The effect of seeding rate on plant establishment and pollinator diversity within conservation land

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Abstract

Pollinators such as native bees, butterflies, beetles, and flies provide us with the crucial ecosystem service of pollination that helps keep diversity in habitats and aid in the production of agriculture. Recently, this production and biodiversity has decreased as pollinator populations have been slowly declining, primarily caused by conventional agriculture methods. A potential solution to this problem is the use of Conservation Reserve Program (CRP) that offer a balance between farming practices and conservation techniques. One of these CRP techniques is the establishment of CP42 (pollinator habitat) sites using Natural Resource Conservation Program (NRCS) approved seeding mixes that consist of a mix of native pollinator-friendly floral species and grasses. This project focused on examining these techniques, specifically looking at Indiana-NRCS sites and comparing seeding records to observed plant establishment, and how floral diversity effects pollinator abundance. This was done using seeding records provided by the IN-NRCS and field observations of observed plant species, plant cover, and pollinator abundance, recorded over a four-month period of June-September. Seeding records was found to have no significant relationship to plant establishment and there was a lack of sufficient data to make

complete comparisons observing the effect on pollinator diversity. However, the general observations did not show evidence of a relationship. The findings from this study could still be useful as it provides insight into improvements that could be made in seed mixes for CP42 or other habitats, while also identifying future research questions regarding pollinator abundance and plant diversity at these types of sites.

Introduction

Pollinators are a crucial group of organisms to human prospects and ecosystems alike. They are what drives many of our crops in agriculture and what keeps forests, fields, grasslands, and many other places thriving with new life. Insect pollinators provide an important ecosystem service, pollinating nearly 75% of all flowering plants globally and nearly 1,200 food crops annually (Porto et al. 2020). These ecosystem services provided by native pollinators and non-native honeybees are incredibly valuable on a crop per year basis, but managed honeybees are not sustainable while native bees are sustainable, natural, and work in an agricultural system when utilized correctly. The agricultural value of pollinators is estimated between $267B and $657B annually (Porto et al. 2020) which drives many farmers who are aware of this topic to have an interest in trying new methods to preserve pollinator populations, as an increase in insect-pollinator ecosystem services can result in increased yields and profits (Tarakini et al. 2020, Christmann et al. 2021).

Currently, many methods of conventional agriculture are not sustainable and cause negative affects to pollinator and ecosystem health with minimal benefits in terms of increased yield and production for crops (Lark et al. 2020) such as habitat destruction, use of insecticides that cause accidental population damage to non-target organisms, misuse of pesticides such as over-spraying and using the wrong insecticide to treat various pests (Chabert and Sarthou. 2020). These unsustainable methods combined with global pollution and habitat destruction for other human needs, has resulted in around a 59% loss of primary pollinators including native bees and honeybees, in the past 50 years with agriculture production increasing by nearly 300% to combat rising food demands (Potts et al. 2010). These pollinator losses are an increased threat to biodiversity and human needs alike as they negatively affect both local ecosystems, and production rates of agricultural crops wherever pollinator declination has occurred (Potts et al. 2010). This could contribute to the grand challenge of food security and sustainability (Purdue 2022, UN Food and Agriculture organization, 2022) as around 35% of global annual food crops are reliant on pollinators, which are currently facing large declines (Porto et al. 2020).

An innovative solution to the problem of pollinator declination and unsustainable agriculture is the use of voluntary conservation agriculture programs. These programs are federal programs through the United States Department of Agriculture (USDA), Natural Resource Conservation Service (NRCS) and the Farm Service Agency (FSA) that incentivize farmers and landowners to participate in these practices or provide their land for conservation purposes. These programs are classified as either land retirement programs, which is the process in which the supplied land is taken out of agriculture production for conservation use or as working land programs, which require the landowners to maintain agricultural production and use specific conservation practices (USDA 2022).

One of these programs is the Conservation Reserve Program (CRP), which was introduced in 1985 as a voluntary land-retirement program with the goal of converting acres of ecologically sensitive farmland into conservation areas to reduce soil erosion and improve ecosystem health. This program offers 10-year contracts to qualifying landowners that provides them with annual monetary compensation per acre in return for a portion of their property being converted into CRP habitat (USDA 2022). Of specific relevance for pollinator conservation is CRP practice CP42 (pollinator habitat), which was introduced in 2008. This CP42 land is planted with a mix of at least nine NRCS approved pollinator-friendly native wildflowers along with a 20% native grass component. The goal of CP42 is to provide a beneficial habitat for pollinators and important native species while offering an incentive for farmers and landowners to enroll (USDA 2022). A benefit of the CP42 land is that can be planted alongside agricultural land if the general requirements are met and a 20-foot strip of land and at least 0.5 acres are provided allowing it to act as both a land-retirement and working land program.

This could provide a solution to the problem of unsustainable agriculture and pollinator declination through planting of these NRCS-approved seed mixes and regulation of floral species on this CP42 or other agricultural land. These and other conservation agriculture methods utilize provided portions of agricultural land that would normally be used for conventional agriculture methods that cause harm to the soil and local insect populations to grow sustainable habitats instead (Middleton et al. 2021). This allows for an increase in ecosystem services such as pollination as well as an increased ability to use natural predators as a biological control as an alternative to methods like insecticide application to increase crop yields (Chabert and Sarthou. 2020). The process of using seed mixes for floral plantings to increase pollinators and natural predators has shown promise as a solution for conservation efforts, with a recent study showing an increase in pollinators after floral seed mixes had been planted (Middleton et al. 2021). The process of planting pollinator seed mixes in restoration land or stripped land is also an effective way to return biodiversity to a local ecosystem as it has been shown that plant-insect interactions play a large role in ecosystems health and development (Underwood et al. 2020). Another benefit of these seeding mixes and conservation efforts is the process of returning depleted nutrients to the soil and reducing soil erosion caused by conventional agriculture (Christmann et al. 2021). These pollinator-seed mixes have also been shown to increase pollinator populations without increasing the populations of negative predatory insects (Middleton et al. 2021, Nichols et al. 2022).

A current limitation for small farmers and consumers who want to help pollinator conservation without enrolling in these programs is the lack of availability to proper pollinator seeding mixes (Havens and Vitt. 2016, Nichols et al. 2022). A simple solution to this problem is encouraging the creation of new seed mixes or easy accessibility to NRCS-approved seed mixes that contain pollinator-friendly plants and wildflowers. This would allow smaller farmers the option of cheaper, more effective, seed mixes in the current market that could influence a larger increase in pollinator populations within the areas they are used. While seed mixes often increase pollinator populations, sometimes local crops located next to the planted mix do not see an increase in yields from pollination (Middleton et al. 2021).

This project is focused on comparing pollinator diversity and abundances, plant field observations, and seeding records obtained from various conservation sites and to see if there were differences in the insect-plant interactions. My initial hypothesis was that the seeding records provided will reflect what plants are observed in the field and plants with a higher seeding rate (oz/ac) will compose a larger portion of the observed plant species. My secondary hypothesis was that conservation areas that were seeded with a higher diversity in the seeding mixes will see a larger amount of floral growth and pollinator abundance due to the increased floral populations and diversity among local florae.

Methods

Experimental Design

The data obtained for this project was collected from three Conservation Reserve Program sites where CP42 pollinator habitats were installed in Indiana (Fig.1). Each of the sites was at minimum three years old (the minimum amount of time for establishment of plants at a CRP site in Indiana). The size of these sites ranged from 1.5-to 2.6ha and each was seeded with a mix of native pollinator-friendly flowering plant (forb) and grass (graminoid) species approved by the Indiana Natural Resources Conservation Service (IN-NRCS). The seeding records for these sites were provided by IN-NRCS, with the permission of contract holders. The local vegetation of each site was recorded by estimating the percent visual cover occupied by flowering plants (identified to species) using 0.5m x 0.5m releves (Fig. 2) along a 500m W-transect through the site twice monthly from June through September.

The insect population data was collected over the same period of June through September using tri-colored pan traps mounted on wooden stakes using metal brackets (Fig. 3) consisting of a white, yellow, and blue bowl on each trap as these colors are known to be most effective at attracting pollinator species (Buffington et al. 2020). The pan traps were positioned within a site as a transect of three traps, spaced 5m apart, ensuring any trap was at least 15m from the edge of the field (Fig. 4). Pan traps were filled with collecting fluid (dish detergent and water) and left for 24-36 hours before collecting. Pan trapping was performed at sites two times per month. Collected pollinators were pinned and identified to morphogroup (large groups that are morphologically similar), including known pollinator taxa in orders Hymenoptera, Diptera, and Lepidoptera.

Statistics

Seeding rate (oz/ac) was compared to field cover (%) to see visible trendlines. A Pearson correlation (R) test was performed on the data using JMP statistics software. Pollinator abundance was compared per site using morphogroup diversity and total count abundance.

Figure 1. Images of various sites from Indiana located on IN-CRP land.

Figure 2. Image of the 0.5m x 0.5m releve used for sampling within site.

Figure 3. Image of blue, yellow, and white pan trap set up on wooden stake.

Figure 4. Image of the spacing and distribution of pan traps set up across site at least 15m from the edge of the field/neighboring habitat.

Results

As expected, the number of vegetative forbs decreased in all sites over the period of June-September as forbs bloomed and died back. In all sites vegetative forbs made up the largest portion of plant cover on average with blooming forbs making up the second largest portion of plant cover on average (Table 1). Dead vegetation and open ground ("Dead/open") showed an increase across all three sites over June-September. Site 1 showed the highest amount of graminoid plant cover while Site 2 had the least graminoid plant cover. The proportion of graminoids gradually increased in all three sites over the June-September period.

Table 1 – Plant cover and pollinator data by site

Site	Sown floral richness (No. species)	Observed floral richness (No. species)	Pollinator Diversity (No. morpho groups)	Total pollinator abundance	Total forb abundance (% cover)	Flowering forb abundance (% cover)	Graminoid abundance (% cover)
1	52	36	8	319	71.192	59.51	17.78
2	10	34	8	96	79.407	62.17	4.99
3	9	24	8	217	70.294	31.42	15.649

All sites had the presence of eight diverse morphogroups (Table 1), but all three sites did not share identical morphogroups with each site containing at least one unique group. The count of flowering plant species was higher than what was seeded at Sites 2 and 3, but lower at Site 1 where the most species were seeded (Table 1). Pollinator abundance was higher at Site 1 as expected, but lower at Site 2 despite having a higher count of flowering plant species than Site 3. Site 1 had no significant correlation between seeding rate (oz/ac) and field cover (%) of plants (Fig. 5) with $P = 0.9059$ and $R^2 = 0.000282$. Site 2 also found no significant correlation between the seeded rate of plants and plant field cover (Fig. 6) with a $P = 0.7907$ and $R^2 = 0.002101$. Site 3 had no correlation either between seeding rate and plant field cover (Fig. 7) with a $P = 0.2960$ and $R^2 = 0.049502$. Most of the observed plant species were seeded but some species not included in the seedings records were also present, such as native pollinator-friendly goldenrods. Site 1 saw the growth of 13 unseeded species of common pollinator-friendly plants and weeds, with 17 of the 39 seeded species absent from observations. Site 1 had a seeding success rate of 56.41% based on these observations. Site 2 saw the growth of 27 unseeded species that were primarily pollinator-friendly plants used in seeding mixes and a few pollinator-friendly native weed species. Site 2 saw the growth of 7 of the 8 seeded species, with a seeding success rate of 87.5%. Site 3 saw the growth of 17 unseeded species that were a mix of pollinator-friendly plants and native pollinator-friendly weeds. Site 3 had all 7 of its seeded species observed with a seeding success rate of 100%.

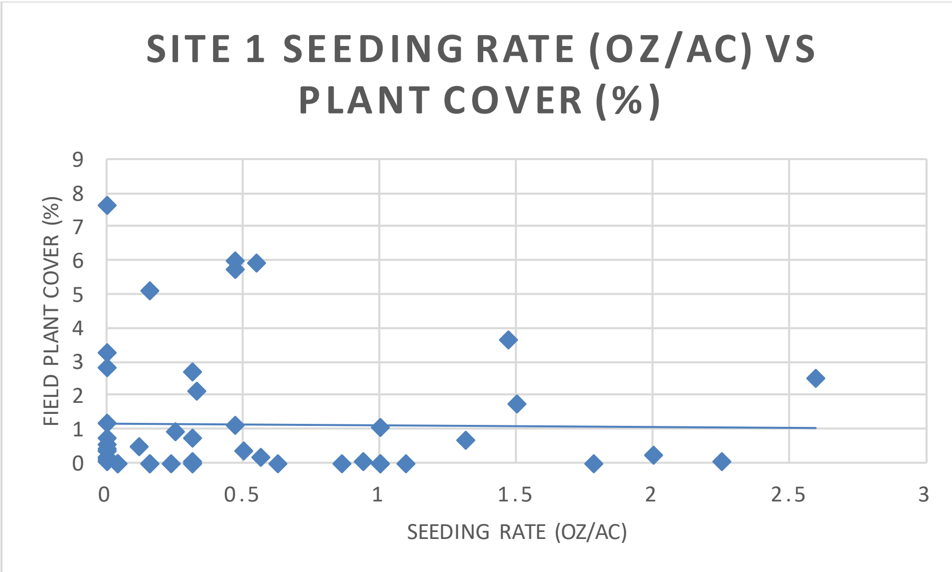

Figure 5. Graph of Site 1 using a correlation with linear fit to compare seeding rate and field plant cover percent. No statistically significant correlation was found with a P = 0.9059 and R^2 = 0.000282

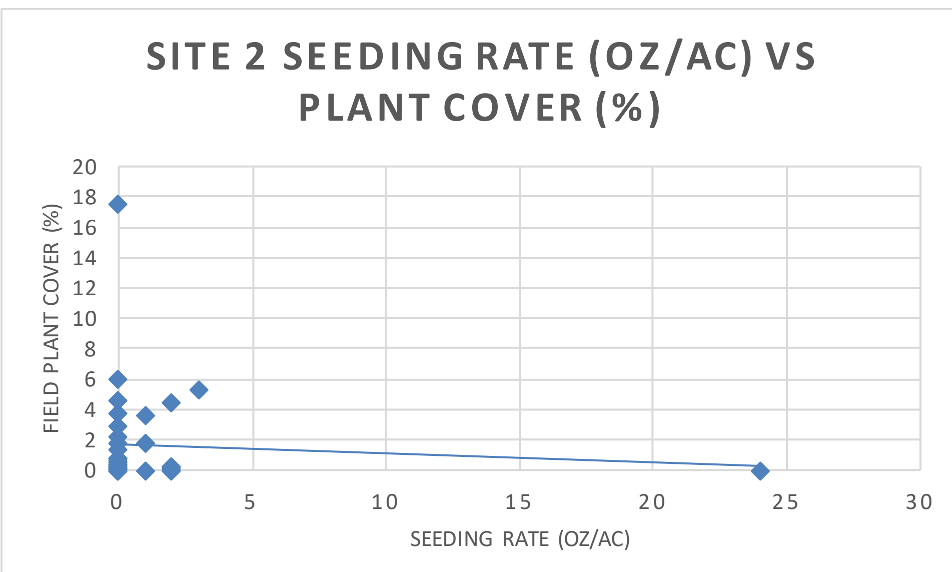

Figure 6. Graph of Site 2 using a correlation with linear fit to compare seeding rate and field plant cover percent. No statistically significant correlation was found with a P = 0.7907 and R^2 = 0.002101.

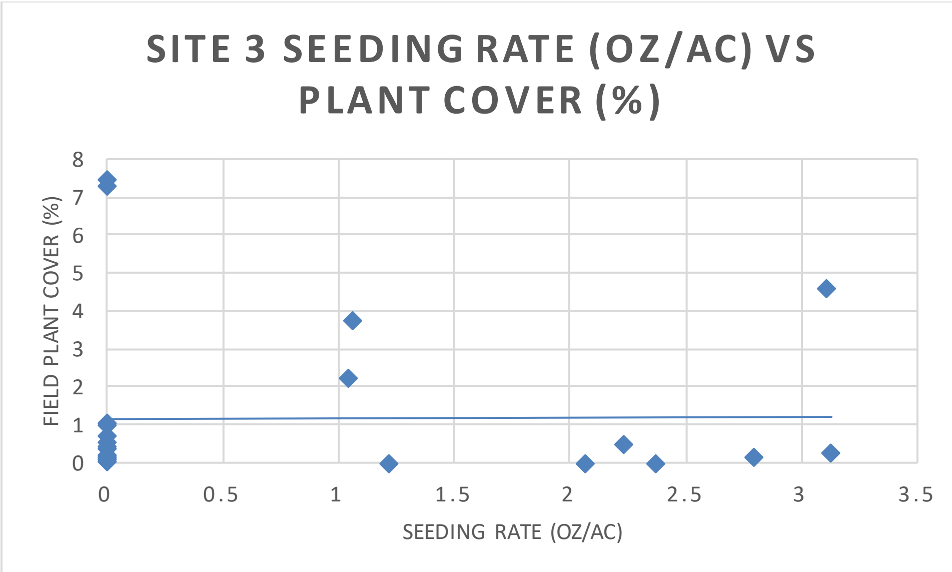

Figure 7. Graph of Site 3 using a correlation with linear fit to compare seeding rate and field plant cover percent. No statistically significant correlation was found with a $P = 0.2960$ and $R^2 = 0.049502$.

Discussion

The focus of this project was to use data collected from three IN-CRP sites to compare the seeding rates, plant cover, and pollinator abundance of each site to assess plant seeding vs establishment and the influence on pollinator diversity. The initial hypothesis of this project that seeding records would directly reflect observed plant cover was not supported. The secondary hypothesis that floral diversity and abundance would directly influence pollinator abundance was also not supported, but there was a lack of sufficient pollinator data to make a strong correlation. The pollinator diversity was the same level (8 morphogroups) at each site, but each site had a different mix of morphogroups. This may be caused by the variance in different plant species per site (Ebeling et al. 2008) but could also be influenced by a failure to catch specific taxa in pan traps as not all groups are guaranteed to be caught (Buffington et al. 2020).

Pollinator abundance was highest at Site 1 which was expected as it had the highest diversity of species both seeded and observed. Pollinator abundance was unexpectedly low at Site 2 despite a high amount of plant species diversity, with many of the observed plants being plants that are normally used in pollinator-friendly seeding mixes. This leads us to the suggestion below that the seeding records may have been incomplete, but it is also possible that this low amount of pollinator diversity was observed in Site 2 due to the quality of the external land surrounding the site. This low pollinator abundance may have been caused by unfavorable habitat climate factors such as nearby agriculture, human interference, an increase in predation and other factors that may have driven pollinator abundance down (Ebeling et al. 2008, Baracchi 2019). All three sites showed no correlation between seeding rate (oz/ac) of plants and observed plant cover percent (Figs. 5-7). There are many possible explanations for this finding, one of which is that many of these seeded species established initially but died out over the 3+ years since the IN-CRP land was seeded (USDA 2022). Another possible explanation is that due to the size of these sites and the randomness at which the samples were taken, it is possible that many of the seeded species were present but not observed. Another possible explanation is that many of the seeded species were much smaller visually than the wild native species (such as large goldenrod plants) that caused the percent of plant cover to be much lower among seeded plant species (Havens and Vitt 2016). It is also possible that the seeding records provided by the IN-NRCS, and contract holders were not complete.

With no significant correlations found the results from this project could still be useful in providing data to improve current IN-NRCS seed mixes based off what plants we saw establish which could aid in the establishment of better IN-NRCS land overall. The lack of a significant correlation between the plants seeded rate and observed plant cover could also be used to convince contract holders and shareholders that an improvement is needed in CRP land planting techniques as a higher seeding rate will not always mean a larger presence of those plants.

Despite finding no significant correlation among the seeding and percent cover data, the seeded species were observed to have at least a 56.41% or higher success rate for still having establishment years after initial seeding. The observed relationship between the amount of floral diversity and floral cover to pollinator abundance is something that would be worth looking into for future studies as there was an implied relationship between them with the small amount of data we had. This leaves the question that if floral diversity was increased would we see a direct correlation between floral diversity and pollinator abundance? How would it affect pollinator morpho group diversity? It would be useful to see future studies that contain a more detailed observations and data regarding floral cover and pollinator abundance to look for a correlation. This would allow us to gain insight into how much CRP-land floral abundance affects pollinator abundance directly and answer the previously mentioned questions.

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Appendix

Seeding record by site (Species seeded)

Site 1	Annual Gaillardia	Site 1	Partridge Pea	Site 1	Yellow Coneflower
Site 1	Autumn Sneezeweed	Site 1	Partridge Pea	Site 2	Blue Vervain
Site 1	Black-eyed Susan	Site 1	Perennial Lupine	Site 2	Canada Wildrye
Site 1	Blanket flower	Site 1	Plains Coreopsis	Site 2	Common Evening Primrose
Site 1	Blue Vervain	Site 1	Prairie Aster	Site 2	Foxglove Beardtongue
Site 1	Blue Wild Indigo	Site 1	Prairie Cinquefoil	Site 2	Golden Alexanders
Site 1	Butterfly Milkweed	Site 1	Purple Coneflower	Site 2	Marsh Blazing star
Site 1	Canada Milkvetch	Site 1	Purple Coneflower	Site 2	Ohio Spiderwort
Site 1	Clasping Coneflower	Site 1	Purple Prairie clover	Site 2	Purple Coneflower
Site 1	Common Milkweed	Site 1	Rattlesnake Master	Site 2	Rosinweed
Site 1	Dense Blazing Star	Site 1	Riddell's Goldenrod	Site 2	Stiff Goldenrod
Site 1	False Aster	Site 1	Rocky Mt Bee Plant	Site 3	Alsike Clover
Site 1	False Sunflower	Site 1	Rough Blazing Star	Site 3	Black eyed Susan
Site 1	Foxglove Beardtongue	Site 1	Roundhead Lespedeza	Site 3	Foxglove Beardtongue
Site 1	Gloriosa Daisy	Site 1	Shell Leaf Beardtongue	Site 3	Ladino White Clover
Site 1	Golden Alexander	Site 1	Showy Tick Trefoil	Site 3	Obedient Plant
Site 1	Grayhead Coneflower	Site 1	Smooth Blue Aster	Site 3	Purple Coneflower
Site 1	Indian Blanket	Site 1	Smooth Penstemon	Site 3	Sweet Black-eyed Susan
Site 1	Leadplant	Site 1	Spiderwort	Site 3	Tall Coreopsis
Site 1	Lemon Mint	Site 1	Stiff Goldenrod	Site 3	Wild Bergamot
Site 1	Mexica Red Hat	Site 1	Thick spike Gayfeather		
Site 1	Mexican Hat	Site 1	Upright Coneflower		
Site 1	Mountain Mint	Site 1	Virginia Wild Rye		
Site 1	New England Aster	Site 1	White Prairie clover		
Site 1	New England Aster	Site 1	White Wild Indigo		
Site 1	New Jersey Tea	Site 1	Wild Bergamot		
Site 1	Pale Purple Coneflower	Site 1	Wild Senna		

Morphogroups per site (observed)

Site 1	Black Longhorn	Site 2	Black Longhorn	Site 3	Black Longhorn
Site 1	Bumble	Site 2	Bumble	Site 3	Blue Sweat Bee
Site 1	Fly	Site 2	Carpenter	Site 3	Bumble
Site 1	Green Sweat Bee	Site 2	Fly	Site 3	Carpenter
Site 1	Thin thorax wasp	Site 2	Green Sweat Bee	Site 3	Fly
Site 1	Lepidoptera	Site 2	Hornet	Site 3	Green Sweat Bee
Site 1	Paper Wasp	Site 2	Large Bee Flies	Site 3	Hornet/wasp
Site 1	Striped Longhorn	Site 2	Striped Longhorn	Site 3	Striped Longhorn

List of observed plant species by site

Autumn Sneezeweed	Site 1	Rocky Mountain Bee Plant	Site 1
Black eyed susan	Site 1	Showy tick trefoil	Site 1
Blue Vervain	Site 1	Smooth Blue Aster	Site 1
Blue Wild Indigo	Site 1	Stiff Goldenrod	Site 1
Butterfly weed	Site 1	Tall blazing star	Site 1
Canada fleabane	Site 1	Velvet leaf	Site 1
Canada goldenrod	Site 1	White Prairieclover	Site 1
Canada Milkvetch	Site 1	White Wild Indigo	Site 1
Canada thistle	Site 1	Wild bergamot	Site 1
Clasping Coneflower	Site 1	Wild senna	Site 1
Common evening primrose	Site 1	Yellow coneflower	Site 1
Common horsemint	Site 1	Blue vervain	Site 2
Common lamb's quarters (white goosefoot)	Site 1	Calico aster	Site 2
Common milkweed	Site 1	Canada fleabane	Site 2
Common mountain mint	Site 1	Canada goldenrod	Site 2
Common spiderwort	Site 1	Pale-leaved sunflower	Site 2
False Aster	Site 1	Partridge pea	Site 2
False sunflower	Site 1	Prairie rose	Site 2
Firewheel	Site 1	Purple coneflower	Site 2
Foxglove penstemmon	Site 1	Queen Anne's lace	Site 2
Giant ragweed	Site 1	Red clover	Site 2
Golden Alexander	Site 1	Rosinweed	Site 2
Grey headed coneflower	Site 1	Rough stem goldenrod	Site 2
Hairy white oldfield aster (frost aster)	Site 1	Slender ladies' tresses	Site 2
Hedge bindweed	Site 1	Stiff leaved goldenrod	Site 2
Ivy-leaved morning glory	Site 1	Stiff sunflower	Site 2
Leadplant	Site 1	Three-nerved goldenrod	Site 2
New England aster	Site 1	White avens	Site 2
New Jersey Tea	Site 1	White sanicle (white snakeroot)	Site 2
Partridge Pea	Site 1	Wild burgamot	Site 2
Perennial Lupine	Site 1	Wingstem	Site 2
Plains coreopsis	Site 1	Yellow coneflower	Site 2
Prairie Aster	Site 1	Canada thistle	Site 2
Prairie Cinquefoil	Site 1	Climbing bindweed	Site 2
Prairie coneflower	Site 1	Common evening primrose	Site 2
Prickly lettuce	Site 1	Common milkweed	Site 2
Purple coneflower	Site 1	Common ragweed	Site 2
Purple prairie clover	Site 1	Daisy fleabane	Site 2
Queen Anne's lace	Site 1	Devil's beggarticks	Site 2
Rattlesnake master	Site 1	Foxglove penstemmon	Site 2
Riddell's Goldenrod	Site 1	Golden alexander	Site 2

Hairy white oldfield aster (frost aster)	Site 2	White clover	Site 3
Indian tobacco	Site 2	Common milkweed	Site 3
Ohio Spiderwort	Site 2	Bull thistle (Spear thistle)	Site 3
Marsh Blazingstar	Site 2	Purple coneflower	Site 3
Narrow-leaved Mountain mint	Site 2	Late boneset	Site 3
Nodding spurge	Site 2	Yellow coneflower	Site 3
Canada goldenrod	Site 3	Tall white aster	Site 3
False dragonhead	Site 3	Tall coreopsis	Site 3
Black eyed susan	Site 3	False sunflower	Site 3
Wild bergamot	Site 3	Daisy fleabane	Site 3
Foxglove penstemmon	Site 3	Wild lettuce	Site 3
Red clover	Site 3	Lucerne (Alfalfa)	Site 3
Hairy white aster	Site 3	Showy tick trefoil	Site 3
Queen Anne's lace	Site 3	Canada thistle	Site 3
Calico aster	Site 3	Flax leaf fleabane	Site 3

List of all observed plant species

Autumn Sneezeweed
Black eyed Susan
Blue Vervain
Blue Wild Indigo
Bull thistle (Spear thistle)
Butterfly weed
Calico aster
Canada fleabane
Canada goldenrod
Canada Milkvetch
Canada thistle
Clasping Coneflower
Climbing bindweed
Common evening primrose
Common horsemint
Common lamb's quarters
Common milkweed
Common mountain mint
Common ragweed
Common spiderwort
Daisy fleabane
Devil's beggar ticks
False Aster
False dragonhead
False sunflower
Fire wheel
Flax leaf fleabane
Foxglove penstemon
Giant ragweed
Golden Alexander
Grey headed coneflower
Hairy white aster
Hairy white Oldfield aster (frost aster)
Hedge bindweed
Indian tobacco
Ivy-leaved morning glory
Late boneset
Leadplant
Lucerne (Alfalfa)
Marsh Blazing star
Narrow-leaved Mountain mint
New England aster
New Jersey Tea
Nodding spurge
Ohio Spiderwort
Pale-leaved sunflower
Partridge Pea
Perennial Lupine
Plains coreopsis
Prairie Aster
Prairie Cinquefoil
Prairie coneflower
Prairie rose
Prickly lettuce
Purple coneflower
Purple prairie clover
Queen Anne's lace
Rattlesnake master
Red clover
Riddell's Goldenrod
Rocky Mountain Bee Plant
Rosinweed
Rough stem goldenrod
Showy tick trefoil
Slender ladies' tresses
Smooth Blue Aster
Stiff Goldenrod
Stiff leaved goldenrod
Stiff sunflower
Tall blazing star
Tall coreopsis
Tall white aster
Three-nerved goldenrod
Velvet leaf
White avens
White clover
White Prairie clover
White sanicle (white snakeroot)
White Wild Indigo
Wild bergamot
Wild lettuce
Wild senna
Wing stem
Yellow coneflower