N O T E

Assessing Pollinator Seed Mix Plantings for the Presence of Undesirable Plant Species in the Livestock Pasture System[1]

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Pollination leads to fertilization and seed production, ensuring a new generation of plants that eventually provide food for animals and other species (Klein et al. 2007, Proc. R. Soc. B: Biol. Sci. 274:303–313). Across the globe, approximately 87% of flowering plants rely on animal pollinators such as bees, butterflies, flies, bats, and birds for pollination (Winfree et al. 2011, Annu. Rev. Ecol. Evol. Syst. 42:1–22). Among these pollinators, bees are the most effective for both native and wild flowering plant species (Winfree 2010, Ann. N. Y. Acad. Sci.1195:169–197). Research has shown that pollination significantly increases fruit and vegetable production through an increase in seed production (Reilly et al. 2020, Proc. R. Soc. B: Biol. Sci. 287:20200922; Allen-Perkins et al. 2022, Ecol. 103:e3614). Maximizing crop production through the use of pollinators is a well-established agricultural practice. In 2005, pollination services provided by insects contributed $215 billion to the U.S. economy, benefiting approximately 75% of crop species and facilitating the reproduction of approximately 94% of wild flowering plants (Vanbergen 2013, Front. Ecol. Environ. 11:251–259).

Bees, which are crucial pollinators, require a variety of food resources during their developmental stages to meet their nutritional needs (Donkersley et al. 2017, Oecologia 185:749–761). The larval stage of bees requires nutrients for development, whereas adult bees need energy-rich nectar, which can be obtained from a variety of floral sources (Filipiak 2018, Insects 9:85). Flower-rich habitats attract bees, butterflies, and other pollinators (Holland et al. 2015, Biol. Conserv. 182:215–222; Sidhu and Joshi 2016, Front. Plant Sci. 7:363), increasing their abundance and diversity (Tuell et al. 2008, Environ. Entomol. 37:707–718). Developing landscape heterogeneity

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and improving the quality of seminatural habitats can enhance diversity and conserve pollinators (Cole et al. 2017, Agric. Ecosyst. Environ. 246:157–167). The reduction in the diversity of flowering plants is directly linked to the decline of wild bees (Filipiak 2018; Kline and Joshi 2020, Agriculture 10:115). In intensively managed agricultural habitats, where flowers are scarce, fewer pollinators exist (Cole et al. 2017). The management of landscape heterogeneity and the enhancement of seminatural habitats can provide more resources for pollinators (Cole et al. 2017). Therefore, diverse floral abundance is essential for the survival and existence of pollinators.

The abundance of the bee community in livestock pastures is primarily related to postfire age, grazing intensity, and nesting substrates (Potts et al. 2003, Ecol. 84:2628–2642). Grazing livestock can alter pollinator habitats, hinder nesting sites, and reduce vegetation that provides nectar to pollinators (Kearns et al. 1998, Annu. Rev. Ecol. Evol. Syst. 29:83–112). Growing a mixture of native wildflowers can enhance the pollinator population by providing forage resources throughout the season, which can be used in pollinator conservation programs and primarily boosts bee communities (Tuell et al. 2008, Environ. Entomol. 37:707–718; Heller et al. 2019, Sci. Rep. 9:17232). A study has shown that bumblebees were more abundant and diverse in a conservation mix (kale, mixed cereal, linseed, and legume) than in a cereal, grass, and legume mix (Potts et al. 2009, J. Appl. Ecol. 46:369–379). Additional legumes and forbs in grasslands increase the pollinator community (Orford et al. 2016, J. Appl. Ecol. 53:906–915). Pollinators contribute to pollination services and increase seed yield in annual forages such as crimson clover (*Trifolium incarnatum* L.) or hairy vetch (*Vicia villosa* Roth) (Anderson et al. 2011, Seed Production Research OSU 2010:8–10). They also visit plants that are high in specific forb species such as *Taraxacum* species and *Cirsium arvense* (L.) Scopoli (Orford et al. 2016). Thus, including proper forage species is important to increase the pollinator population. Developing landscape heterogeneity and enhancing the quality of seminatural habitats can help enhance diversity and conserve pollinators (Cole et al. 2017; Sidhu and Joshi 2016). The management of landscape heterogeneity and the enhancement of seminatural habitats can add more resources for pollinators (Cole et al. 2017). Therefore, management strategies should focus on incorporating pollinator habitats in grasslands to enhance the existing agri-environment. The main objective of this study was to evaluate the establishment rate of native forbs, legumes, and grasses, including warm season grasses, that are commonly used to develop pollinator habitat in livestock pastures.

This study was conducted at the USDA-Agricultural Research Service Dale Bumpers Small Farms Research Center in Booneville, AR (35.09° N, 93.95° W) during the summers of 2018 and 2019. The soil at the study site is Leadvale silt loam, which is characterized as fine-silty, siliceous, semiactive, thermic Typic Fragiudults. A fragipan at a depth of 0.15 to 1.0 m limits water movement and plant rooting. According to information at https://websoilsurvey.sc.egov.usda.gov, the soil has low natural fertility, is well drained and water permeable, and has medium water-holding capacity. Average monthly temperature during the study period (July and August of 2018 and 2019) ranged between 26 to 29.8°C. The site received 95 mm and 150 mm average rainfall during July and August in both years.

The study was conducted in conventionally managed plots, consisting of six plots, each measuring 0.4 ha. These plots were established as livestock pastures. Before the establishment of the pasture, the field was treated with herbicides,

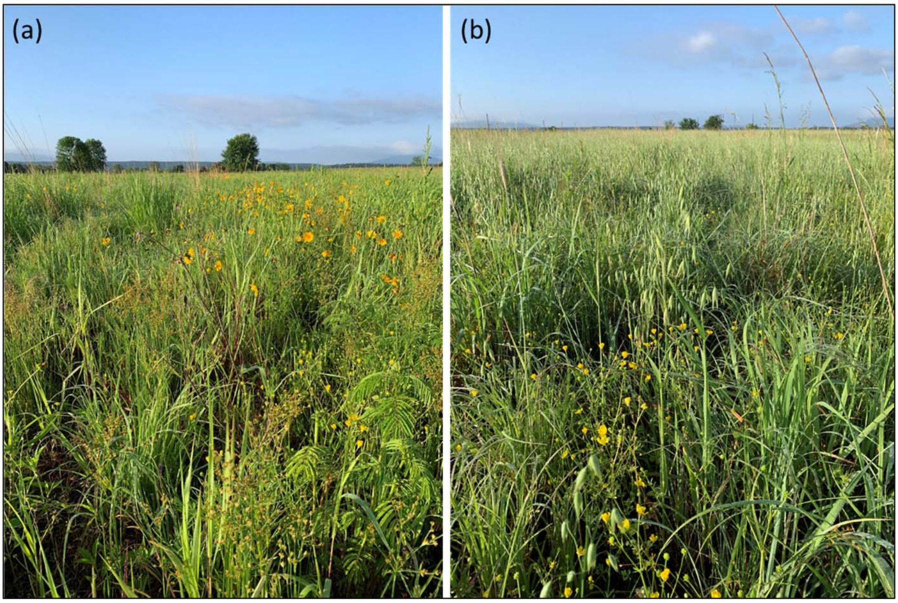

Fig. 1. Pollinator plantings with native forb, legume, and grass seed mix (a) and with warm season grass seed mix (b) in livestock pasture. (Pictures by J. Burke)

including Roundup® (41% glyphosate; Bayer, St. Louis, MO) at a rate of 4.67 liters per ha in June, July, September, and October 2016, as well as in January 2017. Additionally, the field was sprayed with Outrider (Monsanto, St. Louis, MO; 0.096 liters per ha) in September 2016, using a cluster nozzle sprayer (SR: A44117; Continental Belton McAlester, Oklahoma City, OK). The field was then tilled using a Maschio Gaspardo North America Inc. SC 300 machine in October 2016 and rolled using a 12' Big Guy Roller (Grahl Manufacturing, St. Louis, MO).

The plots were sown with a mixture of native forb, legume, and grass plants, as well as native warm season grasses. The warm season grass seed mix consisted of an equal mix of big bluestem (*Andropogon gerardii* Vitman), eastern gamagrass (*Tripsacum dactyloides* [L.]), and Indiangrass (*Sorghastrum nutans* [L.] Nash), with a rate of 8.10 kg/ha for each seed type. The native forb, legume, and grass seed mix included Buck's Hangout (Hamilton Native Outpost, Elk Creek, MO) at a rate of 14.5 kg/ha, as well as the Tallgrass Inexpensive and Tallgrass Exposed Clay subsoil mix (Prairie Moon, Winona, MN) at a rate of 13.44 kg/ha. The planting of these seeds took place in mid-February 2017.

To determine the plant species composition in the plots, a weekly survey was conducted in June and August, using a method previously described by Vogel and Masters (2001, J. Range Manage.54:653–655). The survey involved recording the number and percentage of vegetation cover and floral resources during the sampling period. A wire frame panel containing 36 squares, each measuring 15×15 cm^2, was used. The number of squares containing one or more seeded plants was recorded.

Table 1. Botanical species composition in two different types of seed mixes used for establishing pollinator habitat in livestock pasture system.

Desirable plant species (included in seed mix)	%	Most dominant undesirable species (not included in seed mix) in study plots	%
Native forb, legume and grass seed mix plot			
Elymus virginicus L.	22	*Ambrosia* spp.	27.77
Elymus canadensis L.	16	*Lolium* spp.	13.8
Lespedeza capitata Michaux	11	*Rumex crispus* L.	11.1
Helianthus grosseserratus Martens	11	*Rumex obtusifolius* L.	5.5
Coreopsis grandiflora Nuttall	10	*Papaver somniferum* L.	5.5
Rudbeckia hirta L.	8.6	*Bromus tectorum* L.	<1
Chamaecrista fasciculata (Michaux) Greene	6.6	*Poa pratensis* L.	<1
Parthenium integrifolium L.	<1	*Carex hirta* L.	<1
Achillea millefolium L.	<1	*Lolium* spp.	<1
Callirhoe involucrata (Torrey & A. Gray)	<1	*Callirhoe* spp.	<1
Penstemon digitalis (Nuttall ex Sims)	<1	*Ranunculus eschscholtzii* Schlechtendalii	<1
Echinacea pallida (Nuttall) Nuttall	<1	*Polygonum alpinum* All	<1
Rudbeckia subtomentosa Pursh	<1	*Festuca arundinacea* Schreber	<1
		Vigna unguiculata (L.) Walp	<1
		Ambrosia artemisiifolia L.	<1
		Papaver somniferum L.	<1
		Trifolium campestre Schreber	<1
Warm season grass seed mix plot			
Andropogon gerardii Vitman, *Tripsacum dactyloides* (L.) L.	20–30 each	*Polygonum aviculare* L.	*
		Cyperus rotundus L.	*
Sorghastrum nutans (L.) Nash		*Xanthium strumarium* L.	*

Table 1. Continued.

Desirable plant species (included in seed mix)	%	Most dominant undesirable species (not included in seed mix) in study plots	%
		Ambrosia psilostachya de Candolle	*
		Croton capitatus Michaux	*
		Cynodon dactylon (L.) Persoon	*
		Festuca pratensis Hudson	*
		Hordeum murinum L.	*
		Balsamorhiza sagittata (Pursh) Nuttall	*
		Rumex crispus L.	*
		Trifolium spp.	*

* Individual species percentage not included in the seed-mix.

Sampling was conducted on both the east and west sides of each plot. The recorded counts were then converted into a frequency of occurrence and percentage by dividing the number of squares containing a seeded plant by 100. Nonseeded species were considered undesirable and were also counted.

To create a pollinator-friendly pasture system, it is crucial to identify suitable forage species that are well suited to the specific geographic location. The seed mixes used in this study included both legume and forb species to provide suitable habitats for pollinators. However, the establishment of several forage species was poor, with the percentage of desirable (seeded forage) and undesirable (not seeded) species ranging 40–60% and varying among plots in the forb, legume, and grass seed mix (Fig. 1A). Additionally, around 8.6% of the ground was bare, lacking any forage species. Similarly, the percentage of desirable plants in the warm-season grass plots was as low as 20–30% for *A. gerardii*, *T. dactyloides*, and *S. nutans* (Fig. 1B). Among the three major grass species, all three plots predominantly contained weeds, comprising around 60–70% of the species present. More details on the desirable and undesirable plants are presented in Table 1.

Establishing native flowering forbs and grasses in livestock pastures provides a reliable source of food (nectar and pollen) and habitat for native pollinators throughout the year, which ultimately benefits farmers and society by ensuring an adequate food supply. However, little is known about sustainable livestock pasture systems that support pollinator habitat due to a lack of understanding of the management of insect pollinators and other beneficial arthropods and their ecosystem services in such systems. The establishment of pastures using seed mixes of native forbs, legumes, and grasses and warm season grasses resulted in variable success, with undesirable species often comprising over 50% of the plant community. In three of the six plots, the native forbs, legumes, and grass seed mix included legumes, forbs, and grasses to create suitable infrastructure for pollinators. However, both types of pasture experienced difficulty in excluding undesirable species and weeds, with survival and establishment rates being low. For the forb and legume seed mix, only a few species (*Elymus virginicus* L., *Elymus canadensis* L., *Lespedeza capitata* Michaux, *Helianthus grosseserratus* Martens, and *Coreopsis grandiflora* Nuttall) survived well, whereas the survival rate of desirable species was below 60% and, in some plots, as low as 20%. In plots where native grass seed was used, $<$30% of desirable species thrived, with the remaining plants being either undesirable species or weeds. Despite these challenges, this study provides valuable information regarding flowering forage species that could potentially thrive in livestock pastures in the southeastern United States.

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