2018 Milkweed Production Trials – Combined Report

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THE UNIVERSITY OF VERMONT EXTENSION

2018 MILKWEED PRODUCTION TRIALS

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Milkweed (*Asclepias syriaca*) is a plant native to North America and has recently become the focus of conservation programs as Milkweed is the sole food source for the Monarch butterfly larvae. Milkweed has long been a foe of agricultural operations and as a result populations have been on the decline throughout the United States. To increase the abundance and scale of conservation plantings of milkweed, the USDA Natural Resource and Conservation Service (NRCS) has developed an incentive program to compensate landowners for establishing perennial monarch habitat including planting milkweed. Landowners in northern Vermont have a unique opportunity to expand milkweed acreage by producing it as a crop. The silky fiber (floss) from the milkweed plant has a wide variety of oil/chemical absorbent and clothing applications. The floss has insulative properties similar to goose down, and because of its unique hollow fiber structure, floss is also incredibly light. Furthermore, the floss is equipped with a natural water-repellant waxy coating that allows it to be waterproof while absorbing hydrophobic liquids such as petroleum products. Producing milkweed as a crop will require farms to learn best techniques for cultivating milkweed versus the techniques they currently know which is to eliminate at first sight!

Although milkweed is well adapted to a wide range of soils and growing conditions, economical commercial milkweed production has proven more difficult than initially anticipated. The main obstacle in production is weed pressure during the establishment year. Milkweed can be established during early summer in Vermont, making the slow-growing seedlings vulnerable to weed pressure from fast-growing annuals that are able to take advantage of lower temperatures early in the season. Furthermore, little is known about maintaining a milkweed stand for long-term production once it is established. To support this emerging market, UVM Extension's Northwest Crops and Soils Program conducted three trials investigating best management practices for the establishment of milkweed.

Figure 1. Milkweed in bloom

MATERIALS AND METHODS

Milkweed fertility trials-nitrogen and potassium

Producing optimal yields of any crop requires having adequate levels of nutrients available in the soil. Typically, farmers will test their soils to determine their nutrient content and will receive recommendations on additional fertility required by the crop that they are growing. For milkweed, these required fertility levels have yet to be established. We hypothesize that, as with most crops, providing additional nitrogen will increase plant productivity. In addition, we hypothesize that, as with many deep tap rooted crops, milkweed productivity will increase with increased availability of potassium. However, with both of these, we do not know if the increase in productivity will translate into increased floss yield specifically, or if the level of supplemental fertilizer needed to attain the increased yield will be economical. To help determine optimal and economical fertility strategies that support a high yielding milkweed crop, two fertility trials, investigating additions of nitrogen and potassium, were established in 2018.

The experimental design in each trial was a complete randomized block with four replications. Plots 8' x 35' were imposed into an area of milkweed that was established in 2016. Prior to the addition of fertilizer, the soil in the area was sampled to be analyzed for nutritional content. Fertilizer treatments were hand applied on 31-May in both trials. Plots were also assessed for milkweed populations, height, and flowering status at the time the fertilizer treatments were implemented and again at harvest. Table 1 shows the treatments for each trial. The nitrogen was applied in the form of urea (46-0-0) while potassium was applied in the form of potassium sulfate (0-0-52).

Table 1. Nitrogen and potassium treatments, 2018.

Nitrogen lbs N ac^{-1}	Potassium lbs K ac^{-1}
0	0
25	50
50	75
75	125
100	150

Figure 2. Unripe seeds (left) ripe seeds (right)
(photo credit: Brianna Borders, The Xerces Society)

The plots did not receive any further management throughout the season. Determining the timing of milkweed harvest relies on two key factors: seed ripeness and pod opening. Milkweed pods are ready for harvest when the seeds inside ripen turning a brown color (Figure 2). Plots were monitored for ripeness on a weekly basis by collecting a variety of pods from across the trial area and inspecting them for seed ripeness. However, to minimize floss losses during harvest, pods were harvested when the majority of seeds were ripe but before the pods had broken open. Plots in both trials were harvested on 5-Sep. At harvest, milkweed populations were determined by counting the number of plants within a 0.25m^2 quadrat. The number of the plants that had pods, and the total number of pods were recorded as well. Plant height and pod length were recorded for 5 randomly selected plants out of the quadrat area. The pods from the 5 plants were then weighed and a subsample dried to determine moisture content. A subset of the pods from each plot were also separated into pod, floss, and seed fractions and weighed.

Impact of herbicide use on milkweed stand productivity

Although weed pressure during establishment is known to be a challenge in successful milkweed production, we have yet to understand the impacts of weeds or weed management strategies over the stands' lifetime. As the stands fill in, there are little or no opportunities for mechanical cultivation. Many farmers are implementing chemical weed control in the spring prior milkweed emergence. It is not clear if the application of chemical weed control is necessary and if there is an impact on milkweed yields. To investigate the impact of chemical weed control on milkweed productivity, an herbicide trial was implemented in 2018.

The herbicide trial was implemented in a milkweed stand that was established in 2016. Prior to herbicide application, weed composition and ground cover were measured in each plot. This was done by visually identifying the weed species present in each plot and by using the beaded string method **(**Sloneker and

Moldenhauer, 1977). On 8-May, a treatment of Roundup® was applied in strips leaving unsprayed control areas. Sprayed plots were approximately 18’ x 50’ while control plots were approximately 7’ x 50’. Once the milkweed had emerged, plant populations were measured in each plot by counting the number of plants in two 0.25m^2 quadrats. The trial was harvested on 5-Sep. At harvest, milkweed populations were determined by counting the number of plants within a 0.25m^2 quadrat. The number of the plants that had pods, and the total number of pods were recorded as well. Plant height and pod length were recorded for 5 randomly selected plants out of the quadrat area. The pods from the 5 plants were then weighed and a subsample dried to determine moisture content. A subset of the pods from each plot was also separated into pod, floss, and seed fractions and weighed.

Variations in yield and quality can occur because of variations in genetics, soil, weather, and other growing conditions. Statistical analysis makes it possible to determine whether a difference among treatments is real or whether it might have occurred due to other variations in the field. All data was analyzed using a mixed model analysis where replicates were considered random effects. At the bottom of each table, a LSD value is presented for each variable (e.g. yield). Least Significant Differences (LSDs) at the 10% level (0.10) of probability are shown. Where the difference between two treatments within a column is equal to or greater than the LSD value at the bottom of the column, you can be sure in 9 out of 10 chances that there is a real difference between the two values. Treatments listed in bold had the top performance in a particular column; treatments that did not perform significantly worse than the top-performer in a particular column are indicated with an asterisk. In this example, treatment A is significantly different from treatment C, but not from treatment B. The difference between A and B is equal to 400, which is less than the LSD value of 500. This means that these treatments did not differ in yield. The difference between A and C is equal to 650, which is greater than the LSD value of 500. This means that the yields of these treatments were significantly different from one another.

Variety	Yield
A	**1600***
B	1200*
C	950
LSD (0.10)	500

RESULTS

Weather data were recorded with a Davis Instrument Vantage Pro2 weather station, equipped with a WeatherLink data logger at Borderview Research Farm in Alburgh, VT (Table 2). Growing Degree Days (GDDs) were summarized using the base and maximum temperatures for corn as they are not known for milkweed specifically. Overall, the season was hotter and dryer than normal as temperatures were slightly above normal with a few periods of very hot weather in the middle of the summer and only about 60% of the normal precipitation accumulation. There were only four rain events during this trial’s growing season that produced >0.75” of accumulation. These four events constituted approximately 33% of the total rainfall. Therefore, there were extended periods with very little to no rainfall, the longest of which was approximately 25 days with no rainfall >0.25”. These dry conditions occurred during pod and seed formation and therefore may have impacted development and productivity. However, these warm conditions did provide optimal Growing Degree Days (GDDs) through the season with a total of 2650 GDDs accumulated May-Sep, 439 above normal.

Table 2. 2018 weather data for Alburgh, VT.

Alburgh, VT	May	June	July	August	September
Average temperature (°F)	59.5	64.4	74.1	72.8	63.4
Departure from normal	3.10	-1.38	3.51	3.96	2.76
Precipitation (inches)	1.94	3.74	2.43	2.96	3.48
Departure from normal	-1.51	0.05	-1.72	-0.95	-0.16
Growing Degree Days (50-86°F)	352	447	728	696	427
Departure from normal	154	-27	88	115	109

Based on weather data from a Davis Instruments Vantage Pro2 with WeatherLink data logger.
Historical averages are for 30 years of NOAA data (1981-2010) from Burlington, VT.

Milkweed fertility trials-nitrogen and potassium

Fertility treatments did not significantly vary in terms of yield and many harvest characteristics in either trial (Tables 3 and 4). The number of pods per plant averaged 3.60 and 3.81 with 74.1% and 74.2% of plants having formed pods in the nitrogen and potassium trials respectively. Pods averaged 9.05 and 9.25cm in length and 63.6% and 57.8% moisture content at the time of harvest for the nitrogen and potassium trials respectively. The total pod yields, expressed on a dry matter basis, were 1.05 and 1.30 tons ac^{-1} for the nitrogen and potassium trials respectively. None of these characteristics varied statistically across nutrient application rates. The one characteristic that did vary statistically, however, was plant height. Plant height, measured at harvest, averaged 42.9 and 40.7 inches in the nitrogen and potassium trials respectively. In the nitrogen trial, heights ranged from 39.2 to 45.8 in and were not statistically different. This result was surprising as we would assume that additional nitrogen would be utilized by the plant in its biomass. However, the extremely dry conditions throughout the season likely influenced the availability of nitrogen to the plants. For the potassium trial, heights ranged from 38.0 to 44.5 inches and was statistically different across potassium rates. Interestingly, the tallest plants were observed in the 50 lb K ac^{-1} treatment, which was not statistically similar to any other treatment.

Table 3. Milkweed harvest characteristics, nitrogen trial, 2018.

Nitrogen rate	Pod production		Pod length	Plant height	Pod moisture	Pod yield
lbs N ac^{-1}	pods $plant^{-1}$	% of plants	cm	in	%	DM tons ac^{-1}
0	**4.33**	72.1	9.34	39.2	**61.9**	**1.33**
25	3.92	75.9	8.73	43.6	64.6	1.13
50	3.23	**80.5**	**9.45**	**45.1**	64.1	0.98
75	3.78	68.6	8.99	40.7	64.9	0.99
100	2.74	73.3	8.75	45.8	62.4	0.81
LSD (p = 0.10)	NS	NS	NS	NS	NS	NS
Trial mean	3.60	74.1	9.05	42.9	63.6	1.05

Top performing treatments are indicated in **bold**.
NS – Not significant.

Table 4. Milkweed harvest characteristics, potassium trial, 2018.

Potassium rate	Pod production		Pod length	Plant height	Pod moisture	Pod yield
lbs K ac^{-1}	pods plant^{-1}	% of plants	cm	in	%	DM tons ac^{-1}
0	3.66	65.9	9.09	38.0	57.7	1.33
50	3.88	**83.7**	9.61	**44.5**	60.6	1.34
75	**4.19**	68.4	8.93	39.6	**54.9**	1.31
125	3.35	77.7	8.82	40.9	59.0	1.13
150	3.96	75.4	**9.82**	40.4	56.8	**1.38**
LSD (*p* = 0.10)	NS	NS	NS	3.50	NS	NS
Trial mean	3.81	74.2	9.25	40.7	57.8	1.30

Top performing treatments are indicated in **bold**.
NS – Not significant.

Treatments also did not differ significantly in terms of pod composition across either trial (Tables 5 and 6). The majority of the total pod weight is composed of external pod cover as this was found to be 60.0% and 57.5% for the nitrogen and potassium trials, respectively. The floss, as to be expected, accounted for the smallest fraction at only 16.3% and 17.3% of the total pod weight for the nitrogen and potassium trials, respectively. Based on the pod yields observed in the trial, and the current value estimate for pods at 30% moisture being $0.40 per pound, the value of the crop would be between $1200 and $1500 per acre. However, the actual value that can be realized may be lower as these estimates assume that all of the pods can be harvested from the field without loss.

Table 5. Milkweed pod composition by weight, nitrogen trial, 2018.

Nitrogen rate	Floss	Pod	Seed
lbs N ac^{-1}	% by weight		
0	16.2	60.5	23.3
25	16.3	59.6	24.1
50	**17.6**	**59.4**	23.0
75	16.1	60.5	23.4
100	15.5	60.2	**24.3**
LSD (*p* = 0.10)	NS	NS	NS
Trial mean	16.3	60.0	23.6

Top performing treatments are indicated in **bold**.
NS – Not significant.

Table 6. Milkweed pod composition by weight, potassium trial, 2018.

Potassium rate	Floss	Pod	Seed
lbs K ac^{-1}	% by weight		
0	17.1	58.1	24.8
25	16.4	59.0	24.7
50	**17.8**	**56.0**	**26.2**
75	17.8	57.0	25.2
100	17.5	57.4	25.0
LSD (*p* = 0.10)	NS	NS	NS
Trial mean	17.3	57.5	25.2

Top performing treatments are indicated in **bold**.
NS – Not significant.

As with any crop, some level of loss at harvest is to be expected, however, it is exceptionally difficult with milkweed given the extremely low weight of the floss. Harvesting techniques to minimize floss losses and improve purity and cleanliness are currently being developed. Although the floss is the main component of interest in a milkweed crop, the seed may also present opportunities to recoup value, especially as interest in growing milkweed commercially increases. Therefore, the highest seed and floss yielding treatments are represented as the top performing treatments in the tables above.

Impact of herbicide use on milkweed stand productivity

Weed control treatments did not significantly vary in terms of yield and many harvest characteristics (Table 7). The number of pods per plant averaged 3.73 with 68.4% of plants on average having pods. Pods averaged 8.64 cm in length and plants averaged 40.2 inches in height at the time of harvest. The total pod yield, expressed on a dry matter basis, was 1.12 tons ac^{-1}. None of these characteristics varied statistically across weed control methods. This may be due to the fact that the weed pressure was similar across the treatments as the percent of ground cover from weedy vegetation at the time of harvest was not statistically different between weed control treatments with the control having 44.5% and the herbicide treatment with 39.0%. The one characteristic that did vary statistically, however, was pod moisture with the control producing pods with 3.9% higher moisture than the herbicide treated plants. This suggest that the early herbicide application may have allowed the plants to mature faster than the plants that did not receive weed control. However, no additional yield was gained from the herbicide application and therefore, is likely not cost effective.

Table 7. Milkweed harvest characteristics, weed control trial, 2018.

Weed control	Ground cover	Pod production		Pod length	Plant height	Pod moisture	Pod yield
	%	pods plant^{-1}	% of plants	cm	in	%	DM tons ac^{-1}
Herbicide	39.0	3.60	63.6	8.83	40.4	58.7	1.19
Control	44.5	3.87	**73.1**	8.45	**40.0**	62.6	1.05
LSD (p = 0.10)	NS	NS	NS	NS	NS	3.73	NS
Trial mean	41.8	3.73	68.4	8.64	40.2	60.7	1.12

Top performing treatments are indicated in **bold**.
NS – Not significant.

DISCUSSION

These preliminary data suggest that additional nitrogen or potassium fertilizer at rates between 0-100 and 0-150 lbs ac^{-1} respectively does not increase milkweed floss yield. The additional nutrients appear to have been used by the plant for vegetative growth as, at least for potassium, plant height differed at harvest across the rates. Perhaps larger differences would have been observed given more favorable weather to encourage nutrient transport into the soil profile. Furthermore, larger differences may be seen on more marginal nutrient deficient fields. The soil test results from the test field indicated optimum levels of potassium in the soil. For most crops this would indicate that it would be unlikely to see a yield response if additional potassium was added. In terms of nitrogen, lack of moisture throughout the season likely contributed to lower nitrogen availability in the soil. Furthermore, the few rain events that were experienced throughout the season were >.75" and could have caused leaching or runoff of these nutrients as they are not held by the soil well. Lastly, it would be important to evaluate timing of fertility applications to milkweed. Like most crops, greater amounts of nutrients are required as the plant builds biomass and shifts to the reproductive stage. Later applications of nutrients might have a larger impact on milkweed pod yields more so than early spring applications.

These data also suggest that one singular spring application of herbicide did not increase milkweed floss yield. At the time of harvest, the treatments were similar in the amount of ground cover provided by weeds indicating that, although the application may have increased the milkweed's ability to establish faster, that potential effect did not carry through to the end of the season or impact yield. These data are representative of only one location and year. Further investigation is needed to determine optimal and economical fertility rates and weed control methods for milkweed.

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THE UNIVERSITY OF VERMONT EXTENSION

COMMERCIALLY GROWN MILKWEED AS HABITAT AND FORAGE FOR MONARCH BUTTERFLIES AND OTHER POLLINATORS

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The decline of pollinating insect species including monarch butterflies and some bee species is partly attributed to the loss of forage and habitat associated with land use change (Kremen, Williams & Thorp, 2002; Potts et al., 2010; Winfree, Bartomeus & Cariveau, 2011). As a result, in recent years, there has been a concerted effort to create 'pollinator friendly' gardens and hedgerows of flowering plant species and larval host plants (Morandin & Kremen, 2013; Kim et al., 2006; Pollinator Health Task Force, 2015). Milkweed is an important source of nectar for bees and is the larval host plant of the monarch butterfly (*Danaus plexippus*). Previous research suggests that a loss of agricultural milkweed is a major contributor to the decline of the monarch population (Pleasants & Oberhauser, 2013). A new opportunity to grow and harvest milkweed at the commercial scale has the potential to create large areas of habitat and forage for monarch butterflies and bee species. As our research group and Vermont farmers develop management practices such as IPM strategies and harvesting techniques, it is important to note how these practices coincide with monarch butterfly life cycle and pollinator activity. The development of sustainable management practices for milkweed crops requires an understanding of pollinator activity on milkweed throughout the growing season to reduce any potential negative impacts on pollinator species.

Agricultural chemicals such as pesticides also pose a threat to pollinating insect species (Goulson et al., 2015). In particular, neonicotinoids, a class of systemic pesticides widely used in agriculture and applied as seed dressings on crops, have garnered much attention in recent years. Negative impacts to many pollinator groups are well documented and include butterflies, bumble bees, solitary bees, and honey bees (Cresswell, 2011; Hopwood et al., 2013; van der Sluijs et al., 2013). Field and laboratory experiments suggest that neonicotinoid exposure to adult bees at field realistic doses impairs foraging activity, increases worker mortality, reduces queen production, and weakens bee's immune system (Gill & Raine, 2014; Rundlöf et al., 2015; Arce et al., 2017; Baron et al., 2017; Fauser et al., 2017; Stanley & Raine, 2017; Woodcock et al., 2017). Monarch larvae that ingest milkweed contaminated with clothianidin, a neonicotinoid used in treated corn, experienced sub-lethal and lethal effects (Pecenka & Lundgren, 2015).

Pollinators may become exposed to neonicotinoids through multiple routes. As systemic pesticides, neonicotinoids are expressed not only in leaf tissue of plants but also in pollen and nectar of flowers, where floral visitors may become exposed when foraging (Goulson, 2013; David et al., 2016). Hedgerows of wildflowers grown adjacent to treated crops such as corn can be contaminated by wind-blown dust during sowing or pollen during crop bloom (Botías et al., 2015; Krupke et al., 2017). Due to their persistence in soils, neonicotinoids may also contaminate non-target plants when planted directly into soil that has previously supported a crop grown from neonicotinoid-treated seed (Basley & Goulson, 2018). It is unclear whether commercial milkweed crops, which have the potential to support pollinator communities, could become contaminated with neonicotinoids when planted near treated crops or in soil that previously supported a treated crop. More research is needed to test for contamination potential to milkweed crops near and around treated crops. Results could inform management practices to reduce impact to pollinators that use this plant as a host plant or source of nectar.

We are conducting a two-year study to determine pollinator presence within milkweed crops as well as the potential for contamination of neonicotinoids to milkweed from treated corn. Over the course of two years, we aim to 1) Determine the density and presence of monarch (eggs, larvae, and adults) throughout the growing season to inform management/growing recommendations for commercial milkweed crops. 2) Examine the diversity and abundance of common milkweed pollinators with a focus on bees. 3) Test whether milkweed plants can 'take up' or sequester neonicotinoids from soil that was previously planted with treated corn seed. Results from this study will define the potential for commercial milkweed crops to support pollinator communities and also guide sustainable management practices for this crop.

MATERIALS AND METHODS

In 2018, we conducted surveys at two farm field sites with commercially planted common milkweed (*Asclepias syriaca*): Borderview farm (45.008689, -73.309507) and Dewing farm (44.980554, -72.843054). The plot sizes of milkweed crops at the Borderview and Dewing sites are 14 hectares and 6 hectares, respectively. At each site, we delineated three separate blocks each consisting of 10,000 m^2 for the monarch/pollinator surveys. To estimate milkweed plant density, we counted all milkweed plants within a one square meter quadrat randomly placed 100 times throughout each block for a total of 300 quadrates for each site.

To measure monarch (egg, larvae, adult) presence throughout the milkweed plots, we conducted weekly surveys June 12th- September 3rd. During each survey event, we randomly selected 100 plants within each of the three delineated blocks and inspected each plant for monarch presence. We recorded all eggs, larvae (and instar), and adults (female/male).

To measure pollinator diversity and abundance, we conducted weekly observational and collection surveys during milkweed bloom. For observational surveys, we randomly selected two 50 meter transects within each block and recorded all floral visitors along this transect for 10 minutes on both milkweed flowers and other wildflowers ('weeds'). Floral visitors were identified to morphospecies: *Bombus* (queen), *Bombus* (worker), honey bee, black (big), black (slender), black (tiny), green, and flies. To estimate pollinator diversity, we made collections of floral visitors (with a focus on bees) along two randomly selected 50 meter transects within each block for 10 minutes. All collected specimens were sacrificed, pinned, labeled, and identified to genus or species when possible.

To test neonicotinoid residues in the soil and milkweed leaf tissue, we selected soil (~500 g) and milkweed leaf tissue (~50 g) samples from Borderview on September 24th (2 milkweed samples) and October 3rd, 2018 (21 milkweed samples and 21 soil samples). We initially attempted to collect leaf tissue from milkweed seedlings earlier in the season, but growing conditions and low germination rates prevented earlier collections. We collected four different types of samples: *active corn*: from fields planted with corn in 2018; *milkweed field*: where milkweed has grown for three years but corn was previously planted for three continuous years prior to milkweed; *new field*: where milkweed was seeded in spring of 2018 and grown beside corn; and *new field no corn*: where milkweed was seeded in spring of 2018 but outside of corn plantings. All soil and milkweed samples were collected and stored on -80° C until further analysis. Samples will be analyzed for three neonicotinoid compounds (clothianidin, thiamethoxam, and imidacloprid) at the Vermont Agency of Agriculture laboratory at the University of Vermont.

RESULTS AND DISCUSSION

Milkweed density at Borderview was twice that of Dewing, (Borderview: 24.25 plants/m^2; Dewing: 12.42 plants/m^2). Overall milkweed bloom lasted from June 26th-July 10th. Phenology of milkweed bloom at Borderview was approximately one week before Dewing. Although we did not conduct formal wildflower surveys throughout the fields, we anecdotally note that Dewing had a much higher density of wildflowers throughout the milkweed plots compared to Borderview that supported an abundance of bees. Thus, management strategies for milkweed crops should also consider the presence of wildflowers dispersed throughout the fields and the pollinator communities they support. In 2019, we aim to conduct formal wildflower surveys to examine the importance of these plants on the pollinator community within milkweed crop fields.

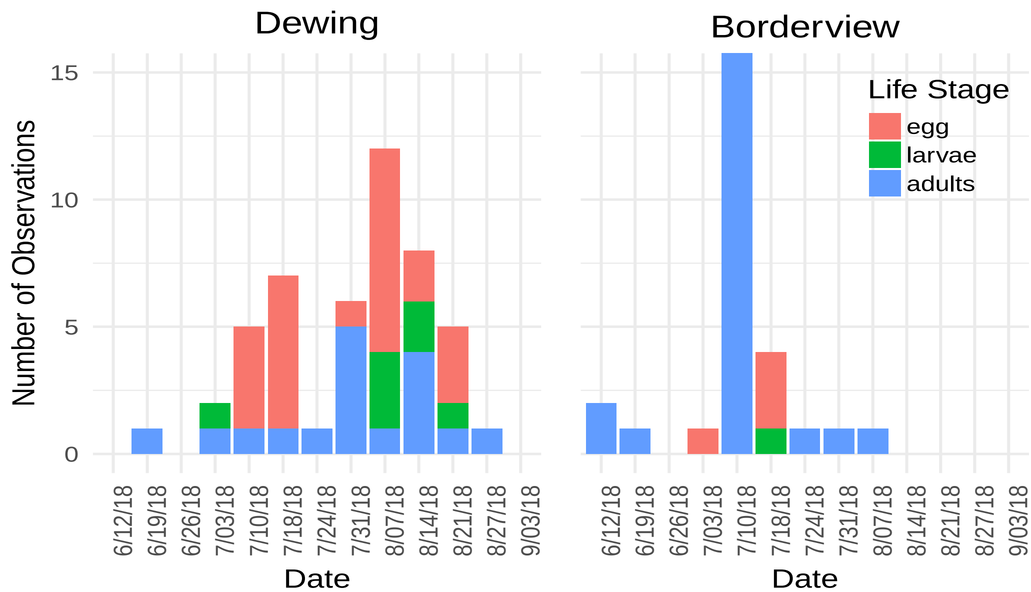

Figure 1. Monarch presence for each site throughout the sampling period. We observed two peaks of monarch activity for Dewing, as expected based on previous monarch studies.

We observed monarch eggs, larvae and adults at both Dewing and Borderview sites throughout the sample period (Figure 1). We observed a higher overall presence of juvenile monarchs at Dewing compared to Borderview. At Dewing, juvenile monarch presence had two peaks: one in early July and one in early August. Observed differences in monarch activity between the two sites could be an artifact of our sampling effort combined with differences in plot size and/or milkweed density. In 2019, we will increase monarch-sampling effort, to capture more monarch activity and further explore potential factors driving the observed differences in monarch presence across the two sites. Results from a power analysis using 2018 data will inform 2019 sampling effort.

Sites were surveyed weekly during the three-week duration of milkweed bloom. During observational surveys, honey bees (*Apis mellifera*) were the most predominant visitor of milkweed flowers followed by worker bumble bees (*Bombus* spp.). We observed a large number of visitors on other flowering plant species growing within the milkweed crops (Table 1, Figure 2). In the collection surveys, collections consisted of bees from the following genera: *Bombus*, *Augochlora*, and *Melissodes* with *Bombus* being the most predominant. Notable sightings included four *B. terricola* (two from Dewing, two from Borderview), a species listed as state threatened in 2015, and one *B. fernaldae* (collected at Dewing on July 10th), representing the forth record of this species in Vermont. In 2019, we plan to continue pollinator surveys and also include surveys for milkweed pests throughout the growing season.

Table 1. Observational data for floral visitors at Borderview and Dewing milkweed crop sites.

Morphotype	Potential genera represented[1]	Observations			
		Borderview		Dewing	
		MW	W	MW	W
Bombus (queen)	*Bombus*	2	1	0	5
Bombus (worker)	*Bombus*	72	0	18	13
Black bees (big)	*Andrena, Osmia*	0	0	5	1
Black bees (slender)	*Andrena, Colletes, Osmia*	1	3	2	7
Black bees (tiny)	*Andrena, Ceratina, Halictus, Lassioglossum*	0	2	1	0
Green bees	*Agapostemon, Augochlora, Augochlorella, Augochloropsis*	0	0	1	0
Apis	*Apis mellifera*	926	5	281	24
Flies	-	17	5	269	25

[1]Adapted from Nicholson & Ricketts, 2019

Floral visitors were identified by morphospecies on both milkweed plants (MW) and other wildflower weeds (W). A list of potential genera represented by each morphospecies is provided.

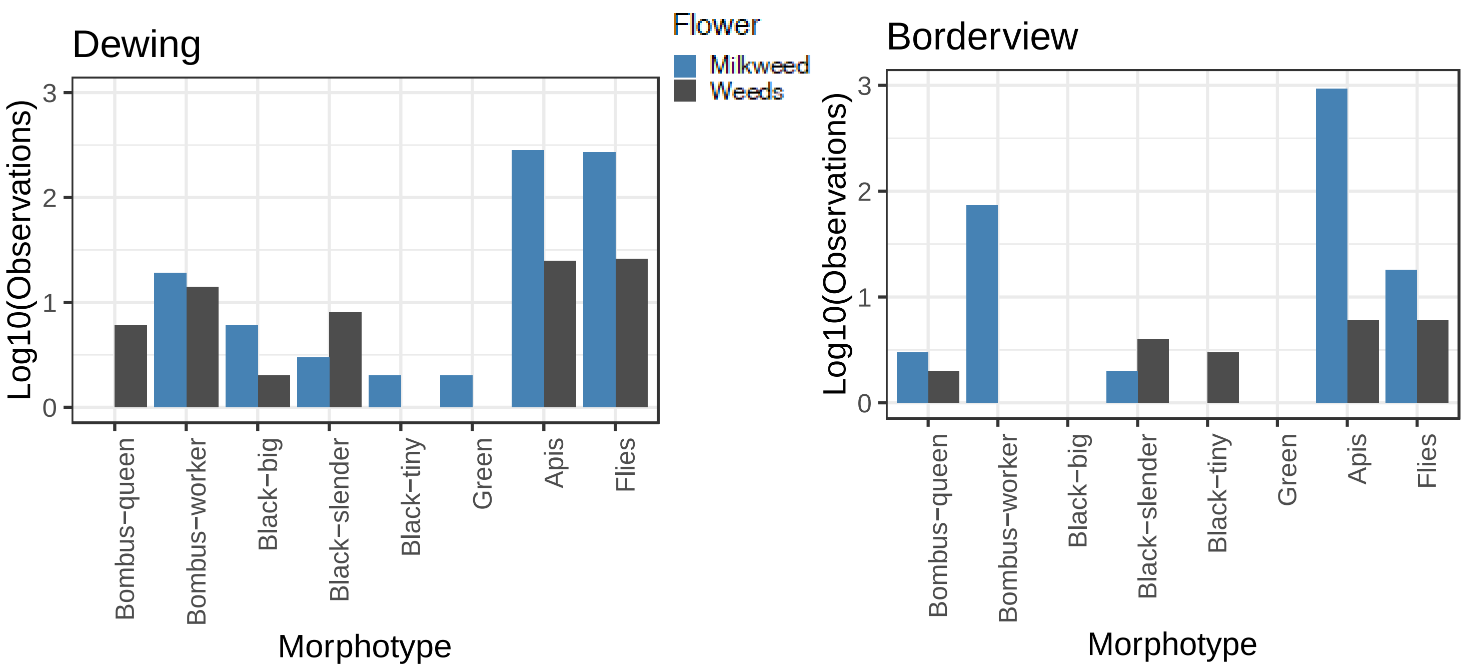

Figure 2. Observational surveys of floral visitors in Dewing and Borderview milkweed crops. Observational surveys were conducted during three weeks of milkweed bloom. All floral visitors to milkweed flowers and wildflowers ('weeds') were recorded by morphotype. Observations have been log10 transformed for visualization.

Results from pesticide testing are not yet available from the Vermont Agency of Agriculture Laboratory. Due to field conditions and low germination rates, we collected samples much later in the season than anticipated. Milkweed and soil samples were collected after corn sowing and when milkweed plants were beginning to senesce. In 2019, we plan to collect samples earlier in the season, including during milkweed bloom and peak monarch activity to capture the height of pollinator activity. Results from 2018 will inform 2019 sampling protocols.

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IMPACT OF MILKWEED CULTIVATION ON DETRITIVORE COMMUNITIES

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Growing milkweed may be beneficial to monarch butterflies, but what impact does it have on other organisms? Detritivores, including earthworms, beetles, ants, springtails, and mites, are an ecological group that live in the soil or litter layer. Detritivores are often used as "healthy soil indicators" (Stork & Eggleton 1992) and provide important soil-related ecosystem services, like creating soil structure and aiding in decomposition (Lavelle et al. 2006). Despite their importance to ecosystem function, detritivores are a relatively understudied group in ecology and in agricultural settings. We know little about how land management affects them or what factors most control their distribution and diversity. Understanding these relationships can help guide management that preserves detritivores and their functions. In this project, we sought to understand how detritivore communities differ under milkweed cultivation as compared to other common New England land uses, including conventional corn, perennial forage, and forest.

MATERIALS AND METHODS

At Borderview Research Farm in Alburgh VT, 100 meter transects were established in nearby fields of milkweed, conventional corn, perennial forage, and forest. Sampling was conducted every 10 meters along the 100 meter transects (10 sampling sites per land use). At each sampling site we used three methods to survey different sets of detritivores. In the first method, we used pitfall traps to collect surface or litter-dwelling organisms. Pitfall traps are collection cups that are placed in the soil with their lids level to the surface (Southwood & Henderson 1994, p. 276). Organisms randomly fall and are trapped in the cups as they move across the soil surface. The second method targeted soil-dwelling and generally smaller organisms. For this method we took soil cores and extracted organisms using Berlese funnels, a technique in which soil is placed in a funnel and exposed to a bright light from above (Southwood & Henderson 1994, p. 229). Organisms attempt to escape the light's heat and dryness by crawling downward and are funneled into a collection cup. Finally, we used the mustard extraction technique to target earthworms (Lawrence &

Bowers 2002). We poured a mustard solution (1 gallon of water with 1/3 cup mustard powder) on a 0.5m x 0.5m section of soil and collected earthworms that emerged within fifteen minutes. Earthworms evacuate the soil because they are irritated by the mustard powder. We chose this method because it has minimal impact on the field, unlike other methods that involve excavating large sections of soil and manually counting earthworms.

All collected organisms were identified, and measured. Identification was aided by the use of the free online site iNaturalist, where posted photos of organisms are identified by the public. The link to this project's iNaturalist collection is here: https://www.inaturalist.org/projects/soil-organisms-of-alburgh-vt. For each plot sampled, we calculated species richness (total number of species) and Shannon's diversity (an index that takes into account the evenness of species) and averaged values for each land use. We also plan to calculate the size distribution of organisms in each land use type.

RESULTS AND DISCUSSION

We found that each land use hosts a unique assemblage of detritivores (Figure 1). Conventional corn plots, for example, were dominated by larger beetles, while perennial forage plots had the highest number of ants, and forest plots had the highest numbers of earthworms and spiders. Milkweed plots were not dominated by any one group of organisms, but had the highest species richness (average number of total species per plot), with around nine different species per plot (Figure 2). Conventional corn had the lowest average species richness (around four species per plot), while perennial forage and forest had intermediate average species richness (five to six species per plot).

These results indicate milkweed's potential to host diverse communities of detritivores. One possible reason for this might be milkweed's perennial lifecycle, which allows detritivore communities and the soil to remain undisturbed for several years. An additional question is to what extent the increase in soil organisms relates to an increase in soil quality under milkweed. If milkweed does increase both detritivore diversity and soil quality on farms, it may be both an ecological and profitable land restoration technique.

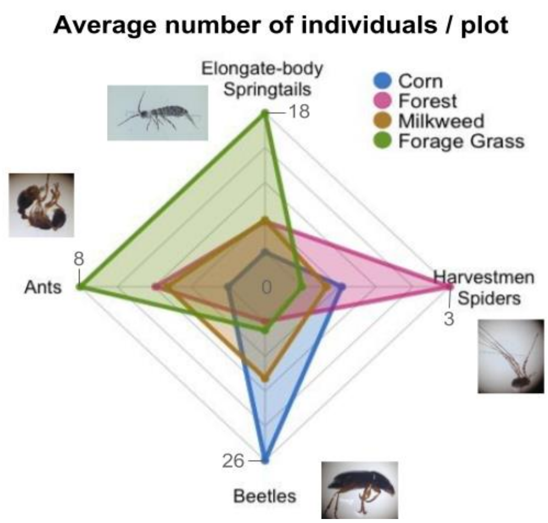

Figure 1. Detritivore communities by land use.

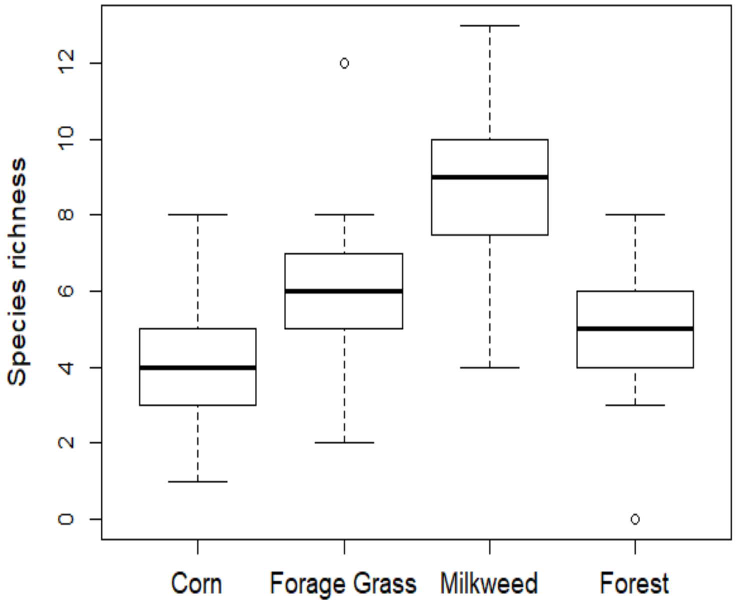

Figure 2. Species richness by land use.

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