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Bees and Other Pollinators in Adjacent Old World Bluestem and Cotton Fields in the Texas High Plains

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ABSTRACT

The rapid decline in water supply for irrigation in the Texas Southern High Plains is encouraging some growers to convert a portion of their irrigated cropland including cotton (*Gossypium hirsutum* L.) to the production of water-frugal perennial forages such as 'WW-B.Dahl' old world bluestem [*Bothriochloa bladhii* (Retz) S.T. Blake, OWB]. WW-B.Dahl OWB is a persistent pasture grass, which has strong inhibitory effects on soil-dwelling ants (Hymenoptera: Formicidae); however, effects of OWB on pollinators in cotton-dominated agroecosystems are not clear. We characterized bees and other pollinators of OWB and an adjacent cotton monoculture at four sampling dates in fall of 2018 using bee bowls. Fifteen families from four insect orders were recovered. Sweat bee (Hymenoptera: Halictidae) was the most abundant family composing 67% of the total individuals recovered. The next abundant family was hover flies (Diptera: Syrphidae), constituting 11% of the total numbers. Total number of pollinators was consistently greater in OWB than in cotton at all sampling dates. Even though insects are not needed for pollination, presence of fairly high numbers of bees and other pollinators in OWB and cotton suggest that both crops may be providing habitat and food resources for pollinators in semi-arid Texas High Plains.

KEYWORDS: Bee bowl trap, cotton-dominant systems, forage systems, insect pollinators, old world bluestem

INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is a dominant annual crop in the semi-arid Southern High Plains of Texas, of which nearly half is irrigated (Allen et al. 2008). WW-B.Dahl [*Bothriochloa bladhii* (Retz) S.T. Blake] old world bluestem is a perennial warm-season forage grass adapted to dryland and low-irrigation conditions (Dewald et al. 1995; Philipp et al. 2007). Converting irrigated cotton land to the production of WW-B.Dahl (henceforth OWB) for hay and grazing cattle (*Bos taurus* L.) in response to reduced water supply for irrigation is a profitable land use option (Allen et al. 2005). Some old world bluestem species emit an aromatic odor caused by essential (volatile) oils (Pinder and Kerr 1980; Villalobos et al. 2003) which may deter some insects (Zalkow et al. 1980). Pastures

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in the Texas High Plains containing OWB had nearly zero red imported fire ants (*Solenopsis invicta* Buren) and harvester ants (*Pogonomyrmex* spp.) compared with adjacent alfalfa (*Medicago sativa* L.) and native grass pastures (Bhandari, West, Longing, Brown, and Green 2018). Similarly, previous studies found a lower abundance of insect pollinators including sweat bees (Hymenoptera: Halictidae) (Bhandari, West, Longing, Brown, Green, and Barkowsky 2018) and canopy-dwelling insects (Bhandari et al. 2018a) in OWB grown in monoculture compared with OWB grown in mixture with alfalfa, alfalfa-alone, and a native grasses mixture. In addition, lower number of horn flies (*Haematobia irritans* L.) was observed in cattle (*Bos taurus* L.) grazing OWB-dominant pasture systems compared to OWB-legume pasture systems (Bhandari et al. 2018b). The reason behind the lower abundance of insect pollinators in OWB compared to other adapted forages is not clear; however, the presence of the insect-favoring alfalfa and diverse native grasses may provide greater food resources and nesting habitat compared to OWB monoculture.

Insect pollinators play a vital role in terrestrial ecosystems by facilitating the reproduction of nearly 87% of the world's wild flowering plant species (Ollerton et al. 2011). However, pollination services are at risk owing to declines in insect pollinators globally (Potts et al. 2010; Kopec et al. 2017), thus threatening the productivity of many food crops (Clough et al. 2014). Agricultural fields serve as favorable pollinator habitat by providing nesting sites and nectar sources even if the crop species is not insect pollinated (Carvell et al. 2007; Ockinger and Smith 2007). Bhandari, West, et al. (2020) reported a fairly high abundance of ground-nesting native bees in corn (*Zea mays* L.) fields, indicating that corn could provide habitat resources for native bees despite not requiring insects for cross pollination. Cotton plants have large flowers that produce pollen and nectar, which can serve as food resources for pollinators. Boll set, seed weight, and lint weight can be increased with floral visitation by pollinators (Pires et al. 2014; Rhodes 2002; Tanda 1984). Up to 16% greater cotton lint yield was reported in some experiments when cotton was visited by honey bees (Tanda and Goyal 1979). Stein et al. (2017) found a significant increase in seed and lint weight when cotton was visited by honey bees and *Tetralonia fraterna* Friese (Hymenoptera: Eucerini). Twenty-six native bee species were collected in cotton fields, of which 20 species had a role in fruit set in cotton and were considered as pollinators. Six species were excluded as pollinators on account of having no role in fruit set (Stein et al. 2017). A recent study found 41 native bee species from three families which dominate Texas cotton fields (Parys et al. 2020). Cusser et al. (2019) found increased abundance and diversity of native bees with increasing density of cotton bloom in southern Texas.

While cotton is widely planted and OWB is expanding its planted area in the Texas High Plains, knowledge of bee and other pollinator communities in adjacent cotton and OWB fields remains sparse. Such information would lead to understanding whether these crops provide pollinator resources, which in turn would benefit the pollination of neighboring crops that do require insect pollinators. Our objective was to characterize the bees and other foraging insects (mostly pollinators) in adjacent OWB grass and cotton in a major cotton-growing region. Results will guide decisions on crop production options and elucidate pollinator conservation strategies.

MATERIALS AND METHODS

Research Site Description. Research was conducted at the New Deal Research Farm of Texas Tech University near Lubbock, TX (33°45' N, 101°47' W; 993 m elevation) during the fall of 2018. Field sampling was performed on a monoculture of WW-B.Dahl OWB pasture established in 2004 and adjacent cotton fields. Details of management history of OWB is provided by Bhandari, West, et al. (2020b). Before cotton planting, Trifluralin 4L herbicide at 2.3 L/ha was incorporated with rolling cultivator on Apr 30, 2018. The cotton cultivar DP 1522 was planted at 98,000 seeds/ha on May 15. Defoliant (Gramoxone SL 2.0) was applied on Oct 4 at 0.6 L/ ha and cotton was harvested on Oct 30. No insecticide or herbicide was applied to cotton during the growing season. Insect pollinators were analyzed and compared between two crop types (OWB and cotton) in a randomized complete block design. Temperatures were recorded with on site with a meteorological station.

Sampling Procedure Using Bee Bowl. The bee bowl method was used to collect bees and other foraging insects (mostly pollinators), which are attracted to bright colors (i.e., fluorescent yellow, blue, and white) (Shapiro et al. 2014). Bee bowls (New Horizons, Upper Marlboro, MD, USA) of 104 mL (painted inside with fluorescent yellow) were used as described by Bhandari et al. (2018d). In brief, bee bowls were set on four dates (Sep 25 and Oct 4, Oct 14, and Oct 20, 2018) between 0900 and 1100 each day on mostly clear-sky days. Ten bee bowls with 5-m distance between adjacent bowls were set on an open ground surface in a transect of 45 m in three field replicates of each crop type. Three transects with a total of 30 bee bowls were set in each field replicate. Each bee bowl was filled with a solution of water and dish soap (Dawn brand liquid soap of 5 to 10 drops per liter of water) to preserve pollinators during sampling. After 8 h, bees and foraging insects from all 30 bee bowls from each field replicate were transferred into labeled glass jars containing 75% ethanol for preservation. Order and family level abundances of each insect taxon were identified and compared between OWB and cotton.

A study on the same site by Bhandari et al. (2018d) revealed that total pollinator abundances were greater in the samples collected from Sep 25 through Oct 20 compared with those collected during late June through early August. Therefore, late September to late October was chosen to collect pollinators in this study. In OWB, bee bowl sampling was performed after grazing was terminated and cattle were removed from the pasture. OWB was in stem-elongation to anthesis stages at the first two sampling dates and at full-bloom to seed-set stages at the latter two sampling dates. Cotton was in the open boll stage at the first two sampling dates, whereas it was in the mature boll stage at the latter two sampling dates. At the second sampling (Oct 4), bee bowls were set in cotton after defoliant was applied. Ambient temperatures were relatively high at the first two sampling dates and declined at the latter two dates (Table 1). There were all-day overcast skies each day after the third sampling (Oct 14) until a day before the last sampling (Oct 20).

Table 1. Air temperature data in the previous week of sampling and on the sampling dates. Temperatures were recorded on site with a meteorological station.

Air temperature (°C)[†]		Sep 25	Oct 4	Oct 14	Oct 20
Previous week of sampling	Maximum	26.5	27.5	19.3	10.2
	Minimum	14.1	14.2	9.5	2.8
	Average	19.9	21.2	14.4	6.3
Sampling date	Maximum	29.8	32.1	17.8	22.2
	Minimum	10.6	18.5	9.9	8.3
	Average	20.2	25.3	13.9	15.3

[†] Temperatures are in the previous week (average of five days) prior to sampling and on the respective sampling date.

Data Analysis. Analysis of variance was used to compare treatments (crop types) with three replications to test within dates in a randomized complete block design, in which individual dates were analyzed separately. The main effect of crop type and crop-type × date interaction were tested with combined dates using 3,14 df in the F-test. For the total insects in the order Hymenoptera and Lepidoptera and families Apidae, Hesperiidae, Pieridae, and Syrphidae, the zero counts were accommodated, and data were normalized using log(x+10) transformation. Data were analyzed using Proc Mixed in SAS 9.4 (Littell et al. 2006) in which crop type was set as a fixed effect and replicate was set as a random effect. Means were compared and differences were considered significant at $P \leq 0.05$.

RESULTS

Fifteen families of bees and other pollinators from four insect orders (Coleoptera, Diptera, Hymenoptera, and Lepidoptera) were recovered over the entire period (Table 2). Very low numbers of Coleopterans prevented their statistical analysis. Sweat bee (Hymenoptera: Halictidae), which composed 67% of the total individuals collected, was the most abundant family. Hover fly (Diptera: Syrphidae) was the second most abundant family, constituting 11% of the total individuals. White and sulfur butterfly (Lepidoptera: Pieridae) and honey bee (Hymenoptera: Apidae) were the next most abundant families accounting for 7% and 5%, respectively. Family Apidae (i.e., honey bee) was recovered in lesser abundance. Two bee families (Halictidae and Apidae) constituted 71% of the total insect pollinators.

Table 2. List of orders and families of insect pollinators, and abundances recovered by bee bowls summed over three transects per field replicate, three replicates, two crop types and four sampling dates.

Order	Family	Common name	Total abundance count
Coleoptera	Meloidae	blister beetle	3
	Chrysomelidae	leaf beetle	1
Diptera	Syrphidae	hover fly	348
Hymenoptera	Halictidae	sweat bee	2118
	Apidae	honey bee	110
	Chrysididae	cuckoo wasp	82
	Ichneumonidae	ichneumon wasp	18
	Pompilidae	spider hawk wasp	7
	Sphecidae	thread-waisted wasp	5
	Megachilidae	leafcutter bee	4
Lepidoptera	Pieridae	white and sulfur butterfly	220
	Hesperiidae	skipper	167
	Lycaenidae	coppers	36
	Nymphalidae	brush-footed butterfly	16
	Noctuidae	moth	5

The total number of pollinating insects did not differ ($P \geq 0.13$) between OWB and cotton at the first two sampling dates (Sep 25 and Oct 4), but OWB had numerically greater means than cotton (Table 3). Crop types differed (*P* < 0.001) in total number of pollinating insects at the latter two sampling dates (Oct 14 and Oct 20) and with dates combined. The trends were similar for the order Hymenoptera. Lepidoptera differed (*P* < 0.001) by crop type such that OWB had greater abundances than cotton at each sampling date and across the dates. The total pollinators, Hymenopterans, and Lepidopterans were affected by crop-type × date interactions (*P* < 0.001), which is explained by the inconsistent numbers of insects of these groups among the sampling dates. Crop types had an effect (*P* < 0.001) on total pollinators and Hymenopteran and Lepidopteran pollinators with the last sampling date (Oct 20) having greater numbers than the previous sampling dates (Table 3).

Table 3. Abundances of total pollinators of the orders Lepidoptera, and Hymenoptera recovered in bee bowls by two crop types during four sampling dates and averaged over three replicates.

Pollinator	Crop type	Sep 25	Oct 4	Oct 14	Oct 20	Mean
		-- - - - - - no. crop type^{-1} - - - - - - - -- - -				
Total	OWB	91.0 a	95.0 a	185.3 a	475.0 a	211.6 a
	Cotton	47.3 a	41.7 a	36.7 b	74.7 b	50.1 b
	Crop effect	*P* = 0.21	*P* = 0.13	*P* < 0.001	*P* < 0.001	*P* < 0.001
	Crop x date	*P* < 0.001				
Hymenoptera	OWB	62.3 a	68.7 a	105.3 a	390.7 a	156.8 a
	Cotton	45.3 a	31.0 a	25.7 b	52.3 b	38.6 b
	Crop effect	*P* = 0.54	*P* = 0.18	*P* < 0.01	*P* < 0.001	*P* < 0.001
	Crop x date	*P* < 0.001				
Lepidoptera	OWB	24.0 a	24.3 a	26.0 a	54.3 a	32.2 a
	Cotton	2.0 b	7.3 b	1.7 b	8.3 b	4.8 b
	Crop effect	*P* < 0.001	*P* < 0.001	*P* < 0.001	*P* < 0.001	*P* < 0.001
	Crop x date	*P* < 0.001				

Means within columns followed by similar letters are not different at *P* ≤ 0.05.

A further analysis of five major families showed that honey bee (Apidae) numbers were greater (*P* < 0.05) in OWB than in cotton both within and across the dates (Table 4). The most abundant Halictidae (sweat bee) abundances were not significant (*P* = 0.27–0.93) between crop types at the first two sampling dates, but abundances were greater in OWB than in cotton. OWB had greater (*P* < 0.01) abundances of Halictidae than cotton at the latter two sampling dates and in combined dates. Crop type interacted with sampling date (*P* ≤ 0.02) for both bee families, Apidae and Halictidae. The Lepidopteran family Hesperiidae (skipper) and Pieridae (white and sulfur butterfly) differed (*P* ≤ 0.02) between crop type, for which numbers were greater in OWB than in cotton but the treatment × date interaction was significant (*P* < 0.01) only for Pieridae. The Dipteran family Syrphidae differed (*P* < 0.01) at one sampling date (Oct 4) out of four and in combined dates. There was no crop-type × date interaction (*P* = 0.08) for Syrphidae.

Table 4. Abundances of Hymenopteran families of Apidae (honey bee) and Halictidae (sweat bee), Lepidopteran families of Hesperiidae (skipper) and Pieridae (white and sulfur butterfly), and Dipteran family of Syrphidae (hover fly) recovered in bee bowls by treatment during four different sampling dates and averaged over three replicates.

Family	Crop type	Sep 25	Oct 4	Oct 14	Oct 20	Mean
		- - - - - - - - - -	- - - - - -	no. crop type^{-1}	- - - - - -	- - - - - - - - - -
Apidae	OWB	13.3 a	8.0 a	2.7 a	10.3 a	8.6 a
	Cotton	1.0 b	0.0 b	0.0 b	1.3 b	0.6 b
	Crop effect	$P < 0.001$	$P < 0.001$	$P = 0.048$	$P < 0.001$	$P < 0.001$
	Crop x date			$P = 0.02$		
Halictidae	OWB	46.3 a	57.3 a	101.7 b	358.3 a	140.9 a
	Cotton	44.0 a	28.0 a	23.7 b	46.7 b	35.6 b
	Crop effect	$P = 0.93$	$P = 0.27$	$P < 0.01$	$P < 0.001$	$P < 0.001$
	Crop x date			$P < 0.001$		
Hesperiidae	OWB	13.3 a	8.0 a	5.0 a	21.7 a	12.0 a
	Cotton	2.0 b	1.7 b	0.0 b	4.0 b	1.9 b
	Crop effect	$P < 0.001$	$P = 0.02$	$P = 0.03$	$P < 0.001$	$P < 0.001$
	Crop x date			$P = 0.22$		
Pieridae	OWB	7.0 a	11.7 a	20.3 b	24.0 a	16.0 a
	Cotton	0.0 b	5.0 b	1.7 b	3.7 b	2.6 b
	Crop effect	$P < 0.001$	$P < 0.01$	$P < 0.001$	$P < 0.001$	$P < 0.001$
	Crop x date			$P < 0.01$		
Syrphidae	OWB	4.3 a	2.0 a	54.0 a	30.0 a	22.7 a
	Cotton	0.0 a	3.3 a	9.0 b	13.3 a	6.4 b
	Crop effect	$P = 0.33$	$P = 0.73$	$P < 0.01$	$P = 0.09$	$P < 0.01$
	Crop x date			$P = 0.08$		

Means within columns followed by similar letters are not different at $P \leq 0.05$.

CONCLUSION AND DISCUSSION

Although OWB and cotton do not require insects for pollination, relatively high numbers of bees and other foraging insects (mostly pollinators) were recovered in those crops. The communities of bees and other pollinating insects may not be affected by the wider planting of perennial OWB in the Texas High Plains where dominant cotton is also likely providing pollinator habitat and food resources, which would help in pollinating surrounding crops in the ecosystem. Multi-year large-scale collections of pollinators at different growth stages of OWB and cotton, including the flowering stage of cotton, is needed to afford a wider regional assessment of bees and other pollinators with OWB and cotton. An unexpected and fairly high number of bees and other insect pollinators in OWB and cotton in this study suggested that they are likely providing habitat and food resources for pollinators.

We had hypothesized that OWB may negatively affect the pollinators in cotton-dominated agroecosystems based on previous work at the same site, wherein monoculture OWB slightly reduced pollinators relative to more diverse pastures (Bhandari et al. 2018d). In the current study, we found consistently greater number of pollinators in OWB than in adjacent cotton fields, which provides evidence that local pollinator populations may not be negatively affected by OWB. Since there was no application of insecticide made in cotton during the growing season, it is not known if there was an effect of herbicide that was applied before cotton planting. Hartley et al. (2004) reported that introduced (non-native) forages managed as a monoculture stand generally harbor lower insect species richness than habitat with diverse native plant species. The greater number of pollinators in the pastures that contained alfalfa and native mixed pasture than OWB in the previous study may be associated with presence of pollinator-friendly (particularly bee) alfalfa and native species habitat (Bhandari et al. 2018d). A recent study in South Texas cotton fields found a total of 5,246 individual native bees representing 41 species during cotton blooming period of which the majority were generalist pollinators (Parys et al. 2020). In the current study, there was no case where pollinator numbers were greater in cotton than in OWB (Table 3). The cotton was in late reproductive stages (open boll to mature boll), whereas OWB was anthesis to full bloom during the sampling. The lower number of pollinators in cotton than OWB was due in part to the lack of cotton blooms and to the presence of blooms of OWB. The finding of sweat bee as the most abundant family in both OWB and cotton agrees with the previous study of Bhandari et al. (2018d).

The similar number of pollinators in cotton on the second sampling date (Oct 4) compared to first and third samplings suggests that defoliant did not have an effect on pollinator numbers since sampling was performed immediately after defoliant was applied on the second sampling date. The greatest numbers of insect pollinators were collected in late October (Oct 20). These results are in line with the previous study to some extent where greater numbers of pollinating insects were collected on Oct 25 than Jun 25 and Aug 3 (Bhandari et al. 2018d). The reasons for the greater numbers of pollinators in late October than late September to mid-October are not clear, but weather conditions between Oct 15 to Oct 19 at least partially explained the differences in pollinator numbers. Skies were continuously overcast from Oct 15 to Oct 19 (one day before the last sampling) and had the lowest temperature (Table 1). Days during the sampling should be at least partially sunny for the pollinators to be active. Pollinators were probably not active during the overcast period, which would induce pollinators to wait until the next favorable sunny day (Oct 20) to become active.

We found unexpectedly high numbers of pollinators in cotton fields despite the late reproductive stage (open boll to mature boll state) of the plants. Rhodes (2002) reported that insect pollinators can help move pollen between flowers in cotton although cotton does not require insects for pollination). Similarly, although cotton is self-pollinating, native bees and honey bees can enhance cotton pollination (Cunningham et al. 2014). The presence of fairly high abundances of bees (particularly sweat bees) in cotton fields (Table 4) indicates that bees may use pollen as a food resource. A recent report of fairly high abundance of native bees (particularly sweat bee) between silking and blister stages in corn suggests that corn could provide resources (i.e., habitat and pollen) for pollinators (Bhandari, Longing, et al. 2020). Unexpectedly high numbers of native bees and other pollinators at a late reproductive stage of cotton in the current study suggests that cotton may provide food and habitat resources.

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