Bee-Friendly Beef: Developing Biodiverse Pastures to Increase Ecosystem Services

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Abstract

The capacity of grasslands to provide ecosystem services, such as pollinator resources, is often limited by lack of plant biodiversity. This is true of grasslands in the eastern US that are dominated by tall fescue (*Festuca arundinacea*) a non-native, cool-season grass that is typically toxic to cattle. This paper summarizes a research project in Virginia, USA exploring the idea that ecosystem services provided by tall fescue-dominated grasslands can be improved by increasing the plant biodiversity available to beef cattle and bees. Within three 6.5 ha tall fescue grasslands, we established 0.8 ha plots with a 17 species mix of native warm-season grasses (NWSGs) and wildflowers. Beginning in 2018, we measured grass and wildflower establishment, attractiveness of wildflowers to bees, abundance and diversity of bee communities in biodiverse pastures and adjacent tall fescue pastures. Many of the 18 species sown established well expect for NWSGs. Competition from wildflowers likely suppressed native grasses and limited forage availability for beef cattle. Cattle largely ignored the wildflowers. This finding suggests that cattle and pollinators can share this biodiverse grassland as their primary foods are mutually exclusive. The total number of bees was almost double in wildflower-enhanced grasslands compared with more typical tall fescue grasslands. We observed most bee landings on purple coneflower (*Echinacea purpurea*) and anise hyssop (*Agastache foeniculum*). Several weedy species such as milkweed (*Asclepias syriaca*) and musk thistle *(Carduus nutans)* were also attractive to bees. Preliminary analyses identified at least 28 bee morphospecies and a distinct bee community present in wildflower pastures. While these results were promising, more research is needed on ways to establish biodiverse grasslands so that a more optimal balance of grasses and wildflowers can be sustained to benefit both cattle production and pollinators.

Introduction

Native and managed bee populations have been declining around the globe (Potts et al. 2016). Although multiple factors contribute to decline, habitat loss is likely the primary driver. Adding bee habitat to agricultural landscapes can bolster existing bee communities, increasing abundance and species richness (Paterson et al. 2019). Pastures and rangeland, which covers 265 million hectares across the United States, could provide enough land area for large-scale wildflower plantings, while still providing forage for cattle (Baude et al. 2016). A land-sharing approach provides an opportunity for agricultural production and conservation of biodiversity (Ekroos et al. 2016) and could help mitigate bee decline (Kovacs-Hostyanszki et al. 2017). A pasture designed for cattle production and bee conservation will mirror a grassland plant community, where grasses dominate but forbs fill other ecological niches. Native warm-season grasses (NWSGs) can provide valuable forage for cattle, especially during the summer months (Moore et al. 2004, Tracy et al. 2010, Backus et al. 2017), and wildflowers will provide food and nesting resources for bees. If managed appropriately, NWSGs and native wildflowers should benefit bee populations and cattle. Little research exists about how using native grasses and wildflowers in pastures affects bee populations and cattle production, however. This project examined several aspects of NWSG-wildflower plantings and their use in pasture systems – namely plant community establishment, attractiveness of different wildflower species to bees, and overall bee abundance and diversity.

Methods and Study Site

The experiment was conducted at the Virginia Tech Shenandoah Valley Agricultural Research and Extension Center (SVAREC) in Raphine, VA from 2018-2019. The study site was in central Virginia (37◦55'56" N latitude, 79◦12'51" W longitude, elevation: 530 m). The region has a humid continental climate, with an average monthly high temperature ranging from 7.9°C in January to 30.7°C in July. Pastureland was divided into nine 6.5 ha experimental units and assigned to three stocking treatments with three replications: 1) rotational stocking where cattle groups were moved through eight equal-sized (0.8-ha) paddocks, 2) the same rotational stocking scheme but with one paddock planted to a biodiverse NWSG + wildflower mixture, and 3) continuous stocking that represented a "business-as-usual" control treatment to reflect grazing practices in the eastern U.S. Establishment of the NWSG + wildflower paddocks was initiated during the fall of 2016 and eventually seeded with a mix of three NWSGs and 15 wildflower species at a rate of 13.5 kg/ha in early June 2017. The seed mix was 70:30 (by seed weight) of NWSGs: wildflowers.

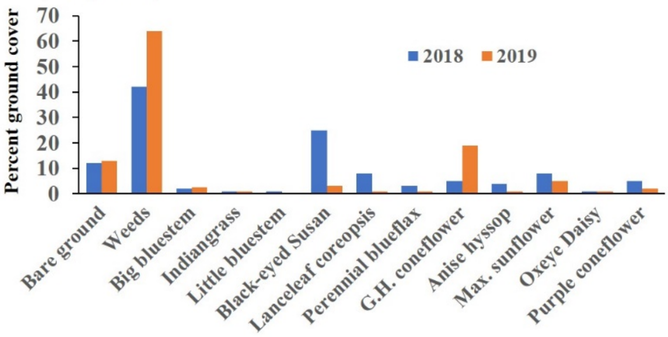
Percent cover of NWSG + wildflower species, weedy species, and bare ground was visually estimated in 0.25-m^2 square quadrats in 2018 and 2019 using a modified Daubenmire method (Daubenmire 1959). Bees were collected to assess abundance and diversity among bee communities. Collections began in June 2018 and 2019 and continued monthly until September. Two sets of traps were placed in each experimental unit consisting of one blue vane trap (SpringStar, Inc., Woodinville, WA, USA) and multi-coloured bee bowls. Bee observations were used to gather information on which flower species were the most attractive. Beginning in May 2018 and 2019, bee landings on all blooming flower species, including weedy species, in all treatments were observed. After assessing flowers blooming on a given day, six random patches of each blooming flower species were observed for one minute each. The size and bloom count of each patch were visually estimated and recorded.

Results

Native Grass/Wildflower Establishment

Overall plant species composition changed substantially from 2018 to 2019. Average percent cover of bare ground was similar in 2018 (14%) and 2019 (15%) (Figure 1). The average cover of weedy species (species not sown as part of the NWSG + wildflower mix, such as thistle, white clover, fleabane, and cool-season grasses increased from 41% in 2018 to 63% in 2019. Coverage of all three NWSG species was minimal in both years. Black-eyed Susan was the dominant wildflower species in 2018, representing an average of 22% of total plant coverage. However, in 2019, it represented less than one percent of average percent cover. Lanceleaf coreopsis, perennial blueflax, and anise hyssop showed similar trends, all declining to less than one percent cover in 2019. In contrast, the coverage of grey-headed coneflower increased from 2018 to 2019. In 2018, grey-headed coneflower was on average 6% of the plant community and increased to 18% in 2019. Two annual species established early (annual gaillardia, partridge pea) but were not present by 2018.

Figure 1. Average percent cover of bare ground, weedy species, and established NWSG and wildflower species in 2018 (blue bars) and 2019 (orange bars).



Bee observations and abundance

Table 1. The average abundance among three pasture treatments in each collection month of 2018 and 2019. Letters indicate significant differences (α = 0.05) and represent pairwise comparisons among treatments within months and years.

	June		July		August		September	
	2018	2019	2018	2019	2018	2019	2018	2019
Continuously stocked	14.3^{A}	6.7^{A}	12.0^{B}	11.7^{A}	14.0^{B}	12.3^{B}	1.3^{A}	5.3^{A}
Rotationally stocked	4.7^{B}	6.3^{A}	13.3^{B}	14.3^{A}	6.3^{C}	13.0^{AB}	2.7^{A}	5.0^{A}
NWSG + wildflower	8.7^{AB}	3.7^{A}	23.3^{A}	19.0^{A}	24.0^{A}	20.7^{A}	3.3^{A}	6.3^{A}

In 2018, bee abundance showed a significant treatment by date interaction effect ($P < 0.001$), so sampling dates were analyzed separately. In July and August, the NWSG + wildflower treatment had significantly more bees present than the continuously and rotationally stocked treatments (Table 1). Bee abundance in 2019 differed by treatment ($P = 0.02$) and date ($P < 0.001$), although there was no significant interaction effect ($P = 0.14$). The NWSG + wildflower treatment again had more bees present in August. Although bees were numerically more abundant in the NWSG + wildflower treatment in July and September, the means were not statistically different from the continuously and rotationally stocked treatments. In the 2018 and 2019 growing seasons, 17 plant species, both sown and weedy, were observed for bee visitations. A total of 442 plants and 312 plants were observed to record bee visitations in 2018 and 2019, respectively. Among sown species, anise hyssop was visited the most frequently by bees in 2018, while grey-headed coneflower was visited the most often in 2019 (Table 2). Among weedy species, milkweed (*Asclepias syriaca*) and pokeweed (*Phytolacca americana*) attracted the most bees in 2018 and 2019, respectively. Bull thistle (*Cirsium vulgare*), anise hyssop, maximilian sunflower, and purple coneflower were consistently attractive to bees in both years.

Table 2. Results of bee observations from 2018 and 2019. Values are means that represent proportion of observations when a bee was present on a bloom (± 1 SE). The planted and weedy species where a bee was observed the most frequently in both years are bolded.

Flower	Type	Observations	
		2018	2019
Anise hyssop	Sown	**0.64 ± 0.07**	0.42 ± 0.15
Black-eyed susan	Sown	0.37 ± 0.09	0.44 ± 0.12
Grey-headed coneflower	Sown	0.33 ± 0.11	**0.61 ± 0.12**
Lanceleaf coreopsis	Sown	0.43 ± 0.11	0.33 ± 0.14
Maximilian sunflower	Sown	0.43 ± 0.09	0.50 ± 0.15
Oxeye daisy	Sown	0.25 ± 0.09	0.17 ± 0.11
Perennial blueflax	Sown	0.31 ± 0.08	0.17 ± 0.17
Purple coneflower	Sown	0.55 ± 0.09	0.42 ± 0.10
Buttercup	Weedy	0.08 ± 0.04	0.08 ± 0.08
Chicory	Weedy	0.67 ± 0.21	0.17 ± 0.11
Fleabane	Weedy	0.18 ± 0.12	0.13 ± 0.06
Horsenettle	Weedy	0.17 ± 0.11	0.16 ± 0.11
Milkweed	Weedy	**0.83 ± 0.11**	0.50 ± 0.22
Pokeweed	Weedy	0.33 ± 0.14	**0.67 ± 0.21**
Queen Anne's lace	Weedy	0.33 ± 0.21	0.22 ± 0.10
Thistle	Weedy	0.56 ± 0.06	0.61 ± 0.07
White clover	Weedy	0.26 ± 0.06	0.19 ± 0.06

Of the 38 bee species identified in 2018, 37 were native (data not shown). The only non-native species was the European honeybee (*A. mellifera*). Nineteen honeybees were collected, 14 of which were in the NWSG + wildflower treatment. There were no known honeybee hives within a 0.5 mile radius of the site, which could have influenced the number of honeybees observed. The NWSG + wildflower treatment had the most diverse community of bees, supporting 28 total species. Eight of those species were found only in that treatment: *Bombus auricomus, Bombus griseocollis, Hylaeus affinis/modestus, Hylaeus mesillae, Lasioglossum callidum, Lasioglossum leucozonium, Lasioglossum pruinosum*, and *Melissodes denticulatus*.

Discussion [Conclusions/Implications]

Although NWSGs were planted as 70% of the seed mix, they composed less than 5% of the final plant community in both 2018 and 2019. During their first year of establishment, NWSGs invest in root growth rather than above-ground biomass (Keyser et al. 2011, 2012). They are easily outcompeted by other, faster growing grasses and broadleaf plants (Harper et al. 2007). Lack of establishment in the pastures was likely caused by competition from both the wildflowers included in the mix and weeds present in pasture seedbanks. Because the NWSGs in our experiment were planted simultaneously with wildflowers, and because they devote most of their resources to root system development, they may not have had enough time to develop adequate above-ground biomass to shade out competing wildflowers and weedy species.

Of the fifteen sown wildflower species, eight that established were attractive to bees. The bloom periods of the sown species were staggered over the course of the growing season so that floral resources were available from May through September, therefore maximizing bee conservation value (Tuell et al. 2008). Most of the wildflower species bloomed during June and July when other nectar and pollen resources were lacking (Koh et al. 2016). If designing a diverse wildflower mix to plant in pastures, we would recommend: lanceleaf coreopsis, perennial blueflax, oxeye daisy, anise hyssop, black-eyed Susan, purple coneflower, grey-headed coneflower, and maximilian sunflower. Several weedy species also attracted many bees. Thistle and milkweed were notably attractive to bees in both years. Thistles and milkweed emit fragrances attractive to pollinators (Theis et al. 2007) and produce high-protein pollen (Russo et al. 2019).

The NWSG + wildflower treatment attracted more bees compared with the other grazing treatments during July and August, especially. Pollinator abundance has been found to positively correlate with the number of wildflower blooms (Blaauw and Isaacs 2014, Angelella et al. 2019), which could explain the higher bee abundances in the NWSG + wildflower treatment. Additionally, the mid- to late summer months are when pollinators traditionally experience a pollen dearth (Koh et al. 2016, Heller et al. 2019). The NWSG + wildflower pastures were blooming in midsummer and had pollen and nectar resources available, which may explain why more bees were present during those dates. This also may help explain why NWSG + wildflower treatment supported a greater diversity of bee species.

In summary, we found that planting a mix of NWSGs and wildflowers as pasture, can attract more bees and a greater diversity of bees than typical tall fescue-based pastures in this region. However, the diverse mix was not ideal if the management goal seeks to improve summer forage availability for cattle along with resources for pollinators. Wildflowers established in much higher densities than expected and likely outcompeted the NWSGs. With few native grasses, the pastures were not viable for cattle production. Different planting methods, to be tested in future experiments, could increase the proportion of grasses present while still maintaining wildflowers, benefitting both cattle and bees. We also noted that thistles and milkweed were highly attractive to bees. While neither weedy species is usually desirable in a pasture, if a producer can maintain a manageable number of thistle and milkweed plants, bee populations in pasture systems could be enhanced with minimal changes to pasture management.

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