8:01:26	0	0	0	0	0
114	114.M1.3to6.16August2019	7:31:24	7:51:50	0	0	0	0	0
115	115.M1.9to12.5September2019	6:33:11	6:45:59	0	0	0	0	0
117	117.M1.9to12.28August2019	7:24:15	8:24:39	0	0	0	0	0
118	118.M1(S).Apis.29July2019	7:48:52	7:49:00	0	0	0	0	0
120	120.M1(S).PF.28July2019	8:25:33	8:30:28	0	0	0	0	0
121	121.M1.9to12.11August2019	8:14:20	8:30:15	0	0	0	0	0
122	122.M1.PM.3September2019	7:59:59	8:00:09	1	0	9	9	8
123	123.M1.Apis.10August2019	8:10:07	8:10:08	0	0	0	0	0
126	126.M1.PF.14August2019	7:42:40	7:43:51	0	0	0	0	0
129	129.M1.PF.12August2019	7:24:54	7:28:28	0	0	0	0	0
130	130.M1.3to6.27July2019	7:02:40	7:17:33	0	0	0	0	0
131	131.M1.Apis.13August2019	7:49:17	7:49:49	0	0	0	0	0
133	133.M1.3to6.20August2019	7:37:12	8:12:45	3	22	180	80	122
135	135.M1.9to12.17August2019	6:31:13	6:59:37	0	0	0	0	0
136	136.M1.3to6.3August2019	6:50:08	7:09:04	2	0	19	19	19
137	137.M1.9to12.15August2019	8:32:04	8:45:44	0	0	0	0	0
138	138.M1.PF.11August2019	8:23:39	8:24:12	0	0	0	0	0
139	139.M1.9to12.15August2019	7:42:08	7:56:40	0	0	0	0	0
141	141.M1.3to6.25August2019	6:40:31	6:49:04	0	0	0	0	0
143	143.M1.3to6.1September2019	8:05:38	8:17:23	0	0	0	0	0
146	146.M1.PF.11August2019	7:21:57	7:23:58	0	0	0	0	0
149	149.M1.Apis.14August2019	7:18:52	7:18:58	0	0	0	0	0

Appendix 14. Fruit set data of pistillate flowers visited by *A. mellifera.* Pollination treatment: SA = single *A. mellifera* visit, 3 – 6 visits, and 9 – 12 visits.

Plant	Pollination date (day of year)	Pollination treatment	Number of visits	Fruit set (Y/N)
3	226	3 to 6	5	N
4	231	9 to 12	9	Y
6	209	SA	1	Y
8	218	SA	1	N
14	229	3 to 6	3	N
15	250	SA	1	N
18	235	9 to 12	10	N
21	228	3 to 6	4	N
26	214	9 to 12	10	Y
27	212	SA	1	N
29	218	SA	1	N
32	213	9 to 12	8	N
34	224	SA	1	N
35	227	3 to 6	3	Y
36	224	SA	1	N
37	212	3 to 6	6	Y
38	232	9 to 12	10	Y
39	213	3 to 6	4	Y
40	215	9 to 12	10	N
44	214	3 to 6	6	N
48	240	3 to 6	4	N
49	212	9 to 12	10	Y
58	219	SA	1	N
68	228	SA	1	N
69	230	3 to 6	5	N
70	240	9 to 12	12	Y
71	216	SA	1	N
76	234	3 to 6	4	Y
78	211	3 to 6	4	N
82	212	9 to 12	10	N
86	223	3 to 6	5	N
87	226	9 to 12	9	Y
89	214	3 to 6	5	N
90	219	SA	1	N
92	224	3 to 6	4	Y
94	216	9 to 12	10	N
95	224	3 to 6	3	Y
96	214	SA	1	N
97	225	3 to 6	5	N
101	208	3 to 6	6	Y

104	214	SA	1	N
106	213	SA	1	N
107	230	9 to 12	11	N
112	232	9 to 12	12	N
113	234	3 to 6	5	N
115	231	9 to 12	9	N
117	211	9 to 12	10	Y
118	227	SA	1	N
121	226	9 to 12	10	Y
123	208	SA	1	N
130	231	3 to 6	5	N
131	222	SA	1	N
133	212	3 to 6	6	N
136	210	3 to 6	4	N
137	231	9 to 12	10	N
140	224	SA	1	N
143	245	3 to 6	6	N
149	223	SA	1	N

Appendix 15. Fruit data. Fruits resulted from single *A. mellifera* (SA) visit, 3 – 6 visits by *A. mellifera* , and 9 – 12 visits by *A. mellifera.*

Plant	Pollination date (day of year)	Pollination treatment	Harvest Date (day of year)	Process date (day of year)	Fruit weight (g)	Fruit height (cm)	Fruit diameter (cm)	Fruit volume (mL)	Fruit brix (°Bx)	Number of seeds	Total seed mass (mg)	Mean seed mass (mg)
4	231	9 to 12	8-Oct	8-Oct	403	94.88	88.05	420	10	80	8542	106.8
6	209	SA	16-Sep	16-Sep	202	76.23	71.58	193.3333	11.5	18	1430	79.4
26	214	9 to 12	21-Sep	21-Sep	208	69.57	77.69	216.6667	10	42	4433	105.5
35	227	3 to 6	4-Oct	5-Oct	379	95.09	91.01	388.3333	10.5	142	16158	113.8
37	212	3 to 6	19-Sep	19-Sep	764	101.13	121.89	800	11.5	182	21166	116.3
38	232	9 to 12	9-Oct	9-Oct	227	86.33	75.01	250	6	75	5923	79.0
39	213	3 to 6	20-Sep	20-Sep	311	85.82	83.13	300	9.5	29	768	26.5
49	212	9 to 12	19-Sep	20-Sep	312	94.97	89.5	330	11.5	41	4002	97.6
70	240	9 to 12	17-Oct	17-Oct	397	94.18	93.94	420	12	165	15807	95.8
76	234	3 to 6	11-Oct	11-Oct	282	79.2	78.8	290	11	52	5699	109.6
87	226	9 to 12	3-Oct	3-Oct	341	103.45	79.75	360	10.5	63	6684	106.1
92	224	3 to 6	1-Oct	1-Oct	501	99.68	101.77	550	11	149	17962	120.6
95	224	3 to 6	1-Oct	1-Oct	316	78.59	96.58	320	10	99	10249	103.5
101	208	3 to 6	15-Sep	15-Sep	349	81.79	92.56	413.3333	10	86	11461	133.3
117	211	9 to 12	18-Sep	18-Sep	394	90.02	97.98	410	10.5	75	9411	125.5
121	226	9 to 12	3-Oct	3-Oct	346	92.82	84.48	360	10.5	124	13035	105.1

Appendix 16. Pollen deposition data for pistillate flowers that set fruit. Pollination treatments: SA = single *A. mellifera*, 3 – 6 visits by *A. mellifera*, and 9 – 12 visits by *A. mellifera*

Plant	Pollination date (day of year)	Pollination treatment	Number of visits	First count	Second Count	Mean pollen count
4	231	9 to 12	9	368	341	354.5
6	209	SA	1	82	70	76
26	214	9 to 12	10	305	280	292.5
35	227	3 to 6	3	608	596	602
37	212	3 to 6	6	669	634	651.5
38	232	9 to 12	10	283	263	273
39	213	3 to 6	4	370	334	352
49	212	9 to 12	10	391	379	385
70	240	9 to 12	12	682	652	667
76	234	3 to 6	4	153	148	150.5
87	226	9 to 12	9	428	445	436.5
92	224	3 to 6	4	483	468	475.5
95	224	3 to 6	3	537	571	554
101	208	3 to 6	6	272	266	269
117	211	9 to 12	10	267	280	273.5
121	226	9 to 12	10	1075	1011	1043

Appendix 17. Behavioral analysis of videos data for *A. mellifera* visits to pistillate flowers that only received visits by *A. mellifera*. Where Video label = (Plant number. Flower number. Pollination treatment [apis = single *A. mellifera*, 3to6 = 3 – 6 visits, and 9to12 = 9 – 12 visits]. Pollination date).

Plant	Video label	Video start time	Video end time	Number of visits	Total nectar duration (sec)	Total stigma duration (sec)	Total stigma movement duration (sec)	Total lobes touched
3	3.F1.3to6.14August2019	6:46:44	6:53:49	5	102	17	5	5
4	4.F1.9to12.19August2019	8:18:42	8:34:53	9	253	16	11	21
6	6.F1(S).Apis.28July2019	6:52:54	6:54:19	1	79	3	3	2
8	8.F1.Apis.6August2019	12:50:39	12:52:13	1	78	0	0	0
14	14.F1.3to6.17August2019	6:30:19	6:42:22	3	65	3	3	5
15	15.F1.Apis.7September2019	7:56:36	7:57:36	1	51	5	4	6
18	18.F1.9to12.23August2019	7:21:50	7:54:43	10	380	30	29	27
21	21.F1.3to6.16August2019	7:05:20	7:19:35	4	168	5	4	8
26	26.F1.9to12.2August2019	7:25:07	7:31:42	10	168	32	26	22
27	27.F1.Apis.31July2019	6:54:15	6:55:08	1	50	3	3	8
29	29.F1.Apis.6August2019	7:28:01	7:29:19	1	70	27	7	6
32	32.F1.9to12.1August2019	7:22:00	7:25:14	8	153	52	26	13
34	34.F1.Apis.12August2019	7:58:44	8:01:44	1	171	4	4	4
35	35.F1.3to6.15August2019	6:35:58	6:54:24	3	390	4	4	3
36	36.F1.Apis.12August2019	8:24:38	8:26:22	1	89	12	12	6
37	37.F1.3to6.31July2019	6:48:44	6:52:48	6	31	44	44	23
38	38.F1.9to12.20August2019	6:50:37	7:02:50	10	430	41	41	32
39	39.F1.3to6.1August2019	8:25:16	8:32:49	4	274	10	10	12
40	40.F1.9to12.3August2019	7:42:42	7:50:57	10	304	63	22	23
44	44.F1.3to6.2August2019	7:17:49	7:21:48	6	40	22	22	16
48	48.F1.3to6.28August2019	8:10:11	8:26:26	4	181	6	6	2
49	49.F1.9to12.31July2019	7:28:01	7:33:34	10	403	53	53	36
58	58.F1.Apis.7August2019	12:46:31	12:48:15	1	100	4	4	6
68	68.F1.Apis.16August2019	8:44:35	8:45:54	1	72	1	1	3
69	69.F1.3to6.18August2019	8:20:54	8:28:44	5	328	22	20	21
70	70.F1.9to12.28August2019	8:06:37	8:35:04	12	522	67	46	35
71	71.F1.Apis.4August2019	8:09:55	8:11:05	1	54	0	0	0
76	76.F1.3to6.22August2019	7:18:42	7:23:17	4	211	9	8	15
78	78.F1.3to6.30July2019	6:48:27	6:52:35	4	125	11	11	12
82	82.F1.9to12.31July2019	6:45:44	6:54:28	10	202	24	22	30
86	86.F1.3to6.11August2019	8:08:19	8:10:54	5	186	121	10	12
87	87.F1.9to12.14August2019	6:39:12	7:06:08	9	923	59	38	35
89	89.F1.3to6.2August2019	7:51:54	7:54:53	5	192	84	23	10
90	90.F1.Apis.7August2019	7:57:04	7:58:40	1	90	9	9	6
92	92.F1.3to6.12August2019	7:52:13	7:56:13	4	330	15	15	14
94	94.F1.9to12.4August2019	8:18:43	8:36:12	10	363	43	41	32

95	95.F1.3to6.12August2019	7:11:07	7:15:43	3	441	29	29	17
96	96.F1.Apis.2August2019	7:22:17	7:22:24	1	0	7	7	7
97	97.F1.3to6.13August2019	6:43:56	7:03:21	5	360	14	14	21
101	101.F1(SE).3to6.27July2019	6:34:11	6:56:23	6	98	5	5	8
104	104.F1.Apis.2August2019	8:03:08	8:04:12	1	43	15	15	9
106	106.F1.Apis.1August2019	7:47:00	7:48:17	1	69	2	2	3
107	107.F1.9to12.18August2019	8:25:39	8:48:15	11	225	20	20	32
112	112.F1.9to12.20August2019	7:46:46	8:17:31	12	1056	70	63	38
113	113.F1.3to6.22August2019	8:21:48	8:37:47	5	414	21	18	14
115	115.F1.9to12.19August2019	6:42:57	6:58:21	9	326	23	20	23
117	117.F1.9to12.30July2019	6:39:28	6:49:45	10	265	22	17	15
118	118.F1.Apis.15August2019	6:57:48	6:59:32	1	89	2	2	2
121	121.F1.9to12.14August2019	8:00:32	8:27:44	10	448	105	89	24
123	123.F1.Apis.27July2019	6:54:15	6:54:17	1	0	2	1	4
130	130.F1.3to6.19August2019	6:41:45	6:56:14	5	148	11	11	10
131	131.F1.Apis.10August2019	8:22:28	8:24:21	1	93	9	9	8
133	133.F1.3to6.31July2019	8:20:17	8:38:01	6	398	7	7	6
136	136.F1.3to6.29July2019	8:14:36	8:25:43	4	262	2	2	3
137	137.F1.9to12.19August2019	7:41:02	7:47:34	10	265	25	25	26
140	140.F1.Apis.12August2019	7:38:56	7:40:51	1	107	4	4	5
143	143.F1.3to6.2September2019	8:23:23	8:30:48	6	213	193	52	24
149	149.F1.Apis.11August2019	6:47:48	6:50:17	1	128	9	9	8

Appendix 18. Behavioral analysis of videos data for *A. mellifera* visits to staminate flowers that only received visits by *A. mellifera*. Where Video label = (Plant number. Flower number. Pollination treatment [apis = single *A. mellifera*, 3to6 = 3 – 6 visits, and 9to12 = 9 – 12 visits]. Pollination date)

Plant	Video label	Video start time	Video end time	Number of visits	Total pollen duration (sec)	Total anther duration (sec)	Total anther movement duration (sec)	Total nectar duration (sec)
3	3.M1.3to6.29July2019	7:08:28	7:13:31	3	0	0	0	19
6	6.M1.Apis.2August2019	7:13:05	7:13:28	1	0	1	1	9
8	8.M1.Apis.31August2019	8:27:01	8:27:40	1	0	0	0	35
14	14.M1.3to6.3September2019	8:20:30	8:33:05	3	3	9	9	130
15	15.M1.Apis.5August2019	8:24:51	8:25:05	1	0	4	4	0
21	21.M1.3to6.7August2019	7:09:15	7:10:25	3	1	1	1	0
27	27.M1.Apis.15August2019	7:02:52	7:03:24	1	0	0	0	27
29	29.M1.Apis.21August2019	6:52:42	6:52:46	1	0	0	0	0
34	34.M1.Apis.7August2019	7:44:27	7:44:33	1	0	1	1	0
36	36.M1.Apis.22August2019	6:52:37	6:52:45	1	0	0	0	6
37	37.M1.3to6.28July2019	6:35:04	6:41:31	5	0	0	0	207
52	52.M1.3to6.29August2019	8:24:21	8:39:14	6	15	39	38	162
56	56.M1.3to6.2August2019	7:11:34	7:13:02	4	26	5	5	10
58	58.M1.Apis.9August2019	7:06:29	7:06:48	1	0	1	1	12
59	59.M1.9to12.2August2019	7:39:08	7:56:28	9	54	9	9	26
68	68.M1.Apis.2August2019	8:00:02	8:02:54	1	0	2	2	123
73	73.M1.9to12.21August2019	7:21:51	7:41:41	9	77	88	88	146
76	76.M1.3to6.10August2019	7:45:30	7:47:32	4	0	15	15	13
78	78.M1.3to6.30July2019	7:13:52	7:15:50	4	18	6	6	10
79	79.M1.9to12.7August2019	7:17:08	7:19:38	10	2	9	9	17
87	87.M1.9to12.13August2019	7:54:04	8:25:35	11	14	35	35	28
89	89.M1.3to6.9August2019	8:01:25	8:16:53	5	103	9	9	119
90	90.M1.Apis.13August2019	8:30:05	8:30:16	1	0	0	0	2
92	92.M1.3to6.11August2019	8:19:25	8:21:43	3	9	66	66	82
96	96.M1.Apis.24August2019	8:36:43	8:36:55	1	0	7	7	6
104	104.M1.Apis.3August2019	7:40:48	7:42:27	1	0	0	0	94
106	106.M1.Apis.10August2019	12:54:22	12:54:28	1	0	0	0	2
112	112.M1.9to12.17August2019	7:43:44	8:01:26	9	2	9	9	126
114	114.M1.3to6.22August2019	7:00:26	7:08:39	3	0	10	10	23
117	117.M1.9to12.29July2019	7:21:42	7:56:03	10	76	68	68	117
118	118.M1(S).Apis.29July2019	7:48:52	7:49:00	1	0	1	1	0
121	121.M1.9to12.11August2019	8:14:20	8:30:15	12	21	36	36	98
123	123.M1.Apis.10August2019	8:10:07	8:10:08	1	0	1	1	0
130	130.M1.3to6.26August2019	8:19:40	8:31:41	4	0	1	1	66
131	131.M1.Apis.13August2019	7:49:17	7:49:49	1	0	12	12	11
139	139.M1.9to12.15August2019	7:42:08	7:56:40	10	16	23	23	60
141	141.M1.3to6.29July2019	6:56:27	7:01:46	4	0	5	5	6
149	149.M1.Apis.14August2019	7:18:52	7:18:58	1	5	5	5	0

Appendix 19. Pollen removal data for staminate flowers. Pollination treatments: SA = single *A. mellifera*, 3to6 = 3 – 6 *A. mellifera* visits, and 9to12 = 9 – 12 *A. mellifera* visits. Pollen removal was calculated by subtracting pollen remaining from mean pollen available.

Plant	Flowering date (day of year)	Pollination treatment	Pollen remaining (mg)	Mean pollen available (mg)	Calculated pollen removed (mg)
3	210	3 to 6	8	21.5	13.5
6	214	SA	23	11.5	0
8	243	SA	15	15.0	0
14	246	3 to 6	6	23.0	17
15	217	SA	14	20.7	6.7
21	219	3 to 6	24	23.5	0
27	227	SA	27	22.7	0
29	233	SA	18	22.5	4.5
34	219	SA	30	24.7	0
36	234	SA	28	29.0	1
37	209	3 to 6	11	26.5	15.5
52	241	3 to 6	4	27.0	23
56	214	3 to 6	20	25.0	5
58	221	SA	25	23.0	0
59	214	9 to 12	10	20.0	10
68	214	SA	10	31.7	21.7
73	233	9 to 12	15	10.0	0
76	222	3 to 6	6	35.0	29
78	211	3 to 6	13	29.0	16
79	219	9 to 12	20	17.0	0
87	225	9 to 12	17	32.0	15
89	221	3 to 6	14	25.0	11
90	225	SA	16	25.0	9
92	223	3 to 6	5	33.0	28
96	236	SA	24	21.0	0
104	215	SA	40	34.0	0
106	222	SA	22	12.0	0
112	229	9 to 12	5	7.0	2
114	234	3 to 6	15	21.0	6
117	210	9 to 12	3	12.0	9
118	210	SA	12	22.5	10.5
121	223	9 to 12	11	32.0	21
123	222	SA	29	26.0	0
130	238	3 to 6	14	23.0	9
131	225	SA	32	26.7	0
139	227	9 to 12	12	23.0	11
141	210	3 to 6	13	16.0	3
149	226	SA	21	29.0	8

Appendix 20. Identity of first and second visitor, and stigma time of second visitor for pistillate flowers. Where Video label = (Plant number. Flower number. Pollination treatment [3to6 = 3 – 6 visits, and 9to12 = 9 – 12 visits]. Pollination date). Visitors: A = *A. mellifera* ; PF = *P. pruinosa* (♀)

Plant	Video label	First visitor	Second visitor	Second visitor stigma time (sec)
3	3.F1.3to6.24August2019	PF	PF	149
4	4.F1.9to12.19August2019	A	A	2
5	5.F1.3to6.1August2019	A	PF	20
7	7.F1.9to12.25August2019	PF	PF	8
10	10.F1.3to6.2August2019	PF	A	3
14	14.F1.3to6.30August2019	PF	PF	26
18	18.F1.9to12.23August2019	A	A	5
21	21.F1.3to6.27August2019	PF	A	0
26	26.F1.9to12.2August2019	A	A	13
28	28.F1.9to12.6September2019	PF	PF	371
32	32.F1.9to12.10August2019	A	A	3
35	35.F1.3to6.15August2019	A	A	0
37	37.F1.3to6.18August2019	A	A	63
38	38.F1.9to12.18August2019	A	PF	83
39	39.F1.3to6.1August2019	A	A	0
40	40.F1.9to12.12August2019	PF	PF	89
44	44.F1.3to6.3September2019	PF	PF	0
47	47.F1.9to12.7August2019	PF	A	7
48	48.F1.3to6.10August2019	A	PF	122
49	49.F1.9to12.29August2019	PF	A	0
52	52.F1.3to6.20August2019	A	PF	119
56	56.F1.3to6.31August2019	PF	A	2
59	59.F1.9to12.22August2019	PF	PF	87
61	61.F1.9to12.6August2019	A	A	0
66	66.F1.9to12.3September2019	PF	A	6
69	69.F1.3to6.9August2019	PF	PF	2
70	70.F1.9to12.9August2019	A	PF	89
73	73.F1.9to12.29August2019	PF	PF	439
76	76.F1.3to6.5August2019	A	A	1
77	77.F1.9to12.7September2019	PF	PF	89
78	78.F1.3to6.21August2019	A	PF	164
82	82.F1.9to12.27August2019	PF	PF	126
86	86.F1.3to6.2September2019	PF	PF	77
87	87.F1.9to12.31August2019	PF	A	0
89	89.F1.3to6.2August2019	A	A	0
92	92.F1.3to6.3September2019	PF	PF	154
94	94.F1.9to12.18August2019	A	PF	293
95	95.F1.3to6.1September2019	PF	A	8
97	97.F1.3to6.23August2019	PF	PF	29

101	101.F1(SE).3to6.27July2019	A	A	0
105	105.F1.3to6.26August2019	PF	A	3
107	107.F1.9to12.8August2019	A	A	0
112	112.F1.9to12.20August2019	A	A	3
113	113.F1.3to6.29August2019	PF	A	0
114	114.F1.3to6.11August2019	A	A	6
115	115.F1.9to12.2September2019	PF	A	8
117	117.F1.9to12.2September2019	PF	PF	11
121	121.F1.9to12.14August2019	A	A	40
130	130.F1.3to6.1September2019	PF	PF	51
133	133.F1.3to6.30August2019	PF	PF	136
135	135.F1.9to12.11August2019	PF	A	27
136	136.F1.3to6.29July2019	A	A	0
137	137.F1.9to12.1September2019	PF	PF	26
139	139.F1.9to12.23August2019	PF	PF	47
141	141.F1.3to6.3August2019	PF	PF	30
143	143.F1.3to6.2September2019	A	A	6

Appendix 21. Identity of first and second visitor, and stigma time of second visitor for staminate flowers. Where Video label = (Plant number. Flower number. Pollination treatment [3to6 = 3 – 6 visits, and 9to12 = 9 – 12 visits]. Pollination date). Visitors: A = *A. mellifera* ; PF = *P. pruinosa*

Plant	Video label	First visitor	Second visitor	Second visitor anther time (sec)
3	3.M1.3to6.24August2019	PF	PF	29
4	4.M1.9to12.31August2019	PF	A	0
5	5.M1.3to6.31August2019	PF	PF	139
7	7.M1.9to12.20August2019	A	A	0
10	10.M1.3to6.5August2019	A	A	3
14	14.M1.3to6.3September2019	A	A	6
18	18.M1.9to12.8August2019	A	A	0
21	21.M1.3to6.1September2019	PF	A	0
26	26.M1.9to12.29August2019	PF	PF	25
28	28.M1.9to12.2September2019	PF	PF	9
32	32.M1.9to12.6September2019	A	A	0
35	35.M1.3to6.31August2019	A	PF	5
37	37.M1.3to6.28July2019	A	A	0
38	38.M1.9to12.30August2019	A	PF	44
39	39.M1.3to6.8August2019	PF	A	0
40	40.M1.9to12.22August2019	A	A	0
44	44.M1.3to6.2August2019	A	A	0
47	47.M2.9to12.9August2019	PF	A	0
48	48.M1.3to6.15August2019	A	PF	439
49	49.M1.9to12.4August2019	A	A	0
52	52.M1.3to6.29August2019	A	A	0
56	56.M1.3to6.23August2019	PF	PF	28
59	59.M1.9to12.3September2019	PF	PF	6
61	61.M1.9to12.10August2019	A	PF	767
66	66.M1.9to12.4September2019	PF	PF	71
69	69.M1.3to6.18August2019	A	PF	8
70	70.M1.9to12.7September2019	PF	PF	20
73	73.M1.9to12.7September2019	A	A	0
76	76.M1.3to6.10August2019	A	A	13
77	77.M1.9to12.23August2019	PF	PF	8
78	78.M1.3to6.30July2019	A	A	1
79	79.M1.9to12.2September2019	A	A	0
82	82.M1.9to12.31August2019	PF	PF	77
86	86.M1.3to6.16August2019	A	PF	49
87	87.M1.9to12.3September2019	PF	A	0
89	89.M1.3to6.20August2019	PF	A	0
92	92.M1.3to6.11August2019	A	A	0
94	94.M1.9to12.18August2019	PF	PF	22
95	95.M1.3to6.17August2019	PF	A	0
101	101.M1.3to6.27August2019	PF	A	2

105	105.M1.3to6.14August2019	PF	A	0
107	107.M1.9to12.5September2019	PF	PF	2
112	112.M1.9to12.17August2019	A	A	2
114	114.M1.3to6.16August2019	PF	A	6
115	115.M1.9to12.5September2019	PF	PF	10
117	117.M1.9to12.28August2019	A	A	1
121	121.M1.9to12.11August2019	A	A	0
130	130.M1.3to6.26August2019	A	A	1
135	135.M1.9to12.17August2019	A	A	0
136	136.M1.3to6.6September2019	PF	PF	49
137	137.M1.9to12.15August2019	A	PF	166
139	139.M1.9to12.15August2019	A	A	0
141	141.M1.3to6.25August2019	PF	PF	131
143	143.M1.3to6.1September2019	A	A	0

Appendix 22. R code for statistical analyses.

```
# Code used for Table 1: Visitation

library("lmtest")
library("rcompanion")


female.flowers <- read.csv("final.version.female.flowers.update.csv", header = T)

male.flowers <- read.csv("final.version.male.flowers.update.csv", header = T)

female.flowers$a2 <- female.flowers$apis^2
female.flowers$pf2 <- female.flowers$pf^2
female.flowers$pm2 <- female.flowers$pm^2
female.flowers$af <- female.flowers$apis*female.flowers$pf
female.flowers$am <- female.flowers$apis*female.flowers$pm
female.flowers$fm <- female.flowers$pf*female.flowers$pm
female.flowers$afm <- female.flowers$apis*female.flowers$pf*female.flowers$pm

#----Model 1----

Model1A <- glm(fruit ~ apis + pf + pm + j.date, data = female.flowers, family = binomial(link = "logit"))
summary(Model1A)
Anova(Model1A, type="II", test="Wald")
lrtest(Model1A)

Model1B <- glm(fruit ~ apis + pf + j.date, data = female.flowers, family = binomial(link = "logit"))
summary(Model1B)
Anova(Model1B, type="II", test="Wald")
lrtest(Model1B)

p.1B <- linearHypothesis(Model1B,"apis = pf")

#----Model2----

fruit <- female.flowers[c(1:41),]
fruit.2 <- fruit[-c(14),]

Model2A <- lm(mean.seed.weight ~ apis + pf + pm + j.date, data = fruit.2 )
summary(Model2A)
AIC(Model2A)

Model2B <- lm(mean.seed.weight ~ j.date, data = fruit.2)
summary(Model2B)
AIC(Model2B)

#----Model 3---
```

```
Model3A <- lm(log(seed.number) ~ apis + pf + pm + pm2 + am + j.date, data = fruit.2)
summary(Model3A)
AIC(Model3A)

Model3B <- lm(log(seed.number) ~ pf + pm + pm2 + am, data = fruit.2)
summary(Model3B)
AIC(Model3B)

p.3A <- linearHypothesis(Model3A,"apis = pf")
#----Model 4----

Model4A <- lm(log(average.pollen.count) ~ apis + pf + pm + a2 + j.date, data = fruit)
summary(Model4A)
AIC(Model4A)

Model4B <- lm(log(average.pollen.count) ~ apis + pf + a2, data = fruit)
summary(Model4B)
AIC(Model4B)

p.4B <- linearHypothesis(Model4B,"apis = pf")
#----Table 3: Model 2A----

male.flowers$a2 <- male.flowers$apis.visit.count^2
male.flowers$pf2 <- male.flowers$pf.visit.count^2
male.flowers$pm2 <- male.flowers$pm.visit.count^2
male.flowers$af <- male.flowers$apis.visit.count*male.flowers$pf.visit.count
male.flowers$am <- male.flowers$apis.visit.count*male.flowers$pm.visit.count
male.flowers$fm <- male.flowers$pf.visit.count*male.flowers$pm.visit.count
male.flowers$afm <-
male.flowers$apis.visit.count*male.flowers$pf.visit.count*male.flowers$pm.visit.count

Model5A <- lm(estimated.pollen.removed ~ apis.visit.count + pf.visit.count + pm.visit.count + pf2 + pm2
+ af + am + j.date, data = male.flowers)
summary(Model5A)
AIC(Model5A)

Model5B <- lm(estimated.pollen.removed ~ apis.visit.count + pf.visit.count + pf2 + pm2 + af + am, data
= male.flowers)
summary(Model5B)
AIC(Model5B)

p.5B <- linearHypothesis(Model5B,"apis.visit.count = pf.visit.count")

#----Figure 1 for Models 1B, 3A, 4B, 5B (used 3A instead of 3B because 3B does not include apis
visitation)------

library("ggExtra")
library("ggplot2")
library("gridExtra")
library("grid")
library("sjlabelled")
```

```
library("sjmisc")
library("sjPlot")
library("sjstats")


coef <- tidy(Model1B, conf.int = TRUE)


coef <- coef[c(2,3),]


p <- ggplot(coef, aes(x = term, y = estimate)) + geom_point(color = c("darkblue", "orange")) +
geom_errorbar(aes(ymin = conf.low, ymax = conf.high), color = c("darkblue","orange"), width = 0.1) +
labs(title = "(A) Fruit set", x= ("Visitors"),y = (expression(beta)))


p1 <- p + scale_x_discrete(name ="Visitor", labels=c("apis" = expression(italic("A.mellifera")), "pf" =
expression(italic("P. pruinosa")))) + ylim(-0.25, 2) + geom_hline(yintercept=0, linetype="dashed", color
= "black") + theme_sjplot2() + geom_text(x = 1, y = 0.75, label = "**") + geom_text(x = 2, y = 1.25,
label = "***") + theme(axis.title.y = element_text(angle = 0, vjust = 0.5), axis.line = element_line(color =
"black"), axis.ticks = element_line(color = "black"))


p1 <- p1 + geom_text(x = 1.5, y = 1.7, label = "p = 0.0309") + annotate("segment",
x=c(1,1,2),xend=c(1,2,2), y= c(1.4,1.45,1.45), yend=c(1.45,1.45,1.4))


coef.4B <- tidy(Model4B, conf.int = TRUE)

coef.4B <- coef.4B[c(2,3),]


k <- ggplot(coef.4B, aes(x = term, y = estimate)) + geom_point(color = c("darkblue", "orange")) +
geom_errorbar(aes(ymin = conf.low, ymax = conf.high), color = c("darkblue","orange"), width = 0.1) +
labs(title = "(C) log Pollen deposition", x= ("Visitors"),y = (expression(beta)))


p3 <- k + scale_x_discrete(name ="Visitor", labels=c("apis" = expression(italic("A.mellifera")), "pf" =
expression(italic("P. pruinosa")))) + ylim(-0.6, 0.6) + geom_hline(yintercept=0, linetype="dashed", color
= "black") + theme_sjplot2() + geom_text(x = 2, y = 0.25, label = "***") + theme(axis.title.y =
element_text(angle = 0, vjust = 0.5), axis.line = element_line(color = "black"), axis.ticks =
element_line(color = "black"))
```

```
p3 <- p3 + geom_text(x = 1.5, y = 0.5, label = "p = 0.0153") + annotate("segment",
x=c(1,1,2),xend=c(1,2,2), y= c(0.3,0.4,0.4), yend=c(0.4,0.4,0.3))



coef.5B <- tidy(Model5B, conf.int = TRUE)



coef.5B <- coef.5B[c(2,3),]



m <- ggplot(coef.5B, aes(x = term, y = estimate)) + geom_point(color = c("darkblue", "orange")) +
geom_errorbar(aes(ymin = conf.low, ymax = conf.high), color = c("darkblue","orange"), width = 0.1) +
labs(title = "(D) Pollen removed", x= ("Visitors"),y = (expression(beta)))



p4 <- m + scale_x_discrete(name ="Visitor", labels=c("apis.visit.count" =
expression(italic("A.mellifera")), "pf.visit.count" = expression(italic("P. pruinosa")))) + ylim(-1, 15) +
geom_hline(yintercept=0, linetype="dashed", color = "black") + theme_sjplot2() + geom_text(x = 1, y =
2.5, label = "**") + geom_text(x = 2, y = 11.7, label = "***") + theme(axis.title.y = element_text(angle =
0, vjust = 0.5), axis.line = element_line(color = "black"), axis.ticks = element_line(color = "black"))



p4 <- p4 + geom_text(x = 1.5, y = 14, label = "p < 0.001") + annotate("segment",
x=c(1,1,2),xend=c(1,2,2), y= c(12.5,13,13), yend=c(13,13,12.5))



grid.arrange(p1,p3, p4, nrow = 1, ncol = 3)

# Table 2: Behavior (Stigma time and anther time)

library("lmtest")
library("rcompanion")

female.flowers <- read.csv("final.version.female.flowers.update.csv", header = T)

male.flowers <- read.csv("final.version.male.flowers.update.csv", header = T)

female.flowers$a2 <- female.flowers$total.a.stigma^2
female.flowers$pf2 <- female.flowers$total.pf.stigma^2
female.flowers$pm2 <- female.flowers$total.pm.stigma^2
female.flowers$af <- female.flowers$total.a.stigma*female.flowers$total.pf.stigma
female.flowers$am <- female.flowers$total.a.stigma*female.flowers$total.pm.stigma
female.flowers$fm <- female.flowers$total.pf.stigma*female.flowers$total.pm.stigma
female.flowers$afm <-
female.flowers$total.a.stigma*female.flowers$total.pf.stigma*female.flowers$total.pm.stigma
```

```
#Removed large pf stigma times

female.flowers2 <- female.flowers[-c(3,31),]

#----Model 1----

Model1A <- glm(fruit ~ total.a.stigma + total.pf.stigma + total.pm.stigma + pf2 + j.date, family =
binomial(link = "logit"), data = female.flowers2)
summary(Model1A)
Anova(Model1A, type="II", test="Wald")
lrtest(Model1A)

Model1B <- glm(fruit ~ total.a.stigma + total.pf.stigma + pf2 + j.date, family = binomial(link = "logit"),
data = female.flowers2)
summary(Model1B)
Anova(Model1B, type="II", test="Wald")
lrtest(Model1B)

#----Model 2----

fruit <- female.flowers[c(1:41),]

fruit.1 <- fruit[-c(3,14,31),]

Model2A <- lm(mean.seed.weight ~ total.a.stigma + total.pf.stigma + total.pm.stigma + pm2 + am + fm +
j.date, data = fruit.1)
summary(Model2A)
AIC(Model2A)

Model2B <- lm(mean.seed.weight ~ total.pf.stigma + total.pm.stigma + pm2 + am + fm + j.date, data =
fruit.1)
summary(Model2B)
AIC(Model2B)

#----Model 3----

Model3A <- lm(log(seed.number) ~ total.a.stigma + total.pf.stigma + total.pm.stigma + j.date, data =
fruit.1)
summary(Model3A)
AIC(Model3A)

#----Model 4----

Model4A <- lm(average.pollen.count ~ total.a.stigma + total.pf.stigma + total.pm.stigma + j.date, data =
fruit.1)
summary(Model4A)
AIC(Model4A)

Model4B <- lm(average.pollen.count ~ total.pf.stigma, data = fruit.1)
summary(Model4B)
```

```
AIC(Model4B)


# Table 3


apis.only <- read.csv("pure.apis.data.update.csv", header = T)

Model14 <- glm(fruit ~ apis, data = apis.only, family = binomial(link = "logit"))
summary(Model14)
AIC(Model14) #66.17484
# apis = 0.017490
plot(Model14)
Anova(Model14, type="II", test="Wald")
lrtest(Model14)

apis.only$log.a.stigma <- log(apis.only$total.a.stigma + 1)

Model14.1 <- glm(fruit ~ log.a.stigma, data = apis.only, family = binomial(link = "logit"))
summary(Model14.1)
AIC(Model14.1) #69.13124
#not significant
plot(Model14.1)
Anova(Model14.1, type="II", test="Wald")
lrtest(Model14.1)

apis.fruit <- apis.only[c(2,3,9,14,16,17,18,22,26,28,32,35,37,40,47,49),]
apis.fruit$apis.log <- log(apis.fruit$apis +1)

Model14.2 <- lm(seed.number ~ apis, data = apis.fruit)
summary(Model14.2)
AIC(Model14.2) #175.5616
#not significant

Model14.3 <- lm(mean.seed.weight ~ apis, data = apis.fruit)
summary(Model14.3)
AIC(Model14.3) #152.6368
#not significant

Model14.5 <- lm(log(average.pollen.count) ~ apis, data = apis.fruit)
summary(Model14.5)
AIC(Model14.5) #33.1495
#not significant


Model14.7 <- lm(mean.seed.weight ~ log.a.stigma, data = apis.fruit)
summary(Model14.7)
AIC(Model14.7) #152.9453
#not significant

Model14.8 <- lm(seed.number ~ log.a.stigma, data = apis.fruit)
```

```
summary(Model14.8)
AIC(Model14.8) #174.1071
#not significant

Model14.9 <- lm(log(average.pollen.count) ~ log.a.stigma, data = apis.fruit)
summary(Model14.9)
AIC(Model14.9) #213.1466

# Table 4

apis.only.male.flowers <- read.csv("apis.only.male.flowers.csv", header = T)

Model14.10 <- lm(estimated.pollen.removed ~ log(apis.visit.count+1), data = apis.only.male.flowers)
summary(Model14.10)
AIC(Model14.10) #272.8481
#marginally significant 0.0918
plot(Model14.10)

apis.only.male.flowers$log.a.anther <- log(apis.only.male.flowers$total.a.anther + 1)

Model14.11 <- lm(estimated.pollen.removed ~ log.a.anther, data = apis.only.male.flowers)
summary(Model14.11)
AIC(Model14.11) #267.8456
# significant

#----Table 5: Model 2B----

male.flowers$log.a.anther <- log(male.flowers$total.a.anther+1)
male.flowers$log.pf.anther <- log(male.flowers$total.pf.anther+1)
male.flowers$log.pm.anther <- log(male.flowers$total.pm.anther+1)

male.flowers$a.al2 <- male.flowers$log.a.anther^2
male.flowers$pf.al2 <- male.flowers$log.pf.anther^2
male.flowers$pm.al2 <- male.flowers$log.pm.anther^2
male.flowers$af.al <- male.flowers$log.a.anther*male.flowers$log.pf.anther
male.flowers$am.al <- male.flowers$log.a.anther*male.flowers$log.pm.anther
male.flowers$fm.al <- male.flowers$log.pf.anther*male.flowers$log.pm.anther
male.flowers$afm.al <-
male.flowers$log.a.anther*male.flowers$log.pf.anther*male.flowers$log.pm.anther

#Removed high pf anther time
male.flowers2 <- male.flowers[-c(83),]

Model5A <- lm(estimated.pollen.removed ~ log.a.anther + log.pf.anther + log.pm.anther + a.al2 + af.al +
j.date, data = male.flowers2)
summary(Model5A)
AIC(Model5A)

Model5B <- lm(estimated.pollen.removed ~ log.pf.anther + log.pm.anther + a.al2 + af.al, data =
male.flowers2)
summary(Model5B)
```

```
AIC(Model5B)

#Figure 2: Effect of first visitor on second visitor

#Effect of first visitor on second visitor stigma or anther time
visitor.order <- read.csv("first.identity.effect.on.second.csv",header = T)

visitor.order$log.second.visitor.stigma.time <- log(visitor.order$second.visitor.stigma.time + 1)


#effect of first visitor on second visitor stigma time if second visitor is apis.


pf.a <- visitor.order$log.second.visitor.stigma.time[c(18:29)]


a.a <- visitor.order$log.second.visitor.stigma.time[c(1:17)]


t.test(a.a, pf.a, alternative = "two.sided", var.equal = FALSE)


#effect of first visitor on second visitor stigma time if second visitor is pf

pf.pf <- visitor.order$log.second.visitor.stigma.time[c(37:56)]


a.pf <- visitor.order$log.second.visitor.stigma.time[c(30:36)]


t.test(a.pf, pf.pf, alternative = "two.sided", var.equal = FALSE)


visitor.order.mf <- read.csv("first.visitor.effect.on.second.mf.csv",header = T)

visitor.order.mf$log.second.visitor.anther.time <- log(visitor.order.mf$second.visitor.anther.time +1)


#effect of first visitor on second visitor stigma time if second visitor is apis.


pf.a <- visitor.order.mf$log.second.visitor.anther.time[c(23:32)]


a.a <- visitor.order.mf$log.second.visitor.anther.time[c(1:22)]


t.test(a.a, pf.a, alternative = "two.sided", var.equal = FALSE)
```

```
#effect of first visitor on second visitor stigma time if second visitor is pf

pf.pf <- visitor.order.mf$log.second.visitor.anther.time[c(40:54)]

a.pf <- visitor.order.mf$log.second.visitor.anther.time[c(33:39)]

t.test(a.pf, pf.pf, alternative = "two.sided", var.equal = FALSE)

#Figure 2

b1 <- ggplot(visitor.order, aes(fill= first.visitor.identity, y=log.second.visitor.stigma.time, x=second.visitor.identity)) + geom_boxplot() + xlab("Second visitor") + ylab("log Mean stigma time (sec)") + scale_fill_manual(values=c("darkblue","orange"), name ="First visitor", labels=c("apis" = expression(italic("A.mellifera")), "pf" = expression(italic("P. pruinosa")))) + scale_x_discrete(labels=c("apis" = expression(italic("A.mellifera")), "pf" = expression(italic("P. pruinosa")))) + theme_classic() + scale_y_continuous(expand = c(0,0), limits = c(0,8)) + geom_text(x = 1, y = 3 , label = "ns") + geom_text(x = 2, y = 5.5, label = "ns") + labs(title = "(A)")

b2 <- ggplot(visitor.order.mf, aes(fill= first.visitor.identity, y=log.second.visitor.anther.time, x=second.visitor.identity)) + geom_boxplot() + xlab("Second visitor") + ylab("log Mean anther time (sec)") + scale_fill_manual(values=c("darkblue","orange"), name ="First visitor", labels=c("apis" = expression(italic("A.mellifera")), "pf" = expression(italic("P. pruinosa")))) + scale_x_discrete(labels=c("apis" = expression(italic("A.mellifera")), "pf" = expression(italic("P. pruinosa")))) + theme_classic() + scale_y_continuous(expand = c(0,0), limits = c(0,8)) + geom_text(x = 1, y = 2, label = "ns") + geom_text(x = 2, y = 6, label = "ns") + labs(title = "(B)")

grid.arrange(b1, b2, nrow = 2, ncol = 1)
```