Environmental Entomology, 48(2), 2019, 343–350
doi: 10.1093/ee/nvy190
Advance Access Publication Date: 10 February 2019
Research

Documenting Potential Sunn Hemp (*Crotalaria juncea* L.) (Fabaceae) Pollinators in Florida

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Subject Editor: Theresa Pitts-Singer

Received 13 September 2018; Editorial decision 7 December 2018

Abstract

Sunn hemp, *Crotalaria juncea* L., is a warm-season legume that can be planted in rotation to cash crops to add nitrogen and organic matter to the soils, for weed growth prevention, and to suppress nematode populations. Sunn hemp flowers also provide nectar and pollen for pollinators and enhance biological control by furnishing habitat for natural enemies. Experiments were conducted in Northern and North Central Florida to evaluate bee populations that visited flowers within mixed plots of sunn hemp and sorghum-sudangrass and plots of two sunn hemp germplasm lines. Collections of bees that visited 'AU Golden' and Tillage Sunn flowers indicated that *Xylocopa virginica* (L.) (Hymenoptera: Apidae), *Xylocopa micans* Lepeletier (Hymenoptera: Apidae), *Megachile sculpturalis* Smith (Hymenoptera: Megachilidae), *Megachile mendica* (Cresson) (Hymenoptera: Megachilidae), and *Megachile georgica* Cresson (Hymenoptera: Megachilidae) were present in large numbers in May through July and then again in October. Although Tillage Sunn seeds planted in March flowered in May, percent bloom and number of bee visits were low. Compared with short day sunn hemp cultivars, 'AU Golden' plants produced flowers early in the season to provide food and habitat for pollinators and have the potential to produce an abundant seed crop in Northern and North Central Florida.

Key words: cover crops, pollinators, sunn hemp, *Crotalaria, Xylocopa*

Vegetable growers plant cover crops, such as grasses, legumes, or brassica species, either before planting or after harvesting their main crop (Snapp et al. 2005, Newman et al. 2014). Cover crops are used to improve soil conditions (Wang et al. 2005, Cherr et al. 2007), suppress weed populations (Adler and Chase 2007, Collins et al. 2008, Mosjidis and 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 and Westbrook 1995, Meagher et al. 2004, Tuan et al. 2014).

Many Florida growers plant sorghum-sudangrass [*Sorghum bicolor* (L.) Moench x *S. bicolor* var. *sudanense* (Piper) Stapf.], 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 utilized by the polyphagous crop pest fall armyworm [*Spodoptera frugiperda* (J. E. Smith) Lepidoptera: Noctuidae; Sparks 1979, Pair et al. 1991], which overwinters in 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 sunn hemp, *Crotalaria juncea* L., and cowpea [*Vigna unguiculata* (L.) Walp.]. 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).

Sunn hemp cover crops have shown potential as a key component in an area-wide management strategy against fall armyworm (Meagher et al. 2004). The first sunn hemp cultivar commercialized in the United States was Tropic Sun (Rotar and Joy 1983), but flowering and seed production in the continental United States was poor due to this variety's flowering response to short days (White and Haun 1965, Mosjidis 2007). A breeding program to increase flowering and seed production was initiated at Auburn University in 2002. The cultivar AU Golden was developed from accession PI322377, which was obtained from the National Plant Germplasm

System (Mosjidis 2014). This new cultivar proved to be an excellent flower and seed pod producer in the Southeastern United States (Mosjidis 2014, Cho et al. 2016, Meagher et al. 2017), confirming its compatibility with local environmental conditions. Seed costs suggest that 'AU Golden' is comparable with sunn hemp lines grown in foreign countries and is much less expensive than the standard cultivar Tropic Sun from Hawaii, demonstrating the potential economic viability of early flowering cultivars of sunn hemp as a cover crop alternative in Florida to improve soils in agricultural landscapes (Meagher et al. 2017).

In addition, cover crops can contribute to another ecological service by producing flowers that provide resources for pollinators and food for natural enemies (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 have an influence on bee visitation and native bee abundance (Saunders et al. 2013, Ellis and Barbercheck 2015).

Our research objectives were to identify which bee species visited sunn hemp flowers and which of those species appeared to actively pollinate the flowers, and determine bee species' visitation levels on sunn hemp throughout the growing season. Previous research to determine which bees pollinated sunn hemp examined only the short-day length cultivar Tropic Sun, which flowered later in the season when most active pollinators were likely not present (Cho et al. 2015). Our study examines pollinator activity on sunn hemp flowers from May until November.

Materials and Methods

Visitations to Sunn Hemp Flowers

We determined which bees were visiting sunn hemp flowers in 2015 and 2016. The 2015 data were collected within plots conducted at Citra, FL (29.41, –82.17) to determine flowering and seed production of a commercial sunn hemp cultivar (detailed in Meagher et al. 2017 and summarized here). 'AU Golden', purchased April 2015 from Petcher Seeds, Fruitdale, AL, was planted at two seed densities and was planted with or without the addition of sorghum-sudangrass to obtain more plant biomass per area with the same amount of sunn hemp seed. Plots were planted on 27 April, 26 June, and 26 August (Meagher et al. 2017), although only the plots planted on 26 June were sampled for bee visitations. The randomized complete block experimental design contained three blocks and four treatments: sunn hemp monocultures at 11.2 kg/ha (SH11), at 44.8 kg/ha (SH44), and bicultures of 11.2 kg/ha sunn hemp plus sorghum-sudangrass at 22.4 kg/ha (SH11SSG), and 44.8 kg/ha sunn hemp plus sorghum-sudangrass at 22.4 kg/ha (SH44SSG). Each plot measured 7.6 × 33.8 m, with 0.3 m between plots. Sunn hemp seed was mixed with a cowpea-type *Rhizobium* inoculant (N-Dure, Verdesian Life Sciences, Cary, NC) before planting and was broadcast by hand and then covered by a roller.

Observations of flower visitations by bees and wasps were made on 26 July (morning) and 27 July (afternoon), 11 September (morning) and 14 September (afternoon), and 24 September (afternoon) and 25 September (morning). In each treatment plot, a 1-m section was marked out using a large ruler and after 1 min, the flowers were observed for 2 min for visiting Hymenoptera that contacted the flowers. Counts of visiting Hymenoptera were made 3 times in each treatment block, for a total of nine observations per treatment. If the species identity of a Hymenoptera visitor was unknown, the insect was collected and later identified.

In a second study in 2016, two lines of sunn hemp were planted on three different dates to ensure that flowers would be available to insect pollinators throughout the growing season. 'AU Golden' (purchased April 2015 from Petcher Seeds, Fruitdale, AL) and Tillage Sunn (purchased March 2014 from Hancock Seed Co., Dade City, FL) were planted at the USDA-ARS Tallahassee Laboratory in Leon Co., FL (30.47, –84.17). Each treatment had four replicates (date x line) for a total of 24 plots. Each plot was 7.6 m per side, with a 2.1-m buffer between plots. The experimental field was prepared with a field cultivator and a preemergent herbicide, pendimethalin (Prowl), was applied at 2.24 kg/ha with a backpack sprayer on 7 March 2016. Mechanical weed control and hand weeding were used in the plots postemergence. Sunn hemp seeds were broadcast at 13.45 kg/ha, raked in, and irrigated with tripod stand sprinklers until germination. The first planting date was 11 March, followed by 28 April and 27 July. The 11 March and 28 April plots were ratooned using hedge trimmers to a height of 55 cm, on 15 June to promote reflowering.

Plots were checked weekly and observed each sample date at 1000 and 1400 h. All plots with over 20% flowering were sampled. Plots were visually divided into four equal quadrats (3.8 m^2). Two people spent 5 min looking at a randomly chosen quadrat per plot and recorded the number and species of pollinator visits to sunn hemp during that time. A pollinator visit was counted if the insect landed on the flower and either entered the flower or could be seen on the keel moving the flower. Species within a genus were grouped when visual species identification of bee visitors during flower census was difficult to obtain due to the insects' small size, similar appearance, and/or disappearance after the 5-min observation period before they could be collected. Insects which landed and moved to the calyx were not counted as pollination visits as they were not likely contacting the reproductive structures of the flower. Novel insect species were captured and later identified. Additionally, percent bloom (number of plants blooming divided by number of plants) per plot was measured. Plots were sampled from 13 May until 18 November, except during inclement weather such as rain or winds above 16 km/h. Plants were killed by the first frost on 21 November.

Statistics

All analyses were conducted using SAS (SAS 9.4, SAS Institute 2012). Kruskal–Wallis one-way analysis of variance tests (PROC NPAR1WAY WILCOXON DSCF) was used to compare visits with 'AU Golden' flowers in 2015 among sampling dates, morning and afternoon sampling, and seeding treatments. For the 2016 flower visit experiment, Pearson correlation analysis (PROC CORR) was used to determine whether bee visits were related to percent bloom. Kruskal–Wallis analyses (PROC NPAR1WAY WILCOXON DSCF) was used to compare the mean number of bee visits of eight different pollinator species during the morning and afternoon for 'AU Golden' and Tillage Sunn flowers, the mean number of visits between the sunn hemp lines, and visits among the three different planting dates (11 March, 28 April, and 27 July).

Results

Visitations to Sunn Hemp

Hymenoptera that visited flowers were counted among sunn hemp plantings during the mornings and afternoons in late August, mid-September, and late September in plots planted on 26 June 2015. *Xylocopa micans* Lepeletier, *Xylocopa virginica* (L.), and *Apis mellifera* (L.) (Apidae) were the most numerous visitors to flowers.

Table 1. Comparison of the mean number of bee visits (±SE) to flowers of 'AU Golden' plants during the morning and afternoon ($n = 36$) of three different sampling dates ($n = 24$), planted at different seed densities ($n = 18$), Citra, FL 2015

Source	*Xylocopa* spp.	Species	Total
		Apis mellifera	
26 Aug.	1.2 (0.5)	0 (0) b	1.4 (0.5) b
11 Sept.	1.2 (0.5)	2.8 (0.8) a	4.1 (1.0) a
24 Sept.	0.2 (0.2)	0.1 (0.09) b	0.5 (0.2) b
	$\chi^2 = 5.34$, df = 2, $P = 0.0693$	$\chi^2 = 22.69$, df = 2, $P < 0.001$	$\chi^2 = 15.24$, df = 2, $P = 0.0005$
Morning	0.6 (0.3)	1.9 (0.6) a	2.6 (0.7)
Afternoon	1.1 (0.4)	0.1 (0.08) b	1.4 (0.4)
	$\chi^2 = 1.4$, df = 1, $P = 0.2372$	$\chi^2 = 9.2$, df = 1, $P = 0.0024$	$\chi^2 = 0.92$, df = 1, $P = 0.3374$
SH11	1.6 (0.7)	1.5 (0.9)	3.2 (1.3)
SH11SSG	0.4 (0.2)	1.3 (0.8)	1.8 (0.7)
SH44	0.3 (0.3)	0.7 (0.4)	1.4 (0.5)
SH44SSG	1.2 (0.5)	0.4 (0.2)	1.6 (0.5)
	$\chi^2 = 4.48$, df = 3, $P = 0.2140$	$\chi^2 = 0.38$, df = 3, $P = 0.9443$	$\chi^2 = 0.37$, df = 3, $P = 0.9456$

The plots were planted on 26 June; SH = sunn hemp at 11.2 or 44.8 kg/ha, SSG = sorghum-sudangrass at 22.4 kg/ha. *Xylocopa* spp. include both *X. virginica* and *X. micans*. Means followed by the same letter within each comparison are not significantly different.

Fewer *Xylocopa* spp. visits were seen in the late September observations, but this difference was not significant (Table 1). Visitations of *Xylocopa* spp. were similar in the mornings and afternoons. More visitations of *A. mellifera* and total Hymenoptera were observed in mid-September (71 d postplanting) than in late August or late September (61 or 90 d postplanting, respectively; Table 1). There were many more *A. mellifera* visitations during mornings than afternoons. The number of bees and wasps visiting flowers was not different among plots planted at a high and low seed density and with or without sorghum-sudangrass added ($P > 0.05$). The overall average was 2.0 ± 0.41 ($n = 72$) visits per 2 min. Other bee and wasp species collected included *Megachile mendica* (Cresson) (Megachilidae), *Campsomeris quadrimaculata* (F.), *Campsomeris plumipes fossulana* (F.), *Scolia nobilitata* (F.) (Scoliidae), *Larra bicolor* (F.) (Crabronidae), and *Polistes major* (Beauvois) (Vespidae).

In 2016, the period between planting date and first bloom for both sunn hemp lines was the same: 63, 43, and 44 d for the first, second, and third plantings, respectively. Warmer weather shortened the length of time from planting to blooming for both lines. For the first planting, 'AU Golden' produced many flowers early (Fig. 1), whereas Tillage Sunn had a short and sparse bloom during the period May–June (maximum bloom at 30%) and did not bloom again until mid-October (Fig. 2). For 14 out of the 22 wk for sunn hemp planted in March, 'AU Golden' plots had at least a mean bloom of 50%. Tillage Sunn did not have any weeks with a mean bloom of 50% or more until the second week of October, when the Tillage Sunn plots bloomed at or above 90% for the last 6 wk of the study. For the second and third planting dates, generally high bloom percentages occurred in September for both sunn hemp lines (Figs. 1 and 2). There was a significant correlation between bee visits and percent bloom for each sunn hemp line and planting date ($P < 0.05$), except for 'AU Golden' during the first planting ($P = 0.1678$).

Eight different bee species or species groups were recorded visiting sunn hemp flowers, with 1,879 and 566 visits recorded for 'AU Golden' and Tillage Sunn, respectively. A common species observed in both sunn hemp plots was the carpenter bee *X. virginica*. Other common bee species observed included *X. micans*, *Megachile sculpturalis* Smith, *M. mendica*, and *Megachile georgica* Cresson, *A. mellifera*, *Lasioglossum* sp., *Bombus impatiens*, *Melissodes bimaculata* and *Melissodes communis*. Although wasps and flies were observed crawling over sunn hemp flowers, they did not enter the flowers in a way to initiate pollination and were not counted as flower visitors.

Bee visitation activity throughout the blooming period varied by species (Fig. 3). In general, there were two active periods, early summer and fall, with a reduced number of visits in late summer. Most species/species groups were observed throughout the blooming period, although at lower numbers in the fall. *Xylocopa micans* and *X. Melissodes* were the most abundant bees in the summer, followed by the introduced *M. sculpturalis*. Both *Xylocopa* species peaked at the end of July. Native leafcutting bees (*Megachile* spp.) and *X. virginica* were the most abundant bee visitors in the fall, but *X. micans* was observed only occasionally in late September and early October. Other pollinator species were seen at higher proportions during the fall than summer. These species included *A. mellifera*, *Megachile* spp., *B. impatiens*, and *Melissodes* spp.

Pollinator activity varied by time of day (Table 2). Visitations were significantly greater in the afternoon for *X. virginica, B. impatiens*, and total bees; *Xylocopa micans, M. sculpturalis*, *Megachile* spp., *Melissodes* spp., *Lasioglossum* sp., and *A. mellifera* visited sunn hemp flowers equally during the morning and afternoon. Planting date had a significant effect on the number of bee visits for *X. micans, M. sculpturalis*, *Megachile* spp., and *A. mellifera*. The *Xylocopa* and *Megachile* bees were seen in the earlier planted plots, whereas *A. mellifera* was more common in the sunn hemp planted in July (Table 3). 'AU Golden' plants had more *X. micans*, *X. virginica*, *M. sculpturalis*, and total bee visits; *B. impatiens* and *A. mellifera*, although with low numbers, were more commonly seen visiting the Tillage Sunn plants (Table 4).

Discussion

Pollination of the large yellow papilionaceous flowers of *Crotalaria* 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 and Van Wyk 2012). Pollination generally requires large-bodied bees, such as *Xylocopa* spp. and *Megachile* spp. (Purseglove 1974, Gerling et al. 1989, Sarkar 2004, Jacobi et al. 2005, Brito et al. 2010, Halbrendt 2010, Amaral-Neto et al. 2015). We documented two species of *Xylocopa* and three species of *Megachile*, along with several large-bodied wasps, that visited the flowers and appeared to vibrate the flowers. It is curious that we did not detect *Bombus* spp. active near our plots in Citra, although they were observed making pollination visits (not robbing

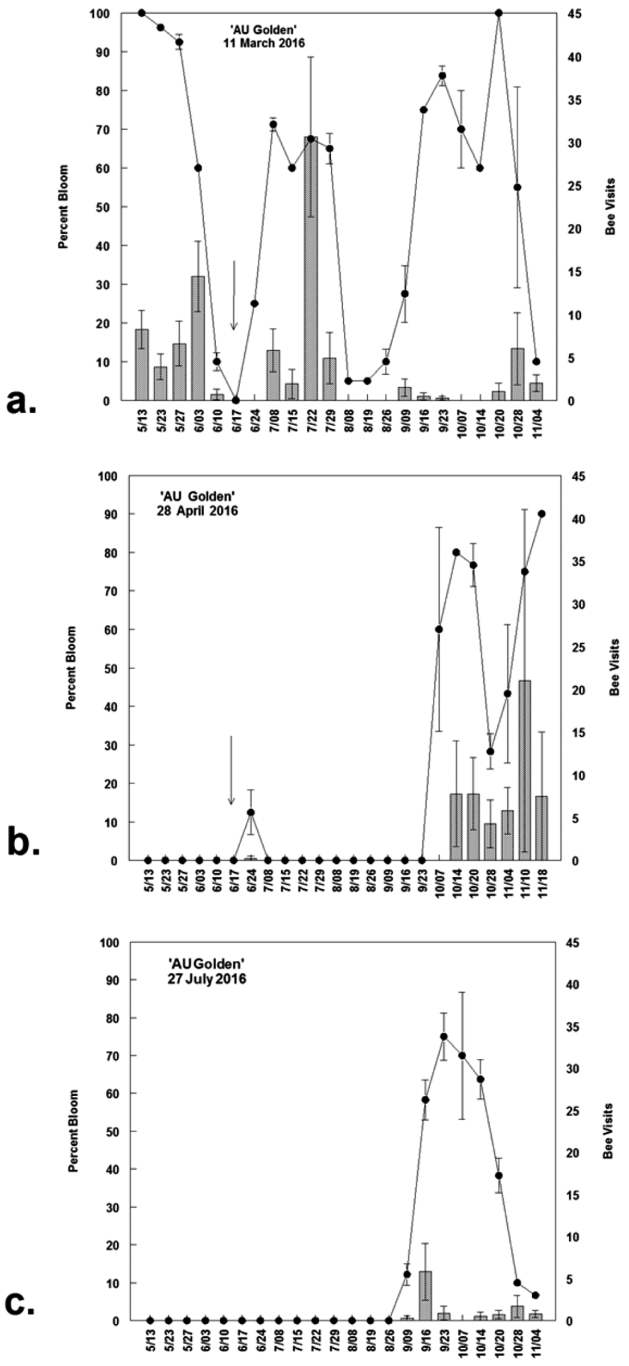

Fig. 1. Mean weekly percent bloom (lines, mean ± SE) of, and bee visits (bars, mean ± SE) to 'AU Golden' flowers by planting date in Tallahassee, Florida. (a) First planting date 11 March 2016; (b) second planting date 28 April 2016; and (c) third planting date 27 July 2016. Means were not transformed. Arrow in (a) and (b) indicates that plants were cut and ratooned. No samples were taken the first week of September or October due to hurricanes.

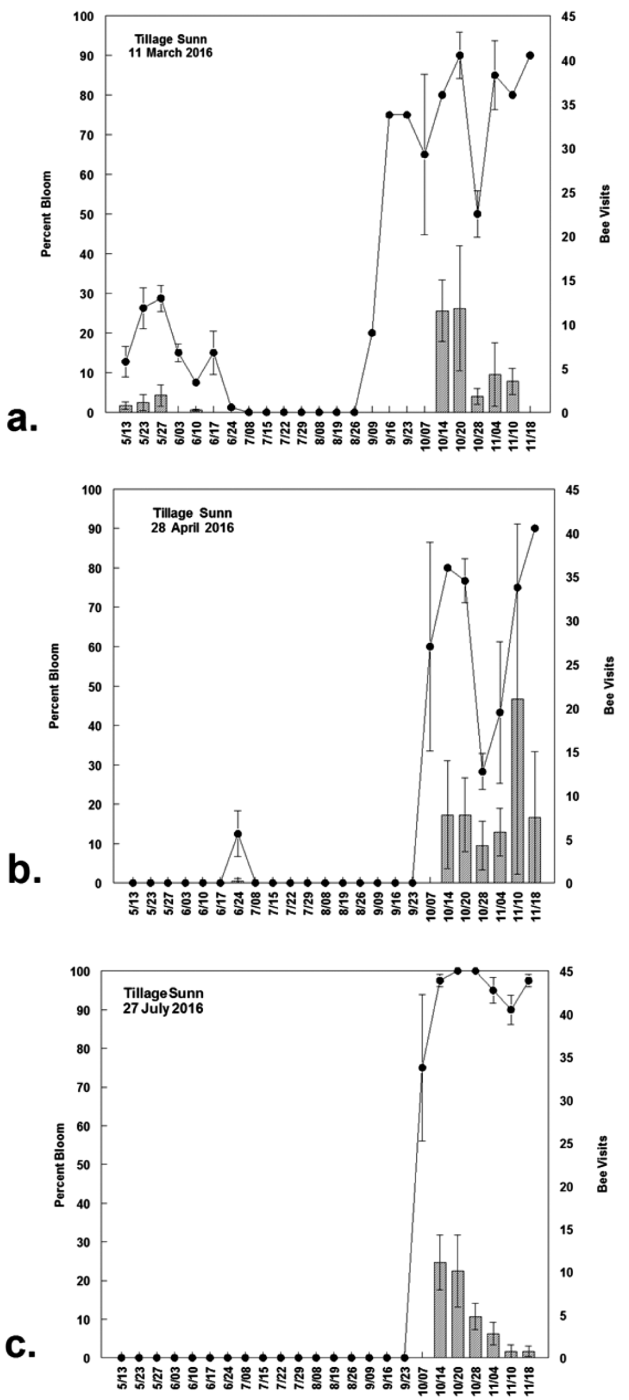

Fig. 2. Mean weekly percent bloom (lines, mean ± SE) of, and bee visits (bars, mean ± SE) to Tillage Sunn flowers by planting date in Tallahassee, Florida. (a) First planting date 11 March 2016; (b) second planting date 28 April 2016; and (c) third planting date 27 July 2016. Means were not transformed. No samples were taken the first week of September or October due to hurricanes.

flowers) in Tallahassee. There are reports from South America that *B. morio* (Swederus) will visit flowers of a sunn hemp relative (*C. vitellina* Ker. Gawl.) (Brito et al. 2010). However, these bees may be acting as nectar thieves (Inouye 1980) by chewing into the side of the flowers, bypassing pollination (Etcheverry et al. 2003, Amaral-Neto et al. 2015).

Our most common sunn hemp visitor, *X. virginica*, has a wide geographical range and reaches further north than any other *Xylocopa* species (Skandalis et al. 2011). The northern populations are univoltine (Balduf 1962; Richards and Course 2015), but populations in Florida may have more than one generation (Howard 1892) and are active longer throughout the season (Hall and Ascher 2010, Skandalis et al. 2011). This bee has a wide host flower range (Gerling et al. 1989, Schlueter and Stewart 2015, Riddle and Mizell 2016) and was previously collected from sunn hemp in North Central Florida (Hall and Ascher 2011). *Xylocopa micans* has a

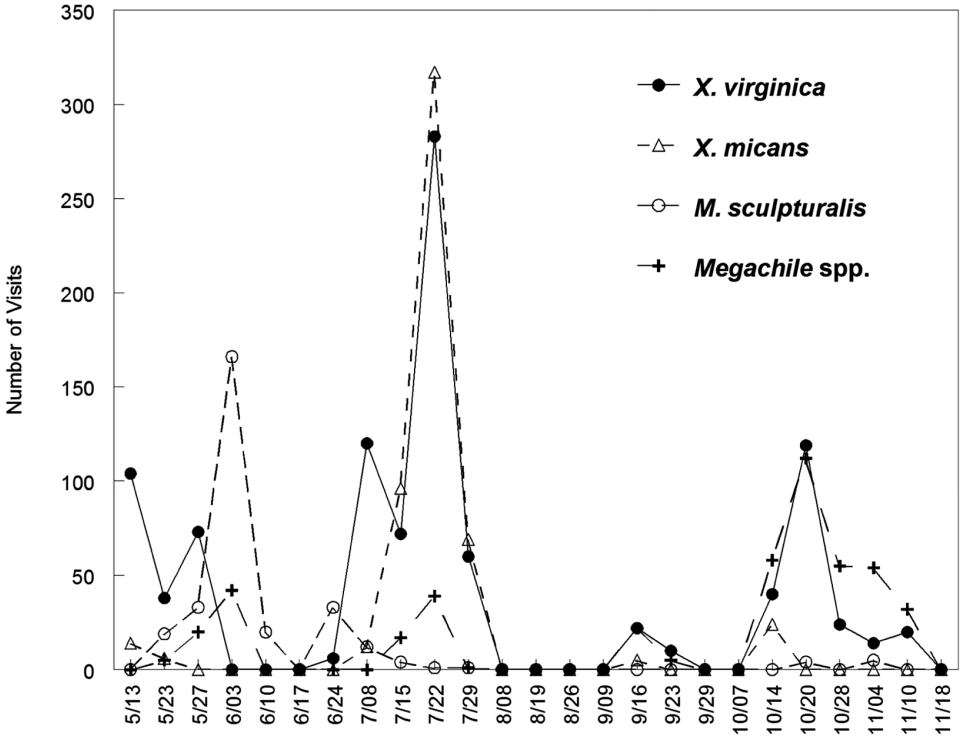

Fig. 3. Total weekly pollination visits to both 'AU Golden' and Tillage Sunn sunn hemp flowers by bee species, Tallahassee, Florida, 2016. A pollinator visit was counted if the insect landed on the flower and either entered the flower or could be seen on the keel moving the flower.

Table 2. Mean (± SE) number of morning (10:00 am) and afternoon (2:00 pm; *n* = 159 and 200, respectively) bee visits to two varieties of sunn hemp flowers

Species	Morning	Afternoon	Kruskal–Wallis (df = 1)
Xylocopa micans	1.5 (0.45)	1.5 (0.55)	$\chi^2 = 0.79$, $P = 0.3731$
Xylocopa virginica	1.7 (0.63) b	3.7 (0.58) a	$\chi^2 = 21.1$, $P < 0.0001$
Megachile sculpturalis	0.2 (0.06)	1.3 (0.53)	$\chi^2 = 0.5$, $P = 0.4990$
Megachile spp.	1.0 (0.29)	1.5 (0.34)	$\chi^2 = 1.5$, $P = 0.2208$
Melissodes spp.	0.04 (0.03)	0.05 (0.03)	$\chi^2 = 1.2$, $P = 0.2775$
Bombus impatiens	0.17 (0.07) b	0.18 (0.1) a	$\chi^2 = 3.9$, $P = 0.0488$
Lasioglossum sp.	0.1 (0.05)	0.2 (0.2)	$\chi^2 = 0.03$, $P = 0.8559$
Apis mellifera	0.3 (0.1)	0.3 (0.1)	$\chi^2 = 1.4$, $P = 0.2344$
Total	4.9 (1.0) b	8.3 (1.0) a	$\chi^2 = 9.0$, $P = 0.0028$

Bee visits to all three planting dates pooled together for both sunn hemp lines, Tallahassee, Florida, 2016. Means followed by the same letter within species are not significantly different.

Table 3. Comparison of the mean number of visits (±SE) by bee species to sunn hemp flowers during three different planting dates (*n* = 169, 108, and 82, respectively), Tallahassee, FL 2016

Species	Planting Dates			Kruskal–Wallis (df = 2)
	11 Mar.	28 April	27 July	
Xylocopa micans	2.3 (0.7) a	1.2 (0.4) a	0.3 (0.3) b	$\chi^2 = 8.8$, $P = 0.0121$
Xylocopa virginica	3.4 (0.8)	2.6 (0.6)	1.6 (0.6)	$\chi^2 = 1.4$, $P = 0.4975$
Megachile sculpturalis	1.5 (0.6) a	0.2 (0.1) b	0.04 (0.04) b	$\chi^2 = 12.9$, $P = 0.0016$
Megachile spp.	0.9 (0.3) b	2.2 (0.6) a	0.7 (0.3) b	$\chi^2 = 7.7$, $P = 0.0209$
Melissodes spp.	0.08 (0.04)	0.03 (0.03)	0 (0)	$\chi^2 = 3.5$, $P = 0.1785$
Bombus impatiens	0.05 (0.03)	0.31 (0.2)	0.27 (0.1)	$\chi^2 = 5.0$, $P = 0.0836$
Lasioglossum sp.	0.2 (0.06)	0.02 (0.02)	0.5 (0.38)	$\chi^2 = 2.8$, $P = 0.2430$
Apis mellifera	0.2 (0.1) b	0.1 (0.06) b	0.7 (0.23) a	$\chi^2 = 10.2$, $P = 0.0062$
Total	8.5 (1.4)	6.8 (1.0)	3.3 (0.6)	$\chi^2 = 2.7$, $P = 0.2572$

Bee visits were pooled for morning and afternoon sample times for both sunn hemp lines. Means followed by the same letter within species are not significantly different.

Table 4. Comparison of the mean number of visits (±SE) by bee species to flowers of 'AU Golden' ($n = 213$) and Tillage Sunn ($n = 146$) plants, Tallahassee, FL 2016

Species	'AU Golden'	Tillage Sunn	Kruskal–Wallis (df = 1)
Xylocopa micans	2.5 (0.6) a	0.2 (0.2) b	$\chi^2 = 21.0$, $P < 0.0001$
Xylocopa virginica	3.7 (0.7) a	1.4 (0.4) b	$\chi^2 = 4.3$, $P = 0.0391$
Megachile sculpturalis	1.2 (0.5) a	0.1 (0.1) b	$\chi^2 = 4.9$, $P = 0.0273$
Megachile spp.	1.1 (0.3)	1.4 (0.4)	$\chi^2 = 0.9$, $P = 0.3557$
Melissodes spp.	0.04 (0.02)	0.05 (0.4)	$\chi^2 = 0.21$, $P = 0.6410$
Bombus impatiens	0.04 (0.02) b	0.4 (0.15) a	$\chi^2 = 5.6$, $P = 0.0178$
Lasioglossum sp.	0.1 (0.04)	0.3 (0.2)	$\chi^2 = 0.3$, $P = 0.5694$
Apis mellifera	0.2 (0.08) b	0.4 (0.1) a	$\chi^2 = 4.3$, $P = 0.0381$
Total	8.8 (1.2) a	3.9 (0.6) b	$\chi^2 = 5.7$, $P = 0.0169$

Means followed by the same letter within species are not significantly different. Bee visits were pooled for all three planting dates and morning and afternoon sample times.

smaller geographic distribution than *X. virginica*, being found from Southeastern Virginia south around the Gulf of Mexico to Texas (Hurd 1955). As with *X. virginica*, it has been collected in North Central Florida as late in the season as October and November (Hall and Ascher 2010). Previous research (McAuslane et al. 1990) determined that males of this species employ different seasonal mating strategies in the southern United States. During the spring, territories are established around floral resources, whereas later in the fall males form leks around nonresource landmarks, such as small hills. This behavior may explain why *X. micans* was observed less often after August in our flower-rich research plots.

Native to Asia, the giant resin bee, *M. sculpturalis*, was an important fraction of the species composition visiting 'AU Golden' sunn hemp. This species was first collected in North America in North Carolina in 1994 (Magnum and Brooks 1997). Since that time its range has expanded rapidly, and it now occurs over most of the Eastern United States from Florida north to Canada (Magnum and Sumner 2003, Hall and Ascher 2010), and west to Kansas (Hinojosa-Díaz 2008). Hall and Avila (2016) found *M. sculpturalis* to be an effective pollinator of sunn hemp, but warned that mutual enhancement of the bee and plant populations could increase the invasive potential of sunn hemp.

Apis mellifera were found in low numbers and do not seem to contribute much to sunn hemp pollination, although managed hives were not near the plots. The nonbee Hymenoptera that where collected, all wasps, are known to visit nectar-bearing plants and drink from flowers to obtain carbohydrates (Krombein 1952, Meagher and Frank 1998, Grissell 2014, Landolt et al. 2014). These species do not collect pollen during floral handling and are thus not consistent or reliable pollinators.

In 2014 plots of 'AU Golden', Tillage Sunn, 'Tropic Sun', and an unknown sunn hemp variety from South Africa were planted in Citra in late April and sampled for flowers and seed pods (Meagher et al. 2017). 'Tropic Sun' and the line from South Africa produced only small numbers of flowers by late September. However, 'AU Golden' seed production yielded an average of 671 kg/ha. Tillage Sunn plants, on the other hand, still contained over 80% developing buds with only 6% of the plants containing seed pods by late September. So even though they were planted at the same time, Tillage Sunn plants did not react the same as 'AU Golden' plants under conditions of longer day lengths in the summer. The March 2016 planting of Tillage Sunn allowed plants to flower, but at a low percentage. High percentages of bloom only occurred in October.

'AU Golden' planted in June and sampled for bees in 2015 averaged a yield of only 30.1 kg/ha, far lower than the yield from plots planted in April (295 kg/ha, Meagher et al. 2017). Although bees were present when we sampled these plots in August and September 2015, we probably would have found larger numbers if we would have sampled the April-planted plots earlier in the season. 'AU Golden' can provide substantial numbers of flowers for several species of pollinators across the growing season. The larger numbers of bees visiting 'AU Golden' reflect their abundant and continued flowering throughout the summer, when most bees are active. In both lines of sunn hemp, relatively large bees in the genera *Xylocopa* and *Megachile* appear to be the most common pollinators in Northern and North Central Florida; however, work is continuing to assess pollinator identification and flower visitation. Although both sunn hemp lines successfully flowered and can provide food and habitat for pollinators and beneficial insects (LeFéon et al. 2013), only the day-neutral 'AU Golden' flowers early enough to produce a seed crop in Northern to North Central Florida.

Acknowledgments

We thank the staff at the University of Florida Plant Science Research and Education Unit in Citra, FL for planting and management of the sunn hemp plots. Thanks also to Cory Stanley-Stahr (EAG Laboratories) and Steven Pelkey (EAG Laboratories), Rachel Mallinger (University of Florida) for identification of the bee and wasp floral visitors, and to Amy Rowley, John Mass, Marcus Edwards, Stephanie Velez, and Rebecca Rabinowitz (USDA-ARS) for technical support. The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the United States Department of Agriculture or the Agricultural Research Service of any product or service to the exclusion of others that may be suitable. This work was supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under Agreement No. 2011-67003-30209.

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