Reciprocal benefits to cotton and bee pollinators in a cotton agroecosystem

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ABSTRACT

Anthropogenic intensification has caused the simplification of many agroecosystems, leaving only small fragments of natural habitat. These fragments of natural habitats within agricultural landscapes may provide ecosystem services to nearby agricultural crops such as natural pest control and pollination. In addition to natural habitat fragments providing these ecosystem services, the agricultural crop itself may provide reciprocal benefits. We hypothesize that cotton provides a resource for local native pollinators which in turn provide pollination services to the cotton plant. Across two years of study in our cotton agroecosystem, we found that native bee diversity, abundance and visitation in cotton is increased when cotton is in proximity to other crops. Out of 4041 individuals, greater than 30 species and morphospecies were detected and 78% consisted of the species *Melissodes tepaneca* (Hymenoptera: Apidae). Examined through two replicated experiments over two years, we also hypothesized that cotton benefits from pollination via native bees facilitating cross-pollination through increasing yield. Cotton bolls that were caged and hand-crossed and bolls on uncaged plants exposed to pollinators had higher pre-gin weight and post gin weight than caged bolls excluded from pollinators. When cotton plants were caged with the local native bee *Melissodes tepaneca*, pre-gin lint weight was 0.8 grams higher in 2018 and 1.18 higher in 2019 than cotton plants excluded from bees resulting in a 12.8% seed cotton increase in 2018 and a 32% increase in 2019. This information can provide insight into future conservation benefits provided to native pollinators and the return services they provide to agriculture in the cotton agroecosystem

OBJECTIVES

I. **Investigate the effects of landscape structure on the diversity and abundance of native bees in the cotton agroecosystem.**

H_0: Native Bee abundance and diversity are equal across the experimental interfaces of cotton-cotton, cotton-sorghum, cotton-natural habitat, sorghum-sorghum or natural habitat alone

II. **Identify benefits of pollination services provided by native bee pollinators on cotton yield.**

H_0: Cotton Plants exposed to caged native bees will have equal cotton seed and lint weight compared to caged plants excluded from pollinators, caged plants that are hand-cross pollinated and uncaged plants.

INTRODUCTION

Pollination services, whether by managed or wild bees are vital in production of many crops. Insects, particularly bees, pollinate 66% of the world's 1,500 crop species and are directly or indirectly essential for an estimated 15–30% of food production [1]. The diversity of native pollinators is important in providing pollination services to a diverse array of crops, many of which receive pollination or unknown pollination benefits from native bees [2]. Under agricultural intensification, as seen in our model cotton agroecosystem where field sizes exceed 125 hectares achieving efficient and productive agricultural land use while conserving biodiversity is an important challenge. With the overall simplification of agricultural landscapes, one should consider landscape composition (number of different habitat types) and configuration (spatial arrangement of habitats) to understand local processes [3]. In our case, the processes are pollination services provided by native pollinators and their movement between patches (agricultural fields and natural habitat) that may serve to benefit cotton production as well as overall agroecosystem health.

FIG 1. Example of Bee Bowls Used

The cotton agroecosystem is one of the most intensely managed, economically, and culturally important field crops. Although cotton is known to be self-pollinating, previous studies suggest it does benefit from cross pollination service given that cotton pollen is too heavy to move between flowers without aided transport, such as provided by insects4. In a pollen limitation study, larger bolls and increased seed and lint weight were seen with addition of outcross pollen (by hand) compared to self-crossed flowers5. In the same study, the diversity of pollinator communities in cotton, including bees, beetles and syrphid flies, was found to be dependent on landscape structure in which higher pollinator diversity was found in areas with a greater abundance of natural habitat intermixed within cotton production. In this study, we investigate the effects of landscape structure on native bee pollinators and native bee-facilitation of cotton cross pollination; in order to inform cotton growers and conservationists of native bees' benefits to cotton and the benefits of planting cotton next to well preserved natural habitat.

STUDY AREA

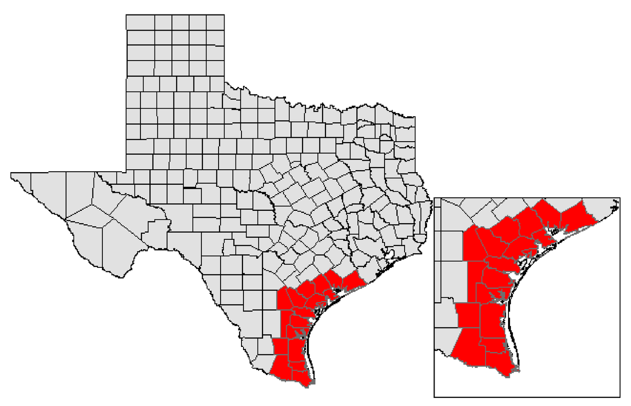
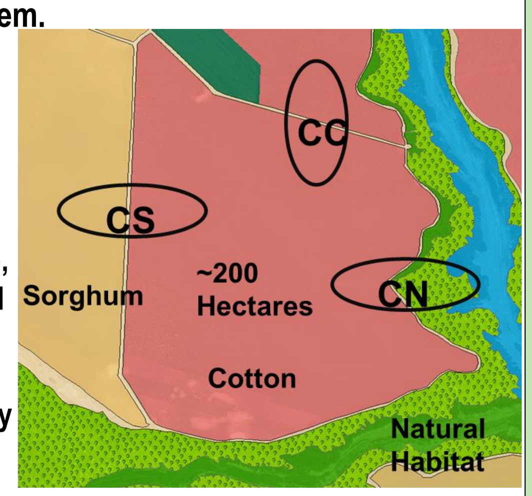


Fig 2. Region of Texas representative of our cotton agroecosystem (**Above**). A female *Melissodes tepaneca* (**Right**) foraging for nectar.

METHODS Objective I

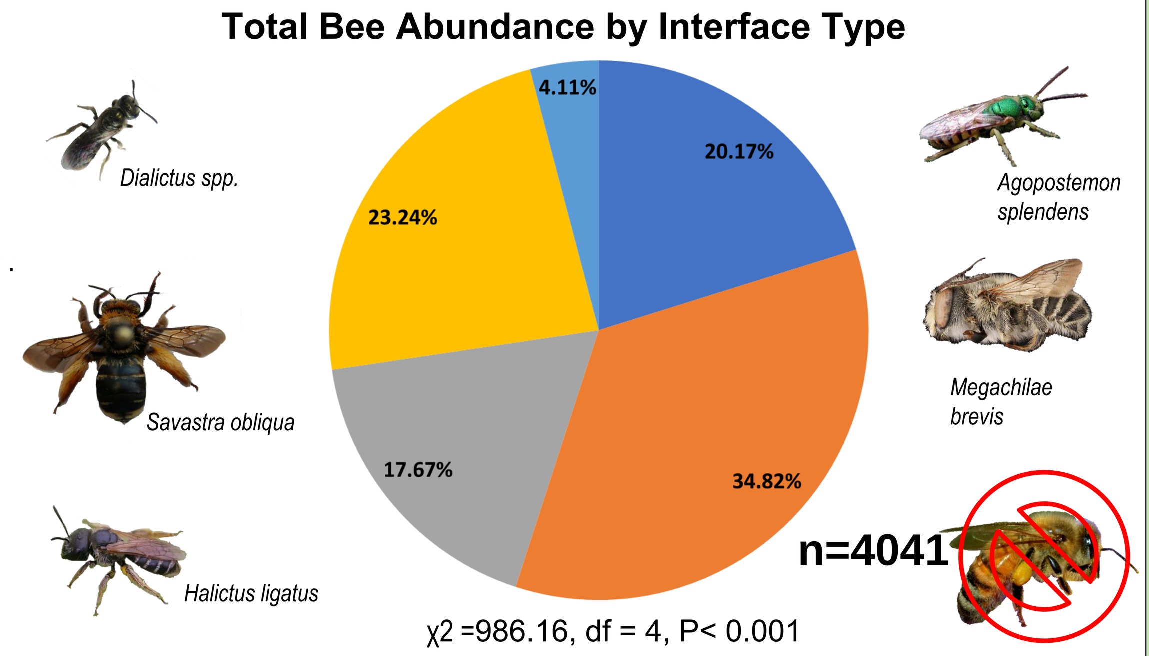
Objective 1: Investigate the effects of landscape structure on the diversity and abundance of native bees in the agroecosystem.

- The Bee bowl method is the most effective, cost-efficient trap the targets native bees in cropping systems [6][7]
- Bee bowls were used to collect bees at the interface between different field adjacencies
- Interfaces consist of: cotton and cotton (CC), cotton and sorghum (CS), cotton and natural habitat (CN), cotton and cotton > 1.6 KM (CCF), and natural habitat alone (NH)
- Five bee bowls were used for each adjacency type



- Traps left out at first bloom, sampled weekly for a 4-week period totaling 20 collection events per interface type
- Bowls were collected after 24-hrs, washed, pinned or mounted and identified to species or morphospecies

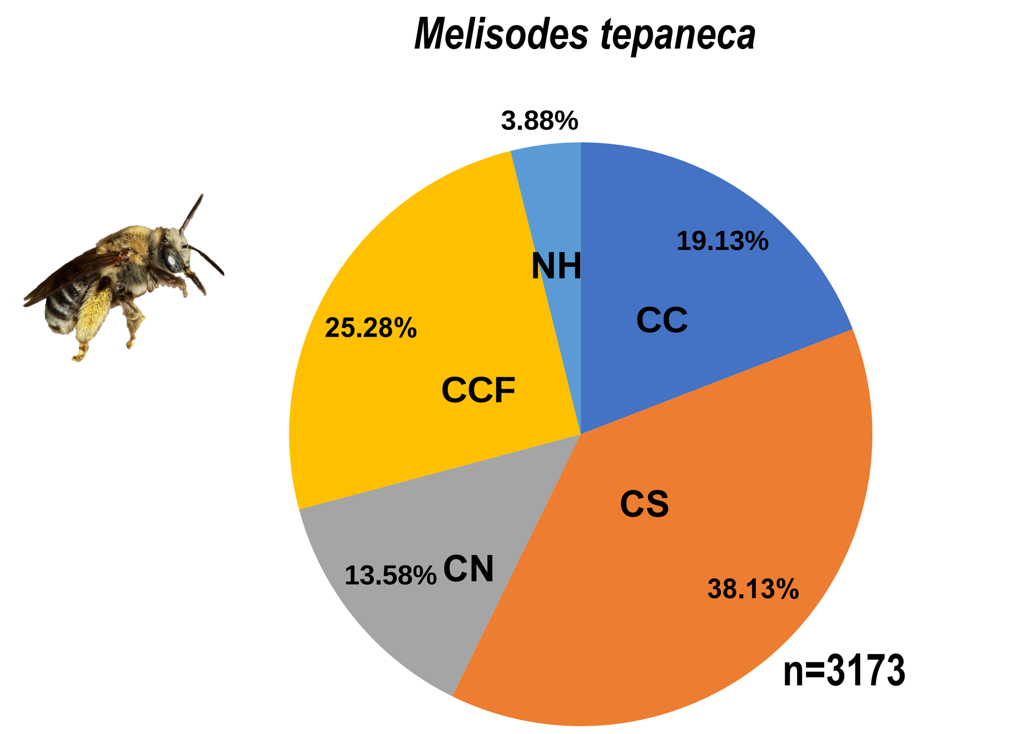
RESULTS: Objective I



$\chi 2$ =986.16, df = 4, P< 0.001

Figure 3: Our total from 20 collection events yielded 4041 individual bee specimens. Of that, 3173 bees were the species *Melisodes tepaneca* (Hymenoptera: Apidae). Another notable genus was *Lasioglosusum* (dialictus), which had 12 separate morphospecies. Less than 10 *Apis melifera* were captured and not observerd as much as other species Most bees were found at the interface of cotton and sorghum fields which encompassed 34% of all bees and 38% of *M. tepaneca*. The interface of natural habitat and cotton contained 36% of bees that were not *M. tepaneca*.

Family	Genera	Species	Specimens
Halictidae	6	15	1075
Megachilidae	1	3	26
Apidae	9	11	4145



$\chi 2$ =222.45, df = 4, P< 0.0001

Figure 3: Our total from 20 collection events yielded 4041 individual bee specimens. Of that, 3173 bees were the species *Melisodes tepaneca* (Hymenoptera: Apidae). Another notable genus was *Lasioglosusum* (dialictus), which had 12 separate morphospecies. Most bees were found at the interface of cotton and sorghum fields which encompassed 34% of all bees and 38% of *M. tepaneca*. The interface of natural habitat and cotton contained 36% of bees that were not *M. tepaneca*.

METHODS: Objective II

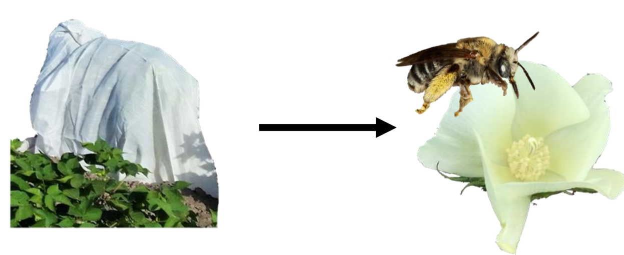
Objective 2: Identify benefits of native bee pollinators on cotton yield

- **Randomized complete block design with 4 treatments and 5 reps**

Cage Experiment: Treatments

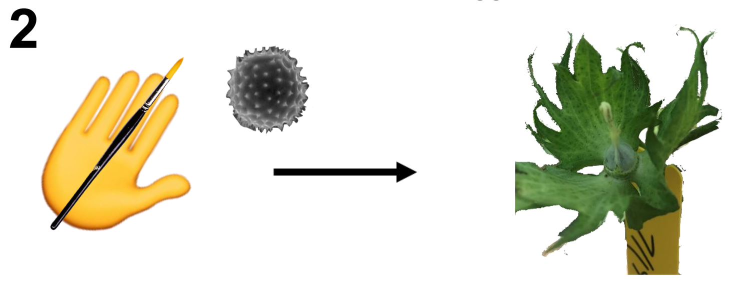
1 Bees actively foraging in cotton were captured via sweep net and placed in vials for direct transfer to caged cotton plants.

Flowers were tagged to ensure only flowers exposed to bees are used in analysis, for resulting lint(yield).



A total of 10 bees per cage we released for 2 days, after 2 days, new flowers were tagged and more bees were added for another 2 days.

2



Hand cross treatments encompassed emasculating flower buds expected to open the preceding morning and then hand pollinating with pollen from adjacent plants.

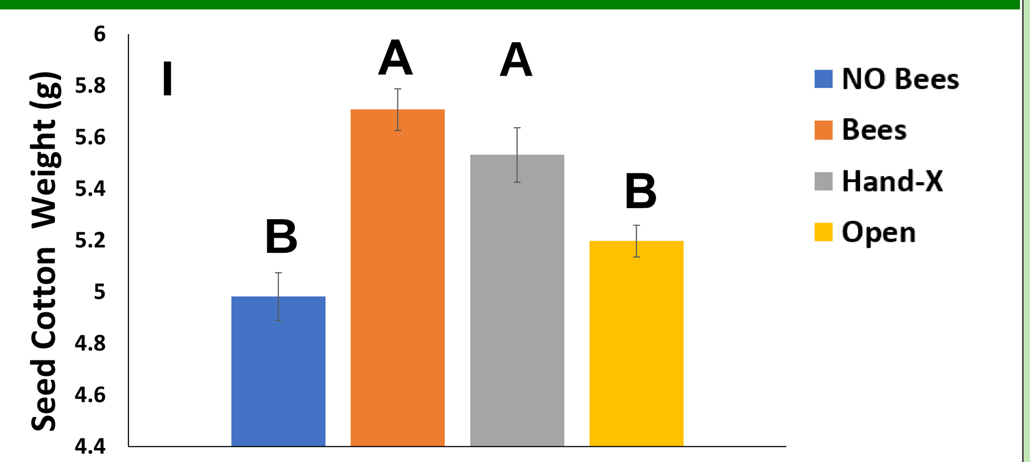
Hand pollinations were done at the same time frame as the bee treatments

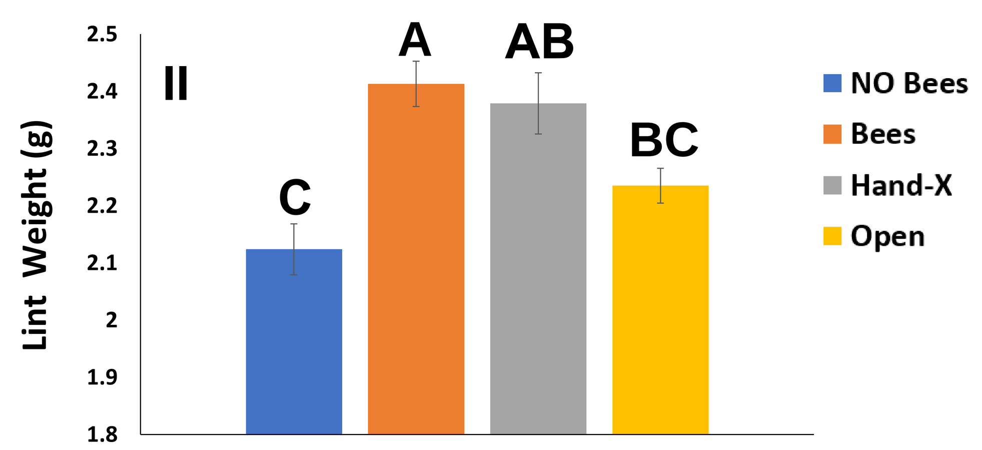
3 **4**

Cotton plants were caged right before first bloom to prohibit pollinator exposure

Cotton Plants exposed to the environment for local pollinators

2018: RESULTS





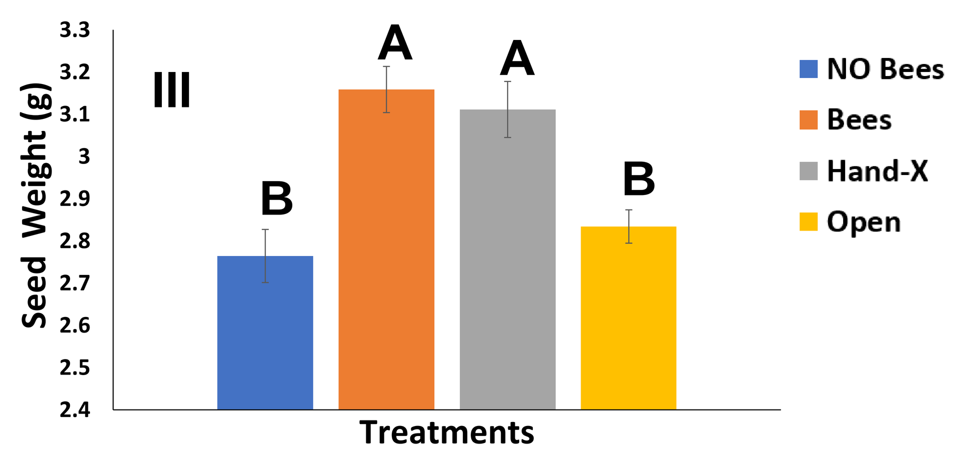


Figure 5. For all three graphs in figure 5, a one-way analysis of variance test was significant (Seed Cotton: d.f. = 3, 196; F= 14.21; P< 0.001) (Lint Weight: d.f. 1, 196; F = 9.73; P< 0.001) (Seed Weight: d.f.= 3, 196; F= 11.99; P< 0.001) respectively. Mean separations tests were ran using Tukey's HSD in which letters indicate significant differences between the means at the α=.05 significance level. In each of the measured variables, seed weight, lint weight and seed weight, bolls exposed to bees and bolls that were hand crossed weighed significantly more than bolls excluded from bees and from outside pollinators. The means in the following line are presented in the following format: Response [($\bar{x}$ of Bees ± std.error), ($\bar{x}$ of Hand-x ± std.error)]. Seed Cotton weight [($\bar{x}$=5.71 ± 0.081), ($\bar{x}$=5.53 ± 0.105)], lint weight [($\bar{x}$=2.41 ± .039), ($\bar{x}$= 2.37 ± 0.11)] and seed weight [($\bar{x}$=3.15 ± 0.054), ($\bar{x}$=3.11 ± 0.066)].

2019: Results

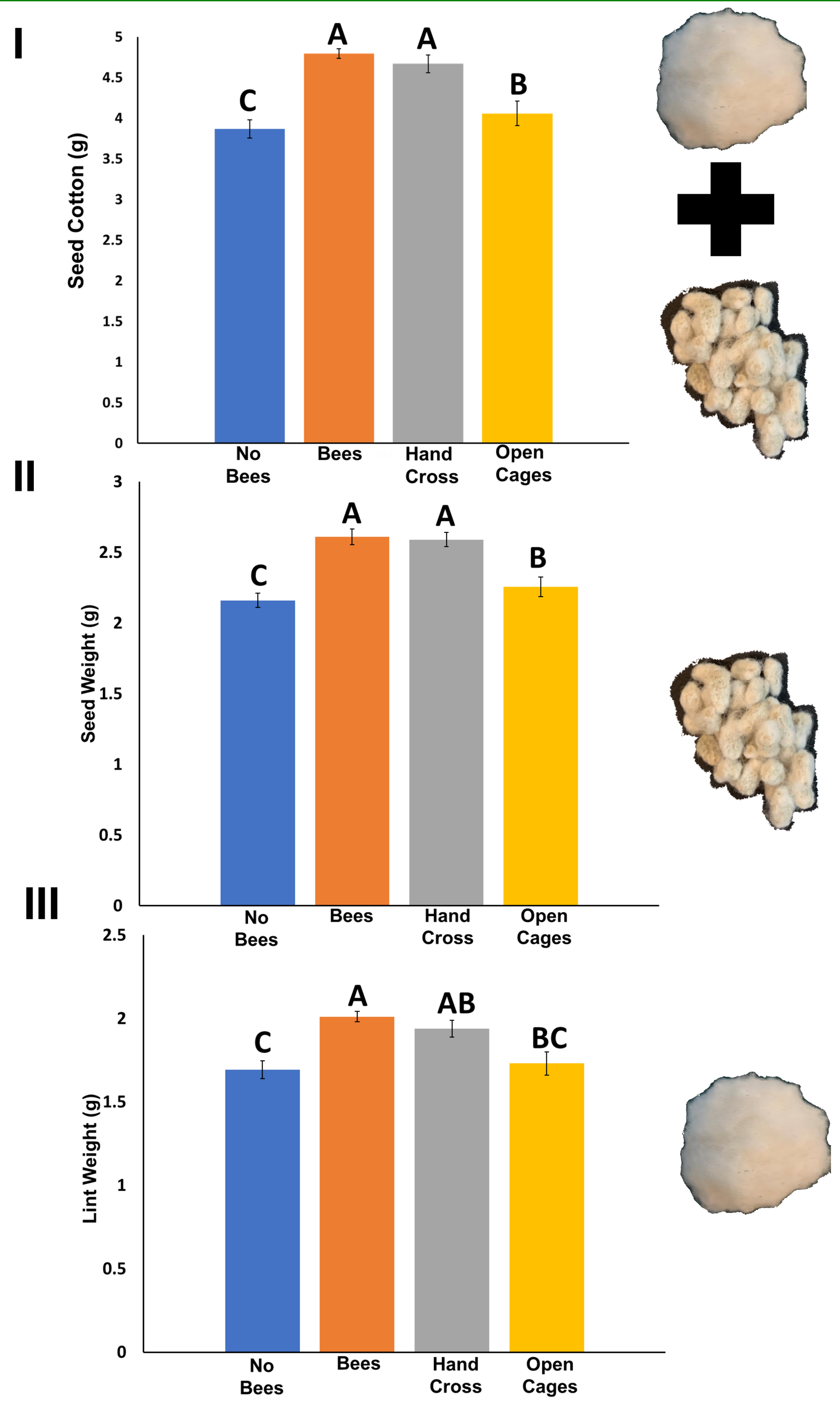


Figure 5.. In 2019, all three variables showed significant differences across the treatments: (**I** Seed Cotton: d.f. = 3, 36; F= 24.18; P< 0.001) (**II** Lint Weight: d.f. 1, 36; F = 12.45; P< 0.001) (**III** Seed Weight: d.f.= 3, 36; F= 11.99; P< 0.001). Mean separations tests were ran using Tukey's HSD in which letters indicate significant differences between the means of treatments at the α= 0.05 significance level for all response variables.

DISCUSSION

Objective 1::The least number of bees found were at the interface of natural habitat and cotton and at traps within natural habitat patches. Out of the 4041 bees, the dominant species was the solitary bee *Melissodes tepaneca* (Hymenoptera: Apidae) with 3173 individuals. The majority of these were found at the interface of cotton and sorghum followed by the interfaces of cotton and cotton, both greater and less than 1.6 Km from natural habitat. This is quite interesting as literature suggests highly intensified agricultural systems with lack of natural habitat can have negative effects on the biodiversity of beneficial insects, including native bees [8]. Our study area is highly intensified with small remnant natural habitat patches; we would expect to see a larger amount and diversity of bees found within natural habitat settings and the interface of natural habitat and cotton, opposed to within the crops. *M. tepaneca* is a ground nesting bee which has the potential to be harmed by deep tillage. However, the numbers and distance found away from natural habitat suggest that these bees are nesting within the cotton and sorghum of this system. Out of 868 'other' bees (non-*M. tepaneca*) in our sampling were found at the interface of cotton and natural habitat (32%) as well as natural habitat alone (23%) which suggests that the natural habitat may be providing different niches for these other bees as *M. tepaneca* appears to dominate within the fields.

Objective 2:: Although cotton is known to self-pollinate, there have been studies showing benefits of cross pollination in increased lint and seed weight. One study, also in Texas, has shown that bolls out-crossed with neighboring pollen had significantly larger seed-cotton weights (up to 18% more) than those bagged and excluded from pollinators or open to pollinators as well as self-crossed bolls (). Here, we took the most common pollinator, M. tepaneca, and caged them on groups of cotton plants. We also hand-crossed bolls to serve as a control. Bolls that were exposed to caged M. tepaneca showed a 14.5% (2018) and a 28% (2019) increase in seed-cotton weight compared to bolls excluded from pollinators. In the same experiment the hand-crossed treatment also showed a 11% (2018) and 23% (2019) increase in seed-cotton weight. This increase was also apparent with lint and seed weights within this experiment. Regardless of bee treatments or not, this data suggests that cotton does have the potential to benefit from pollination via M. tepaneca and potentially other native bee species as hand-crossing also indicates yield benefits.

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