2020 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 declining populations of Monarch butterfly larvae. Milkweed (Image 1) 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 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 due to its unique hollow fiber structure which also makes it 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!


Image 1. Milkweed in bloom

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. In addition to these production challenges, little is known about how milkweed cultivation may impact soil microorganisms such as earthworms, beetles, ants, and mites. These organisms play a number of important ecosystem services in agricultural settings, including aiding in decomposition, soil structure creation, and pest control, but we do not know how these functions may differ in milkweed production systems. Furthermore, much of the research and conservation focus around insects has been focused on the monarch butterfly. However, we do not know what other species are utilizing milkweed plants or how milkweed production techniques may impact their populations or function. To support this emerging market and gain a better understanding of the impacts of milkweed cultivation, UVM Extension's Northwest Crops and Soils Program along with colleagues from the UVM Gund Institute and Plant and Soil Science Department, conducted three trials investigating best management practices for the establishment of milkweed.

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 to produce an optimum crop. 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 nutrient management strategies that support a high yielding milkweed crop, two fertility trials, investigating rates of nitrogen and potassium, were established in 2020.

The experimental design in each trial was a randomized complete block design 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 nutrient concentrations (Table 1). Fertilizer treatments were hand applied on 2-Jun in both trials. At the time fertilizer was applied, all milkweed plants were in vegetative stages ranging from one to four pairs of leaves. Plots were also assessed for milkweed populations and height at the time the fertilizer treatments were implemented and again at harvest. Table 2 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 muriate of potash (0-0-60).

Table 1. Soil nutrient analysis, fall 2019*.

Soil chemical parameter	Value	Interpretation**
pH	6.2	N/A
Organic matter (%)	4.1	N/A
Phosphorous	4.6	Optimal
Potassium	64.7	Medium
Magnesium	82.5	Optimal
Iron	4.2	N/A
Manganese	12.2	N/A
Zinc	1.0	N/A

*Soil test extractant was Modified Morgan.
**Nutrient Recommendations for Field Crops in Vermont.

Table 2. Nitrogen and potassium treatments, 2020.

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

Image 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 (Image 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. 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 10-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 to 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 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 12-May, a treatment of Roundup® was applied to treatment plots. Plots were 20' x 20' in area. No additional management practices were imposed on the trial through the season. The trial was harvested on 10-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. After harvest, ground cover was again assessed using the same methods that were employed at the beginning of the season.

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 was recorded with a Davis Instrument Vantage Pro2 weather station, equipped with a WeatherLink data logger at Borderview Research Farm in Alburgh, VT (Table 3). The region experienced drought conditions for much of the season with little rainfall and warmer than average temperatures. While May was cooler than average, from June to August temperatures were higher than normal. In July, the average temperature in Alburgh, VT was 4.17° F higher than normal. Above average temperatures coincided with little rainfall from May to July. In both May and June, there were periods without rain that lasted nearly two weeks. These conditions occurred while the milkweed was beginning blooming as full bloom was observed by early July. July was also particularly hot and dry. By August a few large rain events were observed, which contributed to average monthly precipitation being 2.86 in. above normal. However, this season's warm conditions did provide optimal Growing Degree Days (GDDs) through the season with a total of 2484 GDDs accumulated May-Sep, 139 above normal.

Table 3. 2020 weather data for Alburgh, VT.

Alburgh, VT	May	June	July	August	September
Average temperature (°F)	56.1	66.9	74.8	68.8	59.2
Departure from normal	-0.44	1.08	4.17	0.01	-1.33
Precipitation (inches)	2.35	1.86	3.94	6.77	2.75
Departure from normal	-1.04	-1.77	-0.28	2.86	-0.91
Growing Degree Days (50-86°F)	298	516	751	584	336
Departure from normal	6	35	121	2	-24

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 affect yield or many of the other harvest characteristics in either trial (Tables 4 and 5). The number of pods per plant averaged 2.67 and 3.13 with 83.1% and 78.2% of plants having formed pods in the nitrogen and potassium trials respectively. Pods averaged 9.55 and 10.0 cm in length and varied significantly by nitrogen rate with longer pods being produced in plots receiving 50 and 100 lbs of nitrogen per acre. Pods averaged 59.2% and 57.0% 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 0.931 and 0.904 tons ac^{-1} for the nitrogen and potassium trials respectively. Plant height also did not vary statistically in either trial averaging 90.4 cm and 80.4 cm in the nitrogen and potassium trials respectively. This result was surprising as we would assume that additional nitrogen would be utilized by the plant in its biomass. However, the dry conditions throughout much of the season likely influenced the availability of nitrogen to the plants. Applying split applications of nitrogen may prove to be more beneficial both for enhanced nitrogen availability throughout the season and since it would likely reduce the risk of loss to the environment. The medium level of potassium available in the soil prior to the implementation of this trial suggests a moderate probability of a crop response given supplementation. Therefore, we'd expect to see some yield response especially at higher levels of fertilization. The fact that no increase was observed for any of the potassium treatments suggests that additional potassium supplementation is not economically viable for milkweed production.

Table 4. Milkweed harvest characteristics, nitrogen trial, 2020.

Nitrogen rate	Pod production		Pod length	Plant height	Pod moisture	Pod yield
lbs N ac^{-1}	pods plant^{-1}	% of plants	cm	cm	%	DM tons ac^{-1}
0	2.47	**93.7**	9.17b†	88.0	64.4	0.692
25	2.12	88.7	9.43b	87.1	**43.5**	0.914
50	2.81	70.6	**10.4a**	88.6	64.4	0.959
75	**3.12**	71.5	9.12b	92.9	58.2	0.928
100	2.83	91.1	9.69ab	**95.4**	65.4	**1.16**
LSD (p = 0.10)‡	NS§	NS	0.731	NS	NS	NS
Trial mean	2.67	83.1	9.55	90.4	59.2	0.931

†Within a column, treatments with the same letter are statistically similar at the p=0.10 level.
‡LSD: least significant difference at p=0.10 level.
§NS: No significant difference among treatments at the p=0.10 level.

Table 5. Milkweed harvest characteristics, potassium trial, 2020.

Potassium rate	Pod production		Pod length	Plant height	Pod moisture	Pod yield
lbs K ac^{-1}	pods plant^{-1}	% of plants	cm	cm	%	DM tons ac^{-1}
0	3.58	77.4	10.1	76.1	54.3	**1.06**
50	3.23	78.3	**10.6**	**86.7**	57.4	1.02
75	**3.61**	85.8	10.1	82.1	57.8	0.842
125	2.55	61.4	8.85	74.4	55.1	0.717
150	2.66	**88.1**	10.3	82.9	**60.5**	0.877
LSD (p = 0.10)†	NS‡	NS	NS	NS	NS	NS
Trial mean	3.13	78.2	10.0	80.4	57.0	0.904

‡LSD: least significant difference at p=0.10 level.
‡NS: No significant difference among treatments at the p=0.10 level.

Treatments also did not differ significantly in terms of pod composition across either trial (Tables 6 and 7). The majority of the total pod weight is composed of external pod cover as this was found to be 61.0% and 58.8% for the nitrogen and potassium trials, respectively. The floss, as to be expected, accounted for the smallest fraction at only 14.6% and 16.3% of the total pod weight for the nitrogen and potassium trials, respectively. Based on the pod yields observed in the trials, and the current value estimate for pods at 30% moisture being $0.40 per pound, the value of the crop would be between $790 and $1300 per acre. However, the actual value that can be realized may be lower as these estimates assume that all pods can be harvested from the field and handled prior to sale without loss.

Table 6. Milkweed pod composition and component yield, nitrogen trial, 2020.

Nitrogen rate	Floss	Pod	Seed	Floss	Pod	Seed
lbs N ac^{-1}	% by fresh weight			lbs ac^{-1} as harvested		
0	14.3	62.5	23.2	555	2783	903
25	15.1	60.5	24.4	489	2432	**789**
50	13.8	63.0	23.2	745	**1955**	1250
75	14.6	**56.4**	**28.9**	650	3399	1285
100	**15.3**	62.6	22.1	**1027**	4205	1487
LSD (p = 0.10) †	NS‡	NS	NS	NS	NS	NS
Trial mean	14.6	61.0	24.4	667	3070	1112

‡LSD: least significant difference at p=0.10 level.
‡NS: No significant difference among treatments at the p=0.10 level.

As with any crops, some level of loss at harvest is to be expected, however, it is exceptionally high 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.

Table 7. Milkweed pod composition and component yield, potassium trial, 2020.

Potassium rate	Floss	Pod	Seed	Floss	Pod	Seed
lbs K ac^{-1}	% by fresh weight			lbs ac^{-1} as harvested		
0	17.0	58.3	24.7	**792**	2712	1148
25	14.4	58.1	27.5	693	2791	1323
50	16.5	59.2	24.4	657	2362	972
75	**17.9**	**57.5**	**24.7**	571	**1836**	**788**
100	15.7	60.8	23.5	699	2700	1043
LSD (p = 0.10) †	NS‡	NS	NS	NS	NS	NS
Trial mean	16.3	58.8	24.9	686	2473	1050

‡LSD: least significant difference at p=0.10 level.
‡NS: No significant difference among treatments at the p=0.10 level.

Impact of herbicide use on milkweed stand productivity

Weed control treatments did not significantly affect yield and most harvest characteristics (Table 8). The number of pods per plant averaged 4.10 with 83.5% of plants having pods. Pods averaged 10.0 cm in length and plants averaged 76.3 cm in height at the time of harvest. The total pod yield, expressed on a dry matter basis, was 0.948 tons ac^{-1}. While none of these characteristics varied statistically across weed control methods, ground cover from weeds, an estimate of weed pressure, was significantly higher in the herbicide plots prior to the treatments being implemented, and did not differ statistically post-harvest (Table 9). Interestingly, if you compare spring and post-harvest measures within a treatment, the herbicide treatment experienced a reduction of approximately 12.0% while the control treatment experienced an increase of approximately 45%. However, differences in weed pressure did not ultimately impact milkweed populations or productivity.

Table 8. Milkweed harvest characteristics, weed control trial, 2020.

Weed control	Ground cover		Pod production		Pod length	Plant height	Pod moisture	Pod yield
	Spring	Post-harvest						
	%		pods plant^{-1}	% of plants	cm	cm	%	DM tons ac^{-1}
Herbicide	83.1	71.0	2.74	82.3	10.1	75.2	71.7	0.909
Control	37.5	82.0	5.46	84.7	10.0	77.4	70.4	0.986
LSD (*p* = 0.10)†	22.5	NS‡	NS	NS	NS	NS	NS	NS
Trial mean	60.3	76.5	4.10	83.5	10.0	76.3	71.1	0.948

‡LSD: least significant difference at p=0.10 level.

‡NS: No significant difference among treatments at the p=0.10 level.

Table 9. Milkweed pod composition by weight, weed control trial, 2020.

Weed control	Floss	Pod	Seed
	% by weight		
Herbicide	15.2	61.6	23.2
Control	15.1	60.9	24.0
LSD (*p* = 0.10)†	NS‡	NS	NS
Trial mean	15.2	61.2	23.6

‡LSD: least significant difference at p=0.10 level.

‡NS: No significant difference among treatments at the p=0.10 level.

This suggests that herbicide application is likely not cost effective in established milkweed stands. However, although the weed pressure as we've quantified it does not appear cost effective, the treatments may be changing the composition of weed types present in the field. Each time ground cover was assessed, dominant weed species were identified. These weeds can be generally categorized as perennials or annuals. Table 10 shows the percent of species that were identified in the plots as characterized by their perennial or annual life cycle. Before the trial was implemented the plots that were to be treated with herbicide hosted approximately 83.3% perennial and 16.7% annual weed species. Post-harvest, after the herbicide treatment was implemented, this inverted to 16.7% perennial and 83.3% annual species. However, this trend did not hold in the control plots. In control plots, prior to trial implementation plots were composed of 79.2% perennial and 20.8% annual weed species. Post-harvest, annual weed species increased, but to a much lower degree than was observed in the herbicide plots as 54.2% perennial species and 45.8% annual species were identified. These data could suggest that the weed populations are differing in composition between weed control treatments and over time, impacts may be seen as a higher proportion of persistent perennial weeds establish in the control plots. Overall, weed pressure at the research site has remained relatively low over the stand's lifespan and therefore, if higher weed pressure is present in a field, a milkweed growth or yield benefit may be seen, impacting the economics of this practice.

Table 10. Weed type prevalence, weed control trial, 2020.

Weed control	Pre-treatment		Post-harvest	
	Perennial	Annual	Perennial	Annual
	% of species identified			
Herbicide	83.3	16.7	16.7	83.3
Control	79.2	20.8	54.2	45.8
Trial mean	81.3	18.8	35.4	64.6

DISCUSSION

These preliminary data suggest that additional nitrogen or potassium fertilizer at rates between 0-100 and 0-150 lbs ac^{-1} respectively do not increase milkweed floss yield. The most recent soil test results from the test field indicated levels of soil K considered moderate (65ppm) for most field crops and therefore, fields with low soil test levels of K may experience a greater yield response to additional fertility applications. In terms of nitrogen, lack of moisture throughout the season likely contributed to lower nitrogen availability in the soil. 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 despite lowering weed pressure. 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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