The importance of native bees, especially cactus bees (*Diadasia* spp) in the pollination of cactus pears

Peter Felker and Ron Bunch

D'Arrigo Bros of California
21777 Harris Road,
Salinas, CA 93908.

Corresponding author: peter.felker@hotmail.com

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ABSTRACT

The edible pulp size of cactus pear fruit is highly correlated with seed content, which in turn is correlated with the effectiveness of pollination. In California commercial orchards, honey bees (*Apis mellifera*) are not nearly as efficient pollinators as the very docile, ground dwelling, solitary, native cactus bee (*Diadasia* spp). Much additional work on native bees is needed to develop practical methods to: a) establish cactus bees on other plantations, b) manipulate the date of emergence to coincide with late/early flowering, c) develop protocols to safely apply pesticides to control insects such as cochineal without harming native bees, and d) develop other native insect pollinators early in the season (February/early March) when *Opuntia* flowers are available but no insect pollinators are available.

Keywords: Cactus pear, cactus bee, pollination.

INTRODUCTION

The production and size of cactus pear fruit in wild and domesticated *Opuntia ficus indica* is not well understood but seems to be related to presence of seeds. Seeds in cactus pear fruit are usually a mixture of apomixis (Tisserat *et al*. 1979; Mondragon, 2001) and fertilization of the egg with pollen, the latter of which requires pollinating insects. The D'Arrigo Bros experience in commercial orchards, is that the common honey bee (*Apis mellifera*) is not an effective pollinator of commercial cactus fruit orchards, while the native ground dwelling, solitary Cactus bee (*Diadasia rinconis*) is a superb cactus pollinator. This communication will explore the issues surrounding the pollination of *Opuntia*.

Gil *et al*. (1977) reported that fertilization is needed for fruit set. Pimienta (1990) suggested that vegetative parthenocarpy cannot exist in cactus pear because the pulp develops from the seed. Tisserat *et al*. (1979) stated that there are many wild and ornamental varieties of *Opuntia* that set fruit without pollination by means of nucellar embryogenesis. Mondragon (2001) examined 17 *Opuntia* crosses and found that most crosses had some apomixis and that the material parent strongly influenced the presence/absence of apomixis. D'Arrigo Bros has also found apomixis in many crosses using parents of Argentine or Chilean greenish fruits similar to Texas A&M 1321 that have very strong percentage of nucellar seeds that are not a result of pollination.

Felker *et al*. (2010) measured many fruit characters in a cross of *O ficus indica* as the female parent and *O. lindheimerii* as the male parent. Many of the progeny of this cross were apomictic and thus genetically identical to the female *O. ficus indica* parent. However, some of the progeny were true sexual crosses as evidenced by at least one trait of the male in the progeny. The significant relationship between fruit size and seed weight shown in Figure 1, clearly illustrates the importance of seed number to edible pulp size. Even in the apomictic "female looking" progeny of this cross, the seed number was positively correlated with fruit size. Possibly hormones secreted by the developing seeds stimulate fruit size.

As the flower of commercial *O. ficus indica* is usually open for only one day, it is important to have a high pollinator population to ensure that all flowers that open on that single day become well pollinated.

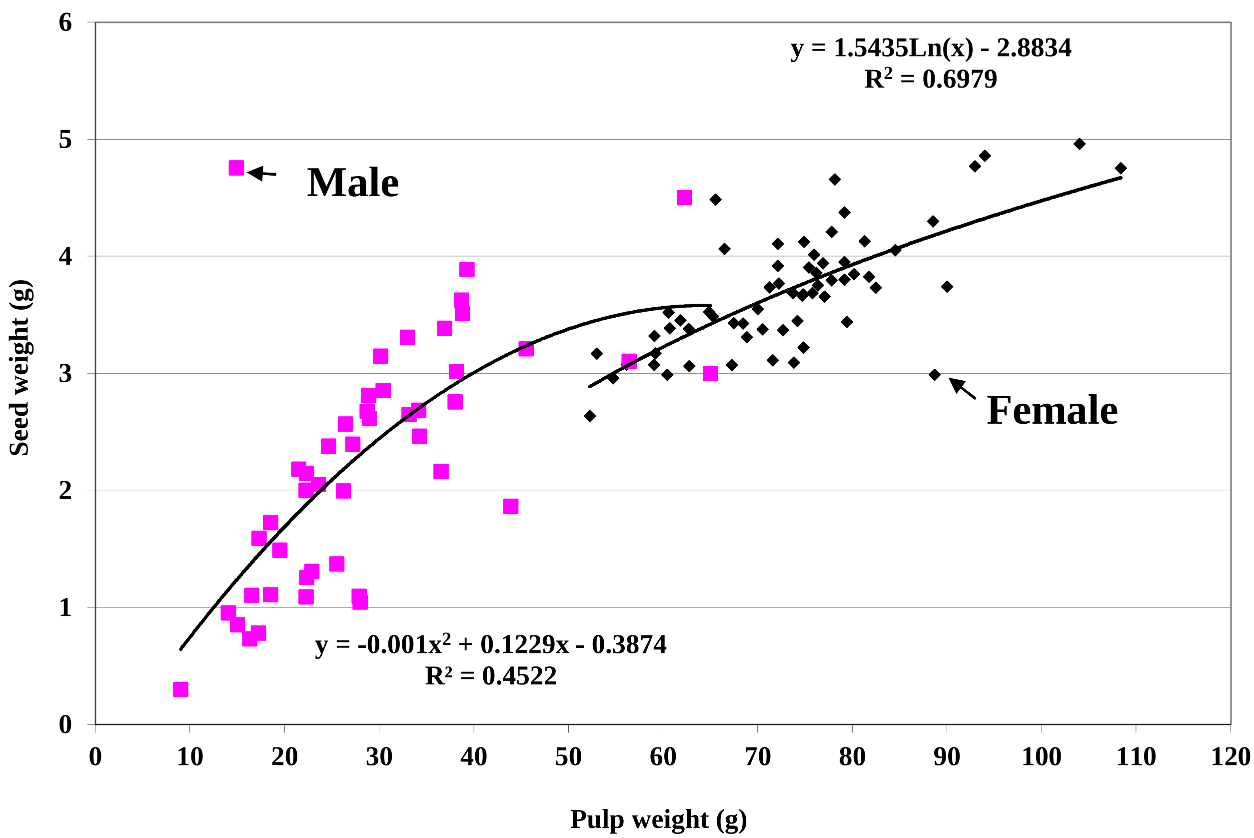

Figure 1. Seed content (g/100 g edible pulp) from 4 year old seedlings of O. *lindheimerii* 1250-a and O. *lindheimerii* 1250-b x O. *ficus indica* 1281 grown in Santiago del Estero, Argentina. The first 4 fruits per plant with greater than 40% color were harvested for these

measurements. The results were ranked within groups of non-apomictic plants with some male traits and apomictic seedlings with female traits (From Felker *et al*. 2010).

The pollination of commercial plantations is further complicated by the range in fruit ripening (and thus flowering 100-120 days earlier) from May to December in the Altiplano of Mexico as can be seen in Figure 2 (Pimienta, 1990). This means that pollinators will need to be available for nearly 7 months during the various flowering times.

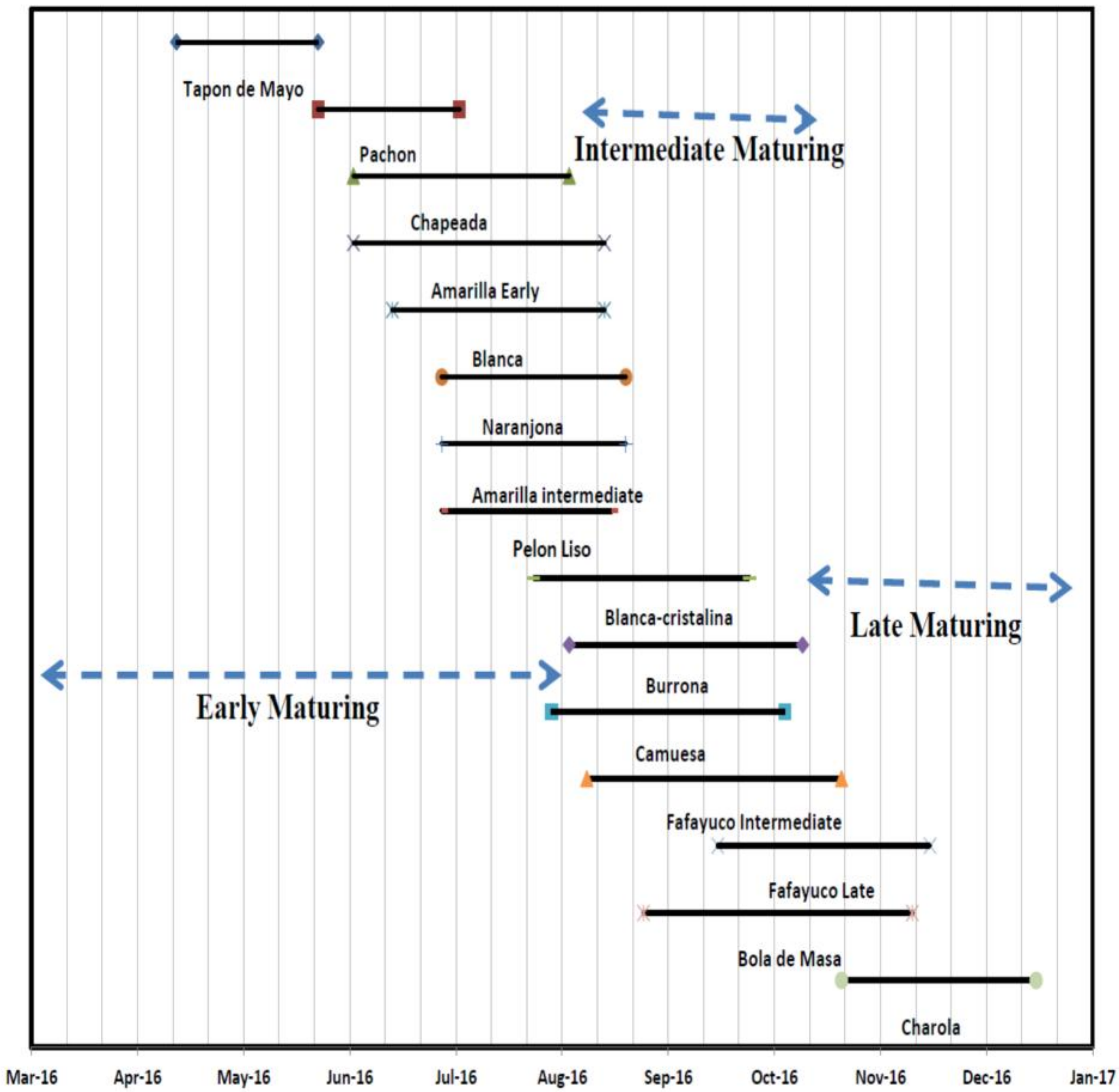

Figure 2. Fruit maturation among *Opuntia* fruit cultivars in the Altiplano of Mexico (Adapted from Pimienta, 1990).

RESULTS

In D'Arrigo Bros commercial plantations, the first really effective pollinators are sweat bees family Halictidae that appear in early March. These bees dive deep into the bottom of the flower. Sometimes there are several sweat bees in the same flower and flowers pollinated by these bees have excellent coverage of pollen on the stigma as can be seen in Photograph 1. These bees are ground nesting bees (Cane, 1992). Early in the season, at the same time as the sweat bees were present, we have observed honey bees (*Apis mellifera*) but they do not provide as good pollen coverage on the stigma as the sweat bees.

Photograph 1. Sweat bees (*Dialictus* spp. James Cane USDA identification) that come out early in the year dive down to the bottom of the flowers and do an excellent job of pollination. Photo taken March 18, 2014 before the arrival of the cactus bees (*Diadasi rinconis*).

By far the most effective pollinator on D'Arrigo Bros cactus plantations are the ground nesting, solitary cactus bee *Diadasia rinconis* (identified by Eric Mussen, UC Davis). D'Arrigo Bros has three ranches with commercial cactus plantations about 15 km apart. In 2014, the cactus bees first appeared on one of these ranches, Ranch 9, on April 28. The cactus bee exit holes from the nests were noted on hard unpaved roads. No exit holes were noted in the loosely disked land between the rows. In a period of approximately 10 days, the number of exit holes changed from zero holes, to holes spaced about 20 cm apart over a 200 meter long stretch of road. A photo of a cactus bee entering one of these holes on the road is shown in Photograph 2 and a diagram made from the excavation of these holes by Ordway (1984) is shown in Figure 5. Ordway (1984) excavated 33 nests of *Diadasia opuntiae* and found that the nests had a vertical burrow 11 to 21 cm long, which slanted for an additional 5 to 9 cm to end in a cell like cavity. We surmise that the fact that these burrows were never found in loose disked ground and only on hard packed ground, resulting from pick up and tractor traffic, is due to the fact that the burrows would cave in on lose ground but remain solid and intact in hard ground.

Photograph 2. Cactus bee (*Diadasia rinconis*) entering a nest on a hard packed field road located in a 25 ha cactus plantation Ranch 9 near Gonzalez, California.

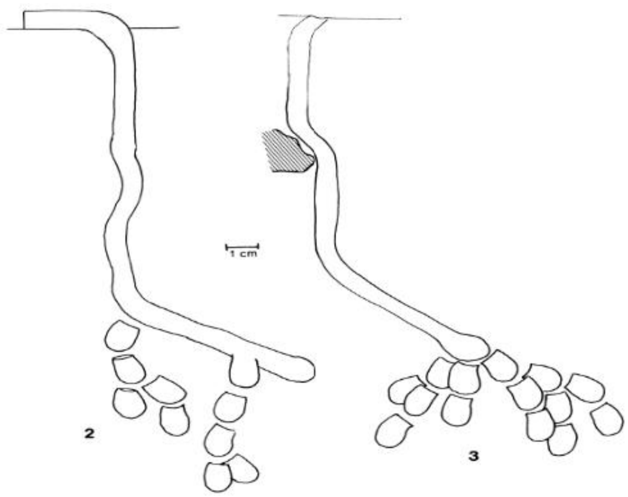

Figure 5. In (2) Nest structure of *D. opuntiae* showing branching nature of side burrows. The branch burrow with cells arising at the top of the angle burrow is unusual for this specie. In 3) Nest structure of *D. opuntiae* showing usual arrangement of branch burrows arising at end of angle burrow. Closely packed cells of branching burrow in this nest give cell arrangement a clustered appearance (From Ordway, 1984).

Cane (1992), examined soil characteristics of 32 species of ground nesting bees across diverse habitats in the United States and found that soil moistures ranged 15 fold across the USA. They also found that no bee nests were found in clay or silt soils and all of the soils contained at least 33% and as much as 94% sand. This author, reported that the bees "painted" a water insoluble substance on the interior of the subterranean nest cells and hypothesized that this was critical in preventing the egg cells from drying out over the winter.

At the end of April when very prolific populations of cactus bees began pollinating cactus on D'Arrigo Bros Ranch 9, there were no cactus bees on Ranch 7 some 15 km distant. In past years cactus bees appeared on Ranch 7 in late June but as there was prolific flower production in May that needed pollination, we tried to provide pollinators earlier in the season on Ranch 7. Thus, we installed nests and larvae of blue orchard mason bees (*Osmia lignaria* family Megachilidae) and with the excellent technical assistance of Stephen Pryor we established a shelter and brought in a hive of bumblebees (*Bombus* spp). Unfortunately, we did not observe any bumblebees or blue mason bees in this plantation after these nests were installed.

Photograph 3. Netting cactus bees as they exited and entered their nests on D'Arrigo Bros Ranch 9 for movement to D'Arrigo Bros Ranch 7. Note the extensive exit holes in the hard packed road.

Following the suggestions of James Cane USDA solitary ground dwelling bee entomologist, we attempted to move some cactus bees from Ranch 9 to Ranch 7. This protocol involved netting the cactus bees as they came out of the nests on Ranch 9 (Photograph 3), transferring the bees to Mason 1 liter glass jars (used for home canning) with punctured lids and crumpled paper, placing the glass jars in a Styrofoam cooler with frozen gel packs and moving these bees to the new location.

The cool temperature in the insulated cooler (10ºC) caused the cactus bees to become very inactive. On May 6, 2014, 45 cactus bees were placed onto the ground in a new location on Ranch 7 before sunrise. Holes of the same size as their exit holes were made in the ground with a screwdriver and as the bees warmed up and began to move, they were gently pushed to the new exit holes, which they entered.

Establishment of these new holes was not possible in loose soil as the holes caved in and thus holes were made in slightly moist soil. These holes were checked later the same day and several days thereafter, but the cactus bees never returned to these holes.

On May 14, 2014 about 60 more cactus bees were collected from Ranch 9 and brought to Ranch 7 where there no bees at this time. This time with the use of thin vinyl surgical type gloves, as the bees recovered from their inactive state in the cold, they were manually placed in open cactus flowers. The gloves were found not to be necessary as the cactus bees were found to be extremely docile walking up ones fingers and hands with no attempt to sting. They also made no attempt to sting when netting the bees. Some of these bees began to work these flowers as the effect of the cold wore off.

It was difficult to monitor the return of these 60 bees to the cactus plants that had been introduced to the cactus bees. Nevertheless approximately 3 months after this last movement, a major colony of cactus bee nesting holes in the ground appeared for the first time on this 40 ha cactus plantation approximately 400 meters from where the cactus bees were placed in open flowers.

In the early summer of 2014, to help with pollination with a new cactus variety whose flowers did not fully open, more than 30 commercial honey bee (*Apis mellifera*) hives were placed adjacent to this new variety. Despite the huge number of honey bees, these bees did not result in extensive coverage of the stigma with pollen on a majority of the cactus flowers. In late June of 2014, cactus bees appeared, probably from wild adjacent pastures, in much lower numbers than the honey bees, but resulted in extensive stigma coverage of pollen on virtually all of the flowers of the difficult to pollinate variety. As can be seen in Photograph 4, a major advantage of the cactus bees over the honey bees is the enormous amount of pollen they carry on their rear legs.

Photograph 4. Cactus bee (*Diadasia rinconis*) pollinating *Opuntia* flowers. Note the extensive pollen on the stigma on the flower to the left and the enormous quantity of pollen on the back legs of the cactus bee that makes them exceptional *Opuntia* pollinators.

DISCUSSION

Various authors have examined insect pollination of both native (Grant *et al*. 1979; Ordway, 1984; McFarland *et al*. 1989; Cane, 1991; Cranshaw, 2012) and cultivated *Opuntias* (Reyes-Aguero *et al*. 2006; Lo Verde and La Mantia, 2011).

MacFarland *et al*. (1989), measured the insects visiting the native *Opuntia imbricata* in southern Colorado and the effects of bagging and self pollination on fruit set. They found that 9 species of solitary bees visited *O. imbricata* flowers and reported that the large solitary bees of the genera *Diadasia* and *Lithurge* were the most important pollinators. These authors did find small *Halictus* bees pollinating their *Opuntia* but they regarded this genus as a pollen thief. Perhaps if they would have measured the pollination earlier in the season, *Halictus* would have been more important. In addition to pollen counts these authors examined the effects of bagging, and self pollination followed by bagging, and stated this species was self incompatible and did not possess apomixis.

Grant *et al*. (1979), who examined pollination of the native *Opuntia lindheimerii* in April and May central Texas found that while beetles do visit *Opuntia* flowers, they are relatively ineffective as pollinators and in fact some beetles are highly destructive to *Opuntia* flowers. These authors suggested that the medium and large bees of the genera *Diadasia, Melissodes, Xylocopa, Bombus, Apis, Lithurge, Megachile and Agapostemon* were the most important pollinators in this ecosystem.

In their analyses of the reproductive biology of *Opuntia*, Reyes-Aguero *et al*. (2006) provided a thorough review of pollinators of this genus. In addition to the genera of pollinators described above, they reported the bumble bee *Bombus pennsylvanicus* on *Opuntia robusta*. This is significant since Tapon de mayo (which is *Opuntia robusta* Figure 2) is the earliest of all *Opuntias* to mature with its flowers being pollinated at least 100 days prior to maturation in May, i.e. February.

In addition to the ground nesting bees described above, other native pollinating bees that have nests in the soft rotted wood are leaf cutter bees (*Megachile* spp), mason blue bees (*Osmia lignaria*) (Parker and Torchio, 1980; Cranshaw, 2012) and bumble bees (*Bombus* spp). These are some of the first bees available for early pollination that have been described on *Opuntia* and perhaps could be better managed (Reyes-Aguero *et al*. 2006).

Not surprisingly, the excellent North America native *Opuntia* pollinator *Diadasia* spp was not found in a survey of *Opuntia* pollinators in Sicily (Lo Verde and La Mantia, 2011). These workers found that the common honey bee (*Apis mellifera*), bumble bees (*Bombus* spp) and the very large wood nesting carpenter bee (*Xylocopa violacea*) were the predominant pollinators on their *Opuntia*s. In spite of the lack of *Diadasia* spp, a comparison of covered versus non covered flowers, found that both fruit size and seed number were much greater in the pollinated flowers.

This work summarizes the enormous advantages of using the native cactus bee *Diadasia rinconis* to pollinate cactus. However this work is just the beginning. Much additional work is needed on important questions such as: 1) how to identify the nesting sites of cactus bees that come into a large commercial plantation, 2) how can colonies of cactus bees can be established on new or existing plantations, 3) to identify the environmental cues for the six week difference in emergence date of cactus bees on two ranches 15 km apart, 4) how can pesticide applications used to control cochineal and other serious pests be managed to avoid significant damage to the cactus bee populations, and 5) what other insect pollinators can be developed/managed to provide good pollination early in the season (February/early March) when *Opuntia* flowers are available but no insect pollinators are available.

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