2023 Organic Forage Fertility Management Trials

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Managing fertility in perennial forages organically is challenging as many allowable sources outside of a dairy farm's own manure are expensive and require mineralization by microorganisms, which can vary widely with conditions. To better understand the yield, quality, and economic impacts of different fertility management strategies, the University of Vermont Extension Northwest Crops and Soils Program initiated a trial in 2023. The trial evaluated the impact of organic fertility management strategies on forage yield and quality of cool season perennial grasses. The grass species selected were orchardgrass and tall fescue. The 2023 growing season was the first full season after establishment, and the first year of the fertility strategies being implemented. In addition, one on-farm site was included to investigate the impact of a fertilizer blend on pasture yield and quality as well as soil health and economic return. This report will summarize the results from this one season, however, understanding the impacts of these strategies on the forage and soil as well as the economics will require evaluation over multiple seasons.

MATERIALS AND METHODS

Trial treatment and management information for the replicated trial are summarized in Table 1. The trial included two grass species and three fertility strategies each replicated six times. Due to poor establishment, only the tall fescue was evaluated in 2023 as the orchardgrass was being re-established. Prior to applying treatments, soils in the trial area were sampled and analyzed for nutrient content. Fertility amendments were based on the soil test recommendation, the crop being grown, and the desired yields. Fertility treatments were initiated in June 2023 following the first hay harvest. Dairy manure and lime were used due to their availability and use within the organic community. Wood ash is also commonly used, but was unavailable at the time this trial was implemented. We hope to include wood ash in future trials. Liquid dairy manure was applied at approximately 3100 gal ac^{-1} and lime was applied at 2000 lbs ac^{-1} after the first harvest to meet the recommendations of the soil test. Plots were then harvested twice following treatment application and evaluated for forage yield and quality. Only manure was applied after the 2nd harvest. Plots were harvested with a Carter flail forage harvester in a 3' x 20' area on 12-Jul and 9-Aug.

Table 1. Perennial forage trial management, Alburgh, VT.

Location	Borderview Research Farm – Alburgh, VT
Species treatments	Tall fescue Orchardgrass
Fertility treatments	Control (no fertility added) Manure only Manure + Lime
Replications	6
Plot size (ft.)	10' x 35'
Manure application	31-May, 3100 gal ac^{-1}
Lime application	9-Jun, 2000 lbs ac^{-1}
Harvest dates	12-Jul and 9-Aug

An approximate 1 lb subsample of the harvested material was collected and dried to calculate dry matter yield and forage quality. Mixtures of true proteins, composed of amino acids, and non-protein nitrogen make up the crude protein (CP) content of forages. Although forage quality encompasses much more than simply protein content, this was a key metric to investigate since the addition of nitrogen can influence yield but also protein content in forages.

In addition to this replicated field trial, a site was established on a partnering farm in northern NY. At this site, two treatments (typical manure application, manure plus custom fertilizer blend) we compared on a diverse grass-legume hay field that is also grazed some through the season. The field, approximately 10 acres in size, was split with one side receiving the typical rate of manure only and the other side receiving the manure plus a custom fertilizer blend (Table 2). The composition of the blend was informed by soil test results from the site.

Table 2. Fertilizer blend composition, 2023.

Product	Total	N	P	K	S	B	Mn	Zn	Cu
					Lbs				
Bonemeal 2-26-0	602	12	157	0	0	0	0	0	0
Rock phosphate 0-14-0	1200	0	168	0	0	0	0	0	0
SOP 0-0-50	900	0	0	450	0	0	0	0	0
90% sulfur	601	0	0	0	541	0	0	0	0
15% Boron	150	0	0	0	0	23	0	0	0
32% Manganese	300	0	0	0	0	0	96	0	0
35.5% Zinc	121	0	0	0	0	0	0	43	0
25% Copper	90	0	0	0	0	0	0	0	23
Soy oil (dust control)	120	0	0	0	0	0	0	0	0
Total	4084	12.0	325	450	541	22.5	96.0	43.0	22.5
Per acre	817	2.41	64.9	90.0	108	4.50	19.2	8.59	4.50

Manure was applied to the entire field (both treatments) in April at a rate of approximately 16 tons ac^{-1}. Following the first harvest, the fertilizer was applied at approximately 817 lbs ac^{-1} to the treatment side of the field. For the remainder of the season, both sides of the field were grazed. Prior to grazing, samples were collected from each side of the field by cutting the material within a 1.125 ft^2 quadrat to the ground. At least four replicate samples were collected within each treatment for each harvest. Samples were weighed and dried to determine yield and dry matter content. Samples were also submitted to DairyOne Forage Testing Laboratory (Ithaca, NY) for forage quality analysis via NIR procedures and mineral content via wet chemistry procedures.

Yield data and stand characteristics were analyzed using mixed model analysis using the mixed procedure of SAS (SAS Institute, 1999). Replications within trials were treated as random effects, and mixtures were treated as fixed. Treatment mean comparisons were made using the Tukey-Kramer HSD procedure when the F-test was considered significant ($p<0.10$). 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 varieties is real or whether it might have occurred due to other variations in the field. At the bottom of each table a p-value is presented for each variable (i.e., yield). P-values that are equal to or less than 0.10 are considered significant with smaller numbers being more significant. Treatments that have a p-value greater than 0.10 are not different from one another, instead any numerical difference seen is due to random chance, not the treatment.

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). Despite a warm dry spring, conditions turned in June bringing cooler and wetter than normal weather. During July in particular, excessive rainfall was experienced over much of the region, accumulating over 6 inches above the normal rainfall for that month. Rainy conditions continued into August coupled with unseasonably cool temperatures averaging almost 4 degrees below normal. This led to approximately 84 fewer Growing Degree Days (GDDs) being accumulated during this trial period. Similar conditions were observed at the Constable, NY site (Table 4). More rainfall was experienced at this site during June while less rainfall was experienced during July. However, rainfall in all months, with the exception of September, exceeded normal precipitation accumulation by more than 1.5 inches. Growing degree day accumulation at this site was 114 fewer than the 30-year normal. While cool season perennial forage grasses thrive under cool moist conditions, this excessive rainfall throughout the season negatively impacted performance with little sunlight for photosynthesis and saturated soils impacting nutrient losses and soil oxygenation.

Table 3. 2023 weather data for Alburgh, VT.

	Jun	Jul	Aug
Average temperature (°F)	65.7	72.2	67.0
Departure from normal	-1.76	-0.24	-3.73
Precipitation (inches)	4.40	10.8	6.27
Departure from normal	0.14	6.69	2.73
Growing Degree Days (base 41°F)	749	991	819
Departure from normal	-44	17	-101

Based on weather data from a Davis Instruments Vantage Pro2 with WeatherLink data logger.
Historical averages are for 30 years of NOAA data (1990-2021) from Burlington, VT.

Table 4. 2023 weather data for Constable, NY.

	Jun	Jul	Aug	Sep
Average temperature (°F)	66.2	72.9	67.7	62.9
Departure from normal	-1.34	0.49	-3.04	0.17
Precipitation (inches)	5.86	8.38	5.98	2.62
Departure from normal	1.60	4.32	2.44	-1.05
Growing Degree Days (base 41°F)	755	988	826	656
Departure from normal	-39	15	-94	4

Based on weather data collected from station KNYMALON26, wunderground.com.
Historical averages are for 30 years of NOAA data (1990-2021) from Burlington, VT.

Impact of Fertility Strategy

Yield and protein content were significantly impacted by fertility strategy (Table 5). Dry matter yield increased by 0.66 tons ac^{-1} (36% increase) when manure alone was added. An additional 0.20 tons ac^{-1} was achieved when lime was added in addition, however this difference was not statistically significant. Similarly, protein levels were approximately 2% higher in plots receiving manure or manure + lime compared to the control, but were similar to one another. When dry matter yield and protein content are considered, the overall protein yield was approximately 69 and 81 lbs ac^{-1} greater when manure + lime and manure only were used respectively.

Table 5. Yield and quality of tall fescue managed under three fertility strategies, 2023.

Fertility treatment	2nd cut	3rd cut	Season yield	CP	Season CP yield
	Dry matter tons ac^{-1}			% of DM	lbs ac^{-1}
Control	0.936	0.570	1.51b†	14.6b	98.3b
Manure only	**1.25**	**1.12**	**2.36a**	16.7a	**179a**
Manure + lime	1.22	0.944	2.17a	**16.9a**	167a
LSD (*p*=0.10) ‡	N/A¥	N/A	0.502	0.849	39.1
Trial mean	1.14	0.877	2.01	16.1	148

†Within a column, treatments followed by the same letter are not significantly different.
‡LSD; least significant difference at the p=0.10 level. The top performing treatment is indicated in **bold.**
¥N/A; statistical analysis was not conducted for each harvest.

Although these data suggest that no additional yield or quality benefit resulted from adding lime with the manure, soil pH changes from lime additions to the soil surface can take six months to a year to manifest as the material must slowly be worked into the soil and broken down by rainfall and microbial activity. Therefore, impacts on forage yield and quality may not be seen until subsequent years.

On-farm Trial Results

At each harvest/grazing, the total available forage was higher in the part of the field that received fertilizer in addition to manure (Table 6). On average, the fertilizer treatment added almost 0.5 tons ac^{-1} additional forage per harvest. Across the 5-acre field and three harvests this equates to 7.5 tons of dry matter.

Table 6. Yield and protein content of pasture managed under two fertility strategies, 2023.

Fertility treatment	2nd harvest	3rd harvest	4th harvest	Average yield per harvest	CP	CP
	Dry matter tons ac^{-1}				% of DM	lbs ac^{-1}
Manure only	1.79	2.00	1.68	1.80	**15.6**	125
Manure + fertilizer	**1.88**	**2.80**	**2.14**	**2.27**	14.4	**150**
p-value†	N/A‡	N/A	N/A	0.032	NS	NS
Trial mean	1.84	2.40	2.00	2.03	15.0	138

†Treatments are considered significantly different when *p* = 0.10 or less.
‡N/A – statistical analysis not performed for this measure.
NS – no significant difference. The top performing treatment is indicated in **bold.**

Protein content was highly variable across the trial and therefore, the treatments were not statistically different from one another. The fertilizer contributed very little additional nitrogen, so the total nitrogen available between the two treatments was similar and therefore, not expected to greatly impact protein content.

Table 7. Micronutrient content of pasture managed under two fertility strategies, 2023.

Fertility treatment	Phosphorus	Potassium	Sulfur	Zinc	Manganese	Copper
	% of DM			ppm		
Manure only	0.374	2.40	0.232	22.9	51.8	6.81
Manure + fertilizer	**0.409**	**2.92**	**0.235**	**41.4**	**122**	**8.19**
p-value†	0.049	0.0003	NS‡	<0.0001	<0.0001	0.020
Trial mean	0.391	2.66	0.233	32.2	87.0	7.50

†Treatments are considered significantly different when $p = 0.10$ or less.
‡NS – statistical analysis not performed for this measure.
The top performing treatment is indicated in **bold.**

The main contribution from the fertilizer was additional macro- and micronutrients (Table 2). For all nutrients added through the fertilizer except for sulfur, the resulting forage contained significantly higher concentrations of these nutrients (Table 7). Phosphorus and potassium concentrations increased by approximately 9 and 22% respectively. Although the sulfur concentration in the plant remained similar between the two treatments, sulfur is a critical nutrient for plants to metabolize nitrogen, create protein, and for nitrogen fixation in legumes. While the additional sulfur may not have been captured in higher concentrations in the plant, its addition may have supported better plant function leading to the increased yields observed. The greatest increase was seen with manganese, which more than doubled in concentration in the fertilized plots. Zinc also increased substantially, increasing by approximately 81%. Copper increased by approximately 20%. All these minerals are critical to supporting animal health. Being a grass-fed dairy farm that must rely on only forges and minerals to supply nutrition to the cows, increasing the mineral concentration of the pasture can help reduce mineral supplementation during the grazing season while supporting health and productive animals. In general, phosphorus, copper, and zinc are several minerals that are likely to be deficient in most forages. Dairy cows require 0.40 % of dry matter to be phosphorus, 30 parts per million (ppm) of zinc and 10 ppm. The addition of fertilizer produced a forage that had nutrient levels that met the NRC recommendations for dairy cattle. Interestingly, the manganese concentrations were nearly 2.4 times the NRC requirement of 50 ppm. In this case, manure was able to supply a sufficient amount of manganese and no further fertilizer should be added.

DISCUSSION

Supporting the nutrient demands, especially nitrogen, of grasses can be exceptionally difficult and expensive to do organically. Recycling nutrients on the farm through manure application can help reduce the need for these costly inputs. However, when manure resources are limited, additional fertility can help support production of high yielding, high quality forages and avoid severely depleting soil nutrient reserves. The addition of fertilizer containing a wide range of macro- and micronutrients to pasture in this study led to an increase of 0.5 tons ac^{-1} of available forage per harvest. In addition, this forage contained significantly higher concentrations of vital minerals including phosphorus, potassium, copper, manganese, and zinc. The addition of lime to liquid manure did not increase yields compared to using liquid manure alone. However, these data only represent one year, and it is known that lime can take several months to a year to affect soil pH and subsequently crop performance. In addition, the extremely challenging weather with excessive rainfall likely led to nutrient losses through leaching and nitrification. The dynamic nature of these nutrients, especially nitrogen, under these conditions likely contributed to the high variation seen across the trials. The replicated field trial will be repeated and expanded to include additional nutrient sources suitable for organic production to more fully understand economical organic forage fertility management options that support high yield and quality.

ACKNOWLEDGEMENTS

Funding for this project was through the Organic Valley Farmers Advocating for Organics (FAFO) grant program. UVM Extension would like to thank Roger Rainville and his staff at Borderview Research Farm in Alburgh for their generous help with the trials. We would like to acknowledge Anna Brown, John Bruce, Kellie Damann, Hillary Emick, Ivy Krezinski, Lindsey Ruhl, Laura Sullivan, and Sophia Wilcox Warren for their assistance with data collection and entry. The information is presented with the understanding that no product discrimination is intended, and no endorsement of any product mentioned, or criticism of unnamed products is implied.

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