Locally adapted pollinator sanctuaries

Abstract

This project experimented with using pollinator sanctuaries on marginal lands to address the serious decline in bee populations experienced in recent decades. Bees, moths, butterflies, beetles and several species of flies help pollinate numerous crops like canola, clovers, alfalfa, several forest and fruit trees as well as various species of vegetables across North America. Among all these insect pollinators, bees perform the most significant role in the natural cross pollination of a wide diversity of crops. The decline is a problematic trend because pollinator populations have a direct impact on future agricultural productivity, forestry & apiculture as well as on the stability of natural ecosystems. Conserving natural insect pollinators like bees is necessary to secure the future of these industries.

This study evaluated the potential of pollinator sanctuaries in 2019 on a site in the dark brown soil zone of southern Alberta. We assessed the impact of early (May) and late (July) seeding dates on establishment of five different kinds of plant mixes. We recommend early seeding as it led to higher establishment of plant species compared to the later seeding (72% vs 54%). Among the different kinds of plant mixes annual, annual-perennial and perennial mixes had higher species establishment, plant density and crop biomass compared to other plant mixes for the early seeding date. Initially, this project planned to include native flower mixes, but we excluded these treatments because we couldn't source the required amount of seeds for our small plots.

Introduction

Insect pollinators like honeybees & native (wild) bees show a gradual decline across the globe (Cutler et al., 2014; Goulson et al., 2015; Kevan et al., 2003; Simon et al., 2010; Stavely et al., 2013; Winfree et al., 2009). Currently we have no viable, long term solutions to slow or reverse bee (pollinator) declines (Winfree et al., 2009). Pollinator sanctuaries established on roadsides, in marginal lands, on reclaimed land (drilling roads), pivot corners, low lying or saline areas could create areas for ecological goods and services (Kremen et al., 2002; Potts et al., 2006; Klein et al., 2007; Ollerton et al., 2011). These mixes could also act as cover crops to promote soil conservation, soil health & soil quality.

Our goal is to develop a long term, comprehensive, cost effective & sustainable pollinator mix to conserve natural insect pollinators & enhance local biodiversity in southern Alberta.

Methods

Site description

The field experiment took place on a rainfed site – Lethbridge Jail Lake site (NE-34-8-21-W4) in southern Alberta. The soil is calcareous dark brown chernozem, loam to clay loam texture with 45% sand, 35% silt, 20% clay and 3% organic matter (OM) (https://soil.agric.gov.ab.ca/agrasidviewer/).

The Lethbridge climate is semi arid. It receives an average of 394 mm of rain annually and its average annual temperature is 5.4 degrees Celsius. Figure 1 shows an overview of monthly temperature and rainfall during summer of 2019. Rainfall in 2019 accumulated to 321.6 mm with only 157.7 mm falling during the growing season (May to August Table 5; Appendix 1). As seen in the graph below, the red line represents accumulated rainfall in 2019 that fell well below average (green line) from March until the end of the year.

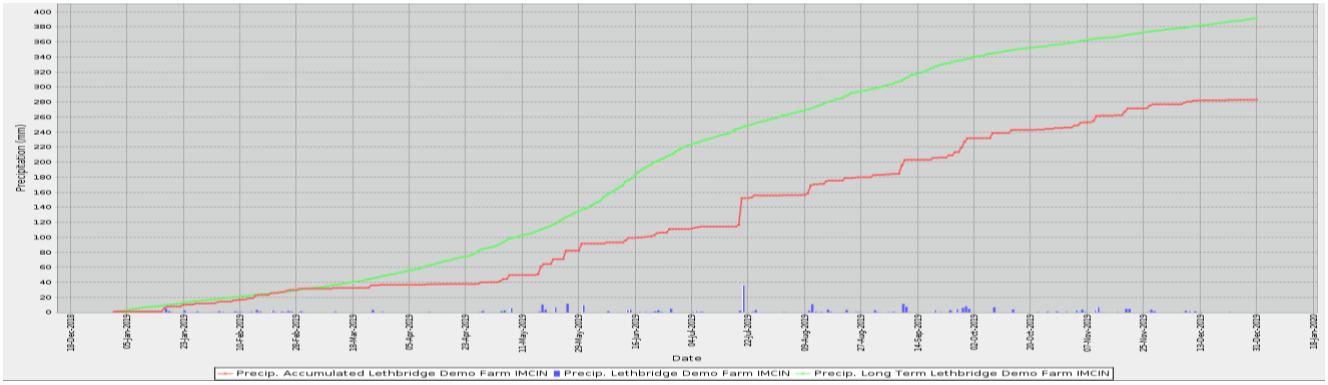


Figure 1. Average rainfall an accumulated in 2019 compared to annual average at the Lethbridge Demo Farm IMCIN station. Acquired from ACIS https://agriculture.alberta.ca/acis/weather-data-viewer.jsp.

Experimental design and treatments

Study design was RCBD (randomized complete block design) with four replicates per treatment in 2m x 6m research plots. As listed below, Farming Smarter seeded 5 treatments for the early seeding date (May 28, 2019) and 7 treatments for the late seeding date (July 10, 2019).

Early seeding date treatments:

1. Annual-Perennial Mix (20 species)
2. Perennial Mix (10 species)
3. Annual Mix (15 species)
4. Commercial bee seed mix (4 species)
5. Commercial Wildflower Mix (17 species)

Late seeding date treatments:

1. Annual-Perennial Mix (20 species)
2. Perennial Mix (10 species)
3. Annual Mix (15 species)
4. Commercial bee seed mix (4 species)
5. Commercial Wildflower Mix (17 species)
6. Alfalfa (pure stand)
7. Sainfoin (pure stand)

Table 6; Appendix 1 lists the species included in each of these mixes.

Data collection & sampling

Technicians determined plant counts by counting plants within 1 m at the front and back of each plot and calculating the average plants per m2. They also took Normalized Difference Vegetation Index (NDVI) measurements with a hand-held Greenseeker to quantify canopy closure (Table 1).

Table 1. Conversion of NDVI measurements to % canopy closure

NDVI range	*Canopy closure (%)*
0.0-0.1	*10*
0.11-0.2	*20*
0.21-0.3	*30*
0.31-0.4	*40*
0.41-0.5	*50*
0.51-0.6	*60*
0.61-0.7	*70*
0.71-0.8	*80*
0.81-0.9	*90*
0.91-1	*100*

The study tracked the number of seeded plant species and the number of species that established in each treatment. We counted all weeds within each plot and collected biomass of crop and weeds from 1 meter at the front and back of each plot and took three measurements of plant height per plot (front, middle and back) to obtain the plant height average. Notes on each species flowering time to create a floral calendar were also taken. Yellow sticky traps and sweep net samples showed pollinator insect diversity.

Statistical analyses

The study used the MIXED procedure of SAS (release 9.1, SAS Institute Inc., Cary, NC), to analyze data with treatments included as fixed effects and with replicate as random effect. We tested the assumption of normality by analyzing residuals for skewness, kurtosis, and the presence of extreme outliers with the UNIVARIATE procedure of SAS. When issues were noted, data was transformed or extreme outliers were excluded. Treatment means were compared with a protected LSD test.

Results

Farming Smarter saw a rich biodiversity of pollinators including honeybees, native bees, moths, butterflies, flies and beetles in the research plots. The diversity of plant species seeded enriched local biodiversity and created a refuge for not only the pollinators, but also passerine birds, waterfowl, game birds, raptors, mammals and reptiles.

Seeding date significantly impacted species establishment, therefore we can't recommend seeding late in the season. Early seeding date had an average of 72% survival compared to 54% for the late seeding (Figure 2 & Figure 3). Species establishment for early seeding improved to 84%, if we excluded poor establishing wildflower mix while establishment was 61% for late seeding. We recommend excluding wildflower mix as it had a very low percent establishment for both seeding dates (Table 2; Appendix 1).

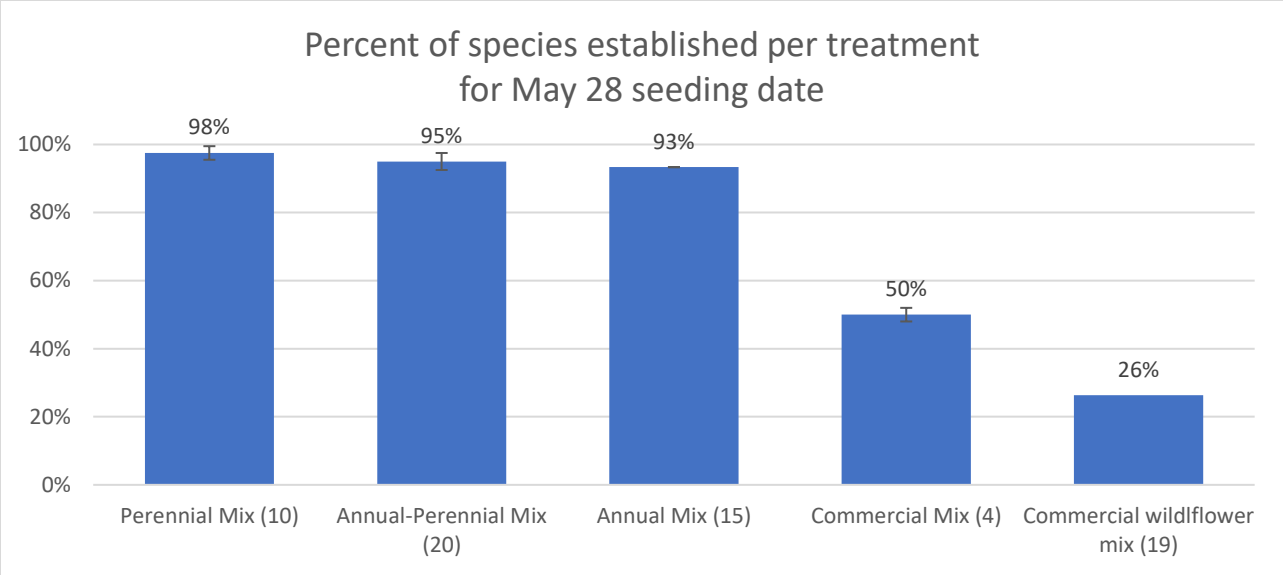


Figure 2. Percent of species established per treatment for May 28, 2019 seeding date

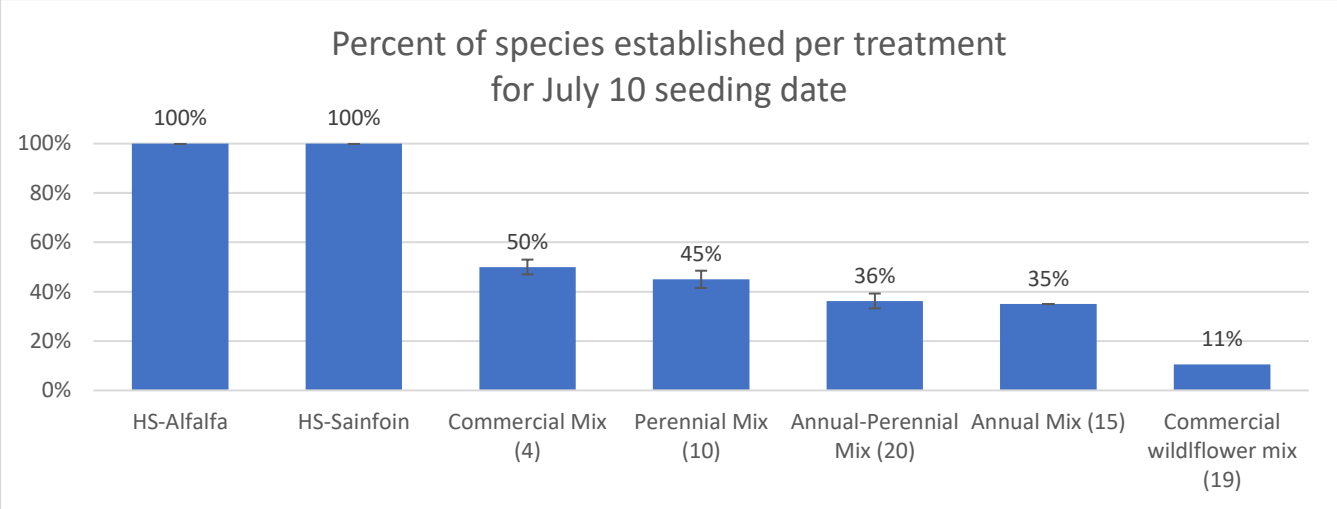


Figure 3. Percent of species established per treatment for July 10, 2019 seeding date

When comparing the average plant density for the early seeded plots, there was no significant difference between annual, annual-perennial and perennial mixes (Table 2).

Table 2. Average plant density per treatment (plants/m2) in both seeding dates (P = <0.0001 early, P = 0.0002 late; SAS Mixed Proc)

	Average of Plant density (plants/m2)	LSD 0.05
May 28/2019		
Annual Mix (15)	20.67	**A**
Perennial Mix (10)	19.75	**A**
Annual-Perennial Mix (20)	16.67	**A**
Commercial Mix (4)	11	**B**
Commercial wildflower mix (19)	4.75	**C**

July 10/2019		
Annual-Perennial Mix (20)	5.75	**A**
HS-Alfalfa	5.5	**A**
Perennial Mix (10)	5	**AB**
Annual Mix (15)	4.25	**B**
HS-Sainfoin	4.25	**B**
Commercial wildflower mix (19)	3	**C**
Commercial Mix (4)	2.5	**C**

Plant density for the wildflower mix was very low and caused significant increase in weed density and competition (Figure 4 & Figure 5). All treatments in the late seeding date had significantly higher biomass than the early seeding date (Figure 5).

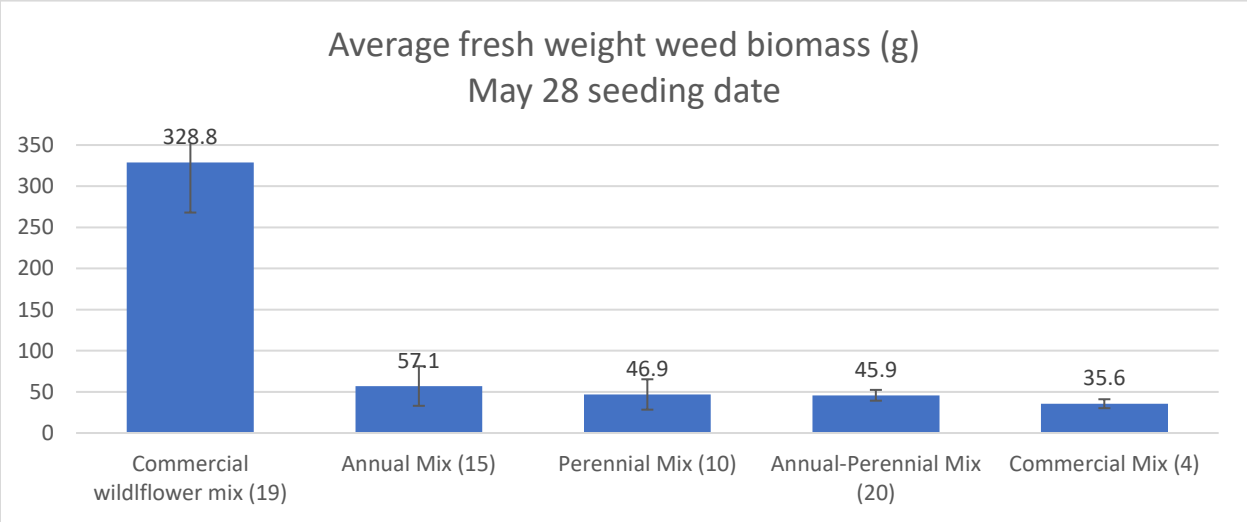


Figure 4. Average of fresh weight weed biomass per treatment for May 28, 2019 seeding date collected on September 6, 2019

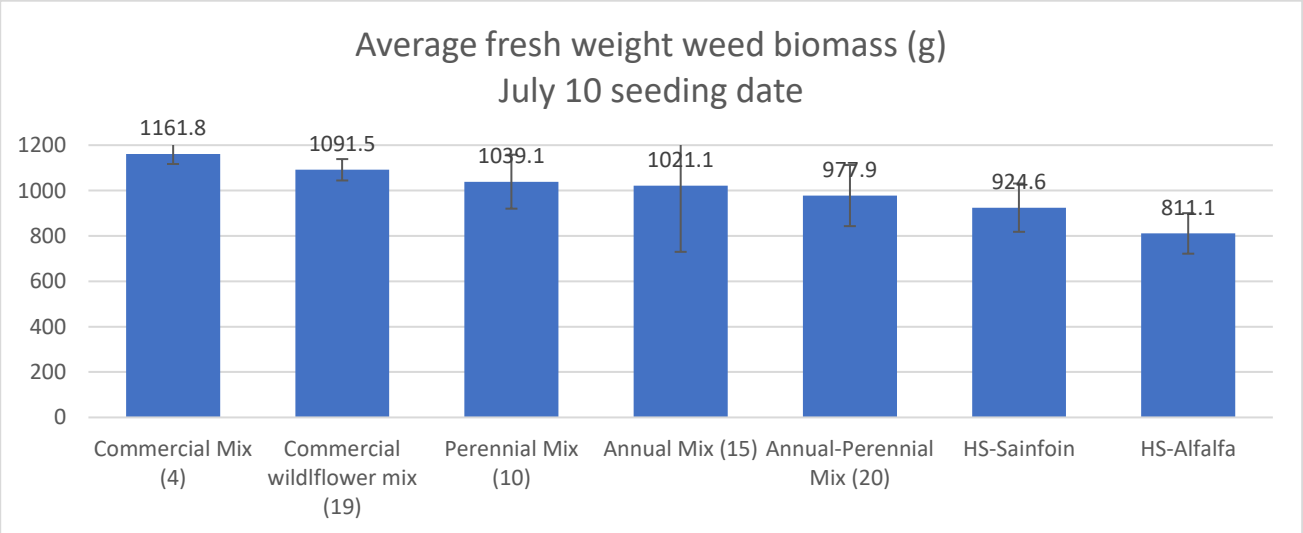


Figure 5. Average of fresh weigh weed biomass per treatment for July 10, 2019 seeding date

Average crop biomass (Table 3) highlights the difference between treatments as well, with the annual, annual-perennial and perennial mixes having higher crop biomass for the early seeding date. No statistical difference between treatments in the late seeding date.

Table 3. Average crop biomass (g) per treatment

	Average of crop biomass fresh wt (g)	LSD 0.05
May 28/2019		
Perennial Mix (10)	391.8	**A**
Annual-Perennial Mix (20)	369.5	**A**
Annual Mix (15)	306.1	**A**
Commercial Mix (4)	174.1	**B**
Commercial wildflower mix (19)	151.6	**B**
July 10/2019		
Annual Mix (15)	61.9	
Annual-Perennial Mix (20)	68.2	
Commercial Mix (4)	58.9	
Commercial wildflower mix (19)	63.6	
HS-Alfalfa	78.9	
HS-Sainfoin	73.6	
Perennial Mix (10)	67.4	

Most species in each mix established easily, outside of wildflowers, and successfully attracted a diversity of pollinator species including Lepidoptera (butterflies), Diptera (flies), Hymenoptera (bees and wasps) and Coleoptera (beetles).

As indicated by the data collected from yellow sticky cards, butterflies and flies increased in abundance across the sampling period, while bees, wasps and beetles declined in abundance (Figure 6 & Figure 7). The movement of hives in and out of the area may account for the abundance of honeybees and may have skewed the numbers.

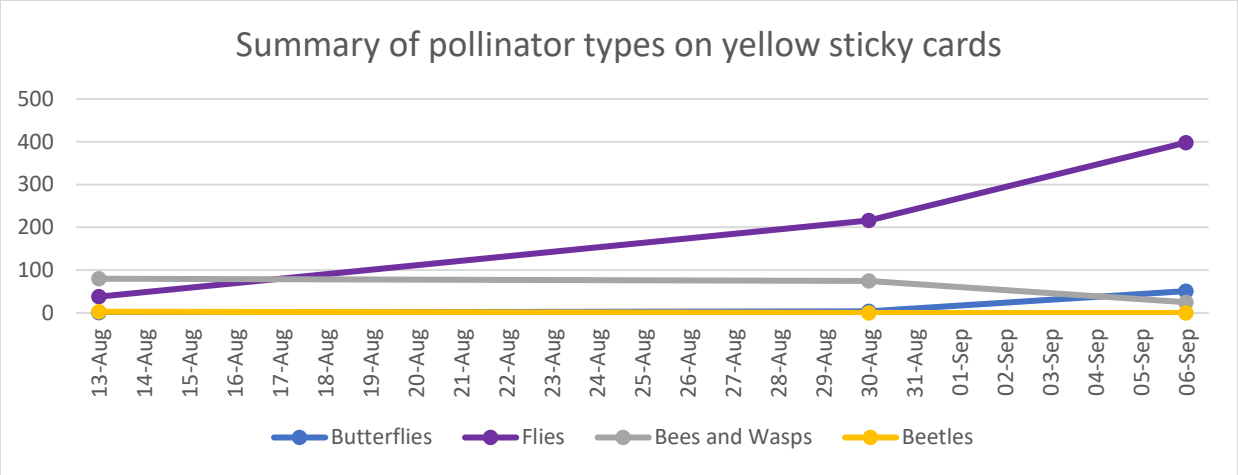


Figure 6. Summary of pollinator types found on 2019 yellow sticky card traps

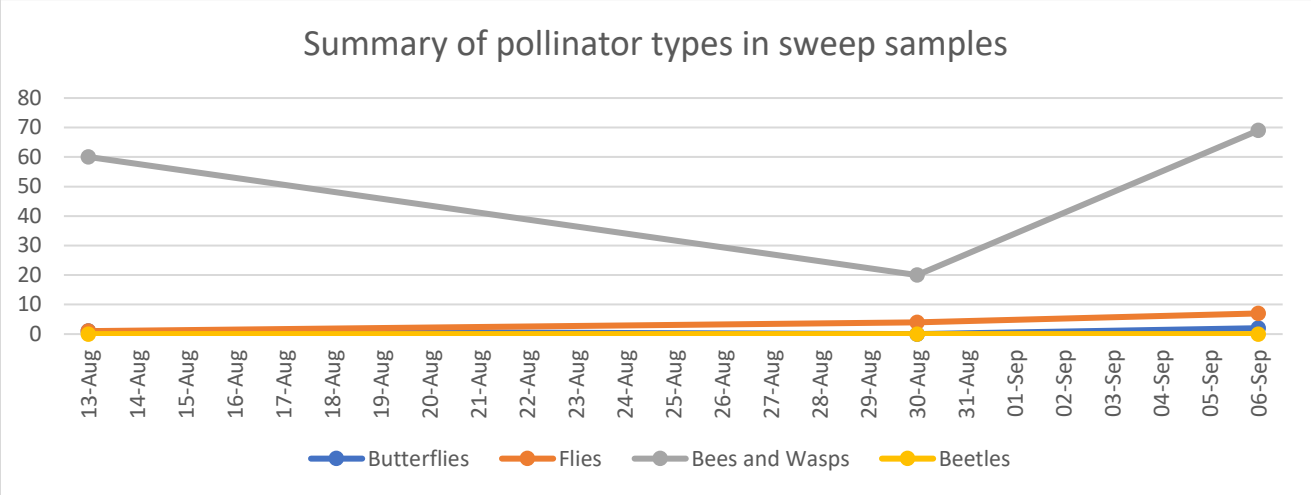
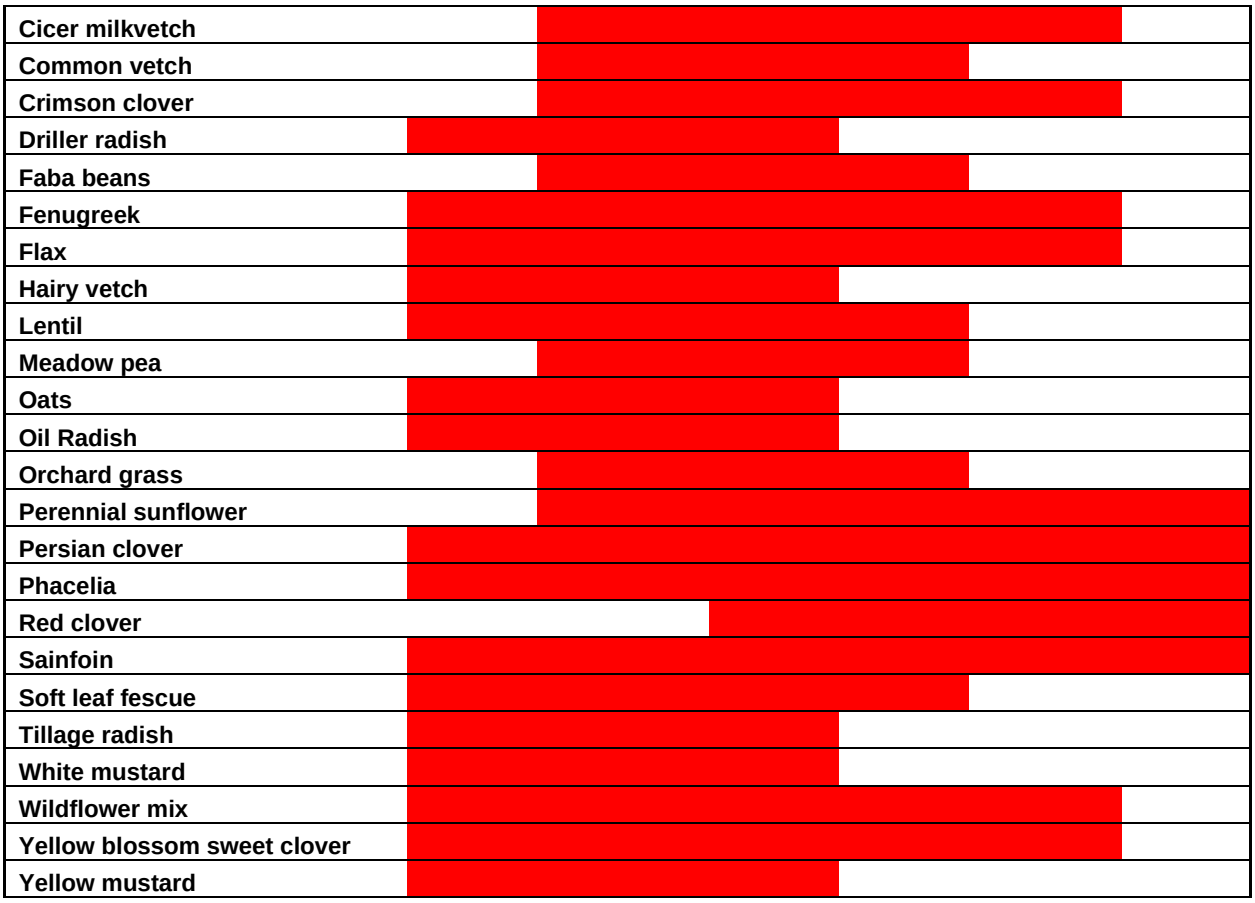


Figure 7. Summary of pollinator types in 2019 sweep net samples

As was expected, the majority of plants flowered between May and September (Figure 9; Appendix 1). The plants flowering early and late in the season provide a source of food when it is scarce. Early flowering species include Balansa and Berseem clover, while late season flowering plants include Alfalfa, perennial sunflower, Persian clover, Phacelia, Red clover and Sainfoin. Floral calendar below shows flowering period for each species (Table 4).

Table 4. Floral calendar

Species	April	May	June	July	August	September	October
Alfalfa							
Annual sunflower							
Balansa clover							
Berseem clover							
Black gram							
Black mustard							
Chickpea							



Conclusion

Numerous agricultural crop species provide a practical solution to creating sustainable, low cost, low maintenance options to meet nesting & foraging needs of insect pollinators like bees. Perennial mixes are ideal for areas that are not going to be managed yearly including along roadways and waterbodies, or marginal lands. Annual mixes with legumes are good options for pivot corners to improve soil quality through nitrogen fixation. Pollinator mixes will create habitat and food for many vertebrates, invertebrates as well as insects.

Most of the crops used in the mixes can be used as forage, therefore they can be seeded into tame pastures or grazing areas for fall grazing.

This project planned to include native flower mix treatments, but the required amount of seeds for our small plots were not available making it impractical to recommend this practice to growers with larger acreages.

Acknowledgements

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Appendix

Table 5. Total rainfall during May to August 2019 on NE-34-8-21 W4 from ACIS

Month	Actual precipitation (mm)	Long term monthly average (mm)
January	13.81	16.8
February	22.68	12.5
March	6.77	21.7
April	3.75	34.8
May	65.29	52.1
June	38.78	78.7
July	33.34	42
August	20.37	39.3
September	60.62	39.7
October	16.47	20.2
November	33.7	17.5
December	6.05	16.2

Table 6. Species included in each of the mixes

Annual-Perennial Mix (20)	
Black mustard	*Brassica nigra*
White mustard	*Sinapsis alba*
Yellow mustard	*Sinapsis alba*
Yellow blossom sweet clover	*Melilotus officinalis*
Berseem clover	*Trifolium alexandrinum*
Balansa clover	*Trifolium michelianum*
Crimson clover	*Trifolium incarnatum*
Fenugreek	*Trigonella foenum-graecum*
Sanfoin	*Onobrychis viciifolia*
Hairy vetch	*Vicia vilosa*
Tillage radish	*Raphanus sativus var.oleifer*
Phacelia	*Phacelia sp.*
Sunflower	*Helianthus annuus*
Flax	*Linum usitatissimum*
Faba beans	*Vicia faba*
Meadow pea	*Latghyrus pratensis*
Chickpea	*Cicer arietinum*
Black gram	*Vigna mungo*
Lentil	*Lens culinaris*
Alfalfa	*Medicago sativa*
Perennial Mix (10)	
Alfalfa	*Medicago sativa*
Hairy vetch	*Vicia vilosa*
Cicer milkvetch	*Astragalus cicer*
Sainfoin	*Onobrychis viciifolia*
Crimson clover	*Trifolium incarnatum*

Red clover	*Trifolium pratense*
Orchard grass	*Dactylis glomerata*
Soft Leaf Fescue	*Festuca arundinacea*
Sunflower	*Helianthus sp*
Phacelia	*Phacelia sp.*
Perennial Rye Grass	*Lolium pernenne*
Annual Mix (15)	
Berseem clover	*Trifolium alexandrinum*
Balansa clover	*Trifolium michelianum*
Fenugreek	*Trigonella foenum-graecum*
Oil Radish	*Raphanus sativus*
Driller Radish	*Raphanus sativus var.oleifer*
Flax	*Linum usitatissimum*
Green Lentil	*Lens culinaris*
Red Lentil	*Lens culinaris*
Faba beans	*Vicia faba*
Chickpea	*Cicer arietinum*
Forage peas	*Pisum sativum*
Meadow peas	*Latghyrus pratensis*
Sunflower	*Helianthus annuus*
Phacelia	*Phacelia sp.*
Oats	*Avena sativa*
Commercial Mix (4)	
Balo brand Phacelia	*Phacelia sp.*
Laser brand Persian clover	*Trifolium sesupinatum*
Ebena brand Common vetch	*Vicia sativa*
Winner brand berseem clover	*Trifolium alexandrinum*
Commercial wildflower mix (17)	
Pheasant's Eye; summer pheasant's eye	*Adonis aestivalis*
Pot marigold	*Calendula officinalis*
Cornflower	*Centaurea cyanus*
Wallflower	*Erysimum cheiri*
Max chrysanthemum	*Leucanthemum maximum*
Plains coreopsis	*Coreopsis tinctoria*
Garden cosmos	*Cosmos bipinnatus*
Rocket larkspur/ wild delphinium	*Delphinium consolida*
Sweet William	*Dianthus barbatus*
foxglove	*Digitalis purpurea*
Purple coneflower	*Echinacea purpurea*
Golden poppy	*Eschscholzia californica*
Annual/showy baby's breath	*Gyssophila elegans*
Perennial flax	*Linum perenne*
wild lupine	*Lupinus perennis*
Common poppy	*Papaver rhoeas*
Black eyed Susan	*Rudbeckia hirta*
Chinese hound's tongue*	*Cynoglossum amabile*
Rose mallow*	*Hibiscus syriacus*

**Not included on the label of included plant species, but established*

Figure 8. Picture showing the yellow sticky traps

Table 7. Percent of species in mixes that were established in both seeding dates

	Average of % species established
May 28/2019	**72%**
Annual Mix (15)	93%
Annual-Perennial Mix (20)	95%
Commercial Mix (4)	50%
Commercial wildflower mix (19)	26%
Perennial Mix (10)	98%
July 10/2019	**54%**
Annual Mix (15)	35%
Annual-Perennial Mix (20)	36%
Commercial Mix (4)	50%
Commercial wildflower mix (19)	11%
HS-Alfalfa	100%
HS-Sainfoin	100%
Perennial Mix (10)	45%

Table 8. Average weed biomass (g) per treatment (P=<0.0001 early, P=0.006 late)

	Average of weed biomass fresh wt (g)	LSD 0.05
May 28/2019		
Commercial wildflower mix (19)	328.8	**A**
Annual Mix (15)	57.1	**B**
Perennial Mix (10)	46.9	**B**
Annual-Perennial Mix (20)	45.9	**B**
Commercial Mix (4)	35.6	**B**
July 10/2019		
Commercial Mix (4)	1161.8	**A**
Commercial wildflower mix (19)	1091.5	**A**
Perennial Mix (10)	1039.1	**AB**
Annual-Perennial Mix (20)	977.9	**ABC**
HS-Sainfoin	924.6	**BC**
HS-Alfalfa	811.1	**C**
Annual Mix (15)	795.83	**C**

Table 9. Yellow sticky card trap sample summary

	13-Aug	30-Aug	06-Sep	Total Abundance
Butterflies (Lep)	1	4	51	56
Flies (Dip)	38	216	398	652
Bees and Wasps (Hym)	80	75	25	180
Beetles (Col)	3	0	0	3
Total Abundance	**122**	**295**	**474**	**891**

Table 10. Vegetative samples period summary

	13-Aug	30-Aug	06-Sep	Total Abundance
Butterflies (Lep)	1	0	2	3
Flies (Dip)	1	4	7	12
Bees and Wasps (Hym)	60	20	69	149
Beetles (Col)	0	0	0	0
Total Abundance	**62**	**24**	**78**	**164**

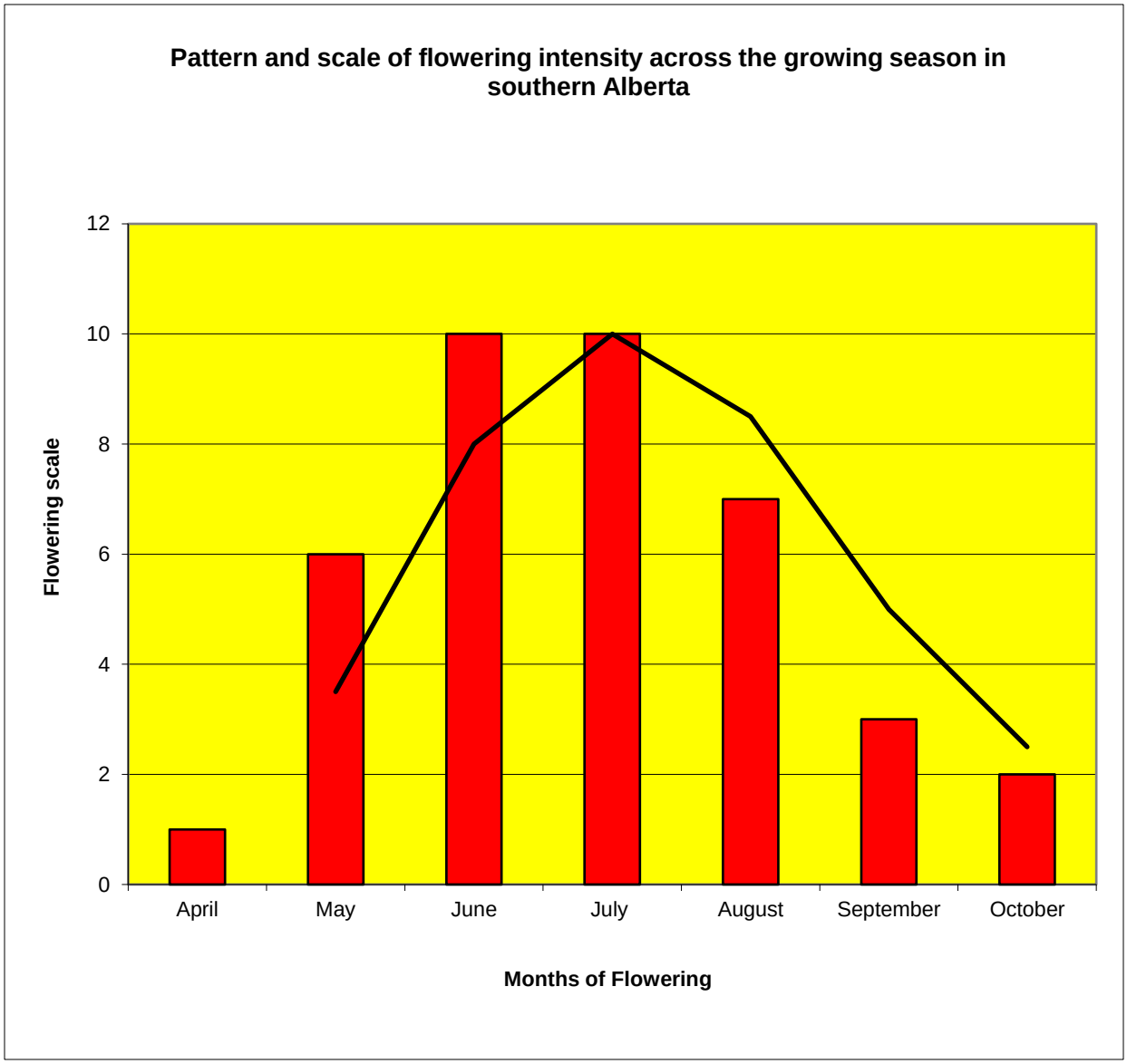

Figure 9. Number of species flowering each month