Final Report: Best Management Practices for Pollinator Habitat in the Southeast U.S.

1 INTRODUCTION AND BACKGROUND

Bee communities are important to the pollination of over 66% of the world's crop species (Roubik 1995) and over 80% of all flowering plant species (Moisset and Buchmann 2010). Many native and endemic plants depend on the specialized pollination services of native bees and other important pollinating insects (Moisset and Muchmann 2010). Currently, a high level of uncertainty exists regarding the status of native bee communities throughout the United States, and concern for declines in both managed and native bee populations has sparked scientific evaluations at the national level (Koh et al. 2016). Koh et al. (2016) modeled bee abundance declines of 23% between 2008 and 2013. This decline has been shown to be associated with conversion of natural habitats to row crops (Koh et al. 2016). The provision of sufficient forage has been shown to be a key element in supporting and promoting native bee populations within human impacted landscapes (Williams et al. 2015). Recent government incentives in the United States have promoted the planting of native wildflowers to benefit pollinators, yet the testing of specific plants and their ability to attract and support wild bee abundance and diversity has been lacking (Williams et al 2015). The Natural Resources Conservation Service (NRCS) commonly recommends a list of wildflower species for landowners to plant to attract native bees, yet the attractiveness of the wildflower species has not been scientifically evaluated. The purpose of this study is to investigate the efficacy of pollinator habitat established by the NRCS and Farm Service Agency (FSA) Farm Bill-supported programs, and to determine which native wildflowers recommended by the NRCS are the most attractive to the native bees of Alabama.

2 OBJECTIVES

Since 2008, the NRCS and the FSA have promoted pollinators through compensating practices throughout Alabama that create suitable habitat for native bees on private lands. Little is known about the phenology of these sites in terms of the wildflowers that persist there and the native bees that utilize them. Furthermore, little is known about which wildflowers species are the most attractive to native bees.

- ***Research objective 1***- Evaluate the status of already established NRCS and FSA-sponsored pollinator habitat in Alabama.

- ***Research objective 2-*** Investigate Best Management Practices for pollinator habitat through experimental plantings in Alabama.
- ***Research objective 3-*** Evaluate the attractiveness of different wildflower species to native bees through experimental plantings in Alabama.

3 METHODS

Objective 1:

Site Selection

Seventeen sites were selected throughout North, Central, and South Alabama occurring within Baldwin, Coosa, Franklin, Geneva, Jackson, Lauderdale, Mobile, and Pickens County (Figure 3-1). All wildflower plots were established on private land between 2012 and 2018 and were greater than 0.5 acres in size. At each site, landowners planted a mixture of wildflower species that were recommended by the NRCS. Each wildflower seed mixture contained at least three spring, summer, and fall blooming wildflower species to provide constant forage for native bees throughout the year.

Vegetation Monitoring

Vegetation sampling was performed at each site during the summer and fall of 2018 and the spring of 2019. We followed vegetation-sampling protocols found within Pywell et al. (2014), with modifications. For example, Pywell et al. (2014) sampled vegetation by means of twenty 0.5 X 0.5 m quadrats randomly positioned within a field following a linear 100 m transect, whereas, we placed forty 1.0 m^2 quadrats spaced by 1.0 m along a linear 200 m transect in the center of each wildflower plot (Figure 3-2). Each established wildflower plot differed in size and shape. Therefore, the number of quadrats was scaled as a proportion of the total acreage of each wildflower plot (forty 1 m^2 quadrats per 2.5 acres), and transects were meandered as to remain centered within each wildflower plot. For each 1 m^2 quadrat, we calculated the percent cover for bare ground, grass, woody vegetation, forbs, and wildflowers as a subset of forbs. Bare ground was defined as bare dirt without any living or dead vegetation. Grass was defined as any grasses present; woody vegetation was defined as any woody vegetation including tree species and dead limbs or sticks. Forbs were defined as any herbaceous flowering plant other than a grass, and wildflowers were defined as any wildflower species the landowner planted in their seed mix that was present in its vegetative or blooming state. In addition to the vegetation assessments, we also recorded if any blooming wildflower species were present (both planted and naturally occurring) within each quadrat as well as the total number of flowers for each species. A pairwise correlation matrix was performed in R. to investigate all pairwise correlations between the percent cover types.

Bee Monitoring

We performed bee sampling at each site during the summer and fall of 2018 and during the spring of 2019. Bees were netted while walking along a transect within the wildflower plot. For each 2.5 acre wildflower plot, we spent 20 minutes sweep netting and identifying bees along a 200 m transect. We walked along the transect and sweep netted bees that were observed visiting wildflowers that were within 1 m of each side of the transect (Figure 3-3). For each bee netted, the wildflower species the bee was visiting was noted and the bee was either identified in the field when possible or stored in ethanol to be identified in the lab. Each collected bee was pinned, identified, and databased.

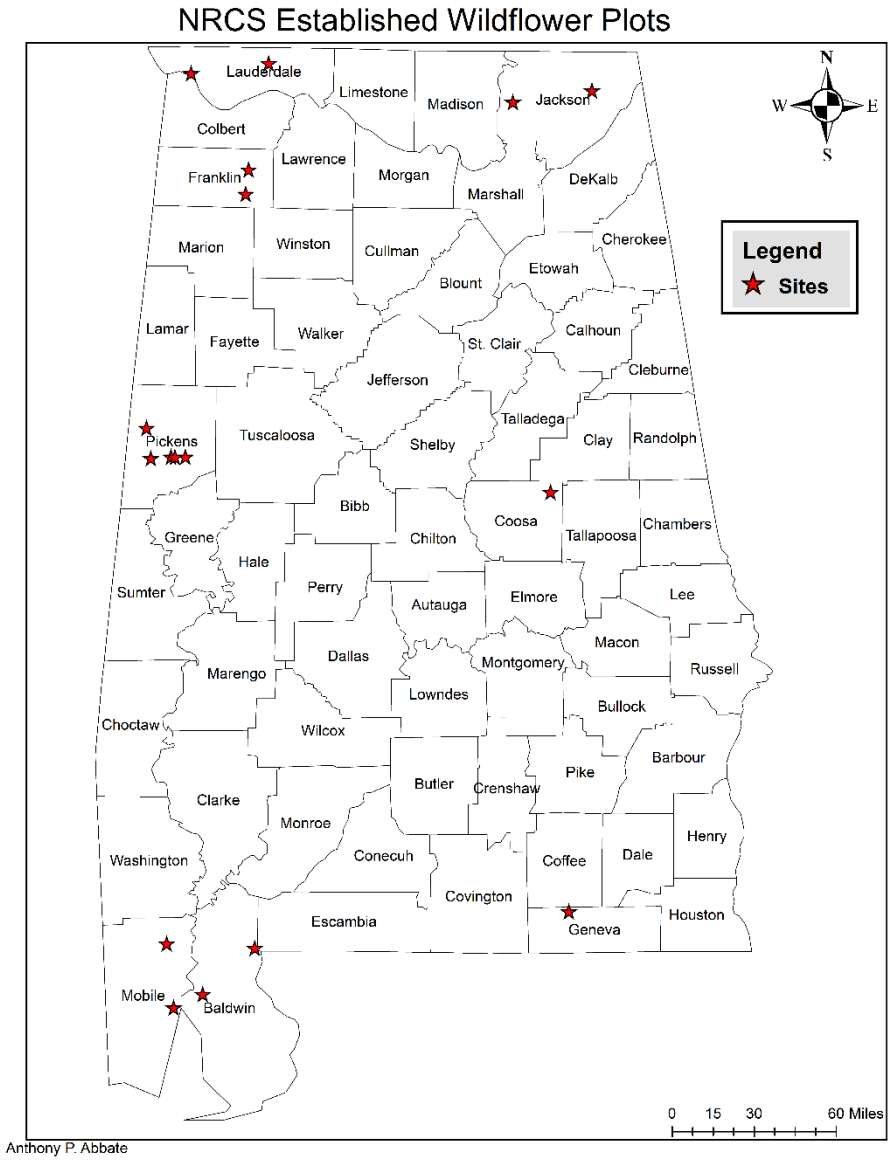

Figure 3-1. Seventeen established NRCS wildflower sites occurring throughout southern, central, and northern Alabama.

Figure 3-2. *Helianthus angustifolius* blooms within a 1 m^2 quadrat. The percent cover (bare ground, grass, woody vegetation, forbs, and wildflowers) was calculated for each 1 m^2 quadrat, and the total number of blooms were counted for each flowering plant species.

Figure 3-3. Sweep netting transect established within a wildflower plot in Coosa County, Alabama. Bees observed visiting blooms within 1 m of each side of the transect were netted and identified. The length and time spent sweep netting bees were scaled depending upon the size of the wildflower plot.

Objective 2:

Site Selection and experimental design

Three sites were chosen to conduct experimental wildflower plantings in Lee, Tallapoosa, and Macon Counties (Figure 3-4) and were established in the fall of 2017. The wildflower plot in Lee County was established at the Auburn University Poultry and Animal Nutrition center in Auburn, Alabama, and had previously been maintained as a lawn. The Tallapoosa county wildflower plot was established at Auburn University's Piedmont Research Unit in Camp Hill, Alabama, and had been previously used as pastureland. Lastly, the wildflower plot in Macon County was established at Auburn University's E.V Smith Research Center and had been used as an agricultural site where they rotated soybean, corn, peanut, and other agricultural crops. The soil types occurring within the Poultry, Camp Hill and EV Smith sites were Piedmont, Piedmont, and Coastal Plain, respectively. Each site was treated with glyphosate (max rate with TopTurf Surfactant) in early November of 2017 and treated again in late March to kill all present vegetation. All sites were disked in March 2018 to ready the soil for seeding.

Twenty-four species of wildflowers were chosen to investigate best management practices for establishing and maintaining wildflower plots (Table 3-1). The wildflower species were chosen based upon their seed availability, price, native status, sun and water requirements, lack of pollinator information in the literature, and lack of knowledge of successful establishment post seeding as well as recommendations by NRCS and Roundstone Native Seed LLC. Each established wildflower plot was approximately 30 m X 30 m, and wildflowers were planted in a grid pattern alternating each row by 1 m^2 and 1.5 m^2 (Figure 3-5). Each 1 m^2 plot was used to plant each individual wildflower species with 6 replicates per species (total of 144 1 m^2 plots per site). Each 1.5 m^2 space between the 1 m^2 wildflower plots was designated as a buffer (Figure 3-5). Before the planting of seeds, the surface of the recently disked soil was compacted with a seedbed roller (Figure 3-6). Seeds were then spread over the surface of the dirt at specific seeding rates provided by Roundstone Native Seed LLC (Table 3-1) and were compacted again with a seedbed roller to optimize seed/soil contact. Site visits and best management recommendations were given by the NRCS throughout the two growing seasons. Based upon best management recommendations, a select 2EC herbicide was applied throughout the growing season to limit competition between the wildflower species and unwanted grass species. The select 2EC herbicide was applied when grasses within the wildflower plots reached a height of 6”. The select 2EC herbicide was not applied to any *Eryngium yuccifolium* plots as this particular wildflower is damaged by the herbicide. Additionally, any invasive, fast-growing plants were hand pulled on a weekly basis throughout the year to limit competition with the wildflower species. They included Bermuda grass (*Cynodon dactylon*), Chinese Tallow (*Triadica sebifera*), Johnson Grass (*Sorghum halepense*), Pokeweed (*Phytolacca Americana*), and Sicklepod (*Cassia obtusifolia*). At the end of the fall season once all wildflowers went to seed, we mowed each wildflower plot to a vegetation height of 6’’.

Vegetation Monitoring

Vegetation sampling was performed every 3 to 4 weeks from June to November of 2018 and 2019. During each sampling event, we calculated the percent cover for bare ground, grass, woody vegetation, forbs, and wildflowers as a subset of forbs within each 1 m^2 wildflower plot. The number of flowers for each wildflower species within each 1m^2 plot was also totaled.

Bee Monitoring

Bee surveys were conducted weekly from June to November of 2018 and again from June to November 2019 when wildflowers were in bloom. For each 1m^2 plot that contained blooming wildflowers, we spent 10 minutes monitoring the flowers and sweep netted any visiting bees. All bees sweep netted during the survey were stored in plastic vials to avoid multiple counts of a single insect. If the bee could be identified in the field, the species was recorded along with the plot number and date of capture and was then released at the end of the ten-minute survey. Bees that could not be identified in the field were stored in ethanol along with the plot number and date, and were later pinned, identified, and added to the database in the laboratory.

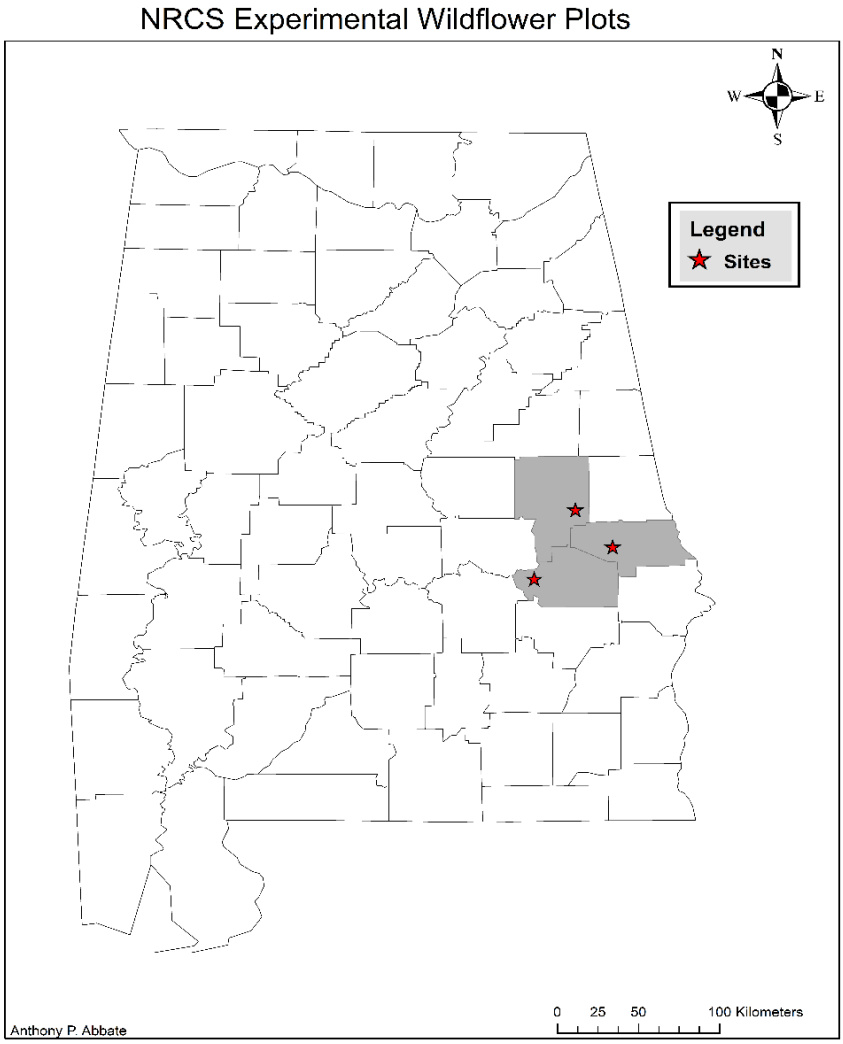

Figure 3-4. NRCS Experimental Wildflower plots within Lee (Poultry), Tallapoosa (Camp Hill), and Macon Counties (EV Smith).

Table 3-1. The twenty-four wildflower species and their seeding rates chosen to be planted within the experimental wildflower plots in Lee (Poultry), Tallapoosa (Camp Hill), and Macon Counties (EV Smith).

Species Number	Binomial Name	Common Name	Seeding rate ($g/1m^2$)
1	*Asclepias tuberosa*	Butterfly Milkweed	0.44
2	*Symphyotrichum pilosum*	Heath Aster	0.27
3	*Baptisia alba*	White Wild Indigo	0.98
4	*Chamaecrista fasciculata*	Partridge Pea	0.98
5	*Chamaecrista nictitans*	Small Partridge Pea	0.49
6	*Coreopsis tinctoria*	Plains Coreopsis	0.31
7	*Coreopsis tripteris*	Tall Coreopsis	0.57
8	*Dalea candida*	White Prairie Clover	0.47
9	*Dalea purpurea*	Purple Prairie Clover	0.42
10	*Desmanthus illinoensis*	Illinois Bundleflower	0.49
11	*Desmodium floridanum*	Florida Ticktrefoil	0.98
12	*Eryngium yuccifolium*	Rattlesnake Master	0.76
13	*Eupatorium roundifolium*	Roundleaf Throughwort	0.24
14	*Gaillardia pulchella*	Blanket flower	0.78
15	*Helenium autumnale*	Sneezeweed	0.24
16	*Helianthus angustifolius*	Narrow-Leaved Sunflower	0.37
17	*Lespedeza violacea*	Violet Lespedeza	0.56
18	*Monarda fistulosa*	Bergamot	0.24
19	*Monarda punctata*	Spotted Beebalm	0.20
20	*Ratibida pinnata*	Greyheaded Coneflower	0.41
21	*Rudbeckia amplexicaulis*	Clasping Coneflower	0.31
22	*Solidago rugosa*	Rough Goldenrod	0.30
23	*Verbesina alternifolia*	Yellow Wingstem	0.67
24	*Verbesina virginica*	White Wingstem	0.47

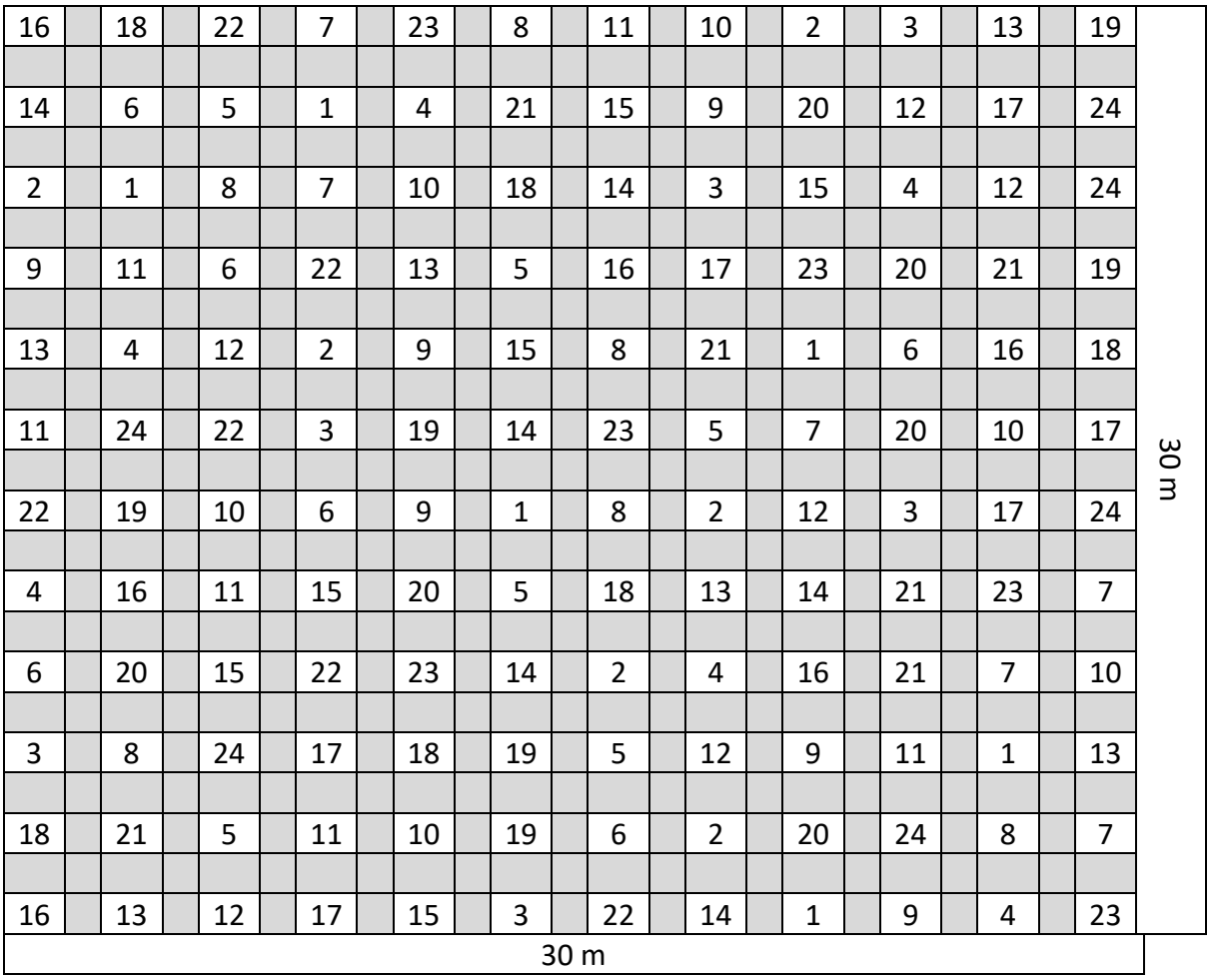

Figure 3-5. Experimental design of wildflower plots at Lee (Poultry), Tallapoosa (Camp Hill), and Macon Counties (EV Smith). Numbers correspond to wildflower species in Table 3-1. Shaded areas represent 1.5 m^2 buffers while unshaded areas with numbers represent 1 m^2 wildflower subplots.

Figure 3-6. Experimental wildflower plot at Poultry (Lee County); recently rolled with a seedbed roller in preparation for seeding wildflowers. Unrolled areas (darker rows) between wildflower plots represent the 1.5 m^2 buffers.

Objective 3:

Site Selection and experimental design

In the spring of 2019, an additional wildflower plot was established at the Auburn University Poultry and Animal Nutrition center in Auburn, Alabama. Eighteen mature wildflower species (Table 3-2) were sourced from a nursery in Florida and were transplanted in a randomized block design with four replicates per species (Figure 3-7). The number of mature wildflowers transplanted per 1 m^2 ranged from four to nine plants to achieve one hundred percent vegetation cover within the 1 m^2 plot, depending on the growth habit of each individual wildflower species. The plot layout followed the plot measurements of the established wildflower plots in Lee, Tallapoosa, and Macon Counties with each subplot and buffer being 1 m^2 and 1.5 m^2 in size, respectively. After all wildflowers were transplanted, a sheet of Kraft paper was placed on the ground around each plant, and mulch was placed on top of the Kraft paper to help retain soil moisture and prevent the growth of grasses and weeds. All wildflowers were heavily watered at the time of transplant and were watered every four days for three weeks after transplanting to ensure their survival.

Table 3-2. The eighteen wildflower species chosen to be planted as mature plants at the Auburn University Poultry and Animal Nutrition center in Auburn, Alabama, with planting rates per 1 m^2.

Species Number	Binomial Name	Common Name	Plants/1 m^2
1	*Asclepias tuberosa*	Butterfly Milkweed	6
2	*Symphyotrichum pilosum*	Frost Aster	4
3	*Baptisia alba*	White Wild Indigo	4
4	*Chamaecrista fasciculata*	Partridge Pea	4
5	*Chamaecrista nictitans*	Sensitive Partridge	9
6	*Coreopsis lanceolata*	Lance-leaved	9
7	*Desmanthus illinoensis*	Illinois Bundleflower	9
8	*Desmodium floridanum*	Florida Ticktrefoil	9
9	*Echinacea purpurea*	Purple Coneflower	9
10	*Eryngium yuccifolium*	Rattlesnake Master	4
11	*Gaillardia pulchella*	Blanket flower	5
12	*Helianthus angustifolius*	Narrow-Leaved	4
13	*Monarda fistulosa*	Bergamot	4
14	*Monarda punctata*	Spotted Beebalm	4
15	*Ratibida pinnata*	Greyheaded	4
16	*Rudbeckia hirta*	Black-eyed Susan	9
17	*Solidago rugosa*	Wrinkled-Leaved	4
18	*Verbena hastata*	Blue Vervain	5

Flower and Bee Monitoring

During the growing season, we monitored and recorded the number of blooms in any 1 m^2 plots that contained blooms on a weekly basis from May to November 2019. Any plots containing at least one flower were surveyed for 10 minutes documenting any visiting bees. All bees observed visiting the flowers of the planted wildflower species were netted and stored in plastic 5 mL vials for the duration of the 10-minute survey as to not count any bee twice. After the ten-minute survey the bees were either identified in the field and released or placed in a cooler and brought back to the lab to be pinned, identified, and databased. Identifying information such as plot number, date, and time of day was recorded for each netted bee.

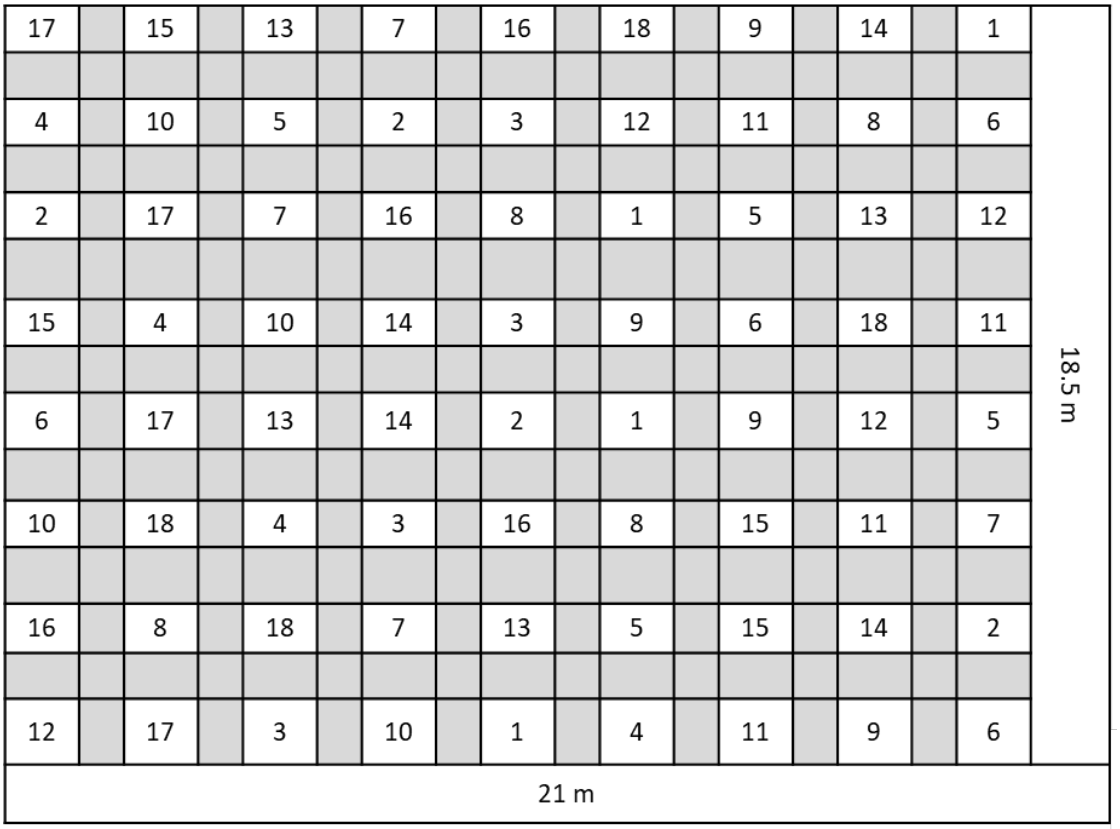

Figure 3-7. Arrangement of the 18 wildflower species planted as mature potted plants in a randomized block design at the Poultry Science Building at Auburn University.

4 RESULTS

Objective 1: Results

Vegetation Monitoring

Of the 59 wildflower species planted by landowners, we observed only 17 wildflower species in bloom and across all sites (Table 4-1). Thirteen wildflower species planted across all sites had a high rate of success (>50% occurrence in blooming state across sites) and they included *Chamaecrista fasciculata, Chamaecrista nictictans, Coreopsis lanceolata*, *Coreopsis tinctoria, Helianthus angustifolius, Monarda citriodora, Penstemon digitalis, Pycnanthemum tenufolium, Rudbeckia hirta, Solidago nemoralis, Symphyotrichum novae-angliae, Tephrosia virginiana,* and *Verbena hastata* (Table 4-1).

The vegetation surveys revealed that across all sites that the percentage of bare ground was approximately 10%, grasses were about 35%, and woody vegetation was <10%. Forbs covered about 50% (Figure 4-1), with wildflowers making up about 25% of the forbs (Figure 4-2). Sites that contained high percentages of grasses within the wildflower plots contained lower percentages of forbs. Through a correlation matrix, significant correlations were observed between multiple cover types (Figure 4-3). The strongest correlation was observed between the percentage of grasses and forbs. For each 1% increase in the coverage of grass, we observed a 0.73% decrease in forbs ($P<0.001$, $r^2=0.73$) (including wildflowers).

Bee Monitoring

A total of 589 bees belonging to 44 taxa were captured during the summer and fall of 2018, and the spring of 2019 (Table 4-2). *Bombus* spp. was the most abundant taxon collected, followed by *Lasioglossum* spp., *Apis mellifera*, *Bombus impatiens*, and *Halictus poeyii*. Flowers of plants in the genus *Solidago* attracted the greatest abundance of bees followed by *Coreopsis lanceolata*, *Verbena* spp., and *Passiflora incarnate*, with *Coreopsis lanceolata* attracting the greatest diversity of bee species followed by *Verbena* sp., *Solidago* spp., *Rudbeckia hirta*, *Helianthus angustifolius* (Table 4-2).

Table 4-1. Summary table of the vegetation surveys completed during the summer and fall of 2018 and the spring of 2019. The top row of the table represents the wildflowers that were planted by the landowners (landowner properties along the left column). An "X" represents that the landowner planted that particular species of wildflower, and an "X" that is colored in green represents that the flowering state was observed during the spring, summer, or fall. Species with an asterisk (*) are the author's recommendations because they either had a high occurrence rate across field sites (along the bottom of the figure) or they were observed to attract an abundance and diversity of native bees.

Site	Date Planted	*Chamaecrista nictictans*	*Monarda citriodora*	*Tephrosia virginiana*	*Solidago nemoralis*	*Chamaecrista fasciculata**	*Rudbeckia hirta**	*Pycnanthemum tenuifolium**	*Coropsis lanceolata**	*Verbena hastata**	*Coreopsis tinctoria**	*Helianthus angustifolius**	*Penstemon digitalis*	*Symphyotrichum novae-angliae*	*Asclepias tuberosa**	*Echinacea purpurea**	*Liatris*	*Ratibida pinnata*	*Achillea millefolium*	*Asclepias syriaca*	*Aster laevis*	*Baptisia australis*	*Baptisia tinctoria*	*Centrosema virginianum*	*Cichorium intybus*	*Coreopsis grandiflora*	*Coreopsis leavenworthii*	*Coreopsis pulchra*	*Coreopsis tripteris*	*Dalea purpurea*	*Desmanthus illinoensis*
Tallapoosa	2016						**X**		X						**X**									X							
F298	2016					**X**	**X**		**X**		**X**					**X**															X
F612	2018					**X**	**X**		**X**							X															X
F4252	2016					**X**	**X**		X						X	X	X	X	X	X		X				X					
F4195 T13551	2016					**X**	**X**		X							X	**X**			X		X									
F6417 T6096	2013					X	**X**		**X**	**X**	**X**	X	X	X	X	X				X											X
F3141 T9812	2016				**X**	**X**	**X**	**X**	**X**	**X**						**X**															X
F2054	2016					**X**	**X**	**X**	**X**	**X**		**X**				X															X
F2904	2016					**X**	**X**	X	**X**	**X**		X				X															X
F1958	2017					**X**	**X**		**X**	X	**X**					**X**					X										X
F9898 T12512	2015						X		**X**		**X**				X	X															
F9898 T12513	2015								**X**		X				X	X															
F10171	2016					**X**	**X**		X	X	**X**	X				**X**															X
F3635 T10531	2011					**X**	X									X		X													X
F3497	2016		**X**			**X**	**X**		**X**		X			**X**	**X**	X	X	X	X								X	X		X	X
F1977 T 2517	2015	**X**					**X**		**X**	**X**		**X**				**X**													X		X
F1534	2012					**X**	**X**		**X**		X					**X**									X						X
F8864 T13299	2017			**X**		**X**	**X**	**X**	X	X	X	**X**	**X**		**X**	X		**X**					X	X							
Total Sites Planted		1	1	1	1	14	17	4	17	8	9	6	2	2	7	17	3	4	2	3	1	2	1	1	1	1	1	1	1	1	12
% flowers present		100	100	100	100	93	88	75	71	63	56	50	50	50	43	35	33	25	0	0	0	0	0	0	0	0	0	0	0	0	0

Site	Date Planted	*Desmodium canadense*	*Desmodium perplexum*	*Dracopis amplexicaulis*	*Eryngium yuccifolium*	*Eupatorium perfoliatum*	*Eutrochium purpureum*	*Gaillardia pulchella**	*Gilia*	*Helianthus maximiliani*	*Helianthus sp.*	*Heliopsis helianthoides*	*Monarda citriodora*	*Liatris spicata*	*Lobelia cardinalis*	*Lupinus*	*Lupinus perennis*	*Monarda fistulosa**	*Monarda punctata**	*Phlox*	*Pycnanthemum pilosum*	*Ratibida columnifera*	*Salvia splendens*	*Solidago altissima*	*Solidago stricta*	*Symphyotrichum lateriflorum*	*Symphytrichum ericoides*	*Trifolium repens*	*Verbesina virginca*	*Vernonia*
Tallapoosa	2016		X											X																
F298	2016									X												X								
F612	2018																													
F4252	2016	X			X		X					X	X				X	X			X									X
F4195 T13551	2016	X			X							X				X													X	
F6417 T6096	2013					X						X			X	X		X											X	
F3141 T9812	2016									X																				
F2054	2016																													
F2904	2016																								X					
F1958	2017																							X						
F9898 T12512	2015																													
F9898 T12513	2015																													
F10171	2016																							X						
F3635 T10531	2011											X		X				X												
F3497	2016		X	X	X			X	X							X			X	X			X							
F1977 T 2517	2015																									X				
F1534	2012										X																	X		
F8864 T13299	2017									X		X		X				X							X		X			
Total Sites Planted		2	2	1	3	1	1	1	1	3	1	5	1	3	1	3	1	4	1	1	1	1	1	2	2	1	1	1	2	1
% flowers present		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

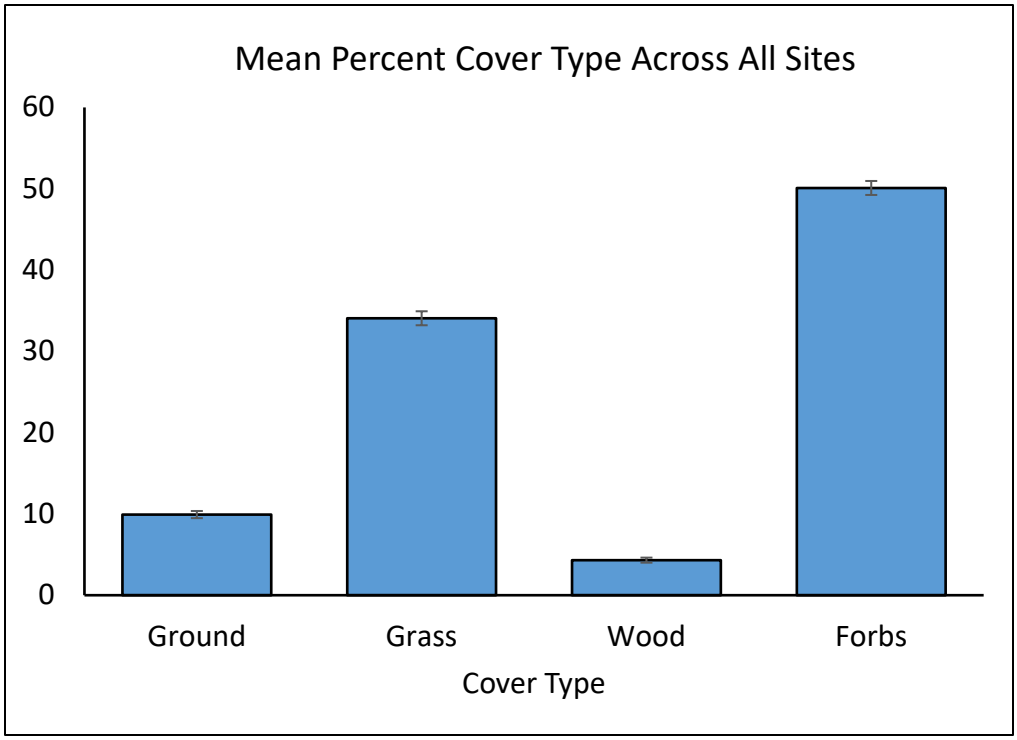

Figure 4-1. Mean cover type across all NRCS landowner wildflower plots over the summer and fall of 2018, and the spring of 2019.

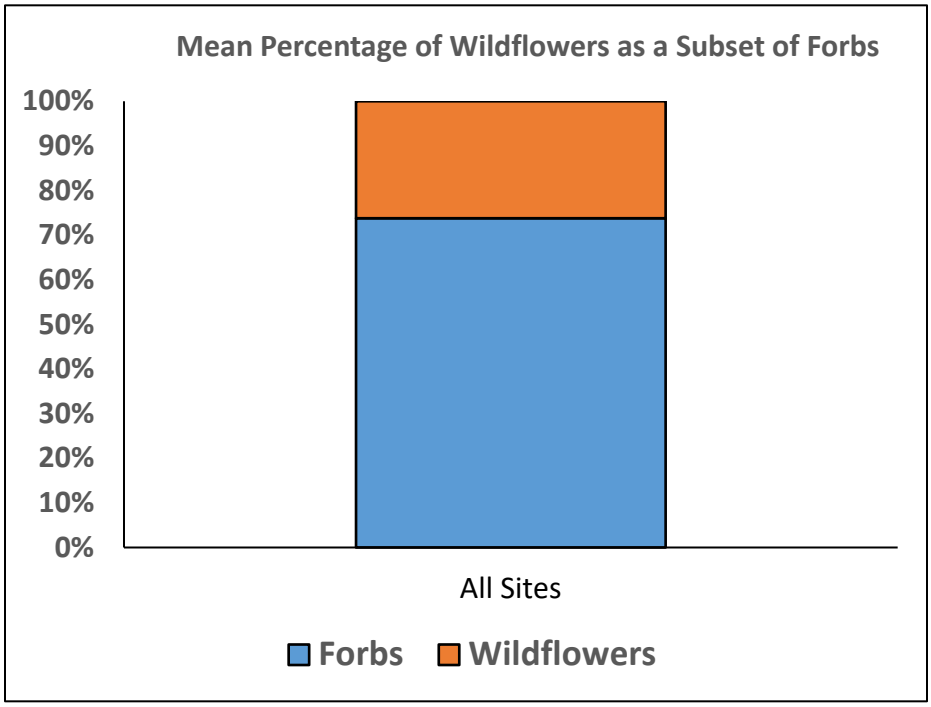

Figure 4-2. Graph shows the percentage of wildflowers as a subset of forbs with all sites pooled.

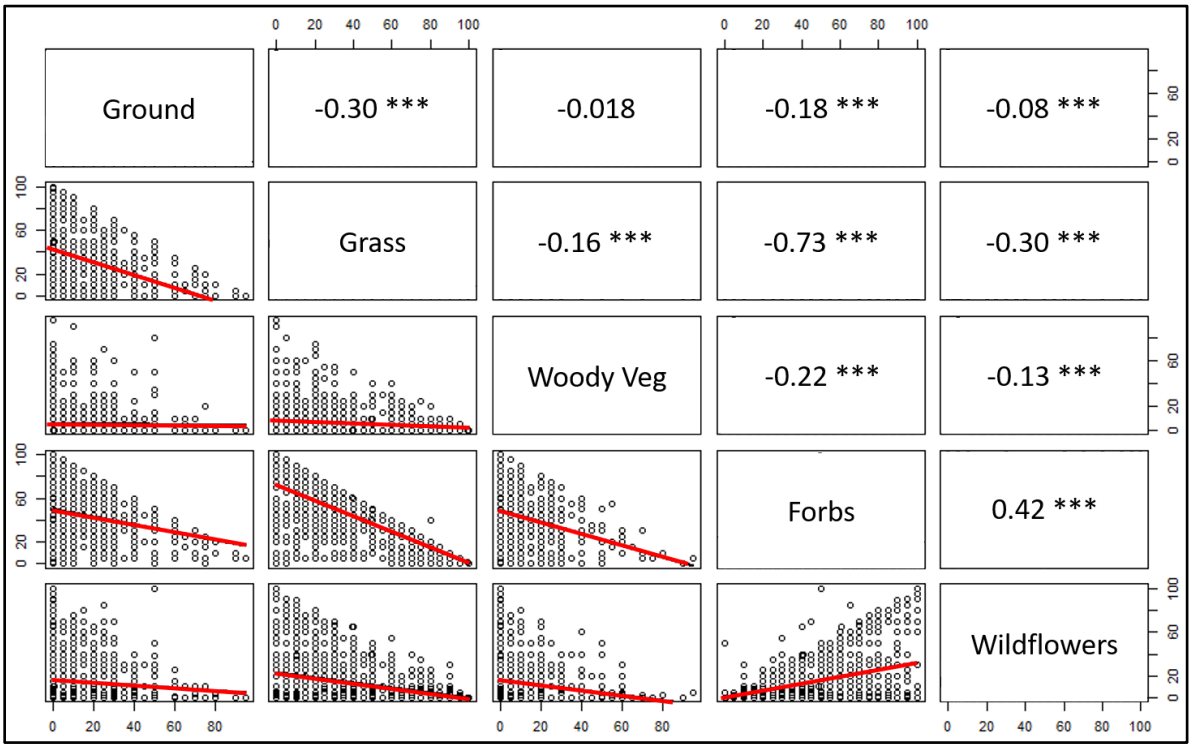

Figure 4-3. Correlation matrix for all vegetation cover types across all 18 experimental sites. Both X- and Y-axis represent the percent cover for each cover type. Numerical values on the upper panel of the figure are the R-squared values followed by a significance level. P-values (0, 0.001, >0.05) = (***, **," ")

Table 4-2. The total number of bee taxa visits to each wildflower species from the summer and fall of 2018 and the spring of 2019 across all NRCS Statewide wildflower plots.

Bee Taxon	*Agalinis purpurea*	*Agalinis tenufolia*	*Asclepias* spp.	*Asclepias tuberosa*	*Chamaecrista fasciculata*	*Chrsium vulgare*	*Coreopsis lanceolata*	*Coreopsis sp.*	*Coreopsis tinctoria*	*Cymphotrichum* spp.	*Daucus carota*	*Echinacea purpurea*	*Erigeron strigosus*	*Eryngium yuccifolium*	*Galactia volubilis*	*Helianthus angustifolius*	*Lespedeza cuneata*	*Mimosa* microphylla	*Mitracarpus hirtus*	*Molsa dianthera*	*Monarda citriodora*	*Monarda fistulosa*	*Parthenium integrifolium*	*Passiflora incarnata*	*Penstamon digitalis*	*Plantago* spp.	*Pycnanthemum tenufolium*	*Ranunculus bulbosus*	*Rudbeckia hirta*	*Solanum carolinense*	*Solidago* spp.	*Solidago virgaurea*	*Symphytrichum patens*	*Tephrosa virginica*	*Unknown*	*Verbena* spp.	# of Wildflowers visited	Total Bees
Agapostemon sericeus																1																					1	1
Agapostemon splendens		1					1																														2	2
Agapostemon virescens																															1					1	2	2
Andrena gardineri																												1									1	1
Andrena rudbeckiae																													2								1	2
Anthidellum perplexum																			1																		1	1
Anthophora bomboides																									5												1	5
Apis mellifera				1	4		2									1															90	4				6	7	108
Augochlorops is metallica																																				3	1	3
Bombus auricomus						1																															1	1
Bombus bimaculatus																								1	2	1					1					1	5	6
Bombus griseocolis		1		10	1	1	1					1				1								2		4				1							10	23
Bombus impatiens		1			5																3	2		23			2				6					6	8	48
Bombus pensylvanicus					1																														2	2	3	5
Bombus sp.		10					12									4															100					2	5	128
Ceratina calcarta							1																						2								2	3
Ceratina strenua							2																														1	2
Coelioxys germanus																																				1	1	1
Halictus parallelus							4																						3								2	7
Halictus poeyi							20	1		3		1		1		6							1						4		3		1			6	11	47

Bee Taxon	*Agalinis purpurea*	*Agalinis tenufolia*	*Asclepias* spp.	*Asclepias tuberosa*	*Chamaecrista fasciculata*	*Chrsium vulgare*	*Coreopsis lanceolata*	*Coreopsis sp.*	*Coreopsis tinctoria*	*Cymphotrichum* spp.	*Daucus carota*	*Echinacea purpurea*	*Erigeron strigosus*	*Eryngium yuccifolium*	*Galactia volubilis*	*Helianthus angustifolius*	*Lespedeza cuneata*	*Mimosa* microphylla	*Mitracarpus hirtus*	*Molsa dianthera*	*Monarda citriodora*	*Monarda fistulosa*	*Parthenium integrifolium*	*Passiflora incarnata*	*Penstamon digitalis*	*Plantago* spp.	*Pycnanthemum tenuifolium*	*Ranunculus bulbosus*	*Rudbeckia hirta*	*Solanum carolinense*	*Solidago* spp.	*Solidago virgaurea*	*Symphytrichum paters*	*Tephrosa virginica*	*Unknown*	*Verbena* spp.	# of Wildflowers visited	Total Bees
Halictus rubicundus							1																													1	1
Hoplitis pilosifrons							1																													1	1
Hylaeus affins																															1					1	1
Lasioglossum sp.		3		1	8		15	1	1	1	1		8			3				3					1				4		64					14	114
Megachile brevis			1										1		1		1																	2			5	6
Megachile campanule																																		3			1	3
Megachile gemula																																		1			1	1
Megachile mendica							1												3																	9	3	13
Megachile parallela																															1						1	1
Megachile petulans																1	1																	1		5	4	8
Megachile relativa							1																														1	1
Megachile rotundata							2																														1	2
Megachile sp.	1																																				1	1
Megachile texana																													2								1	2
Megachile xylocopoides				1			1																						2								3	4
Melissodes bimaculatus																		1	1																		2	2
Melissodes communis																								1					1							1	3	3
Melissodes dentriculatus							1																														1	1
Melissodes trinodis																2																					1	2
Osmia bucephala						1																															1	1
Osmia georgica							7																														1	7
Stelis sp.																																			1		1	1

Bee Taxon	*Agalinis purpurea*	*Agalinis tenufolia*	*Asclepias* spp.	*Asclepias tuberosa*	*Chamaecrista fasciculata*	*Chrsium vulgare*	*Coreopsis lanceolata*	*Coreopsis sp.*	*Coreopsis tinctoria*	*Cymphotrichum* spp.	*Daucus carota*	*Echinacea purpurea*	*Erigeron strigosus*	*Eryngium yuccifolium*	*Galactia volubilis*	*Helianthus angustifolius*	*Lespedeza cuneata*	*Mimosa* microphylla	*Mitracarpus hirtus*	*Molsa dianthera*	*Monarda citriodora*	*Monarda fistulosa*	*Parthenium integrifolium*	*Passiflora incarnata*	*Penstamon digitalis*	*Plantago* spp.	*Pycnanthemum tenuifolium*	*Ranunculus bulbosus*	*Rudbeckia hirta*	*Solanum carolinense*	*Solidago* spp.	*Solidago virgaurea*	*Symphytrichum paters*	*Tephrosa virginica*	*Unknown*	*Verbena* spp.	# of Wildflowers visited	Total Bees
Xylocopa micans																			1												3					3	**3**	**7**
Xylocopa virginica		3																						2			1				1			2	1		**6**	**10**
# of Bee Taxa Attracted	1	6	1	4	5	3	17	2	1	2	1	2	2	1	1	8	2	1	4	1	1	1	1	5	3	2	2	1	8	1	11	1	1	5	3	13		
Total Bees	1	19	1	13	19	3	73	2	1	4	1	2	9	1	1	19	2	1	6	3	3	2	1	29	8	5	3	1	20	1	271	4	1	9	4	46		**589**

Objective 2: Results

Vegetation Monitoring

Vegetation monitoring occurred during the growing season of 2018 and 2019 at EV Smith and at Poultry. A second year of surveying was not conducted at Camp Hill due to a lack of established wildflowers. Within EV Smith and Poultry, low percentages of bare ground, wood, and forbs were observed within all the experimental plots throughout the season, with high percentages of grass cover occurring in all wildflower plots (Figure 4-4). We also observed that planted wildflower species made up a small percentage of the forbs observed in each experimental plot (Figure 4-5). A correlation matrix revealed multiple significant correlations between cover types (Figure 4-6). The strongest significant correlation was observed between the percentage of grasses and forbs. For every 1% increase in grass cover, we observed a 0.99% decrease in the percentage of forbs ($P<0.0001$, $r^2=0.89$) and thus wildflowers.

All species of wildflowers planted at Camp Hill, EV Smith, and Poultry were observed in their vegetative states during the 2018-2019 growing season (Table 4-3). In 2018, Poultry contained the greatest diversity of wildflowers observed (18 species), followed by EV Smith (13 species), and Camp Hill (10 species). In 2019, Poultry contained the greatest diversity of wildflowers in their vegetative state (22 species), followed by EV Smith (19 species).

Of the 24 species of wildflowers planted at Camp Hill, EV Smith, and Poultry, 20 reached maturity and flowered during the 2018 - 2019 growing seasons (Table 4-4). In 2018 Poultry contained the greatest diversity of wildflowers in bloom (9 species) followed by EV Smith (7 species), and Camp Hill (1 species). *Chamaecrista fasciculata* was the only species that was observed blooming at every site. In 2018, four species of wildflowers were observed blooming at both EV Smith and Poultry: *Chamaecrista nictictans, Gaillardia pulchella, Helianthus angustifolius*, and *Verbesinia virginica*. In 2019, fourteen species of wildflowers bloomed at both EV Smith and at Poultry: *Asclepias tuberosa*, *Symphyotrichum pilosum, Chamaecrista fasciculata* and *nictitans*, *Coreopsis tinctoria* and *tripteris*, *Desmodium floridanum*, *Gaillardia pulchella*, *Helianthus angustifolius*, *Lespedeza violacea*, *Monarda fistulosa* and *punctata*, *Rudbeckia amplexicaulis*, and *Verbesina virginica*.

Through our flower count surveys, we determined that *Chamaecrista fasciculata* contained the greatest number of floral blooms (4808 total flowers) throughout the growing season followed by *Chamaecrista nictitans* (2719 total flowers) and *Monarda punctata* (783 total flowers) (Figure 4-7).

Bee Monitoring

We captured a total of 952 bees while conducting sweep-netting surveys. We conducted a total of 851 ten-minute sweep netting surveys (8510 sampling minutes) over the two sampling seasons (2018-2019). Across all seasons and sampling events, a total of 291 bees were netted at Poultry, 661 at EV Smith, and zero bees were netted at Camp Hill. We documented a total of 36 bee taxa visiting planted wildflowers within our experimental plots (Table 4-5). *Halictus poeyii* was the most abundant bee captured visiting our experimental wildflower plots (563), followed by *Lasioglossum* sp. (74), *Apis mellifera* (54), and *Bombus impatiens* (41). The

wildflower species *Gaillardia pulchella* attracted the greatest number of bees (677) followed by *Chamaecrista fasciculata* (109) and *Helianthus angustifolia* (38). Conversely, *Gaillardia pulchella* attracted the greatest diversity of bees (27), followed by *Chamaecrista fasciaulata* (15) and *Helianthus angustifolia* (8).

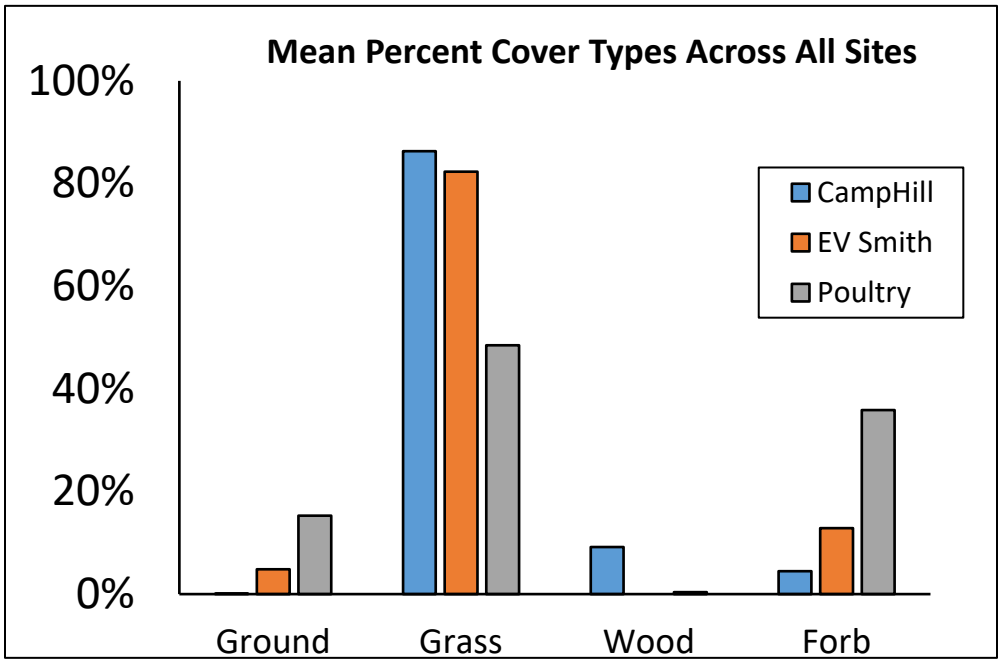

Figure 4-4. Average percentages of ground, grass, wood, and forbs between the three experimental plots located in Lee (Poultry), Macon (EV Smith), and Tallapoosa (Camp Hill) Counties.

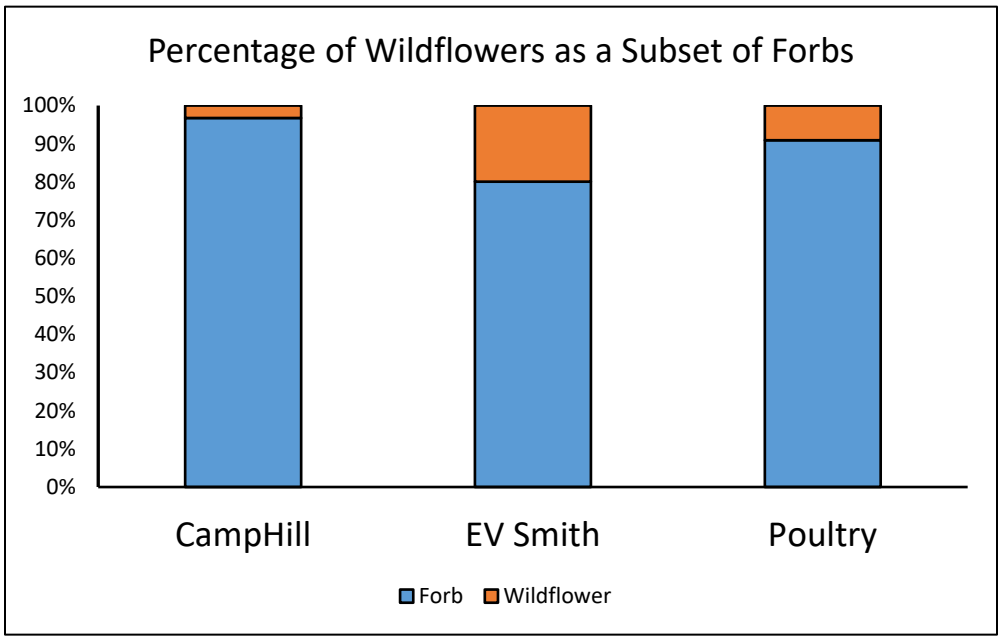

Figure 4-5. Percentage of wildflowers as a subset of forbs between each site over the 2018 and 2019 growing seasons.

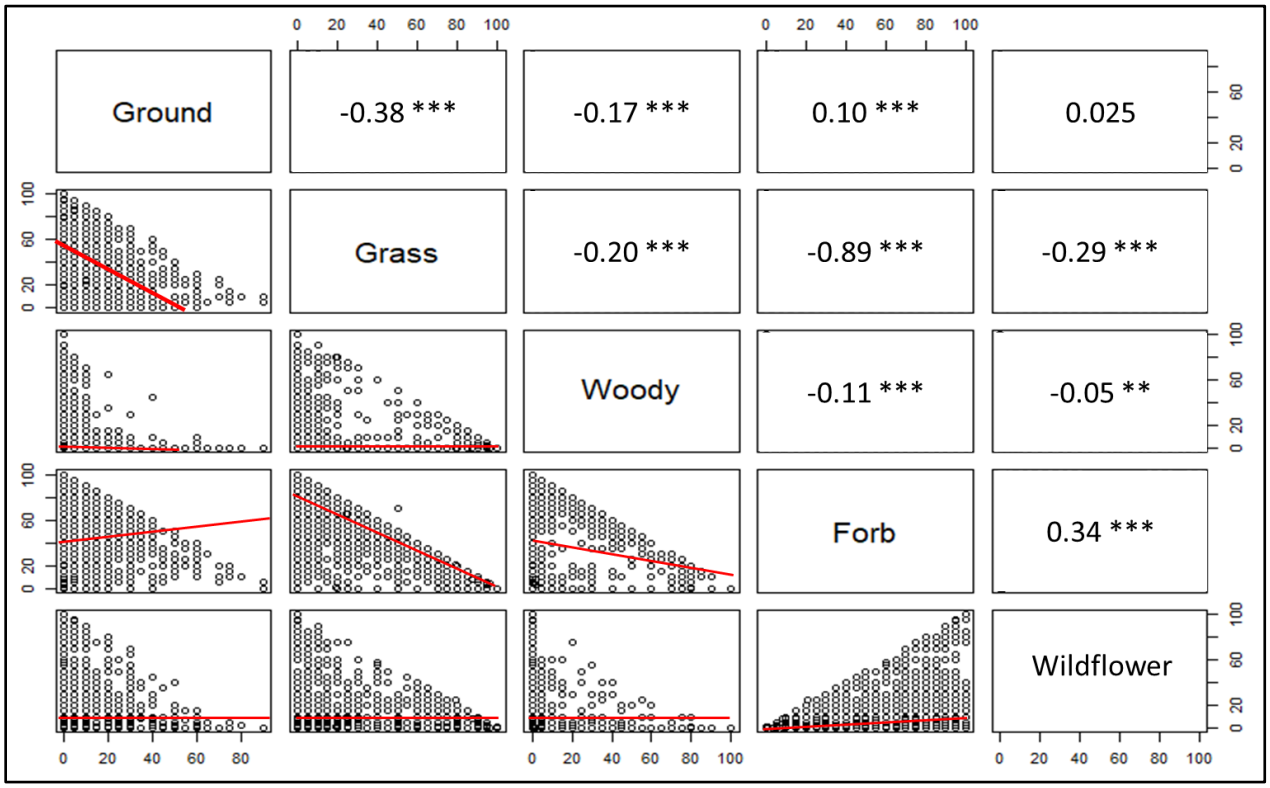

Figure 4-6. Correlation matrix for all vegetation cover types across both sites (EV Smith and Poultry). Both X- and Y-axis values represent the percent cover for each cover type. Numerical values on the upper panel of the figure are R-squared values followed by a significance level. P-values (0, 0.001, >0.05) = (***, **," ").

Table 4-3. Wildflower species present in their vegetative growth during the 2018 and 2019 growing season (shaded).

		Wildflower Species																						
Year	**Site**	***Asclepias tuberosa***	***Symphyotrichum pilosum***	***Baptisia alba***	***Chamaecrista fasciculata***	***Chamaecrista nictitans***	***Coreopsis tinctoria***	***Coreopsis tripteris***	***Dalea candida***	***Dalea purpurea***	***Desmanthus illinoensis***	***Desmodium floridanum***	***Eryngium yuccifolium***	***Eupatorium roundifolium***	***Gaillardia pulchella***	***Helenium autumnale***	***Helianthus angustifolius***	***Lespedeza violacea***	***Monarda fistulosa***	***Monarda punctata***	***Ratibida pinnata***	***Rudbeckia amplexicaulis***	***Solidago rugosa***	***Verbesina alternifolia***	***Verbesina virginica***
2018	Camp Hill			■	■	■	■		■	■	■				■					■		■			
	EV Smith	■			■	■			■	■	■	■			■		■		■	■			■	■	
	Poultry	■	■	■	■	■	■	■			■	■		■	■	■	■		■	■	■		■	■	
2019	EV Smith	■	■	■	■	■	■	■		■		■	■		■	■	■	■	■	■	■		■	■	
	Poultry	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■		■	■	■	■	■	■	■

Table 4-4. Summary table of the planted wildflower species that bloomed (shaded) during the 2018 and 2019 growing season.

		Wildflower Species																						
Year	**Site**	***Asclepias tuberosa***	***Symphyotrichum pilosum***	***Baptisia alba***	***Chamaecrista fasciculata***	***Chamaecrista nictitans***	***Coreopsis tinctoria***	***Coreopsis tripteris***	***Dalea candida***	***Dalea purpurea***	***Desmanthus illinoensis***	***Desmodium floridanum***	***Eryngium yuccifolium***	***Eupatorium roundifolium***	***Gaillardia pulchella***	***Helenium autumnale***	***Helianthus angustifolius***	***Lespedeza violacea***	***Monarda fistulosa***	***Monarda punctata***	***Ratibida pinnata***	***Rudbeckia amplexicaulis***	***Solidago rugosa***	***Verbesina alternifolia***	***Verbesina virginica***
2018	Camp Hill				■																				
	EV Smith				■	■									■		■			■			■	■	
	Poultry	■			■	■	■	■				■			■		■							■	
2019	EV Smith	■	■		■	■	■	■				■		■	■		■	■	■	■		■	■		■
	Poultry	■	■		■	■	■	■			■	■			■	■	■	■	■	■	■		■	■	■

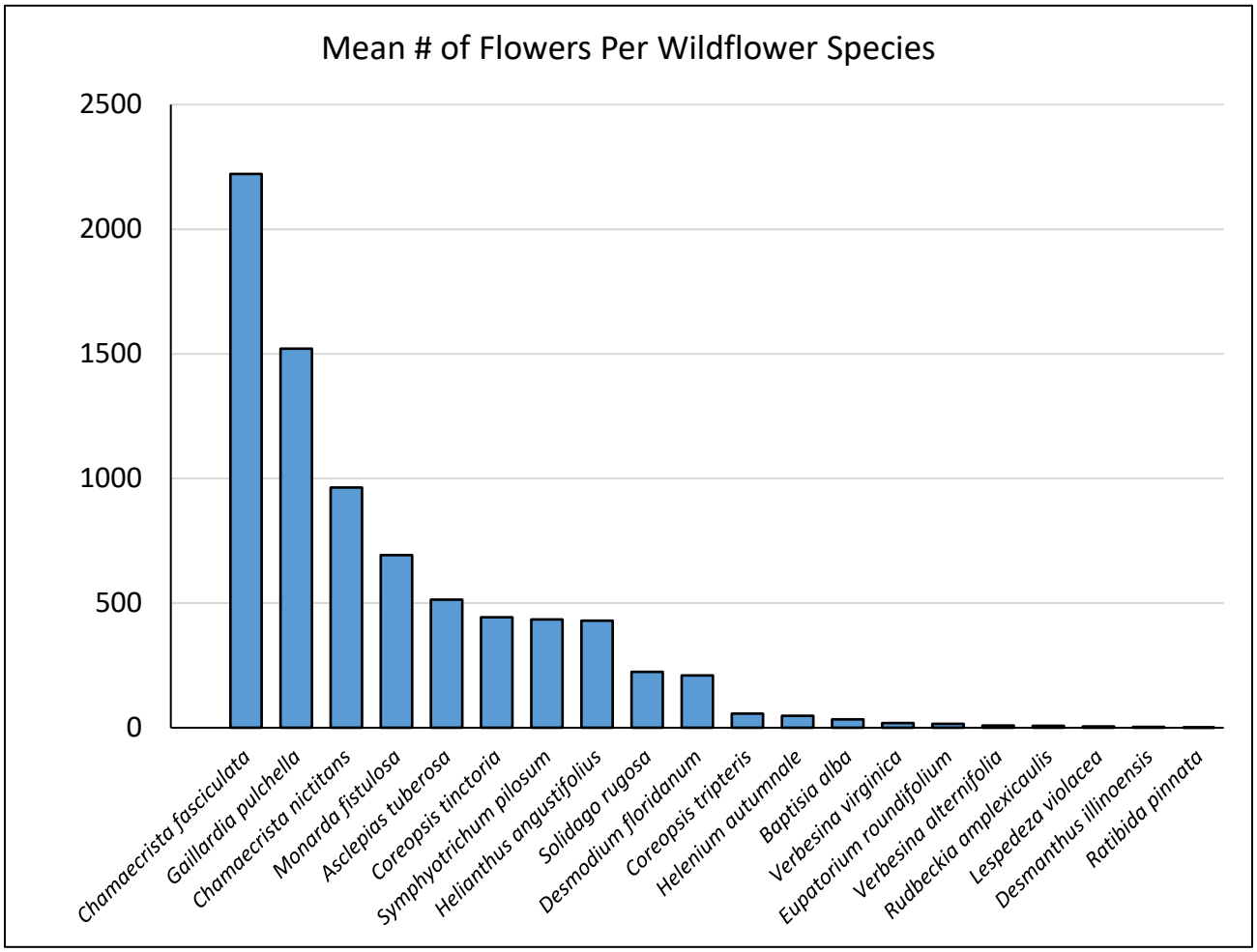

Figure 4-7. Mean number of flowers per wildflower species across the two flowering seasons at EV Smith and Poultry (2018-2019).

Table 4-5. All bee taxa sweep netted off planted wildflowers in our experimental plots during the 2018 and 2019 growing season at EV Smith and Poultry. Column to the far right represents the total number of bees netted per bee taxon. The bottom row represents the total number of bees netted off each wildflower species.

	Wildflower Species																					
Bee Species	***Asclepias tuberosa***	***Baptisia alba***	***Chamaecrista fasciculata***	***Chamaecrista nictitans***	***Coreopsis tinctoria***	***Coreopsis tripteris***	***Desmanthus illinoensis***	***Desmodium floridanum***	***Eupatorium roundifolium***	***Gaillardia pulchella***	***Helenium autumnale***	***Helianthus angustifolius***	***Lespedeza violacea***	***Monarda fistulosa***	***Monarda punctata***	***Ratibida pinnata***	***Rudbeckia amplexicaulis***	***Solidago rugosa***	***Symphyotrichum pilosum***	***Verbesina alternifolia***	***Verbesina virginica***	**Grand Total**
Agapostemon sericeus										1												**1**
Agapostemon splendens			1							12				1								**14**
Anthophora terminalis										2												**2**
Apis mellifera	6		15		2					13					18							**54**
Bombus bimaculatus	1		12											6								**19**
Bombus griseocollis			1							4				8								**13**
Bombus impatiens			36							4				1								**41**
Bombus spp.			16	1	1					3												**21**
Dieunomia heteropoda										1												**1**
Halictus parallelus				1						5		6										**12**
Halictus poeyii	4				22	7				501		26							1		2	**563**
Halictus rubicundus					1					3												**4**
Lasioglossum spp.	2		2	1				1		62	1			1	2				1	1		**74**
Megachile brevis			1							1												**2**
Megachile campanule			1																			**1**
Megachile mendica	3									14												**17**
Megachile petulans										3												**3**
Megachile rotundata			3																			**3**
Megachile spp.			8																			**8**
Melissodes bimaculatus	1									3												**4**
Melissodes boltoniae/fumosus										1												**1**
Melissodes communis			1							19		1			2						1	**24**

	Wildflower Species																					
Bee Species	***Asclepias tuberosa***	***Baptisia alba***	***Chamaecrista fasciculata***	***Chamaecrista nictitans***	***Coreopsis tinctoria***	***Coreopsis tripteris***	***Desmanthus illinoensis***	***Desmodium floridanum***	***Eupatorium roundifolium***	***Gaillardia pulchella***	***Helenium autumnale***	***Helianthus angustifolius***	***Lespedeza violacea***	***Monarda fistulosa***	***Monarda punctata***	***Ratibida pinnata***	***Rudbeckia amplexicaulis***	***Solidago rugosa***	***Symphyotrichum pilosum***	***Verbesina alternifolia***	***Verbesina virginica***	**Grand Total**
Melissodes comptoides	1		1			1				2					3							**8**
Melissodes dentiventris						1				1		1										**3**
Melissodes druriellus										1												**1**
Melissodes fimbriatus												1										**1**
Melissodes fumosas										4		1										**5**
Melissodes niveus																		1				**1**
Melissodes tampaneca										2												**2**
Melissodes trinodis										3		1										**4**
Svastra obliqua										6												**6**
Triepeolus concavus										1												**1**
Triepeolus lunatus										3												**3**
Tripeolus georgicus												1										**1**
Xylocopa micans			7												2							**9**
Xylocopa virginica			4							2				7	12							**25**
Total Bees	**18**	**0**	**109**	**3**	**26**	**9**	**0**	**1**	**0**	**677**	**1**	**38**	**0**	**24**	**39**	**0**	**0**	**1**	**2**	**1**	**3**	**952**
Bee Diversity	**7**	**0**	**15**	**3**	**4**	**3**	**0**	**1**	**0**	**28**	**1**	**8**	**0**	**6**	**6**	**0**	**0**	**1**	**2**	**1**	**2**	

Objective 3: Results

Vegetation Monitoring

Of the 18 planted mature wildflower species, seventeen bloomed during the 2019 growing season. *Baptisia alba* was the only wildflower species that did not flower. Of the wildflower species that did bloom, *Symphyotrichum pilosum* contained the greatest average number of flowers followed by *Monarda punctata, Verbena hastata, Asclepias tuberosa,* and *Chamaecrista nictitans* (Figure 4-8).

Bee Monitoring

A total of 1024 bees belonging to 27 taxa were documented visiting the seventeen planted wildflower species during the 2019 season. Overall, six species of wildflowers attracted more than 50 individual bees: *Gaillardia pulchella* (313), *Verbena hastata* (130), *Asclepias tuberosa* (129), *Echinacea purpurea* (103), *Rattibida pinnata* (63), and *Rudbeckia hirta* (58) (Table 4-6). The average number of bees per replicate per wildflower species are depicted in Figure 4-9. Additionally, *Gaillardia pulchella* attracted the greatest average diversity (richness) of bees (23) followed by *Verbena hastata* (18), *Asclepias tuberosa* (16), and *Echinacea purpurea* (14) (Figure 4-10).

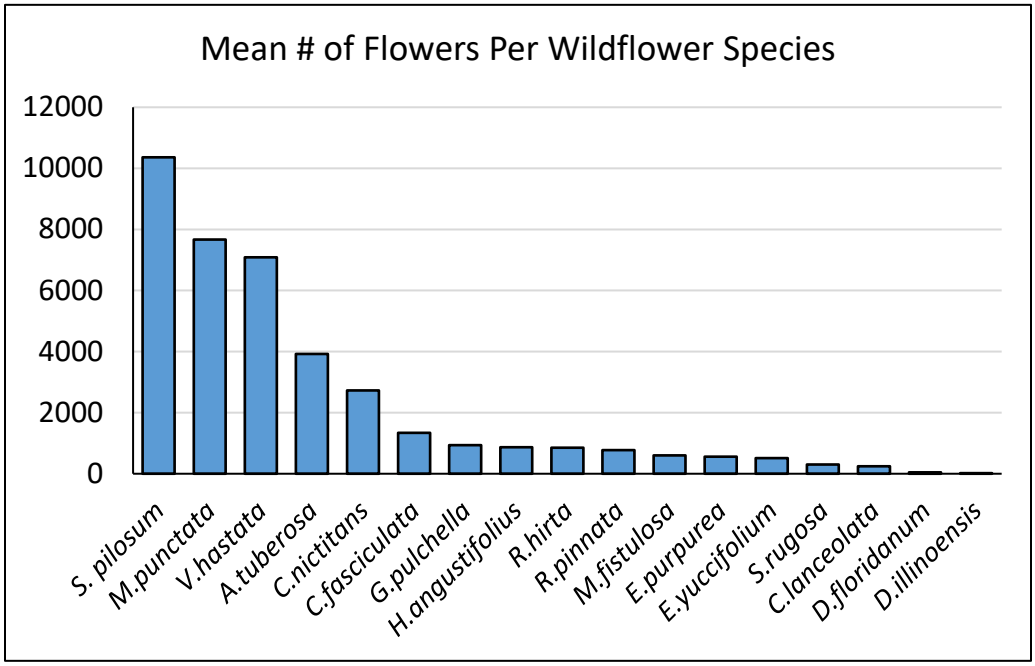

Figure 4-8. Mean number of flowers per replicate per wildflower species during the 2019 growing season.

Table 4-6. Total number of bees captured visiting each wildflower species during the 2019 growing season.

Wildflower Species	Common Name	Total Bees
Gaillardia pulchella	Blanket Flower	313
Verbena hastata	Blue Vervain	130
Asclepias tuberosa	Butterfly Milkweed	129
Echinacea purpurea	Purple Coneflower	103
Ratibida pinnata	Greyheaded Coneflower	63
Rudbeckia hirta	Black-eyed Susan	58
Symphyotrichum pilosum	Frost Aster	47
Coreopsis lanceolata	Lance-leaved Coreopsis	41
Chamaecrista fasciculata	Partridge Pea	38
Eryngium yuccifolium	Rattlesnake Master	30
Helianthus angustifolius	Narrow-Leaved Sunflower	22
Monarda fistulosa	Bergamot	18
Monarda punctata	Spotted Beebalm	14
Desmanthus illinoensis	Illinois Bundleflower	7
Solidago rugosa	Wrinkled-Leaved Goldenrod	6
Chamaecrista nictitans	Sensitive Partridge Pea	3
Desmodium floridanum	Florida Ticktrefoil	2
	Total	**1024**

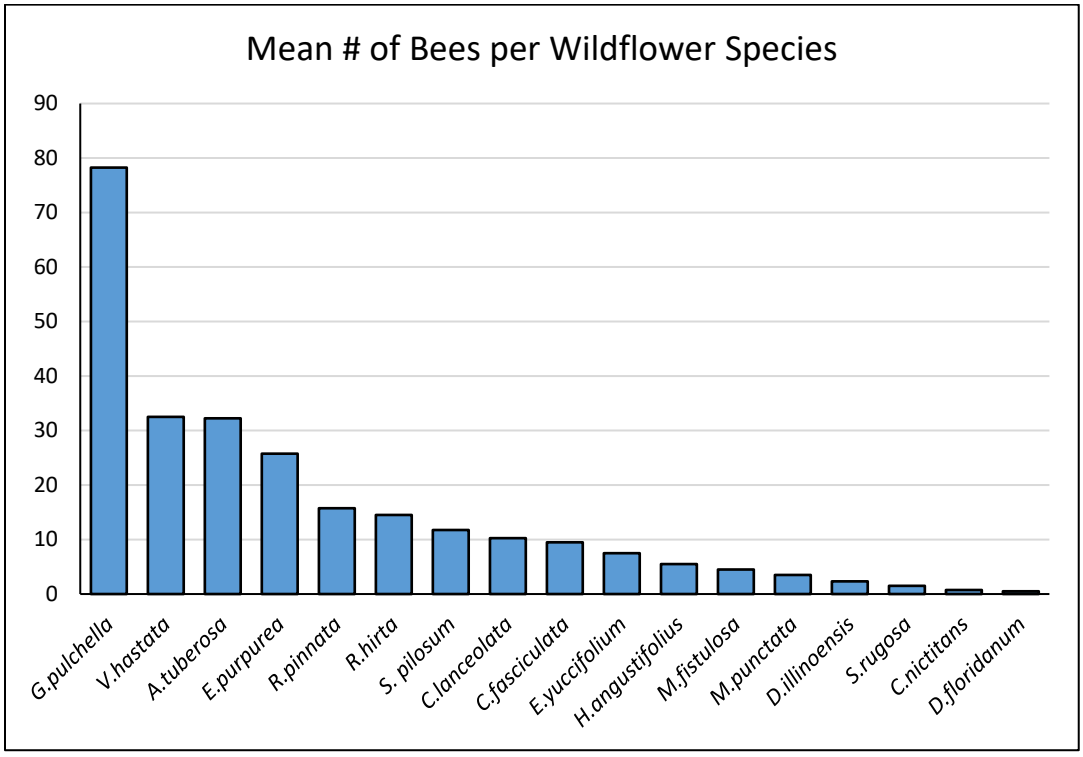

Figure 4-9. Mean number of bees per replicate per wildflower species documented during the 2019 growing season.

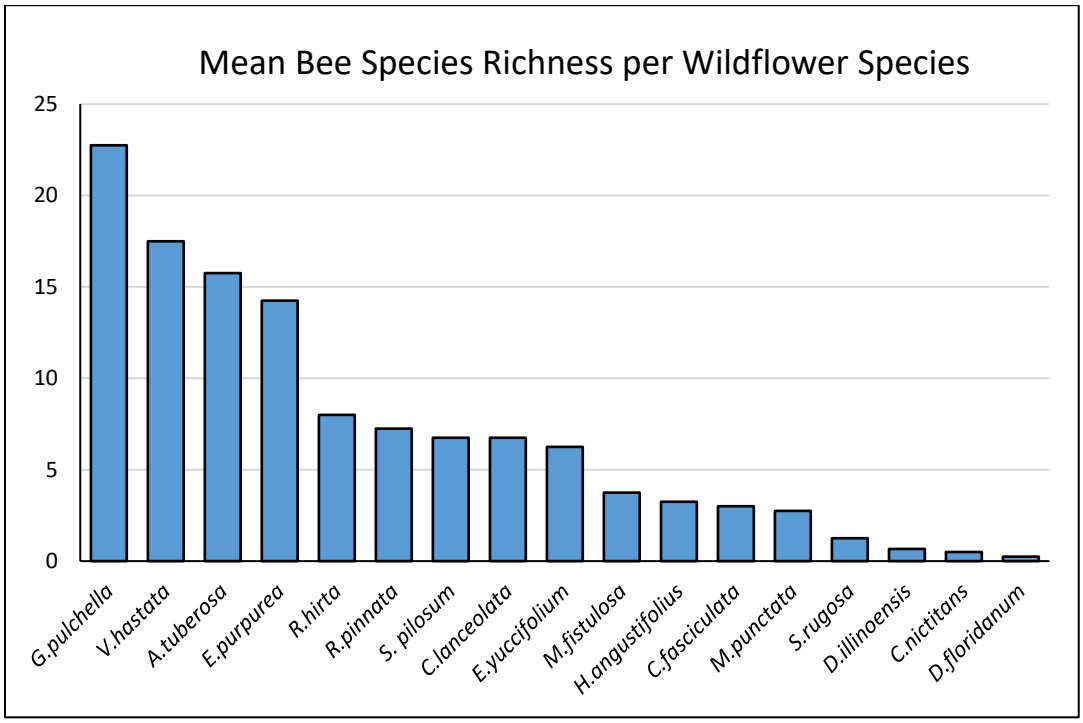

Figure 4-10. Mean bee species richness per replicate per wildflower species during the 2019 season.

Conclusions

The vegetation surveys conducted across the statewide wildflower plots and in Lee, Tallapoosa, and Macon Counties shed important light onto the factors that influence the establishment and ultimate success of planted wildflower species. The correlation matrices revealed the strongest negative correlations between the percentage of grasses and the percentage of forbs, and thus the percentage of wildflower vegetation present within the wildflower plots. It appeared that the establishment of wildflowers directly after seeding is greatly weakened by the competition with grasses. We observed that if non-native grasses are not controlled, they take over and outcompete native wildflower species. Due to the high degree of competition between grasses and the wildflower species planted in Lee, Tallapoosa, and Macon County, few wildflowers species successfully occupied 100% vegetation cover within each 1 m^2 sub-plot. For this reason, other best management practices including prescribed burns were not feasible. Instead, after discussions with the state biologist, we focused our attention on understanding the relationship between specific wildflowers and their bee visitors. It is clear from both the stakeholder survey and experimental plots that more efforts need to focus on management practices that directly reduce the percentage of non-native grasses to limit competition with planted wildflowers.

Overall, certain wildflower species persisted in the environment even years after planting and establishment, and some attract greater abundances and diversities of native bees than others.

Between the wildflower plots planted between 2012 and 2018 across the state of Alabama and the experimental wildflower plots established in Lee, Tallapoosa, Macon counties in 2018 and 2019, we recommend the planting of the following wildflower species: *Asclepias tuberosa, Chamaecrista fasciculata, Coreopsis lanceolata, Coreopsis tinctoria, Echinacea purpurea, Gaillardia pulchella, Helianthus angustifolius, Monarda fistulosa, Monarda punctata, Pycnanthemum tenufolium, Ratibida pinnata, Rudbeckia hirta, Solidago* sp., *Symphyotrichum pilosum,* and *Verbena hastata.* These wildflowers are established easily and attract a great number and diversity of bees. In addition, this list of wildflower species attracted a great diversity of not only common bee species, but also rare and uncommon species. Because the phenology of the statewide wildflower plots was not tracked over multiple years following seeding, there could have been certain wildflower species that were highly attractive to native bees but not present after the wildflower plot had aged over time. We recommend future work should investigate the development of wildflower seed mixes that contain our recommended wildflower species. Special attention should be placed on optimizing percent composition of each species to promote long-lasting diversity of the plants in the landscape.

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