HortScience 58(8):922–934. 2023. https://doi.org/10.21273/HORTSCI17146-23

Pollinators and Other Insect Visitations on Native and Ornamental Perennials in Two Landscapes

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Keywords. *Baptisia*, honey bees, *Hylotelephium*, *Monarda*, *Symphyotrichum*, wild bees

Abstract. **Many pollinator insects, especially honey bees [*Apis mellifera* Linnaeus (Apidae)] and wild bees, are experiencing population decline because of forage and habitat losses. Planting perennial flowering taxa is one method of increasing pollinator habitat. The objectives of this study were to evaluate the potential of 27 native species and ornamental perennial cultivars to determine their ability to attract insect pollinators in a rural and an urban landscape in North Dakota, assess the potential of these perennials to attract other beneficial insects and insect pests, and identify the bee species visiting these perennials. Five to eight native species and/or ornamental cultivars each from four genera, *Monarda* L. (bee balm), *Hylotelephium* H. Ohba (stonecrop), *Baptisia* Vent. (wild indigo), and *Symphyotrichum* Nees (aster), were tested. Weekly observations of individual plants during flowering and their pollinator visitations from 2018 to 2020 indicated that insect pollinators were present for the earliest flowering perennials in June and until the latest flowering perennials during the second week of October or the first freeze. A total of 16,194 insect pollinators were observed, and 87.8% of these pollinator visitations were Hymenoptera and Diptera. Significant landscapes × perennial flowering taxa interactions were detected for all insect groups, except for syrphid flies, for which both main effects were significantly different. Overall, honey bees and beetles preferred to visit *Hylotelephium* and *Symphyotrichum*. The wild bees, lepidopterans, and syrphids preferred *Hylotelephium*, *Symphyotrichum*, and *Monarda*. Tachinids preferred *Symphyotrichum*. Blow flies preferred *Hylotelephium*. More beneficial insect visitations (i.e., 96.0%) and fewer insect pest visitations (i.e., 30.4%) were counted on the rural landscape. A total of 3311 bee individuals were identified as species from the following families: Apidae, Andrenidae, Colletidae, Megachilidae, and Halictidae. Thirty-one and 21 bee species were unique to the rural and urban landscapes, respectively. The two most common wild bees were *Ceratina calcarata* Robertson on the cultivar *S. oblongifolium* (Nutt.) G.L. Nessom October Skies and *Lasioglossum imitatum* (Smith) on some *Monarda* and *Hylotelephium*. These findings suggest that pollinator visitations are influenced by the landscape and varied among the perennial flowering taxa in some cases. However, all evaluated perennial flower taxa would be suitable for attracting and supporting pollinators in rural or urban landscape settings in the northern Great Plains.**

Numerous pollinators, including honey bees [*Apis mellifera Linnaeus* (Apidae)], bumble bees [*Bombus Latreille* spp. (Apidae)], and other wild bees, butterflies, moths, flies, and beetles are important pollinators of many cultivated crops and help achieve seed set and fruit production (Kevan et al. 1990; Klein et al. 2007; McGregor 1976; National Research Council 2007; Thapa 2006). However, the overall decline of pollinators is a concern not only for United States citizens but also for the global population (Dicks et al. 2021; Johnson and Corn 2015; Vasiliev and Greenwood 2021; Woteki 2013; Zattara and Aizen 2021). Habitat fragmentation and loss, pesticide usage, diseases, parasites, intraspecific and interspecific competition between native and invasive species, and climate change are factors that lead to pollinator declines (Goulson et al. 2015; National Research Council 2007; Potts et al. 2010; Soroye et al. 2020; Wagner et al. 2021). For example, native bees and butterflies were once abundant in North Dakota and other northern states. Currently, the rusty patched bumble bee (*Bombus affinis* Cresson) (US Fish and Wildlife Service 2017), dakota skipper [*Hesperia dacotae* (Skinner)], and poweshiek skipperling [*Oarisma Poweshiek* (Parker)] (US Fish and Wildlife Service 2014) are species that historically have been present in North Dakota and/or Minnesota and are now listed by the Endangered Species Act of 1973 as endangered or threatened.

Because of pollinator decline, private and public entities such as the Xerces Society (Xerces Society 2022), the United States Fish and Wildlife Service (US Fish and Wildlife Service 2022), and US Department of Agriculture (US Department of Agriculture 2022) have been promoting pollinator conservation. Strategies for promoting pollinator conservation include encouraging landowners and home gardeners to plant pollinator-friendly plants in gardens and pastures to provide habitats for native bees and butterflies.

Pollinator conservation in home gardens and backyards is currently a popular topic, especially in residential areas. Towns, cities, and suburbs can provide habitats for numerous pollinator insects as well as other beneficial insects and floral insect pests because of their diverse and unique managed environments (Harris et al. 2016, 2022; Mader et al. 2011; Melathopoulos et al. 2020). Recently, more than 80.0% of landscape architects surveyed indicated that United States consumers are more likely to request native plants, drought-tolerant native plants, and low-maintenance plants for their residential landscapes (American Society of Landscapes Architects 2018).

Native plant species are recommended for planting (Holm 2014; Mader et al. 2011) because they coevolved with native pollinators with regard to flowering time, floral morphology, pollinator rewards, and geographical covariations (Alexandersson and Johnson 2002; Anderson and Johnson 2008, 2009; Bloch and Erhardt 2008; Ehrlich and Raven 1964; Marquis 2004). Thus, because of specific ecological interactions, innate floral morphologies, and different visitation rates of pollinators, many flower species are constrained to interact with specific pollinators (Thompson 2001). However, home gardeners may have negative perceptions of native plants because they have a reputation for being less attractive and messy (Beck et al. 2002; Nassauer 1995). Homeowners may be more willing to plant a mix of native species and ornamental cultivars rather than just native species. We propose the evaluation and identification of species and ornamental cultivars to determine their pollinator attractiveness in the northern United States.

During the breeding process, improved cultivars may lose some of their natural traits that are attractive to pollinators (Wilde et al. 2015). Ornamental flower cultivars are bred and/or selected to improve traits, such as compact plant height (Flemer 1979), elaborate flower form (e.g., double flowers) (Anonymous 1935), vibrant flower colors, flower abundance (Ault 2008), foliage color (Tenczar and Krischik 2007), bloom time (Ault 2009), and disease resistance (Oudshoorn 2012), to satisfy aesthetic flower demands from consumers (Wilde et al. 2015). Attractive petal color was the most common floral characteristic preferred by consumers (Hopkins et al. 2022). Some ornamental cultivars have been heavily bred for aesthetic purposes and may have lost their ability to produce pollen and nectar because of this breeding and selection process. Therefore, it is important to identify which cultivars are the best for pollinator gardens.

Some cultivars and non-native plant species are used by pollinators (Ricker et al. 2019; Rollings and Goulson 2019), especially when food sources are scarce (Braman and Griffin 2022; Mach and Potter 2018; Marquardt et al. 2021; Riddle and Mizell 2016) and outside of the normal flowering season (Salisbury et al. 2015). Home gardeners, landowners, and landscapers desire to create pollinator gardens and hospitable habitats, but they may be discouraged if nationally recommended cultivars are not well-adapted to grow in their state. Numerous native species and ornamental cultivars are available for sale to the consumer horticulture market, but few contain documented pollinator attraction information.

Studies of insect pollinator visitations to flowering plants have been conducted to assess floral attractiveness (Mach and Potter 2018; Marquardt et al. 2021; Ricker et al. 2019; Rollings and Goulson 2019); however, beneficial insect and insect pest visitations to ornamental flowers have not been sufficiently discussed and little information is available. Beneficial insects such as lady beetles, lacewings, and minute pirate bugs (Walliser 2014) as well as insect pests such as stink bugs, blister beetles, and grasshoppers commonly visit ornamental flowers in gardens (Harris et al. 2016, 2022; Khan et al. 2019). The availability of beneficial insects in an ecosystem can help regulate the pest plant population density and can lead to a healthy ecosystem equilibrium (Getanjaly et al. 2015).

Limited research of ornamental cultivars has been conducted to determine their ability to provide ecosystem services to pollinators and other insects in North Dakota landscapes. Our objectives of this research study were to evaluate the potential of 27 perennial native species and ornamental cultivars to determine their ability to attract insect pollinators in rural and urban landscapes in North Dakota, assess the potential of these 27 perennial flowering taxa to attract other beneficial insects as well as insect pests, and determine which native and non-native bee species are visiting these 27 taxa.

Materials and Methods

Twenty-seven herbaceous perennial flowering taxa from four genera comprising a mix of native species and ornamental cultivars were planted on 21 Jun 2018, at the North Dakota State University (NDSU) Horticulture Research Farm near Absaraka, ND (rural landscape; 46.991581 °N, −97.351462 °W), and on 19 Jun 2018, at the NDSU Horticulture Research and Demonstration Gardens in Fargo, ND (urban landscape; 46.891274 °N, −96.810014 °W). The area surrounding the plots of the rural landscape had 3.6% developed land cover (i.e., land covered with diverse buildings and paved surfaces, such as roads and parking lots), whereas the urban landscape had 88.6% developed land cover; both types of land cover were within a 3-km radius centered from the experimental area according to 2019 cropland data layer using CropScape (US Department of Agriculture, National Agricultural Statistics Service, Cropland Data Layer 2022). The 3-km radius was selected based on the forage distances of wild bees and honey bees. Most wild bees forage approximately 0.5 km from their nests (Gathmann and Tscharntke 2002; Zurbuchen et al. 2010a, 2010b), whereas the average forage distance for honey bees is less than 2.6 km away from their nests (Couvillon et al. 2015; Kirk Visscher and Seeley 1982; Seeley 1995).

Herbaceous perennial native species and ornamental cultivars of the following genera were evaluated: *Baptisia*, *Hylotelephium*, *Monarda*, and *Symphyotrichum* (Table 1). These genera are considered pollinator-friendly by United States gardening industry. Of the 27 evaluated taxa, eight are species native to the United States, including five native to North Dakota and/or Minnesota (US Department of Agriculture, Natural Resources Conservation Service 2022). Two of the three remaining taxa are native to the Midwest, and the final taxon is native to the southeastern United States. In Table 1, the scientific name, common name, native or cultivar status, flower color, and commercial source for each perennial are summarized. Only the native species *Symphyotrichum oblongifolium* was started from seed at one of the NDSU greenhouses; the other 26 perennial taxa were purchased from different nurseries.

At each landscape, perennial flowering taxa were arranged in a randomized complete block design with six replication rows. A single plant was considered an experimental unit. Plants of the same genus were planted together at random within a replication row, and genera were arranged at random within each replication row. Each replication row was 25 m long. The distance between replication rows and genera groups was 1.5 m. The distance between plants was 0.76 m.

Before planting, a black landscape fabric weed barrier (Dewitt Pro 5; Dewitt, Sikeston, MO, USA) was stapled to the ground of each replication row to control weeds. Plants were watered at least once or twice each week during the first year, depending on the temperature and rainfall, until plants were established. Plot edges (beyond weed barrier) and plant bases were weeded by hand when needed. During early spring (before regrowth began), dead vegetation was pruned to ∼15 cm. Plants were not fertilized or sprayed with insecticides or fungicides.

When plants were in bloom, observations of pollinators, other beneficial insects, and floral insect pests were conducted from June to October. Each flowering plant was observed for 3 min on a weekly basis, and all observations were conducted during 1 d per study site. All insects that visited or contacted the flowers were counted and recorded, avoiding duplication when possible. Immature insects such as eggs, caterpillars, or pupae and adult insects such as ants (Formicidae) and aphids (Aphididae) were not counted during this study. Visitation counts were conducted between 10:00 and 16:00 HR, when pollinators are most active, and on days when temperatures were warmer than 10 °C, the wind speed was less than 25 km/h, and there was no rain. Native species and cultivars were evaluated for 2 years at each landscape for *Monarda*, *Hylotelephium*, and *Symphyotrichum* in 2018 and 2019, and for *Baptisia* in 2019 and 2020 (most *Baptisia* plants were already blooming when purchased in 2018).

When possible, wild bees were collected during the observation period; however, some bees escaped capture. Specimens of other insect groups were not collected. Bees were captured using a black handheld D-cell-powered insect aspirator (Fulton MX-pp1/U; Gempler's, Janesville, WI, USA), which comprised a collector container (45 mm × 25 mm, length by internal diameter), or hand-collected using only the aspirator collector container and its lid. When necessary, collector containers with bees were immediately submerged in a 0.95-L clear plastic container (HomeFresh RD 32 oz; Placon Corporation, Madison, WI, USA) filled with 500 mL of tap water to slow their movement and prevent escape. Subsequently, they were transferred to a 4-dram vial (BioQuip Products Inc., Rancho Dominguez, CA, USA) that contained 85% alcohol and labeled with the corresponding field data information.

In the laboratory, collected bees were processed according to the procedures of Droege (2010). Bees were identified to the

Received for publication 8 Mar 2023. Accepted for publication 25 May 2023.
Published online 19 Jul 2023.
We thank J. Forness, M. Herrera Grant, and E. Miller for their help with the field work. We thank Dr. J. Jawahar for the statistical analysis advice. This project was funded in part by the United States Department of Agriculture–North Dakota Department of Agriculture, Specialty Crop Block Grant Program (No. 17-379), and in part by the United States Department of Agriculture, National Institute of Food and Agriculture, Crop Protection and Pest Management Extension Implementation Program (no. 2021-70006-35330).
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Table 1. Native species and ornamental cultivars, common names, origin, flower color, and source of the perennial flowering plant.

Scientific name	Common name	Native or cultivar	Flower color	Source of perennial flowering plant
Baptisia alba (L) Vent var. *alba*	White wild indigo	Native[i]	White	Bluebird Nursery, Inc., Clarkson, NE, USA
Baptisia australis (L) R. Br.	Blue wild indigo	Native[ii]	Blue purple	Bluebird Nursery, Inc., Clarkson, NE, USA
Baptisia australis (L) R. Br. var. *minor* (Lehn.) Fernald	Blue wild indigo	Native[ii]	Light blue	Bluebird Nursery, Inc., Clarkson, NE, USA
Baptisia 'American Goldfinch'	American Goldfinch wild indigo	Cultivar	Yellow	Bachman's Wholesale Nursery, Farmington, MN, USA
Baptisia 'Brownie Points'	Brownie Points wild indigo	Cultivar	Caramel brown	Walters Gardens, Inc., Zeeland, MI, USA
Baptisia 'Grape Taffy'	Grape Taffy wild indigo	Cultivar	Deep reddish-purple	Bachman's Wholesale Nursery, Farmington, MN, USA
Baptisia 'Indigo Spires'	Indigo Spires wild indigo	Cultivar	Deep violet purple	Bachman's Wholesale Nursery, Farmington, MN, USA
Hylotelephium 'Autumn Fire'	Autumn Fire stonecrop	Cultivar	Rose	Bachman's Wholesale Nursery, Farmington, MN, USA
Hylotelephium 'Autumn Joy'	Autumn Joy stonecrop	Cultivar	Deep rose-red	Bachman's Wholesale Nursery, Farmington, MN, USA
Hylotelephium 'Cherry Truffle'	Cherry Truffle stonecrop	Cultivar	Reddish purple	Bachman's Wholesale Nursery, Farmington, MN, USA
Hylotelephium 'Neon'	Neon stonecrop	Cultivar	Bright neon pink	Bachman's Wholesale Nursery, Farmington, MN, USA
Hylotelephium 'Night Embers'	Night Embers stonecrop	Cultivar	Mauve pink	Bachman's Wholesale Nursery, Farmington, MN, USA
Monarda fistulosa L.	Wild bergamot	Native[iii]	Lavender	Bachman's Wholesale Nursery, Farmington, MN, USA
Monarda punctata L.	Spotted bee balm	Native[iv]	Pale yellow	Bluebird Nursery, Inc., Clarkson, NE, USA
Monarda didyma L. 'Grand Parade'	Grand Parade bee balm	Cultivar	Lavender–purple	Bluebird Nursery, Inc., Clarkson, NE, USA
Monarda didyma 'Jacob Cline'	Jacob Cline bee balm	Cultivar	Bright red	Bluebird Nursery, Inc., Clarkson, NE, USA
Monarda didyma 'Marshall's Delight'	Marshall's Delight bee balm	Cultivar	Purplish pink	Bluebird Nursery, Inc., Clarkson, NE, USA
Monarda didyma 'Purple Mildew Resistant'	Purple Mildew Resistant bee balm	Cultivar	Purple	Bluebird Nursery, Inc., Clarkson, NE, USA
Monarda didyma 'Raspberry Wine'	Raspberry Wine bee balm	Cultivar	Red burgundy	Bluebird Nursery, Inc., Clarkson, NE, USA
Symphyotrichum laeve (L.) Á. Löve & D. Löve	Smooth blue aster	Native[iii]	Light lavender	Bachman's Wholesale Nursery, Farmington, MN, USA
Symphyotrichum novae-angliae (L.) G.L. Nesom	New England aster	Native[iii]	Bright rose-purple	Bachman's Wholesale Nursery, Farmington, MN, USA
Symphyotrichum novae-angliae 'Alma Potschke'	Alma Potschke aster	Cultivar	Bright rose-pink	Bluebird Nursery, Inc., Clarkson, NE, USA
Symphyotrichum novae-angliae 'Purple Dome'	Purple Dome aster	Cultivar	Deep purple	Bluebird Nursery, Inc., Clarkson, NE, USA
Symphyotrichum oblongifolium (Nutt.) G.L. Nesom	Aromatic aster	Native[iii]	Light purple	Prairie Moon Nursery, Winona, MN, USA[v]
Symphyotrichum oblongifolium 'Dream of Beauty'	Dream of Beauty aster	Cultivar	Pink	Bluebird Nursery, Inc., Clarkson, NE, USA
Symphyotrichum oblongifolium 'October Skies'	October Skies aster	Cultivar	Lavender-blue	Bluebird Nursery, Inc., Clarkson, NE, USA
Symphyotrichum oblongifolium 'Raydon's Favorite'	Raydon's Favorite aster	Cultivar	Bright blue-lavender	Bluebird Nursery, Inc., Clarkson, NE, USA

[i] Native to southeastern United Sates (US Department of Agriculture, Natural Resources Conservation Service 2022).
[ii] Native to midwestern United Sates, but not to North Dakota and Minnesota (US Department of Agriculture, Natural Resources Conservation Service 2022).
[iii] Native to North Dakota and Minnesota (US Department of Agriculture, Natural Resources Conservation Service 2022).
[iv] Native to Minnesota (US Department of Agriculture, Natural Resources Conservation Service 2022).
[v] This native *Symphyotrichum oblongifolium* was the only plant species that was started from seed in a greenhouse at North Dakota State University.

species level when possible using the taxonomic literature (Gibbs 2010, 2011; Gibbs et al. 2013; McGinley 1986; Michener 2007; Mitchell 1960, 1962; Onuferko 2017; Roberts 1972; Sheffield et al. 2011), the identification guides on the Discover Life website (Ascher and Pickering 2020), and identified reference specimens. Specimens that could not be reliably assigned a species epithet were given a unique "morphospecies" identifier. A Leica M125 stereoscope with a Leica DFC450 camera and image processing software (North Central Instruments, Inc., Brooklyn Park, MN, USA) were used to examine each bee. Location labels containing all collection data were affixed to each specimen. Identification labels and voucher specimen labels with a unique project identifier were also affixed to each specimen. Voucher specimens reside in the NDSU Extension Entomology collection housed at 206 Waldron Hall, NDSU, Fargo, ND, USA.

Statistical analysis. All insect visitation counts per plant in their respective insect groups (i.e., honey bees, wild bees, wasps, syrphid flies, tachinid flies, blow flies, butterflies, beetles, other beneficial insects, and floral insect pests) were added across each season year for each landscape. Subsequently, these data were analyzed using a two-way mixed-model analysis of variance (ANOVA) ($P < 0.05$) using the GLIMMIX procedure in SAS (SAS Institute 2013). The landscape, perennial flowering taxa, and their interactions were assigned as fixed effects in the ANOVA table for each insect group; replication was considered a random effect in the experiment. The factor year was combined and, accordingly, removed from the model. Multiple comparisons were performed when appropriate using the LSMEANS/LINES procedure with Tukey's honestly significant difference test (Tukey 1953) at an alpha level of 0.05 in SAS (SAS Institute 2013).

Additionally, percentage compositions for some specific insects [e.g., blues (Lycaenidae)] were calculated to show more details of the main insect groups (or orders in some cases, e.g., Lepidoptera) visiting the perennial flowering taxa. The percentage composition for each main insect group was calculated based on the total visitation counts of that specific insect member of that group and the total visitation counts of the entire main group; for example, the total visit count of syrphid flies was divided by the total Diptera visitation count and then multiplied by 100. Similarly, the percentage composition of a specific insect among four genera was calculated; for example, the total visitation count of *Vanessa cardui* (Linnaeus) (Nymphalidae, Lepidoptera) from all *Baptisia* plants was divided by the total visitation count of *V. cardui* from the four genera and multiplied by 100. These percentages were calculated across rural and urban landscape years. The percentage compositions of bees and wasps were calculated separately for the Hymenoptera group. The percentage compositions for the beneficial insects or the insect pests were

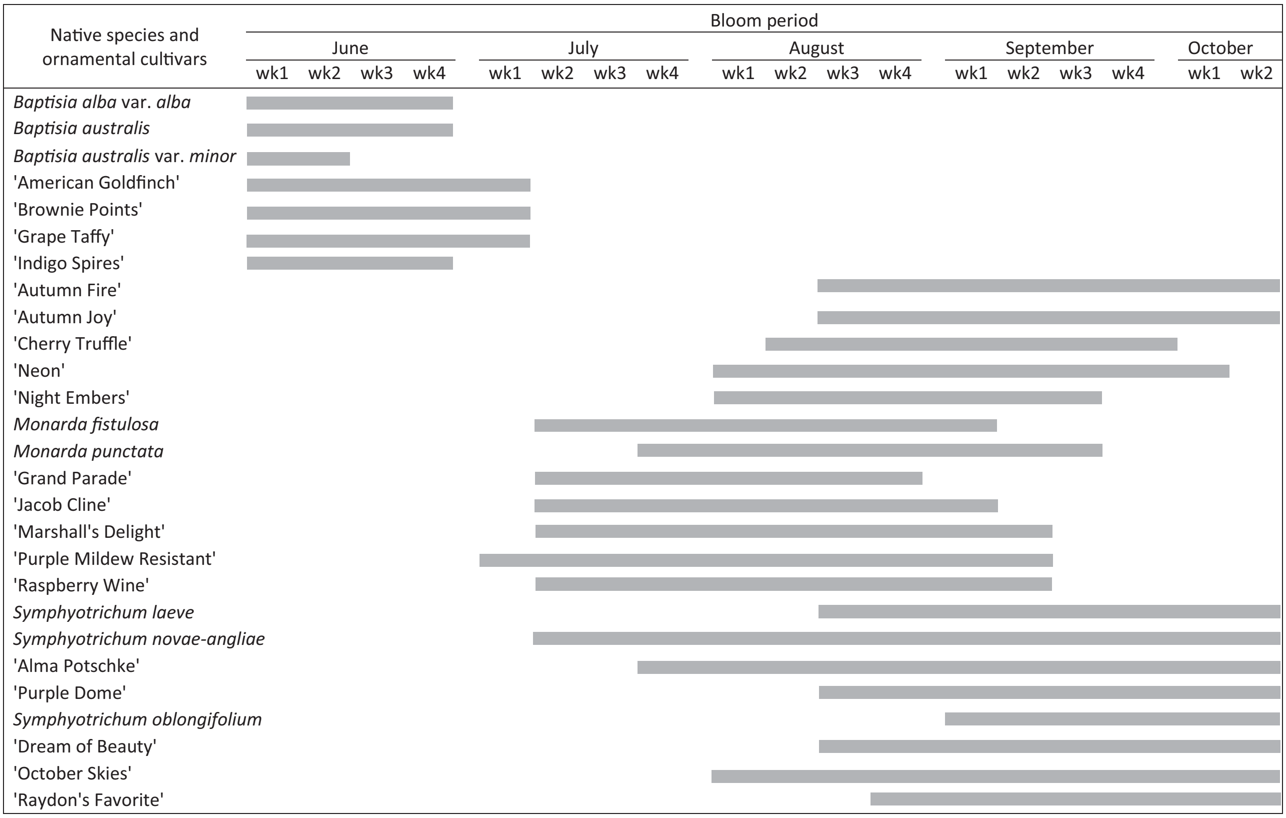

Fig. 1. Bloom period of the native species and ornamental cultivars in North Dakota. This represents the bloom of the first plant to the end of the bloom of the last plant within the taxa.

calculated based on all insects that were assigned in that respective group.

Heat maps were generated to show density, range, and diversity of captured bee species per perennial flowering taxa across landscapes using conditional formatting in Microsoft Excel 2016 (Microsoft, Redmond, WA, USA). Colors on heat maps were used to represent density ranges of bee species on each perennial flowering plant. Additionally, for each bee species, we indicated what percentage of perennial flowering taxa (i.e., of the 27 species/cultivars evaluated) they visited, and whether a bee species was captured at rural, urban, or both landscapes. Specimens that were identified only to the genus level were counted as one species to create the heat maps. Count visitation data of honey bees were also used in these maps.

Results

The bloom time varied for the four genera (Fig. 1). Both landscapes had plants flowering from the beginning of June to the second week of October or until the first heavy freeze. More specifically, the *Baptisia* plants were the first to bloom; this began the first week of June and persisted until the last week of June or first week of July. Most *Monarda* plants began blooming the second week of July; this ended the first or second week of September. Some *Hylotelephium* cultivars began blooming in early August; this continued until the end of September or first week of October; however, 'Autumn Fire' and 'Autumn Joy' continued to bloom until the second week of October. *Symphyotrichum* species and cultivars began blooming in July through August; this continued to bloom until the second week of October or the first heavy freeze. Some *Symphyotrichum* species and cultivars did not complete flowering before a heavy freeze (low temperature of $<-2\,^{\circ}\mathrm{C}$) ended the growing season in both study years.

A total of 17,606 insects were observed and counted across both landscape sites and years. From this total, 16,194 were insect pollinators, 631 were other beneficial insects, and 781 were floral insect pests. Pollinator counts were composed of Hymenoptera (4481 rural and 3816 urban), Diptera (3722 rural and 2206 urban), Lepidoptera (1314 rural and 360 urban), and Coleoptera (270 rural and 25 urban). The beneficial insect counts represented members of Hemiptera and Neuroptera (606 rural and 25 urban) orders. Members of Coleoptera, Hemiptera, and Orthoptera represented the insect pest group (237 rural and 544 urban).

Statistically significant landscape × perennial flowering taxa interactions were detected for honey bees, wild bees, and wasps of the order Hymenoptera (Table 2). Mean visitations of honey bees at the rural landscape (Table 3), regardless of native species or cultivar status, were not significantly different among all perennial taxa. However, at the urban landscape, honey bee visitations to the native species *S. novae-angliae* and its cultivar, Alma Potschke, were significantly greater than those of the remaining perennial taxa, with the exceptions of 'Autumn Fire', 'Autumn Joy', 'Cherry Truffle', and 'Night Embers'. Additionally, *S. novae-angliae*, 'Alma Potschke', 'Night Embers', 'Autumn Joy', and 'Cherry Truffle' at the urban landscape had significantly higher numbers of honey bee visits than all the rural landscape taxa.

Hylotelephium 'Autumn Fire' and 'Autumn Joy' (Table 3) at the rural landscape attracted significantly higher numbers of wild bees than all the remaining perennial taxa at both landscapes, with the exception of 'Night Embers'. Additionally, 'Autumn Joy' from the rural landscape and the native species *M. punctata* from the urban landscape had more wasp visitations than the rest of the taxa regardless of landscapes, with the exceptions of 'Autumn Joy' at the urban landscape and 'Autumn Fire' at both landscapes. Overall, the native species *B. alba* var. *alba*, *B. australis*, and *B. a.* var. *minor* had no or fewer visits with Hymenoptera.

No statistically significant landscape × perennial flowering taxa interaction was observed for mean syrphid fly (Syrphidae, Diptera) visitations (Table 2). However, significant differences were detected for the main effects of landscape and perennial flower taxa. Syrphid fly visits at the rural landscape were 69.2% significantly greater than those at the urban landscape. The native species *S. novae-angliae* (Table 4) had the

Table 2. Analysis of variance of attractiveness of insect pollinators and other insects.

Analysis	Effect	df	*F* value	*P*
Honey bees	Landscape	1, 589	81.97	<0.0001
	Perennial flower	26, 589	10.32	<0.0001
	Landscape × Perennial flower	26, 589	5.45	<0.0001
Wild bees	Landscape	1, 589	63.41	<0.0001
	Perennial flower	26, 589	8.78	<0.0001
	Landscape × Perennial flower	26, 589	6.55	<0.0001
Wasps	Landscape	1, 589	2.39	0.1225
	Perennial flower	26, 589	9.25	<0.0001
	Landscape × Perennial flower	26, 589	2.02	0.0022
Syrphidae	Landscape	1, 589	14.10	0.0002
	Perennial flower	26, 589	8.20	<0.0001
	Landscape × Perennial flower	26, 589	1.40	0.0933
Tachinidae	Landscape	1, 589	8.69	0.0033
	Perennial flower	26, 589	3.31	<0.0001
	Landscape × Perennial flower	26, 589	2.61	<0.0001
Calliphoridae	Landscape	1, 589	1.13	0.2886
	Perennial flower	26, 589	8.79	<0.0001
	Landscape × Perennial flower	26, 589	2.20	0.0006
Lepidoptera	Landscape	1, 589	17.25	<0.0001
	Perennial flower	26, 589	5.73	<0.0001
	Landscape × Perennial flower	26, 589	2.95	<0.0001
Coleoptera	Landscape	1, 589	16.85	<0.0001
	Perennial flower	26, 589	4.27	<0.0001
	Landscape × Perennial flower	26, 589	3.97	<0.0001
Other beneficial insects	Landscape	1, 589	32.30	<0.0001
	Perennial flower	26, 589	3.70	<0.0001
	Landscape × Perennial flower	26, 589	3.36	<0.0001
Insect pests to flowers	Landscape	1, 589	32.30	<0.0001
	Perennial flower	26, 589	3.70	<0.0001
	Landscape × Perennial flower	26, 589	3.36	<0.0001

df = degrees of freedom.

highest numbers of syrphid fly visits compared with those of the other taxa, but this number was not significantly different from those of the native *S. laeve* or the *S. oblongifolium* cultivar October Skies. *Symphyotrichum laeve* and 'October Skies' were also not significantly different from *Hylotelephium* 'Autumn Joy' and *S. novae-angliae* 'Alma Potschke' in terms of attracting syrphids. Additionally, in the Diptera order, the landscape × perennial flowering taxa interaction was significant for Tachinidae and Calliphoridae flies (Table 2). The native *S. laeve* at the rural landscape (Table 4) attracted significantly more tachinid flies than all the other perennial flower species and cultivars at both landscapes. There was no significant difference between the remaining perennial taxa. Similarly, *S. laeve* at the rural landscape had significantly more Calliphoridae fly visits, but this attraction was not significantly different from that of *Hylotelephium* 'Autumn Fire' at both landscapes and of 'Autumn Joy' and 'Night Embers' at the urban landscape. All *Baptisia* and *Monarda* and the other *Symphyotrichum* taxa had significantly fewer Calliphoridae visitations at the rural and urban landscapes.

A landscape × perennial flowering taxa interaction was also detected for Lepidoptera and Coleoptera insect visitations (Table 2). At the rural landscape (Table 5), the *Hylotelephium* cultivars Autumn Fire, Autumn Joy, and Neon had significantly more butterfly visits than all *Baptisia*, *Monarda*, and *Symphyotrichum* (except the rural native *S. novae-angliae*) taxa. However, the rural 'Autumn Joy' and 'Neon' at both landscapes were not significantly different from the rural *S. novae-angliae* in terms of Lepidoptera visits. Regarding Coleoptera mean visitations, the native *S. novae-angliae* species at the rural landscape attracted the most visits compared with all the remaining perennial taxa at both landscapes.

The landscape × perennial flowering taxa interaction was also significant for other beneficial insects and floral insect pests (Table 2). The mean visits of other beneficial insects at the rural landscape (Table 5) were not significantly different among 'Autumn Fire', 'Autumn

Table 3. Visitations (mean ± *SEM*) and comparison of the interaction between the perennial flowering taxa and landscape type for Hymenoptera (average number of insects per plant) across the sampling period in North Dakota.

	Honey bees		Wild bees		Wasps	
Perennial flower	Rural	Urban	Rural	Urban	Rural	Urban
Baptisia alba var. *alba*	0.0 ± 0.0 f	0.0 ± 0.0 f	0.0 ± 0.0 e	0.0 ± 0.0 e	0.0 ± 0.0 d	0.0 ± 0.0 d
Baptisia australis	0.0 ± 0.0 f	0.2 ± 0.2 f	0.0 ± 0.0 e	1.9 ± 0.8 de	0.0 ± 0.0 d	0.0 ± 0.0 d
Baptisia australis var. *minor*	0.0 ± 0.0 f	0.1 ± 0.1 f	0.0 ± 0.0 e	0.6 ± 0.4 de	0.0 ± 0.0 d	0.0 ± 0.0 d
'American Goldfinch'	0.0 ± 0.0 f	0.5 ± 0.3 f	1.3 ± 0.4 de	2.3 ± 0.7 de	0.3 ± 0.2 d	0.1 ± 0.1 d
'Brownie Points'	0.1 ± 0.1 f	0.2 ± 0.1 f	0.6 ± 0.2 e	3.3 ± 0.8 cde	0.1 ± 0.1 d	0.3 ± 0.1 d
'Grape Taffy'	0.0 ± 0.0 f	0.3 ± 0.2 f	0.9 ± 0.3 de	1.5 ± 0.4 de	0.3 ± 0.1 d	0.1 ± 0.1 d
'Indigo Spires'	0.0 ± 0.0 f	0.5 ± 0.3 f	0.7 ± 0.3 e	4.6 ± 0.9 cde	0.3 ± 0.3 d	0.1 ± 0.1 d
'Autumn Fire'	1.6 ± 0.6 f	18.3 ± 4.1 abcde	53.4 ± 12.7 a	3.0 ± 0.1 cde	1.9 ± 0.6 abcd	2.5 ± 1.0 abc
'Autumn Joy'	0.8 ± 0.3 f	24.1 ± 7.5 abc	52.0 ± 10.1 a	5.0 ± 1.8 cde	3.0 ± 0.9 a	2.7 ± 1.1 ab
'Cherry Truffle'	1.4 ± 0.6 f	19.9 ± 9.2 abcd	11.5 ± 4.7 cde	2.0 ± 0.8 de	0.2 ± 0.2 d	0.3 ± 0.2 d
'Neon'	0.3 ± 0.1 f	5.3 ± 1.5 def	25.4 ± 6.4 bc	2.5 ± 0.8 de	0.7 ± 0.3 cd	0.9 ± 0.3 bcd
'Night Embers'	4.3 ± 0.9 ef	25.3 ± 5.8 abc	34.1 ± 4.9 ab	7.6 ± 1.8 cde	0.7 ± 0.4 dc	0.3 ± 0.1 d
Monarda fistulosa	0.0 ± 0.0 f	0.3 ± 0.1 f	17.1 ± 7.5 bcde	15.6 ± 5.5 bcde	0.3 ± 0.2 d	0.6 ± 0.4 cd
Monarda punctata	0.0 ± 0.0 f	4.6 ± 1.4 f	5.3 ± 1.8 cde	11.1 ± 3.7 cde	0.5 ± 0.3 d	3.8 ± 1.1 a
'Grand Parade'	0.0 ± 0.0 f	0.3 ± 0.3 f	23.4 ± 8.2 bcd	5.3 ± 2.0 cde	0.1 ± 0.1 d	0.0 ± 0.0 d
'Jacob Cline'	0.0 ± 0.0 f	0.1 ± 0.1 f	4.5 ± 2.2 cde	2.4 ± 1.0 de	0.0 ± 0.0 d	0.5 ± 0.3 d
'Marshall's Delight'	0.1 ± 0.1 f	0.3 ± 0.2 f	21.3 ± 10.8 bcde	5.9 ± 2.5 cde	0.1 ± 0.1 d	0.5 ± 0.4 d
'Purple Mildew Resistant'	0.0 ± 0.0 f	0.0 ± 0.0 f	17.8 ± 6.6 bcde	7.7 ± 3.3 cde	0.2 ± 0.1 d	0.6 ± 0.3 cd
'Raspberry Wine'	0.1 ± 0.1 f	0.0 ± 0.0 f	20.3 ± 8.0 bcde	4.7 ± 1.9 cde	0.0 ± 0.0 d	0.2 ± 0.1 d
Symphyotrichum laeve	1.2 ± 0.4 f	13.8 ± 2.4 bcdef	5.7 ± 1.8 cde	3.1 ± 0.9 cde	0.4 ± 0.3 d	0.3 ± 0.1 d
Symphyotrichum novae-angliae	6.2 ± 2.3 def	29.9 ± 6.3 a	13.3 ± 3.4 bcde	4.3 ± 1.3 cde	0.2 ± 0.1 d	0.3 ± 0.1 d
'Alma Potschke'	7.2 ± 1.2 def	27.5 ± 9.6 ab	10.2 ± 2.9 cde	2.1 ± 0.7 ed	0.3 ± 0.1 d	0.2 ± 0.1 d
'Purple Dome'	0.9 ± 0.2 f	4.1 ± 2.1 ef	0.8 ± 0.4 e	0.3 ± 0.2 e	0.1 ± 0.1 d	0.1 ± 0.1 d
Symphyotrichum oblongifolium	0.1 ± 0.1 f	3.5 ± 1.6 f	1.3 ± 0.7 de	1.1 ± 0.9 de	0.0 ± 0.0 d	0.1 ± 0.1 d
'Dream of Beauty'	0.6 ± 0.3 f	2.8 ± 0.5 f	5.7 ± 2.3 cde	0.5 ± 0.2 e	0.5 ± 0.3 d	0.1 ± 0.1 d
'October Skies'	1.3 ± 0.5 f	12.8 ± 2.9 cdef	11.1 ± 4.3 cde	9.1 ± 2.5 cde	0.3 ± 0.3 d	0.1 ± 0.1 d
'Raydon's Favorite'	0.0 ± 0.0 f	2.3 ± 1.3 f	0.3 ± 0.2 e	0.1 ± 0.1 e	0.1 ± 0.1 d	0.1 ± 0.1 d

Means sharing the same letter within a column and between rural and urban landscape columns for each insect group indicate no statistically significant difference based on a two-way mixed-model ANOVA ($P < 0.05$) and LSMEANS/Lines Tukey's with an α level of 0.05.

Table 4. Visitations (mean ± *SEM*) and comparison of the interaction between the perennial flowering taxa and the landscape type for Diptera (average number of insects per plant) across the sampling period in North Dakota.

	Syrphidae (Syrphids)		Tachinidae (Tachinids)		Calliphoridae (Blow flies)	
Perennial flower	Rural	Urban	Rural	Urban	Rural	Urban
Baptisia alba var. *alba*	0.0 ± 0.0 aD	0.1 ± 0.1 aD	0.0 ± 0.0 b	0.0 ± 0.0 b	0.0 ± 0.0 d	0.0 ± 0.0 d
Baptisia australis	0.0 ± 0.0 aD	1.3 ± 0.4 aD	0.0 ± 0.0 b	0.0 ± 0.0 b	0.0 ± 0.0 d	0.1 ± 0.1 d
Baptisia australis var. *minor*	0.0 ± 0.0 aD	0.2 ± 0.1 aD	0.0 ± 0.0 b	0.0 ± 0.0 b	0.0 ± 0.0 d	0.0 ± 0.0 d
'American Goldfinch'	2.3 ± 0.5 aD	1.3 ± 0.4 aD	0.0 ± 0.0 b	0.0 ± 0.0 b	0.5 ± 0.3 d	0.2 ± 0.2 d
'Brownie Points'	1.3 ± 0.4 aD	1.0 ± 0.4 aD	0.0 ± 0.0 b	0.0 ± 0.0 b	0.5 ± 0.3 d	0.4 ± 0.3 d
'Grape Taffy'	1.8 ± 0.6 aD	1.8 ± 0.6 aD	0.0 ± 0.0 b	0.0 ± 0.0 b	0.1 ± 0.1 d	0.3 ± 0.1 d
'Indigo Spires'	1.5 ± 0.5 aD	2.9 ± 1.1 aD	0.0 ± 0.0 b	0.0 ± 0.0 b	0.4 ± 0.3 d	0.0 ± 0.0 d
'Autumn Fire'	15.2 ± 3.9 aCD	5.3 ± 1.5 aCD	0.5 ± 0.3 b	0.1 ± 0.1 b	4.4 ± 2.5 ab	4.6 ± 1.3 ab
'Autumn Joy'	18.6 ± 4.7 aBCD	6.7 ± 1.6 aBCD	0.5 ± 0.3 b	0.0 ± 0.0 b	2.4 ± 0.8 bcd	3.8 ± 1.1 abc
'Cherry Truffle'	6.3 ± 2.7 aD	3.1 ± 1.3 aD	0.0 ± 0.0 b	0.0 ± 0.0 b	0.2 ± 0.2 d	0.6 ± 0.4 d
'Neon'	15.4 ± 4.0 aCD	6.0 ± 1.3 aCD	0.4 ± 0.3 b	0.2 ± 0.2 b	0.9 ± 0.5 cd	1.7 ± 0.6 bcd
'Night Embers'	15.9 ± 4.0 aCD	5.2 ± 1.5 aCD	0.0 ± 0.0 b	0.0 ± 0.0 b	1.1 ± 0.5 cd	2.6 ± 0.7 abcd
Monarda fistulosa	5.3 ± 2.2 aD	10.8 ± 3.6 aD	0.0 ± 0.0 b	0.0 ± 0.0 b	0.4 ± 0.3 d	0.2 ± 0.1 d
Monarda punctata	7.9 ± 2.7 aD	6.4 ± 1.7 aD	0.0 ± 0.0 b	0.0 ± 0.0 b	0.1 ± 0.1 d	0.2 ± 0.1 d
'Grand Parade'	7.2 ± 3.0 aD	8.4 ± 2.8 aD	0.0 ± 0.0 b	0.0 ± 0.0 b	0.0 ± 0.0 d	0.0 ± 0.0 d
'Jacob Cline'	1.5 ± 0.7 aD	3.3 ± 1.1 aD	0.0 ± 0.0 b	0.0 ± 0.0 b	0.1 ± 0.1 d	0.0 ± 0.0 d
'Marshall's Delight'	5.8 ± 2.2 aD	6.6 ± 2.7 aD	0.1 ± 0.1 b	0.0 ± 0.0 b	0.0 ± 0.0 d	0.0 ± 0.0 d
'Purple Mildew Resistant'	6.3 ± 2.6 aD	9.1 ± 3.0 aD	0.0 ± 0.0 b	0.0 ± 0.0 b	0.0 ± 0.0 d	0.1 ± 1.0 d
'Raspberry Wine'	6.4 ± 2.6 aD	9.8 ± 3.7 aD	0.0 ± 0.0 b	0.0 ± 0.0 b	0.0 ± 0.0 d	0.0 ± 0.0 d
Symphyotrichum laeve	35.9 ± 13.7 aAB	18.3 ± 5.3 aAB	3.8 ± 2.0 a	0.2 ± 0.1 b	5.7 ± 2.0 a	0.4 ± 0.3 d
Symphyotrichum novae-angliae	43.5 ± 13.4 aA	25.3 ± 8.3 aA	0.8 ± 0.4 b	0.3 ± 0.3 b	0.4 ± 0.3 d	0.2 ± 0.1 d
'Alma Potschke'	18.9 ± 5.5 aBCD	4.8 ± 1.4 aBCD	0.3 ± 0.2 b	0.0 ± 0.0 b	0.5 ± 0.3 d	0.3 ± 0.2 d
'Purple Dome'	2.4 ± 0.8 aD	2.0 ± 1.0 aD	0.0 ± 0.0 b	0.0 ± 0.0 b	0.2 ± 0.1 d	0.1 ± 0.1 d
Symphyotrichum oblongifolium	10.3 ± 5.2 aD	5.7 ± 3.7 aD	0.2 ± 0.2 b	0.2 ± 0.1 b	0.0 ± 0.0 d	0.0 ± 0.0 d
'Dream of Beauty'	16.0 ± 7.2 aD	1.6 ± 0.6 aD	0.7 ± 0.5 b	0.0 ± 0.0 b	1.0 ± 0.4 cd	0.0 ± 0.0 d
'October Skies'	32.0 ± 11.6 aABC	19.1 ± 5.7 aABC	0.6 ± 0.2 b	0.3 ± 0.2 b	1.0 ± 0.3 cd	0.2 ± 0.1 d
'Raydon's Favorite'	5.0 ± 2.6 aD	1.1 ± 0.6 aD	0.1 ± 1.0 b	0.0 ± 0.0 b	0.0 ± 0.0 d	0.0 ± 0.0 d

There was no significant interaction between landscape and perennial flower for Syrphidae; therefore, uppercase letters for the Syrphidae group indicate comparisons of the main effect of perennial flowers and lowercase letters indicate comparisons of the interaction.

Means sharing the same letter within a column and between rural and urban landscape columns for each insect group indicate no statistically significant difference based on a two-way mixed-model ANOVA ($P < 0.05$) and LSMEANS/Lines Tukey's at an α level of 0.05.

Joy', 'Neon', *S. laeve*, *S. novae-angliae*, and *S. oblongifolium* 'Dream of Beauty'. The rural 'Autumn Fire', 'Autumn Joy', and *S. laeve* also attracted significantly more beneficial insects than all perennial taxa grown in the urban landscape. Regarding insect pests (Table 5), the urban *Baptisia* 'Brownie Points' and 'Indigo Spires' attracted the greatest number of pests compared with the remaining rural and urban

Table 5. Visitations (mean ± *SEM*) and comparisons of the interaction between the perennial flowering taxa and the landscape type for Lepidoptera, Coleoptera, beneficial insects, and insect pests (numbers of insects per plant) across the sampling period in North Dakota.

	Lepidoptera (Butterflies and moths)		Coleoptera (Beetles)		Other beneficial insects		Insect pests	
Perennial flower	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Baptisia alba var. *alba*	0.0 ± 0.0 c	0.0 ± 0.0 c	0.0 ± 0.0 b	0.0 ± 0.0 b	0.0 ± 0.0 d	0.0 ± 0.0 d	0.0 ± 0.0 f	0.0 ± 0.0 f
Baptisia australis	0.0 ± 0.0 c	0.0 ± 0.0 c	0.0 ± 0.0 b	0.0 ± 0.0 b	0.0 ± 0.0 d	0.0 ± 0.0 d	0.0 ± 0.0 f	0.3 ± 0.1 ef
Baptisia australis var. *minor*	0.0 ± 0.0 c	0.0 ± 0.0 c	0.0 ± 0.0 b	0.0 ± 0.0 b	0.0 ± 0.0 d	0.0 ± 0.0 d	0.0 ± 0.0 f	0.0 ± 0.0 ef
'American Goldfinch'	0.3 ± 0.2 c	0.0 ± 0.0 c	0.0 ± 0.0 b	0.0 ± 0.0 b	0.0 ± 0.0 d	0.0 ± 0.0 d	0.4 ± 0.3 ef	5.1 ± 1.3 bc
'Brownie Points'	0.1 ± 1.0 c	0.0 ± 0.0 c	0.0 ± 0.0 b	0.0 ± 0.0 b	0.0 ± 0.0 d	0.0 ± 0.0 d	0.1 ± 0.1 f	10.8 ± 2.3 a
'Grape Taffy'	0.9 ± 0.5 c	0.0 ± 0.0 c	0.0 ± 0.0 b	0.0 ± 0.0 b	0.0 ± 0.0 d	0.0 ± 0.0 d	0.1 ± 0.1 f	3.9 ± 1.0 cde
'Indigo Spires'	0.4 ± 0.2 c	0.0 ± 0.0 c	0.0 ± 0.0 b	0.0 ± 0.0 b	0.0 ± 0.0 d	0.0 ± 0.0 d	0.0 ± 0.0 f	8.6 ± 1.6 ab
'Autumn Fire'	28.5 ± 12.0 a	2.2 ± 0.9 c	0.3 ± 0.2 b	0.4 ± 0.3 b	8.0 ± 3.4 ab	0.3 ± 0.2 cd	0.7 ± 0.4 ef	2.0 ± 0.7 cdef
'Autumn Joy'	24.1 ± 9.2 ab	2.3 ± 1.0 c	1.0 ± 0.3 b	0.1 ± 0.1 b	9.1 ± 3.9 a	0.3 ± 0.2 cd	0.5 ± 0.3 ef	2.7 ± 1.3 cdef
'Cherry Truffle'	0.5 ± 0.3 c	0.1 ± 0.1 c	0.6 ± 0.3 b	0.2 ± 0.1 b	0.2 ± 0.1 d	0.1 ± 0.1 d	0.5 ± 0.5 ef	0.4 ± 0.3 ef
'Neon'	14.5 ± 7.9 abc	9.5 ± 3.9 bc	0.8 ± 0.3 b	0.2 ± 0.1 b	2.9 ± 1.6 abcd	0.3 ± 0.2 cd	1.1 ± 0.4 def	0.9 ± 0.7 def
'Night Embers'	3.3 ± 2.2 c	0.3 ± 0.3 c	1.3 ± 0.4 b	0.6 ± 0.2 b	0.8 ± 0.4 cd	0.1 ± 0.1 d	1.3 ± 0.4 def	1.8 ± 0.6 cdef
Monarda fistulosa	0.9 ± 0.7 c	0.2 ± 0.2 c	0.0 ± 0.0 b	0.0 ± 0.0 b	0.0 ± 0.0 d	0.0 ± 0.0 d	0.0 ± 0.0 f	0.3 ± 0.2 ef
Monarda punctata	0.2 ± 0.1 c	0.3 ± 0.1 c	1.1 ± 0.5 b	0.3 ± 0.1 b	1.8 ± 0.7 bcd	0.3 ± 0.2 cd	1.8 ± 1.0 cdef	0.9 ± 0.5 def
'Grand Parade'	0.3 ± 0.3 c	0.2 ± 0.1 c	0.0 ± 0.0 b	0.0 ± 0.0 b	0.0 ± 0.0 d	0.1 ± 0.1 d	0.3 ± 0.1 ef	0.8 ± 0.3 def
'Jacob Cline'	0.1 ± 0.1 c	0.0 ± 0.0 c	0.0 ± 0.0 b	0.0 ± 0.0 b	0.0 ± 0.0 d	0.0 ± 0.0 d	0.0 ± 0.0 f	0.5 ± 0.3 ef
'Marshall's Delight'	1.5 ± 1.1 c	0.4 ± 0.2 c	0.1 ± 0.1 b	0.0 ± 0.0 b	0.0 ± 0.0 d	0.0 ± 0.0 d	0.3 ± 0.2 ef	0.4 ± 0.3 ef
'Purple Mildew Resistant'	0.7 ± 0.3 c	0.0 ± 0.0 c	0.0 ± 0.0 b	0.0 ± 0.0 b	0.0 ± 0.0 d	0.0 ± 0.0 d	0.2 ± 0.1 f	0.8 ± 0.6 def
'Raspberry Wine'	0.8 ± 0.5 c	0.2 ± 0.1 c	0.3 ± 0.3 b	0.0 ± 0.0 b	0.0 ± 0.0 d	0.1 ± 0.1 d	0.4 ± 0.3 ef	0.3 ± 0.2 ef
Symphyotrichum laeve	3.3 ± 1.3 c	0.5 ± 0.3 c	2.8 ± 1.2 b	0.2 ± 0.1 b	9.4 ± 4.1 a	0.1 ± 0.1 d	1.2 ± 0.6 def	0.5 ± 0.3 ef
Symphyotrichum novae-angliae	10.0 ± 4.5 bc	6.8 ± 2.5 c	9.7 ± 4.5 a	0.2 ± 0.1 b	6.8 ± 2.7 abc	0.1 ± 0.1 d	4.4 ± 1.7 cd	0.8 ± 0.3 def
'Alma Potschke'	8.8 ± 3.4 c	3.3 ± 1.3 c	3.0 ± 1.2 b	0.0 ± 0.0 b	2.0 ± 0.9 bcd	0.0 ± 0.0 d	2.8 ± 0.8 cdef	1.0 ± 0.5 def
'Purple Dome'	0.3 ± 0.2 c	0.7 ± 0.4 c	0.2 ± 0.1 b	0.1 ± 0.1 b	0.8 ± 0.3 cd	0.0 ± 0.0 d	1.2 ± 0.5 def	0.2 ± 0.1 f
Symphyotrichum oblongifolium	1.3 ± 0.8 c	0.3 ± 0.3 c	0.1 ± 0.1 b	0.0 ± 0.0 b	0.0 ± 0.0 d	0.0 ± 0.0 d	0.0 ± 0.0 f	0.3 ± 0.2 ef
'Dream of Beauty'	3.7 ± 2.2 c	0.2 ± 0.1 c	0.3 ± 0.3 b	0.0 ± 0.0 b	6.0 ± 4.0 abcd	0.2 ± 0.1 d	1.0 ± 0.5 def	0.5 ± 0.3 ef
'October Skies'	4.2 ± 2.0 c	2.9 ± 1.0 c	0.8 ± 0.4 b	0.0 ± 0.0 b	2.4 ± 1.3 bcd	0.3 ± 0.1 cd	1.4 ± 0.5 cdef	1.6 ± 0.5 cdef
'Raydon's Favorite'	0.8 ± 0.5 c	0.0 ± 0.0 c	0.3 ± 0.3 b	0.0 ± 0.0 b	0.3 ± 0.2 cd	0.0 ± 0.0 d	0.3 ± 0.2 ef	0.0 ± 0.0 f

Means sharing the same letter within a column and between rural and urban landscape columns for each insect group indicate no statistically significant difference based on a two-way mixed-model ANOVA ($P < 0.05$) and LSMEANS/Lines Tukey's at an α level of 0.05.

Table 6. Percentages of specific insect groups visiting perennial flowering taxa in North Dakota across the rural and urban landscapes.

Main group and order	Insect species and/or common name	Percentages within insect groups (%)	Insect percentage composition among genera (%)			
			Baptisia	*Hylotelephium*	*Monarda*	*Symphyotrichum*
Insect pollinators						
Hymenoptera[i]						
	Honey bee, *Apis mellifera* Linnaeus (Apidae)	33.3	0.8	45.5	2.5	51.1
	Bumble bees, *Bombus* Latreille spp. (Apidae)	6.5	16.5	14.4	44.8	24.3
	Other wild bees	60.2	2.6	47.4	35.6	14.5
	Yellowjackets (Vespidae)	8.8	0.0	65.4	15.4	19.2
	Parasitic wasps	53.4	10.2	66.2	6.4	17.2
	Other wasps	37.8	0.9	31.5	64.9	2.7
Diptera						
	Syrphids (Syrphidae)	91.0	3.4	21.7	21.1	53.8
	Tachinids (Tachinidae)	1.8	0.0	18.4	0.9	80.7
	Blow flies (Calliphoridae)	7.2	6.8	62.6	2.8	27.8
Lepidoptera						
	Blues (Lycaenidae)	0.1	0.0	50.0	50.0	0.0
	Monarch butterfly, *Danaus plexippus* (Linnaeus) (Nymphalidae)	0.8	0.0	76.9	0.0	23.1
	Painted lady, *Vanessa cardui* (Linnaeus) (Nymphalidae)	43.9	2.3	62.6	5.9	29.3
	Red admiral, *Vanessa atalanta* (Linnaeus) (Nymphalidae)	0.5	0.0	33.3	11.1	55.6
	Other brush-footed butterflies (Nymphalidae)	0.4	0.0	0.0	28.6	71.4
	Skipper butterflies (Hesperiidae)	0.4	14.3	14.3	71.4	0.0
	Eastern tiger swallowtail, *Papilio glaucus* (Linnaeus) (Papilionidae)	0.1	0.0	0.0	100.0	0.0
	Sulphurs and whites (Pieridae)	30.4	0.0	55.7	1.2	43.1
	Other butterflies	0.7	25.0	16.7	16.7	41.7
	Celery looper, *Anagrapha falcifera* (Kirby) (Noctuidae)	18.5	0.0	70.0	0.7	29.4
	Diamondback moth, *Plutella xylostella* (Linnaeus) (Plutellidae)	0.1	0.0	100.0	0.0	0.0
	Snowberry clearwing, *Hemaris diffinis* (Boisduval) (Sphingidae)	0.1	0.0	0.0	100.0	0.0
	Other moths	4.0	0.0	64.2	6.0	29.4
Coleoptera						
	Goldenrod soldier beetles, *Chauliognathus pensylvanicus* (De Geer) (Cantharidae)	1.7	0.0	60.0	40.0	0.0
	Northern corn rootworm, *Diabrotica barberi* Smith & Lawrence (Chrysomelidae)	82.0	0.0	18.2	5.0	76.9
	Spotted cucumber beetle, *D. undecimpunctata* Mannerheim (Chrysomelidae)	2.7	0.0	0.0	0.0	100.0
	Lady beetles (Coccinellidae)	8.8	0.0	61.5	23.1	15.4
	Leaf beetles (Chrysomelidae)	4.8	0.0	7.1	0.0	92.9
Beneficial insects[ii]						
Hemiptera						
	Ambush bugs (Reduviidae)	3.2	0.0	80.0	10.0	10.0
	Damsel bugs (Nabidae)	0.5	0.0	66.7	0.0	33.3
	Insidious flower bug, *Orius insidiosus* Say (Anthocoridae)	90.8	0.0	40.7	3.5	55.9
Neuroptera						
	Lacewings (Chrysopidae)	5.6	0.0	40.0	11.4	48.6
Flower insect pests[iii]						
Coleoptera						
	Ash-gray blister beetle, *Epicauta fabricii* LeConte (Meloidae)	44.1	100.0	0.0	0.0	0.0
	Black blister beetles, *Epicauta* Dejean spp. (Meloidae)	0.6	0.0	40.0	0.0	60.0
Hemiptera						
	Leafhoppers (Cicadellidae)	0.4	0.0	100.0	0.0	0.0
	Lygus bugs, *Lygus* Hahn spp. (Miridae)	32.8	2.3	20.3	18.4	59.0
	Stink bugs (Pentatomidae)	0.9	14.3	0.0	57.1	28.6
Orthoptera						
	Grasshoppers (Acrididae)	20.6	0.0	53.4	19.9	26.7
	Katydids (Tettigoniidae)	0.1	0.0	0.0	100.0	0.0
	Tree crickets (Gryllidae)	0.5	0.0	0.0	0.0	100.0

[i] Percentages within insect group for Hymenoptera were calculated for bees and wasps separately.

[ii] Percentages within insect group were determined based on all insects (regardless of insect orders) for the beneficial insects.

[iii] Percentages within insect group were determined based on all insects (regardless of insect orders) for the flower insect pests.

flowers, but 'Indigo Spires' did not significantly differ from the urban 'American Goldfinch'. Besides these three *Baptisia* cultivars, no significant differences occurred between the remaining species and cultivars in terms of insect pests.

The insect pollinator composition in the order Hymenoptera and within the bee group was mainly composed of wild bee (including bumble bees) visitations, at 66.7%, and honey bee visitations, at 33.3% (Table 6). Parasitic wasps were the most predominant insects among the wasp group, with 53.4% of visits. The Diptera order was composed mostly (91.0%) of syrphid flies. The most common butterfly was the painted lady butterfly (*V. cardui*), with 43.9% of visits, followed by sulphurs and whites (Pieridae), with 30.4% of visits, and the celery looper moth [*Anagrapha falcifera* (Kirby) (Noctuidae)], with 18.5% of visits. The northern corn rootworm (*Diabrotica barberi* Smith & Lawrence [Chrysomelidae)] was the most common beetle within the Coleoptera pollinators, with 82.0% of visits. The beneficial insect category was composed mainly of the insidious flower bug [*Orius insidiosus* Say (Anthocoridae)] visitations. The most common insect pests of flowers were the ash-gray blister beetle [*Epicauta fabricii* LeConte (Meloidae)], followed by *Lygus* Hahn spp. (Miridae).

The percentage composition of the insect species or group visitations varied among the four plant genera (Table 6). For example, compared with *Hylotelephium*, *Monarda*, or *Baptisia*, *Symphyotrichum* received 51.1% of the honey bee visitations. However, bumble bees with 44.8% of visitations were most commonly found on *Monarda*. *Symphyotrichum* was visited by 53.8% of the syrphids among the four genera; however, only 3.4% of syrphids visited *Baptisia*. Visitations by lepidopterans, coleopterans, beneficial insects, and insect pests also varied among the four plant genera studied.

All bees captured during visitations across both landscapes and years totaled 3311 individuals (i.e., 41.4% of 8003 bee visitations) and represented five families: Apidae, with a total of 20 species (Fig. 2); Andrenidae, with

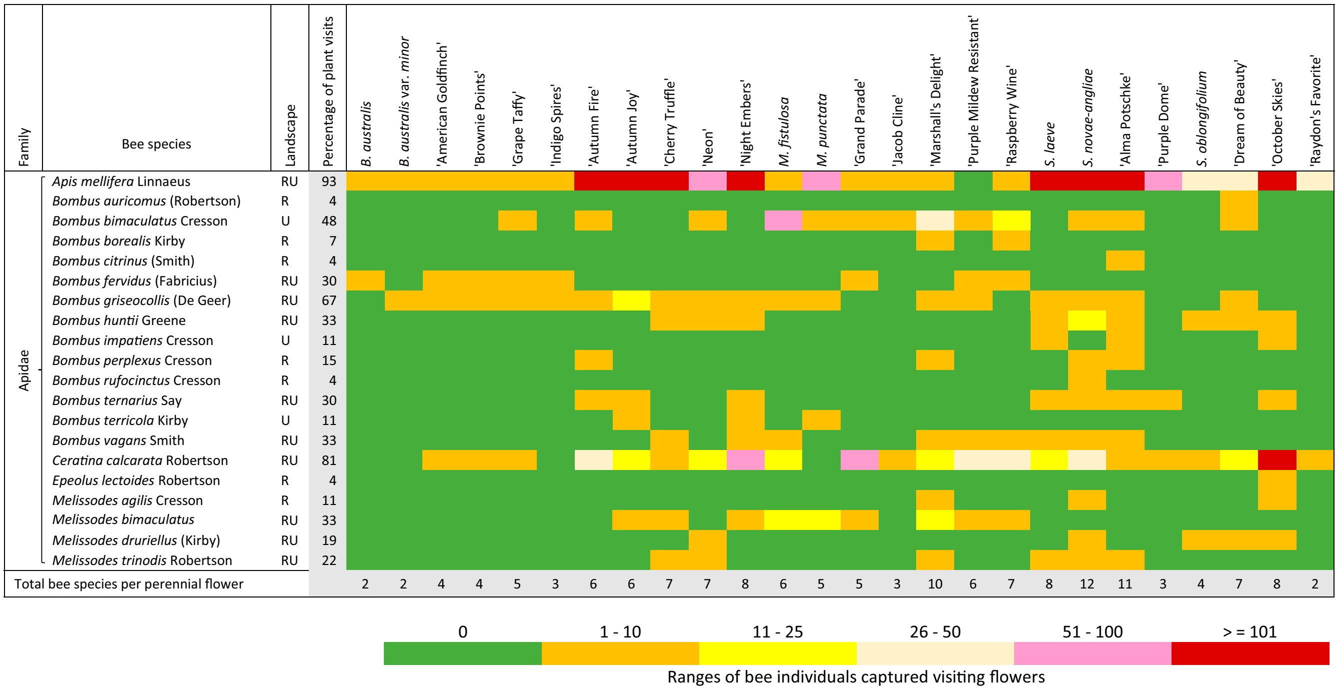

Fig. 2. Heat map of Apidae bee species captured in perennial flowering taxa at rural and urban landscapes in North Dakota during 2018 to 2020. R = rural landscape; U = urban landscape; RU = both landscapes. The percentage of plant visits column indicates the percentage of 27 perennial flowering taxa visited by that bee species. The perennial *B. alba* var. *alba* with zero bee species captured was excluded from the heat map.

four species; Colletidae, with three species; Megachilidae, with 12 species (Fig. 3); and Halictidae, with 33 species (Fig. 4). Totals of 60 and 33 bee species were found at the rural landscape and urban landscape, respectively. Thirty-one species were unique to the rural landscape, whereas only 12 species were unique to the urban landscape; 29 species were common to both landscapes (Figs. 2–4). Clearly, some species were more commonly captured on certain perennial taxa; for example, *Ceratina calcarata* Robertson was most commonly captured on *S. oblongifolium* 'October Skies', with more than 100 individuals captured (Fig. 2). The most commonly captured bee species ranged from 1 to 10 individuals per perennial taxa (Figs. 2–4). Twenty-five percent of the bee species identified during this study were captured

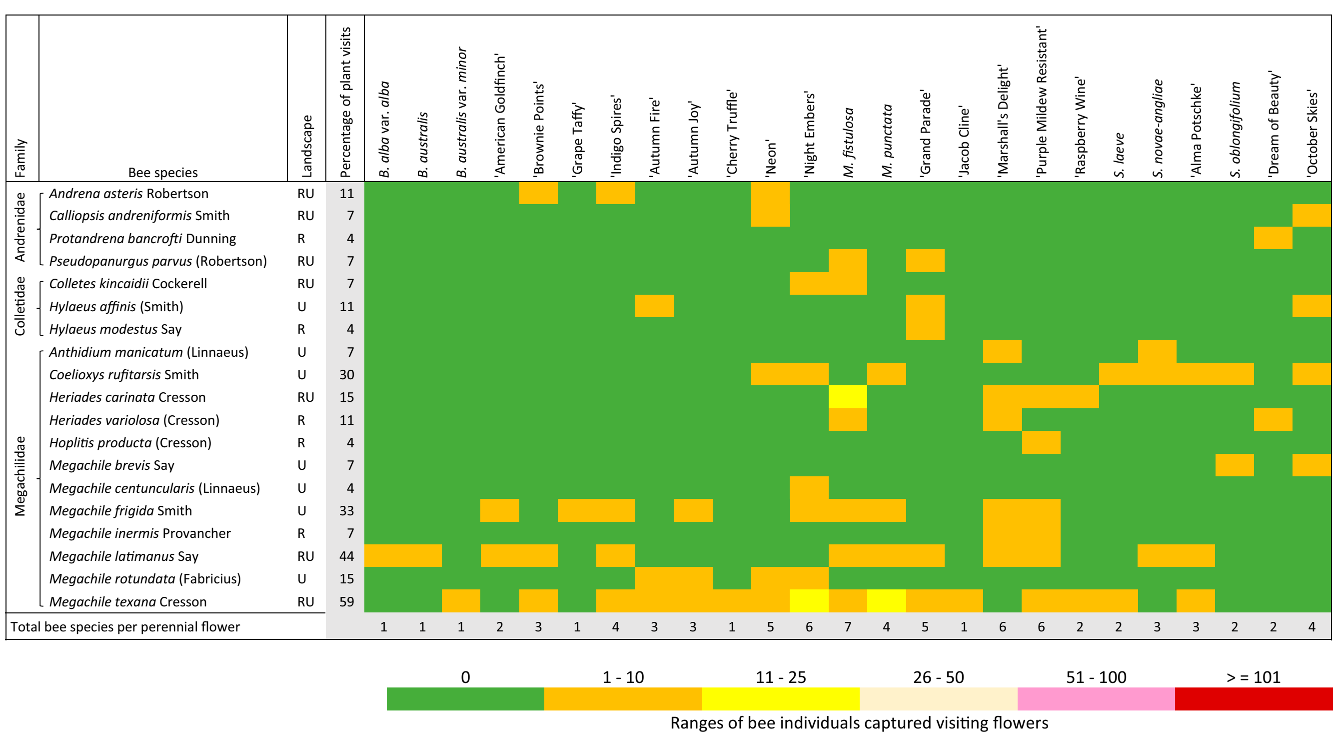

Fig. 3. Heat map of Andrenidae, Colletidae, and Megachilidae bee species captured in perennial flowering taxa at rural and urban landscapes in North Dakota during 2018 to 2020. R = rural landscape; U = urban landscape; RU = both landscapes. The percentage of plant visits column indicates the percentage of 27 perennial flowering taxa visited by that bee species. Perennial taxa (i.e., 'Purple Dome' and 'Raydon's Favorite') with zero bee species captured were excluded from the heat map.

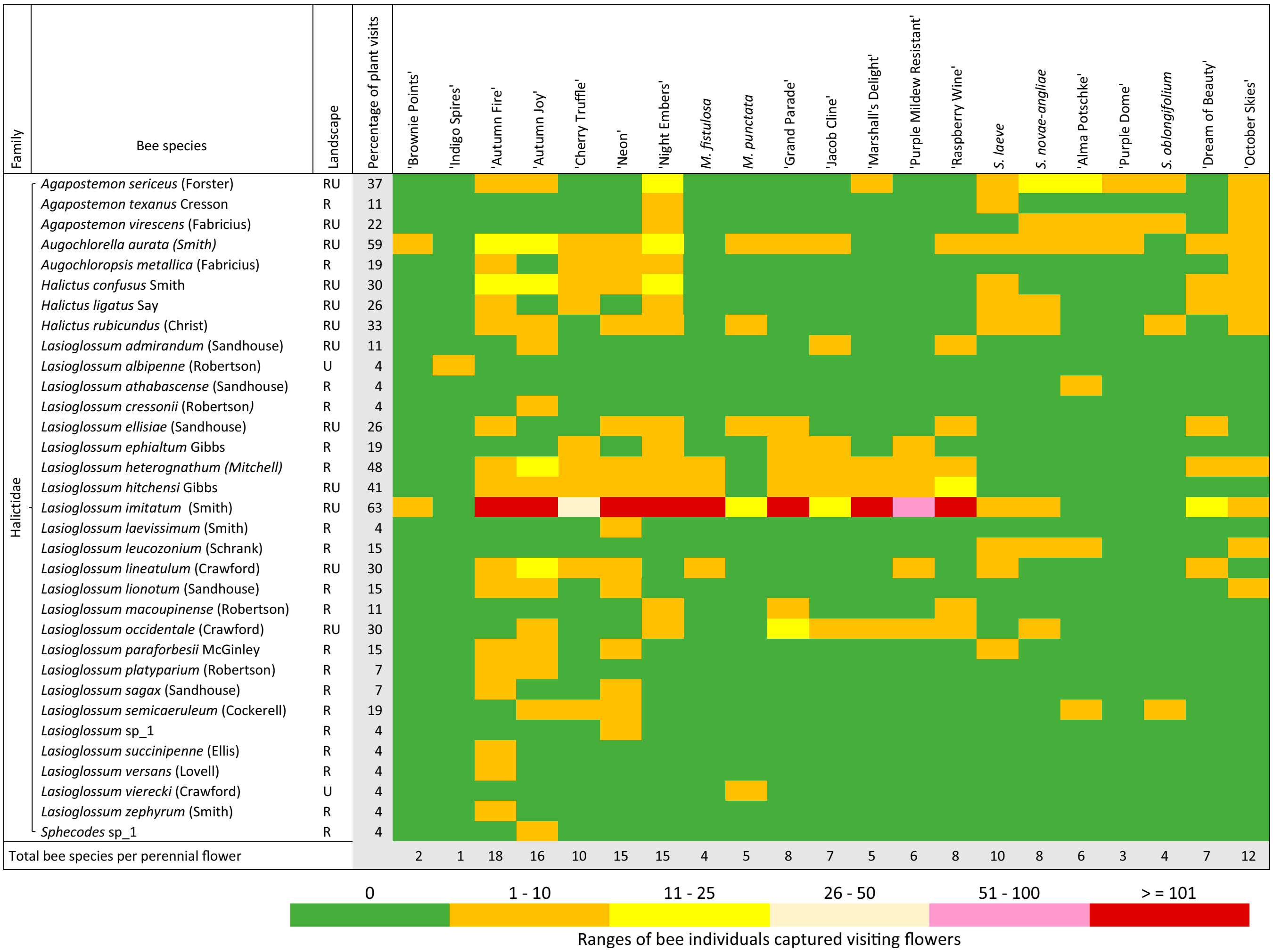

Fig. 4. Heat map of the Halictidae bee species captured in perennial flowering taxa at rural and urban landscapes in North Dakota during 2018 to 2020. R = rural landscape; U = urban landscape; RU = both landscapes. The percentage of plant visits column indicates the percentage of 27 perennial flowering taxa visited by that bee species. Perennial taxa (i.e., *B. alba* var. *alba*, *B. a.* var. *minor*, *B. australis*, 'American Goldfinch', 'Grape Taffy', and 'Raydon's Favorite') with zero bee species captured were excluded from the heat map.

when visiting 1 (4%) of the 27 perennial taxa. Overall, across all bee families (Figs. 2−4), each perennial flowering taxa had a least one captured bee species; the taxa with the greatest bee species diversity were *Hylotelephium* 'Night Embers' (with 29 species visits), followed by 'Neon' and 'Autumn Fire' (both with 27 species visits). In contrast, *B. alba* var. *alba* had the lowest bee diversity, with only one *Megachile latimanus* Say individual captured.

Discussion

Overall, the rural and urban landscapes had blooming plants during the entire season each year. *Baptisia* produced the first flowers at each site, followed by *Monarda*, and the season ended with *Hylotelephium* and *Symphyotrichum*. Multiple researchers have demonstrated that the bee community composition is dependent on available floral resources of a landscape and their phenologies (Bennett and Isaacs 2014; Kraemer and Favi 2005; Richards et al. 2011). For example, *Andrena asteris* Robertson was associated with autumn bloom of *Symphyotrichum* flowers (Wolf and Ascher 2008). Thus, having flowers blooming throughout the season, especially when food is scarce for pollinators, such as early spring and fall, may encourage and support pollinator visitors that are active at those time periods. Exotic species and cultivars can support bees when native plant food sources are scarce (Braman and Griffin 2022; Mach and Potter 2018; Marquardt et al. 2021; Riddle and Mizell 2016). Riddle and Mizell (2016) suggested that some crape myrtle cultivars in the southern United States can be used when other pollen sources are scarce to reduce pollinator stress caused by food shortages. A clear example from this study was high honey bee visitations on *Symphyotrichum*, which flowered in late fall. Assessing the pollinator visits during bloom time leads to understanding their active flight period. Mader et al. (2011) mentioned that providing pollinators with a suitable flowering forage area and environments free of pesticides are good practices for supporting pollinators. All the current evaluated native species and cultivars would be suitable for attracting and supporting pollinators in rural or urban landscape settings in the northern Great Plains. However, in this study, the three *Baptisia* species did not flower in all replications, and flowers were not abundant for those that bloomed. Neither *B. australis* var. *minor*, which is native to the Midwest, nor *B. alba* var. *alba*, which is native to the southeastern United States, is native to North Dakota or Minnesota; consequently, these two taxa may not be well-adapted to grow in North Dakota. In contrast, *B. australis* and some of the ornamental cultivars were attractive to *Bombus* species in the spring and served as a niche in pollinator gardens by providing early season resources.

In this study, we demonstrated that the perennial flowering taxa at the rural landscape had 52.8% greater pollinator visitations when compared with taxa at the urban landscape. Additionally, 65.9% more bee species and 158.3% more unique bee species were found at the rural landscape. Thus, the perennial flowers grown at the rural landscape supported greater numbers and more diversity of pollinators and wild bees. This may be attributable to more diverse habitats near the rural site compared with those near the urban site. Mader et al. (2011) cited that urban landscapes lack suitable habitats to support great pollinator diversity and abundance. Bennett and Isaacs (2014) found that landscape composition had a significant effect on abundance, diversity, and community composition of bees. The surrounding land coverage of the rural landscape site had 126.3% more acreage of diverse vegetation habitats than the urban landscape; this habitat included different forests, shrubland, grass/pasture, and woody/herbaceous wetlands (US Department of Agriculture, National Agricultural Statistics Service, Cropland Data Layer 2022). Highly diverse landscapes offer better nesting and floral resource opportunities for bees (Morrison et al. 2017). Insect and other arthropod biodiversity varies and changes with the surrounding landscape habitat (Gardiner et al. 2009, 2010). The rural site also had larger and more diverse cropland coverage (US Department of Agriculture, National Agricultural Statistics Service, Cropland Data Layer 2022), which may have contributed to the greater number of pollinator visitors. Mader et al. (2011) suggested that heavily developed agricultural lands are not great habitats for supporting the diversity and abundance of pollinators. However, recently, numerous bee species have been documented in North Dakota sunflower and soybean fields (Calles Torrez et al. 2023; Mallinger et al. 2019), with the most common species *Melissodes agilis* Cresson and *Melissodes trinodis* Robertson in both crops (Calles Torrez et al. 2023).

Control programs for mosquitos may have affected pollinator visitations at the urban landscape, but not at the rural landscape. Regular applications of pesticides for controlling mosquitos using broad-spectrum active ingredients, such as synthetic pyrethroids, will kill adult mosquitoes as well as other insects exposed during application. Insecticidal spray around yards and gardens for mosquitoes or biting flies can also be harmful to pollinators, even if all precautions are taken (Smitley et al. 2019). Long and Krupke (2016) found low and high concentrations of pyrethroid insecticides used for controlling mosquitoes and other nuisance pests in pollen collected by honey bees, and they suggested that wild bees and nontarget invertebrates are also exposed to these pesticides. Increased toxicity of pyrethroid and some neonicotinoid insecticides to honey bees was reported as a result of the synergistic effect of ergosterol biosynthesis inhibitor fungicides (Pilling and Jepson 1993; Thompson et al. 2014). Some adult butterflies were also at higher risk when exposed to the mosquito control pesticide Trumpet EC (active ingredient: naled) (Bargar 2012). Overall, our results indicated that the rural and urban landscape effects had an important role in pollinator abundance and diversity. However, we cannot make an inference regarding whether spraying for mosquitos influenced our results. Furthermore, future research should focus on whether pollinators such as honey bees, wild bees, syrphids, butterflies, and other nontarget organisms are affected by this issue, especially in urban landscapes, as suggested by Long and Krupke (2016).

Visitations within insect pollinator groups varied significantly in some cases but not significantly different in other cases among the 27 perennial taxa and between landscapes in our study. However, regardless of the landscapes or native species and cultivars, the honey bees and beetles preferred to visit *Hylotelephium* (rose flower color variations) and *Symphyotrichum* (pink and lavender to purple flower colors). The wild bees, lepidopterans, and syrphids were attracted to *Hylotelephium*, *Symphyotrichum*, and *Monarda* (lavender, pink, red flower colors). Tachinids visited *Symphyotrichum*. Blow flies preferred *Hylotelephium*. These pollinators were most likely attracted by the showy colors of the flowers, as many researchers observed during their studies of other native species and their cultivars (Bischoff et al. 2014; Erickson 1975; Erickson et al. 2020; Ricker et al. 2019), because the color of the petals can signal pollen or nectar rewards (Fambrini et al. 2003; Schlangen et al. 2009; Waser 1983; Waser and Price 1981, 1985; Wojtaszek and Maier 2014). Previous studies found that bees showed preferences for blue and purple flowers, some syrphids preferred yellow and white flowers (Lunau and Maier 1995; Sajjad and Saeed 2010), and moths preferred to visit white flowers (Goyret et al. 2008). Braman et al. (2022) reported that syrphids visited mostly *Symphyotrichum* cultivars that had white or lavender color variations. Most of these colors, except white (only in *Baptisia* genus), were represented within each evaluated genus and could potentially attract similar insects. However, Trunschke et al. (2021) indicated that pollinator selection is more complex than just flower color. Factors such as flower structure, display, height, inflorescence (Erickson et al. 2020; Trunschke et al. 2021), aroma (Bischoff et al. 2014; Erickson 1975; Erickson et al. 2020), volume and quality of nectar (Harder 1986; Hodges and Wolf 1981; Klumpers et al. 2019; Severson and Erickson 1984), and pollen (Gaona et al. 2019; Killewald et al. 2019; Kraemer and Favi 2005; Topitzhofer et al. 2019) can influence pollinator foraging or visitations.

The feeding behavior and proboscis extension of these insect pollinators also could have influenced flower visitations, as Hansen et al. (2012) and Thompson (2001) documented. Honey bees have proportionally shorter tongues and body sizes than bumble bees (Triplehorn and Johnson 2005). Visitations of hawkmoths and some butterflies, both with long tongues, occurred more in plants with larger flowers, and their visits increased with the corolla tube length (hawkmoths) and corolla lobe length (butterflies) (Thompson 2001). Therefore, during this study, 45.5% of honey bee visitations were observed on *Hylotelephium*, and 51.1% were observed on *Symphyotrichum*; both genera have flower types that possess a smaller corolla tube length than *Monarda*. The most bumble bee visitations (44.8%) were observed on *Monarda*, which have flowers with longer tubular corollas. Similarly, bumble bees mainly visited and pollinated *Monarda clinopodia* L., as well as their hybrids in the southern Appalachian Mountains (Whitten 1981). Additionally, *Lasioglossum imitatum* (Smith), which are small bees with short tongues found at both landscapes, commonly visited *Hylotelephium* and *Monarda*. It is not unusual that smaller bees with short tongues also visit flowers that are preferred by larger bees with long tongues (Rollings and Goulson 2019), which was the case with *L. imitatum* visiting *Monarda* during this study. Insect mouthparts and body sizes also vary within a particular insect group (Triplehorn and Johnson 2005), which can explain the preferred taxa variations among the different butterfly species. For example, *Papilio glaucus* (Linnaeus) (Papilionidae) and *Hemaris diffinis* (Boisduval) (Sphingidae), which are long-tongued butterflies, only visited *Monarda*, whereas short-tongued *A. falcifera* mostly visited *Hylotelephium*.

Various studies suggested that wild bees and other pollinators prefer to forage on native plants (Harmon-Threatt and Kremen 2015; Morales and Traveset 2009; Morandin and Kremen 2013; Salisbury et al. 2015; Tuell et al. 2008). In contrast, other studies have generally reported no differences between native species and their cultivars regarding pollinator visitations (Mach and Potter 2018; Ricker et al. 2019). In this study, the native perennial taxa did not receive significantly more visits from wild bees when compared with their respective cultivars. Similar patterns were also found for the other pollinator groups in most cases. Interestingly, some evaluated cultivars had significantly more or similar visits compared with their respective native species. A study performed in central Kentucky to test flowering woody landscape trees and shrubs found no overall differences among native and non-native species in terms of bee visitations; in some instances, some cultivars were frequently visited by bees later in the season in urban settings (Mach and Potter 2018). Based on our results, we suggest that the evaluated perennial native species and their respective cultivars were similar attractors of wild bees and for most pollinator groups, regardless of landscapes and flower genera. Special cases involving the native species being significantly greater attractors of visitors, such as honey bees on *S. novae-angliae* and wasps on *M. punctata* in urban settings and tachinid and blow flies on *S. laeve* and beetles on *S. novae-angliae* in rural settings, may occur. Approximately 60% of the flowering plants were non-native perennial taxa, and we observed several non-native bees, such as honey bees, *Anthidium manicatum* (Linnaeus), *Megachile rotunda* (Fabricius), and *Lasioglossum leucozonium* (Schrank), that were attracted by several of the evaluated cultivars. Pei et al. (2023) also documented that honey bees preferred to visit exotic plants, whereas bumble bees preferred native plants. Therefore, their presence and implications of non-native bees for the native species should be investigated.

Overall, 96.0% of the beneficial insect visitations and 30.4% of the flower insect pest visitations were counted at the rural landscape.

In other words, more insect pests and fewer beneficial insect visitations were counted at the urban landscape. Several studies reported that predator abundance depends on its prey abundance (Huffaker 1958; Start and Gilbert 2017) and other factors, such as the behavior of both individuals (DiRienzo et al. 2013; Klecka and Boukal 2013), body sizes (Klecka and Boukal 2013), and their surrounding landscape (Ali et al. 2020). More insect pest visitations at the urban landscape could also be attributable to the surrounding landscape composition. This landscape had fewer plant alternatives to forage when compared with the surrounding area of the rural landscape (US Department of Agriculture, National Agricultural Statistics Service, Cropland Data Layer 2022). In contrast, the increase of beneficial insect visitations at the rural landscape may be attributable to the surrounding diverse vegetation because it offered greater plant alternatives to harbor more beneficial insects as well as pests (e.g., blister beetles, stink bugs, grasshoppers, and others). However, we observed that the pests had not caused injury to the perennial taxa, except to *Baptisia* 'Brownie Points' and 'Indigo Spires' cultivars. These two cultivars were heavily attacked by ash-gray blister beetle *E. fabricii*, which caused noticeable injury, especially at the urban landscape. Therefore, the visitations of beneficial insects and insect pests to garden flowering plants are other important aspects to consider when selecting perennial flowering plants for gardening or landscaping.

This is the first study to evaluate the response of pollinators and specific bee species, other beneficial insects, and insect pests to perennial flowers associated with these native species and ornamental cultivars in North Dakota. However, future studies should increase the replication of landscape sites to strengthen the robustness of the data. Proactive stewardship is necessary to meet the needs of insect pollinators, including bees, wasps, flies, beetles, moths, and butterflies, to maintain abundant, healthy, and diverse pollinators, which benefit us and other organisms (Braman and Griffin 2022). A mixture of co-blooming (early, mid, and late bloom) flowering plants (Tuell et al. 2008) with short and long corolla tube lengths should be planted to ensure the presence of food for pollinators from spring through late fall. This study, concurrent with others (Braman et al. 2022; Marquardt et al. 2021; Ricker et al. 2019; Rollings and Goulson 2019), showed that certain ornamental cultivars are widely used by diverse groups of insect pollinators. However, ornamental cultivars should be evaluated in detail to determine pollinator attractiveness (Ricker et al. 2019) and the rewards they provide. Ornamental cultivars and native species should be integrated into pollinator gardens in rural and urban landscapes to improve aesthetics as well as attract and nourish pollinators. Our findings also help provide a guide for the selection of flowering plants for citizens of the northern Great Plains who wish to attract and support pollinators in their gardens and backyards, especially in urban areas.

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