Research

Comparison of bee composition in sunn hemp and other cover crops

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Abstract

Cover crops can be planted in rotation with cash crops to improve soils, assist in weed growth prevention, and help suppress plant pathogenic nematode populations. Experiments were conducted in northern and north-central Florida to evaluate bee populations within cover crop plants, including sunn hemp (*Crotalaria juncea* L.), sorghum-sudangrass (*Sorghum bicolor* [L.] Moench × *S. bicolor* var. *sudanense* [Piper] Stapf.), and cowpea (*Vigna unguiculata* [L.] Walp.). Almost 150 bees in 10 species and over 700 bees in 15 species were collected in pan (bee bowls) and blue vane traps, respectively. Both sets of traps captured bees from within all cover crop plots, indicating that these bees forage in disturbed habitats. The dominant bees collected, *Melissodes* spp., are ground-nesting solitary bees which may have been utilizing the ground below the plants and the border plot areas as a nesting site. Only a subset of the species composition associated with the cover crops was relevant to the pollination of sunn hemp, which requires large-bodied bees such as species of *Xylocopa* and *Megachile*.

Key Words: pollinators; *Crotalaria*; *Xylocopa*; *Megachile*

Resumo

Los cultivos de cobertura se pueden plantar en rotación con cultivos comerciales para mejorar los suelos, ayudar en la prevención del crecimiento de malezas y ayudar a suprimir las poblaciones de nematodos patógenos de plantas. Se realizaron experimentos en el norte y centro-norte de la Florida para evaluar las poblaciones de abejas dentro de las plantas de cultivos de cobertura, incluidos cáñamo sunn (*Crotalaria juncea* L.), sorgo-sudangrass (*Sorghum bicolor* [L.] Moench × *S. bicolor* var. *sudanense* [Piper] Stapf.), y caupí (*Vigna unguiculata* [L.] Walp.). Se recolectaron casi 150 abejas de 10 especies y más de 700 abejas de 15 especies en bandejas (tazones para abejas) y trampas de paleta azul, respectivamente. Ambos juegos de trampas capturaron abejas de todas las parcelas de cultivos de cobertura, lo que indica que estas abejas se alimentan en hábitats perturbados. Las abejas dominantes recolectadas, *Melissodes* spp., son abejas solitarias que anidan en el suelo y que pueden haber estado utilizando el suelo debajo de las plantas y las áreas de la parcela fronteriza como sitio de anidación. Solo un subconjunto de la composición de especies asociadas con los cultivos de cobertura fue relevante para la polinización del cáñamo solar, que requiere abejas de gran tamaño, como las especies de *Xylocopa* y *Megachile*.

Palabras clave: polinizadores; *Crotalaria*; *Xylocopa*; *Megachile*

Many Florida vegetable growers plant cover crops either before planting or after harvesting their main crop (Snapp et al. 2005; Newman et al. 2014) to improve soil conditions (Wang et al. 2005; Cherr et al. 2007), suppress weed populations (Adler & Chase 2007; Collins et al. 2008; Mosjidis & Wehtje 2011; Cho et al. 2015), reduce plant parasitic nematode densities (Crow et al. 2001; Bhan et al. 2010; Braz et al. 2016), and reduce insect pest populations (Pair & Westbrook 1995; Meagher et al. 2004; Tuan et al. 2014). One favorite species is sorghum-sudangrass (*Sorghum bicolor* [L.] Moench × *Sorghum bicolor* var. *sudanense* [Piper] Stapf.) (both Poaceae), which is a warm-season annual grass hybrid that is used as a catch crop following harvest of winter vegetables (Newman et al. 2014; Vendramini et al. 2015). However, these crops are important hosts used by the crop pest fall armyworm (*Spodoptera frugiperda* [J. E. Smith]; Lepidoptera: Noctuidae) (Sparks 1979; Pair et al. 1991), which overwinters in southern Florida before dispersing north in the summer months (Nagoshi et al. 2012). Alternative cover crops are of interest to Florida growers to combat the buildup of fall armyworm populations, including cowpea (*Vigna unguiculata*

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[L.] Walp.) and sunn hemp, *Crotalaria juncea* L. (both Fabaceae). Both species are grown alone or mixed with sorghum-sudangrass and used as cover crops or as intercrops with vegetables (Cho et al. 2012; Harrison et al. 2014; Hödtke et al. 2016).

Both cowpea and sunn hemp cover crops have shown potential as key components in an area-wide management strategy for control of fall armyworm (Meagher et al. 2004). Cowpea is an important human food source in many parts of the tropics and subtropics since all parts of the plant can be eaten (Menssen et al. 2017; Xiong et al. 2018). In the USA, southern or black-eyed peas are an important food and are used also as a summer cover crop (Hutchinson & McGiffen 2000; Ngouajio et al. 2003; Wright et al. 2017). The first sunn hemp cultivar commercialized in the US was 'Tropic Sun' (Rotar & Joy 1983), but other varieties or germplasm lines from Africa and Asia also are used as cover crops in the US.

In addition, these cover crops may contribute to another ecological service by producing flowers that provide resources for pollinators and insect food for predators and parasitoids (Campbell et al. 2016). Studies have shown that early season flowering by cover crops can increase pollinator populations, which promote late season pollination in adjacent cash crops (Riedinger et al. 2014). Flower density and the diversity of the cover crop plants may influence bee visitation and native bee abundance (Saunders et al. 2013; Ellis & Barbercheck 2015).

Our research objective was to determine the bee community composition in plots of cowpea, sorghum-sudangrass, and sunn hemp cover crop plants and a standard crop of corn. Our hypothesis was that plots with flowers (cowpeas and sunn hemp) would be more attractive to bees and would result in higher captures in traps.

Materials and Methods

BEE COMMUNITY COMPOSITION IN COVER CROP PLOTS

In 2012, cover crops were planted at the North Florida Research and Education Center, Quincy, Florida, USA (30.5458°N, 84.5990°W) and at the University of Florida Plant Science Research and Education Unit, Citra, Florida, USA (29.4101°N, 82.1732°W). Three cover crop treatments were evaluated: the standard cover crop species sorghum-sudangrass, and the alternative species cowpea and sunn hemp. These experiments were part of a larger study to compare infestation of fall armyworm. Therefore, to encourage infestation of this species, corn (DKC 66-94 RR2, DeKalb Genetics Corp., DeKalb, Illinois, USA) was planted as the fourth treatment plot and served as a non-cover crop control treatment. The experimental design at both locations was a randomized complete block with 4 treatments, 4 replications, and all plots planted to 91.4 cm row centers. Sorghum-sudangrass seed was Forage First Sudax SX-17 sorghum × sudangrass hybrid (Forage First, LaCrosse, Wisconsin, USA, now sold by Forage Genetics International, Nampa, Idaho, USA). Cowpea seed was 'Iron & Clay' and was purchased through local distributors; the seed was mixed with a cowpea-type *Rhizobium* (Rhizobiaceae) inoculant (N-Dure, Verdesian Life Sciences, Cary, North Carolina, USA) before planting. Sunn hemp seed planted at both locations was an unknown germplasm (variety not stated) from South Africa (Petcher Seeds, Fruitdale, Alabama, USA), and was mixed with the same type of *Rhizobium* inoculum before planting. The Quincy 2012 trial was planted 12 Jun and contained 10-row, 15.3 m long plots of the plant species. The Citra 2012 plots were planted 3 Jul, and contained 8-row, 15.3 m long plots of corn ('Trucker's Favorite'), sorghum-sudangrass, cowpea, and sunn hemp. In both locations plot borders were 5.5 m and were disked weekly to prevent weed growth. Since both locations were University of Florida agricultural research stations, a variety of row and vegetable crops were grown nearby.

To potentially capture different bees, we used both bee bowls (pan traps) and blue vane traps to assess the bee community composition in these cover crop plots (Westphal et al. 2008; Joshi et al. 2015). White plastic bowls (12 oz. or 355 mL; Dart Container Corp., Mason, Michigan, USA) were painted with a combination of fluorescent yellow or fluorescent blue with a silica flat binder at the ratio of 473.2 mL to 3.785 L (Guerra Paint and Pigment Corp., New York, New York, USA) (Droege 2015). A set of 1 white, 1 yellow, and 1 blue trap filled with soapy water was placed in each treatment per block plot, equaling 16 traps per color per location. At Quincy 2012, rectangular plastic trays (56 cm × 45 cm × 9 cm) were placed on top of 1.5 m poles. One set of bee bowls were attached to plastic pots that were glued to the bottom of the trays so that the base of the bowl was level with the top of the tray. Each set was randomly placed in each treatment per block (row number by number of paces); bowls were put out 12 Jul and sampling dates were 20 Jul, 27 Jul, 2 Aug, 10 Aug, 16 Aug, and 29 Aug.

Blue vane traps (SpringStar Inc., Woodinville, Washington, USA) were placed at Quincy in 2012 and Citra in 2012. Blue vane traps were hung from 1.5 m poles so that the height of the trap was 1.5 m. Each trap contained an insecticide strip containing 10% 2.2-dichlorovinyl dimethyl phosphate (Hercon® Environmental, Emigsville, Pennsylvania, USA). One blue vane trap was randomly placed in each treatment (row number by number of paces), equaling 4 traps per location and date. Traps were moved from 1 treatment block to another after each sampling collection. Traps at Quincy were put out 12 Jul and sampled 20 Jul, 27 Jul, and 2 Aug, 10 Aug, and 16 Aug; traps at Citra were put out 9 Aug and sampled 17 Aug, 24 Aug, 31 Aug, 11 Sep and 20 Sep. Bees were identified by KMW using various taxonomic keys.

STATISTICS

All analyses were conducted using SAS (2012). Bee bowl and blue vane data for each location and yr were first analyzed using Box-Cox (PROC TRANSREG) and PROC UNIVARIATE to find the optimal normalizing transformation (Osborne 2010). For the bee bowl samples, cover crop treatment differences of numbers of *Melissodes* spp. (Hymenoptera: Apidae) bees and total numbers of bees were compared using a randomized complete block design in PROC MIXED, with cover crop treatment as the fixed variable, and sampling date, date × treatment, treatment × block, and block as the random variables. For the blue vane samples, cover crop treatment differences of numbers of *Melissodes* spp., *Bombus* spp. (Hymenoptera: Apidae), and total number of bees were compared using PROC MIXED, with cover crop treatment as the fixed variable, and sampling date and sampling date × treatment as the random variables. In all analyses LSMEANS with an adjusted Tukey test was used to separate variable means.

Results

COMMUNITY COMPOSITION IN COVER CROP PLOTS

Ten species of bees totaling 147 individuals were found in all 3 colors of the elevated bowls at Quincy in 2012 (Table 1). *Melissodes bimaculata* (Lepeletier) and *Melissodes communis* Cresson (both Hymenoptera: Apidae) were the species collected in the highest numbers, composing 72.8% of the bees collected. There were no differences among cover crop treatments in number of *Melissodes* spp. or total bees collected (Table 2), which was unexpected because our hypothesis was that more bees would be recovered from the cowpea and sunn hemp plots. However, sampling date was a significant random variable ($P = 0.0009$) because fewer bees were collected from Jul through late Aug in 2012 (Fig. 1). All other random variables were not significantly different ($P > 0.05$).

Table 1. Total number of bees (females, males) collected from bee bowl and blue vane traps at Quincy and Citra, Florida, USA, 2011 and 2012. Bee bowls in 2012 were set at a height of 1.5 m and were randomly placed in plots (row number by number of paces). Vane traps were randomly placed in plots.

	Bowl – Quincy 2012 (56 d)	Vane – Citra 2012 (39 d)	Vane – Quincy 2012 (35 d)
Halictidae			
Augochlora pura (Say)	0, 1	0, 0	0, 0
Agapostemon splendens (Lepeletier)	3, 0	0, 1	7, 0
Halictus poeyi Lepeletier	9, 2	0, 0	4, 0
Lasioglossum admirandum (Sandhouse)	0, 0	0, 0	3, 0
L. coreopsis (Robertson)	0, 0	0, 0	2, 0
Apidae			
Apis mellifera L.	4, 0	1, 0	2, 0
Bombus fraternus (Smith)	0, 0	0, 0	1, 0
B. griseocollis (De Geer)	1, 0	0, 0	0, 0
B. impatiens Cresson	14, 0	0, 0	56, 0
B. pensylvanicus (De Geer)	1, 0	12, 0	13, 1
Melissodes bimaculata (Lepeletier)	53, 12	1, 0	196, 11
M. communis Cresson	32, 10	101, 70	72, 58
Melitoma taurea (Say)	0, 0	0, 0	1, 0
Svastra atripes atrimitra (LaBerge)	0, 0	0, 0	1, 0
Ptilothrix bombiformis (Cresson)	0, 0	0, 0	1, 0
Xenoglossa strenua (Cresson)	1, 4	0, 0	60, 39
Xylocopa virginica L.	0, 0	0, 0	2, 0
TOTAL	118, 29	115, 71	421, 109

Large numbers of bees were collected in the blue vane traps in Quincy and Citra, but this was driven by a few species (Table 1). In Quincy, *M. bimaculata* and *M. communis* bees composed 63.6% of the total captures from 15 different species, although there were also large numbers collected of *Xenoglossa strenua* (Cresson) and *Bombus impatiens* Cresson (both Hymenoptera: Apidae). More *Melissodes* spp. bees were collected in traps that were in the corn and sorghum-sudangrass plots than in the cowpea plots; numbers in the sunn hemp plots were intermediate (Table 3). *Bombus* spp. bees (*impatiens* and *pensylvanicus* [De Geer]; Hymenoptera: Apidae) were collected in even numbers across cover crop plots, with between 2 and 5 bees per sampling date. The total number of bees was highest in traps in the corn plots and lowest in the cowpea plots; numbers in the sorghum-sudangrass and sunn hemp were intermediate (Table 3). As with the bee bowl collections, we hypothesized that more bees would be in plots of cowpeas and sunn hemp. Sampling date and sampling date × treatment were significant random variables, because fewer bees were collected as the season progressed and collections in the corn plots were not in the same order date to date as the other cover crop treatments (Fig. 2).

Only 5 bee species were collected in blue vane traps in Citra, with *M. communis* comprising almost 92% of the total numbers. *Melissodes* spp. bees (*bimaculata* and *communis*) were collected evenly across treatments, ranging from 5.6 (cowpea) to 12.2 (corn) bees per date. When *B. pensylvanicus* (De Geer) numbers were added to the analysis, there were higher numbers of bees in the corn plots than the cowpea and sorghum-sudangrass plots (Table 3). As in Quincy, sampling date and sampling date × treatment were significant random variables, because fewer bees were collected as the season progressed (Fig. 3).

Discussion

Bee bowls and blue vane traps may be efficient indicators of species richness in agricultural habitats (Westphal et al. 2008; Joshi et al. 2015). None of our trials were designed to directly compare trapping methods, although certain trends were evident. Blue vane traps captured 3.6 times more bees than bee bowls when used at the same location (Quincy location 2012). *Melissodes bimaculata*, *M. communis*, *X. strenua*, and *B. impatiens* were collected in high numbers in blue vane traps, which has been documented in other studies (Stephen & Rao 2005, 2007; Kimoto et al. 2012; Geroff et al. 2014).

Bee bowls and blue vane traps may show a strong bias in the numbers and types of species found in different habitats, especially *Melissodes* and *Bombus* bees (Saunders & Luck 2013; Rhoades et al. 2017). The dominant bees collected, *Melissodes* spp., are ground-nesting solitary bees which may have been using the non-plant area within

Table 2. Number of *Melissodes* spp. (*bimaculata* and *communis*) and total bees per 3 bowls (mean ± SE) per cover crop treatment in suspended bee bowls (2012, 56 d), Quincy, Florida, USA.

Year	Treatment	*Melissodes* spp.[a]	Total bees[b]
2012	corn	1.04 ± 0.34 a	1.42 ± 0.39 a
	sorghum-sudangrass	0.92 ± 0.36 a	1.17 ± 0.48 a
	cowpea	1.33 ± 0.43 a	1.79 ± 0.48 a
	sunn hemp	1.17 ± 0.35 a	1.75 ± 0.48 a
		F = 0.19; df = 3, 12; P = 0.9014	F = 1.0; df = 3, 12; P = 0.4434

[a]Data were transformed using $Y^{0.5}$. Means followed by the same letter in each yr are not significantly different, $P > 0.05$.
[b]Data were transformed using $Y^{0.25}$. Means followed by the same letter in each yr are not significantly different, $P > 0.05$.

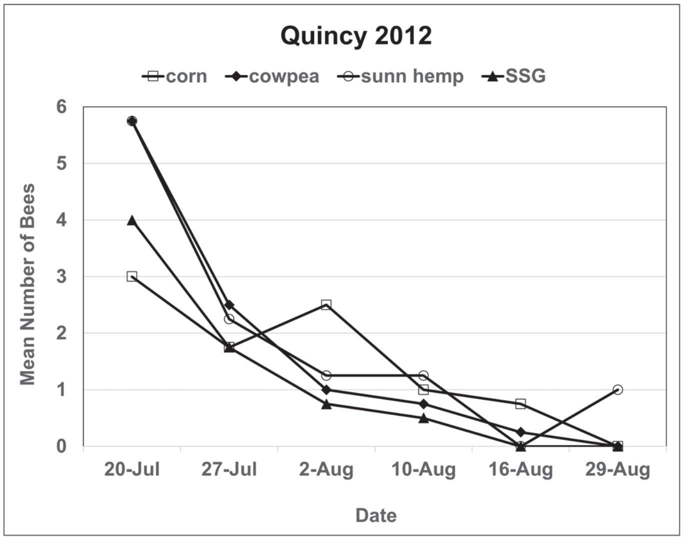

Fig. 1. Mean number of total bees collected in bee bowls within cover crop plots for 6 dates in 2012, Quincy, Florida, USA. SSG = sorghum sudangrass.

the plots and the border plot areas as nesting sites. It appears that *M. bimaculata* capture may be influenced by trap height, because an unpublished study found very few individuals in bee bowls on the ground compared to high numbers that were found in our elevated traps. The squash-specialist species *X. strenua* also may have been nesting in or near our plots, or passing through between nest sites and cucurbit flowers.

Both sets of traps captured bees from within all cover crop plots, indicating that these bees may forage in disturbed habitats (Wheelock et al. 2016). The anemophilous pollen produced by corn and sorghum spp. can be highly attractive to many bee species, including honey bees from feral and managed hives (O'Neal & Waller 1984; Baum et al. 2004; references within Saunders 2018). Wild bee species also are active in corn and sorghum fields, because many species have been collected using different sampling tools (Immelman & Eardley 2000; Gardiner et al. 2010; Wheelock & O'Neal 2016). These wild and managed bee species are not just passing through corn and sorghum fields but are collecting pollen (Immelman and Eardley 2000; Gardiner et al. 2010; Wheelock & O'Neal 2016). We were surprised that more bees were not active in the cowpea and sunn hemp plots; however, these plants did not flower until later in the season (early Aug and late Aug, respectively) when overall bee densities were lower. Perhaps planting these cover crop species in early spring would have attracted more bees to these plants.

Cowpea produces small purple or white papilionaceous flowers and in Africa, honey bees, bumble bees, and the carpenter bee *Xenoglossa flavorufa* (De Geer) (Hymenoptera: Apidae) were found with pollen on their bodies during flowering (Pasquet et al. 2008; Asiwe 2009). Flower color was found to be important in which bees visited plants, because bumble bees preferred purple flowers and honey bees preferred white flowers (Leleji 1973). In the Amazon, pollination from a variety of bee species were shown to play an important complementary role in cowpea production (Vas et al. 1998). No information was found concerning bee species attracted to cowpeas in the US.

Only a subset of the species composition associated with the cover crops, as detected in the bowl and vane traps, was relevant to the pollination of sunn hemp (Meagher et al. 2019). Bee bowl traps have been shown to catch smaller-bodied bees disproportionately relative to larger bees (Cane et al. 2000; Roulston et al. 2007), and may under-sample bee species richness when there are abundant floral resources nearby (Mayer 2005; Wilson et al. 2008; Baum & Wallen 2011). We had hoped that sunn hemp would flower earlier in the season, but because of an error in ordering, a sunn hemp line that has short daylength flowering was used (Meagher et al. 2017). Pollination of the large yellow papilionaceous flowers of *Crotalaria* (Fabaceae) species occurs when bees land on the flower keel and wing petals and force their tongues into the nectar well at the base of the standard petal (Le Roux & Van Wyk 2012). Pollination generally requires large-bodied bees, such as *Xylocopa* spp. (Hymenoptera: Apidae) and *Megachile* spp. (Hymenoptera: Megachilidae) (Jacobi et al. 2005; Brito et al. 2010; Halbrendt 2010; Amaral-Neto et al. 2015). We only documented 2 *Xylocopa* specimens with blue vane traps, although actively counting visiting bees in later studies with other varieties of sunn hemp resulted in finding large numbers of *Xylocopa micans* Lepeletier and *Xylocopa virginica* (both Hymenoptera: Apidae) (Meagher et al. 2019). We believe that sunn hemp lines that successfully produce flowers earlier in the season can provide food and habitat for pollinators and beneficial insects (LeFéon et al. 2013; Meagher et al. 2017).

Traps placed in disturbed agricultural habitats may be used to survey and identify bee species that are present. Results from this study using passive traps and results from Meagher et al. (2019) using direct observations strongly indicate that many bee species are attracted to these cover crop plant species. However, comparing results from both studies suggest that several bee collecting methods are needed to determine which species are active in these habitats.

Table 3. Number of *Melissodes* spp. (*bimaculata* and *communis*), *Bombus* spp. (*fraternus*, *impatiens*, and *pensylvanicus*), and total bees per trap (mean ± SE) per cover crop treatment in blue vane traps, Quincy (35 d) and Citra (39 d), Florida, USA, 2012.

Location	Treatment	*Melissodes* spp.[a]	*Bombus* spp.[b]	Total bees[a]
Quincy	corn	24.0 ± 6.2 a	3.2 ± 1.6 a	35.2 ± 10.6 a
	sorghum-sudangrass	19.0 ± 5.0 a	2.0 ± 0.7 a	28.4 ± 9.7 ab
	cowpea	10.0 ± 6.0 b	5.0 ± 1.5 a	18.2 ± 9.8 b
	sunn hemp	14.4 ± 3.7 ab	4.0 ± 1.8 a	24.2 ± 6.7 ab
		F = 5.1; df = 3, 12; P = 0.0168	F = 0.6; df = 3, 12; P = 0.6371	F = 5.6; df = 3, 12; P = 0.0121
Citra	corn	12.2 ± 4.5 a	1.4 ± 1.0 a	14.0 ± 4.8 a
	sorghum-sudangrass	7.8 ± 5.0 a	0.4 ± 0.4 a	8.0 ± 5.2 b
	cowpea	5.6 ± 3.1 a	0.4 ± 0.4 a	6.0 ± 3.2 b
	sunn hemp	8.8 ± 5.0 a	0.2 ± 0.2 a	9.2 ± 5.3 ab
		F = 2.4; df = 3, 12; P = 0.1158	F = 0.5; df = 3, 12; P = 0.6677	F = 3.8; df = 3, 12; P = 0.0407

[a]Data were transformed using $Y^{0.25}$. Means followed by the same letter in each location are not significantly different, P > 0.05.
[b]Data were log-transformed. Means followed by the same letter in each location are not significantly different, P > 0.05.

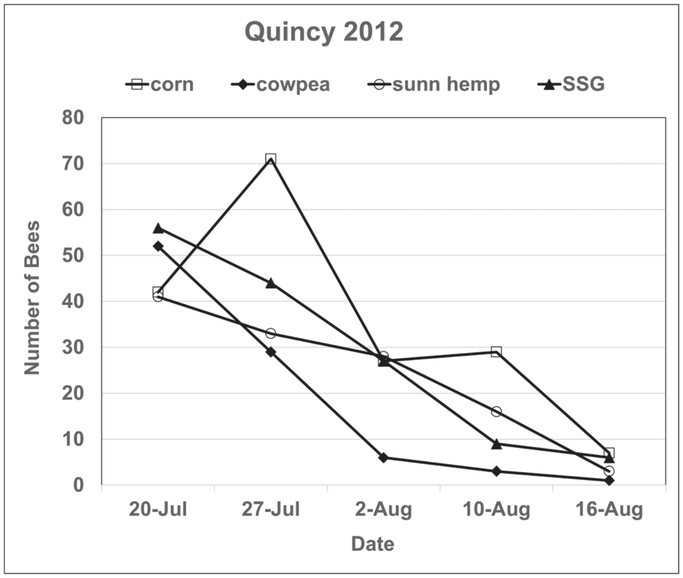

Fig. 2. Total number of bees collected in blue vane traps within cover crop plots for 5 dates in 2012, Quincy, Florida, USA. SSG = sorghum sudangrass.

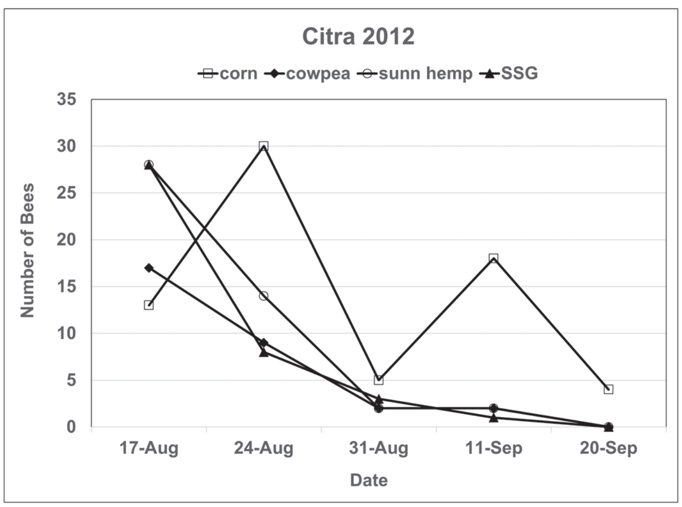

Fig. 3. Total number of bees collected in blue vane traps within cover crop plots for 5 dates in 2012, Citra, Florida, USA. SSG = sorghum sudangrass.

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