NORTHWEST CROPS & SOILS PROGRAM

2023 Legume Variety Trial

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2023 LEGUME VARIETY TRIAL

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In 2021, the University of Vermont Extension Northwest Crops and Soils Team initiated a trial investigating forage yield and quality of varieties of different legume species seeded in monocultures. The species selected were alfalfa, birdsfoot trefoil, red clover, and white clover. These legumes were chosen as they have been shown in previous research to have adequate survivability and forage production in this region. Organic and grass-based dairy systems rely on legumes to help provide balanced nutrition to their animals while also reducing the crop's need for additional nitrogen compared to a pure grass stand. This information therefore may help enhance forage production and quality thereby reducing producers' forage and supplemental feed costs. These varieties were selected and seeded in the spring of 2021 and were ready for harvest in the 2022 growing season. This report reflects data collected in the 2023 growing season and excludes birdsfoot trefoil as those plots were used for another study.

MATERIALS AND METHODS

Forage species and variety information for the trial initiated in 2021 is summarized in Table 1. Varieties of four legume species were planted in monoculture at Borderview Research Farm in Alburgh, VT at 25 lbs ac^{-1}. The plot design was a randomized complete block with five replications. Treatments were legume varieties which were evaluated for forage yield, and quality.

Table 1. Legume species and variety information.

Species	Variety
Alfalfa	Stronghold
	KF Secure BR
	Viking 3200
	4A420P
	KF Enhancer II
Red Clover	Gallant
	Harmonie
	Freedom
	Starfire II
	Red Wing
White Clover	Domino
	Huia
	Legacy
	Kakariki
	Klondike

The soil type at the Alburgh location was a Benson rocky silt loam (Table 2). The previous crop was hemp. The seedbed was moldboard plowed, disked, and finished with a spike tooth harrow. Treatments were seeded on 3-May 2021. Plots were 5' x 20' and replicated 5 times. During the 2021 season, the plots were

mowed occasionally but no data were collected. The 2022 growing season was the first full harvest season. In 2023, plots were harvested with a Carter forage harvester in 3' x 20' area on 31-May, 7-Jul, and 19-Aug.

Table 2. Perennial legume trial management, Alburgh, VT, 2021-2023.

Location	Borderview Research Farm – Alburgh, VT
Soil type	Benson rocky silt loam
Previous crop	hemp
Tillage operations	Moldboard plow, disk and spike tooth harrow
Planting equipment	Great Plains small plot drill
Treatments	20
Replications	5
Plot size (ft.)	5 x 20
Planting date	3-May 2021
Harvest dates (2022)	31-May, 7-Jul, and 19-Aug

An approximate 1 lb subsample of the harvested material was collected and dried to calculate dry matter yield. The subsamples were ground using a Wiley and cyclone mill (UDY Corporation) to attain a 1-mm particle size. These samples were then analyzed using NIR (near infrared reflectance spectroscopy) methods at the E. E. Cummings Crop Testing Laboratory at the University of Vermont (Burlington, VT) on a FOSS DS2500 Forage and Feed Analyzer.

Mixtures of true proteins, composed of amino acids, and non-protein nitrogen make up the crude protein (CP) content of forages. The bulky characteristics of forage come from fiber. Forage feeding values are negatively associated with fiber since the less digestible portions of the plant are contained in the fiber fraction. The detergent fiber analysis system separates forages into two parts: cell contents, which include sugars, starches, proteins, non-protein nitrogen, fats and other highly digestible compounds; and the less digestible components found in the fiber fraction. The total fiber content of forage is contained in the neutral detergent fiber (NDF) which includes cellulose, hemicellulose, and lignin. This measure indicates the bulky characteristic of the forage and therefore is negatively correlated with animal dry matter intake. The portion of the NDF fraction that is estimated to be digestible after 30 hours of fermentation in rumen fluid is represented by the 30- hour NDF digestibility (NDFD). Ethanol soluble carbohydrates (ESC) are simple sugars found in grasses. Water soluble carbohydrates (WSC) include simple sugars as well as fructose polymers called fructans. Several quality metrics are combined to predict net energy needed for lactation (NEL), milk yield per ton of forage, and relative forage quality (RFQ).

Results were analyzed using a general linear model procedure of SAS (SAS Institute, 2008). Replications were treated as random effects, and treatments were treated as fixed. Mean comparisons were made using the Least Significant Difference (LSD) procedure where the F-test was considered significant, at $p<0.10$. 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 between varieties is likely attributable to the treatment or random variation. At the bottom of each table, an LSD value may be presented. 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 treatments. Treatments that were not significantly lower in performance than the highest

value in a particular column are indicated with an asterisk. In this example, A is significantly different from C but not from B. The difference between A and B is equal to 1.5, which is less than the LSD value of 2.0. This means that these varieties did not differ in yield. The difference between A and C is equal to 3.0, which is greater than the LSD value of 2.0. This means that the yields of these varieties were significantly different from one another. The asterisk indicates that B was not significantly lower than the top yielding variety.

Variety	Yield
A	6.0
B	7.5*
C	**9.0***
LSD	2.0

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). In general, the fall of 2022 was warmer and drier than normal. Extended warm weather in the fall allowed stands to continue growth later into the fall and replenish energy reserves prior to freezing conditions. Fall and winter temperatures were above normal, especially in January, which averaged six degrees above the 30-year normal. In 2023, conditions in May and June became cooler and drier with many parts of the region experiencing early season mild drought conditions. However, significant precipitation fell in July and August with 17 inches accumulating during those months. Conditions finally improved in September with warmer temperatures and little rainfall allowing for harvests and other field operations later into the fall. Overall, the trial accumulated 4105 Growing Degree Days (GDDs) in 2023, 10 fewer than the 30-year normal.

Table 3. 2022-2023 weather data for Alburgh, VT.

	2022			2023								
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Average temperature (°F)	51.3	41.5	30.7	26.9	23.6	32.2	48.3	57.1	65.7	72.2	67.0	63.7
Departure from normal	0.96	2.24	2.50	6.01	0.65	-0.07	2.70	-1.28	-1.76	-0.24	-3.73	1.03
Precipitation (inches)	2.56	3.01	2.43	2.04	1.36	2.00	4.94	1.98	4.40	10.75	6.27	2.40
Departure from normal	-1.27	0.31	-0.07	-0.09	-0.41	-0.24	1.87	-1.78	0.14	6.69	2.73	-1.27
Growing Degree Days (base 41°F)	366	188	30	3	19	13	306	499	749	991	819	706
Departure from normal	63	106	30	3	19	-9	91	-40	-44	17	-101	54

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.

Impact of Legume Species

Species differed in dry matter yield across the season (Table 4). Red clover produced the overall highest biomass of 4.30 tons ac^{-1}, which was statistically similar to alfalfa with 4.07 tons ac^{-1}, and white clover produced the lowest biomass at 1.98 tons ac^{-1}. White clover, being shallow rooted and lower growing is expected to produce less biomass than tap rooted, upright growing forages like red clover or alfalfa that can better withstand drought conditions and are more suitable to mechanical harvest.

Table 4. Dry matter yields by legume species, 2023.

Species	1st cut	2nd cut	3rd cut	Season yield
	Dry matter tons ac^{-1}			
Alfalfa	2.00b†	**1.26a**	**0.817a**	4.07a
Red Clover	**2.64a**	1.01b	0.646b	**4.30a**
White Clover	1.26c	0.429c	0.287c	1.98b
LSD (p = 0.10) ‡	0.183	0.093	0.102	0.251
Trial mean	1.97	0.900	0.583	3.45

†Within a column, species with the same letter performed statistically similar to one another.
Top performing treatments are indicated in **bold.**
‡LSD; least significant difference at the p= 0.10 level.

Legume species also differed in forage quality parameters (Table 5). White clover was the top performing species in every quality parameter and was statistically higher than all other species trialed. Protein content was almost 5% higher for white clover than red clover and alfalfa. Interestingly, ESC content was highest for white clover and was more than 2.5% higher than alfalfa but it was only approximately 0.5% higher than the red clover. Fiber digestibility was more than 20% higher for the white clover, which was to be expected as white clover grows less upright and is therefore composed of less stem material that contains a higher proportion of indigestible fiber. These quality differences coalesce into the net energy of lactation and predicted milk yield per ton of forage, which were both highest for white clover at 0.758 Mcal lb^{-1} and 4394 lbs ton^{-1}. These were 0.079 Mcal lb^{-1} and 544 lbs ton^{-1} higher for white clover than the next highest treatment, red clover.

Table 5. Forage quality characteristics by legume species, 2023.

Species	CP	ESC	30-hr NDFD	NEL	Milk yield
	% DM		% NDF	Mcal lb^{-1}	lbs ton^{-1}
Alfalfa	20.1b†	5.11c	51.9c	0.625c	3572c
Red Clover	20.0b	7.29b	54.2b	0.679b	3850b
White Clover	**25.4a**	**7.84a**	**78.5a**	**0.758a**	**4394a**
LSD (p = 0.10) ‡	0.583	0.264	1.71	0.011	65.2
Trial mean	21.8	6.75	61.5	0.687	3938

†Within a column, species with the same letter performed statistically similar to one another.
Top performing treatments are indicated in **bold.**
‡LSD; least significant difference at the p= 0.10 level.

However, while on a dry matter basis the white clover may appear to produce the highest quality forage, it yields significantly less dry matter than the other species. Therefore, if we consider the yield of these quality components and the resulting milk, the performance looks a bit different (Table 6). Due to the low dry matter yields of white clover, it produces the least protein, digestible fiber, and ethanol-soluble sugars (ESC) per acre compared to the other legume species. This ultimately results in a substantially lower predicted milk yield per acre as well. While alfalfa produced the highest digestible NDF yield, the overall higher yield of the red clover ultimately produced more protein, ESC, and milk per acre. These results were similar to those observed in 2021.

Table 6. Forage quality component yields by legume species, 2023.

Species	CP	ESC	30-hr NDFD	Milk yield
	lbs ac^{-1}		tons ac^{-1}	cwt ac^{-1}
Alfalfa	1630a†	414b	**0.841a**	145b
Red Clover	**1640a**	**654a**	0.680b	**160a**
White Clover	1006b	322c	0.483c	88.4c
LSD (p = 0.10) ‡	117	38.5	0.076	9.53
Trial mean	1425	464	0.668	131

†Within a column, species with the same letter performed statistically similar to one another.
Top performing treatments are indicated in **bold.**
‡LSD; least significant difference at the p= 0.10 level.

Impact of Variety-Alfalfa

Alfalfa varieties did not differ statistically in yield at any harvest or overall, but did differ statistically in yield of some quality components on a per acre basis (Table 7). Three of the five varieties trialed produced over four tons of dry matter per acre with the other two producing over 3.5 tons. Protein content was similar for all varieties but when yield is considered, protein yield per acre ranged from 1429 to 1830 lbs ac^{-1}. While ESC content was lowest for variety Viking 3200, its higher dry matter yield contributed to no statistical difference in ESC yield on a per acre basis. Fiber digestibility averaged 51.9% and did not differ statistically between varieties, however, when combined with NDF content and yield, yields of digestible fiber per acre were higher in three varieties than the other two varieties. Combining multiple yield metrics to predict milk yield, we see the highest milk yields from Viking 3200, Stronghold, and KF Secure BR and the lowest from 4A420P.

Table 7. Total dry matter and quality component yields of alfalfa varieties, 2023.

Variety	Total DM yield	CP	ESC	30-hr NDFD	Milk yield
	tons ac^{-1}	lbs ac^{-1}		tons ac^{-1}	cwt ac^{-1}
4A420P	3.68	1429c†	372	0.765b	129c
KF Enhancer II	3.83	1525bc	**436**	0.738b	141bc
KF Secure BR	4.11	1671ab	430	0.889a	145abc
Stronghold	4.23	1695ab	422	0.906a	151ab
Viking 3200	**4.49**	**1830a**	413	**0.909a**	**160a**
LSD (p = 0.10) ‡	NS§	239	NS	0.114	18.5
Trial mean	4.07	1630	414	0.841	145

†Within a column, species with the same letter performed statistically similar to one another.
Top performing treatments are indicated in **bold.**
‡LSD; least significant difference at the p= 0.10 level.
§NS; not statistically significant.

Impact of Variety-Red clover

Red clover varieties differed statistically at the third harvest, with Harmonie providing the least regrowth at that harvest, however, overall yields did not differ statistically (Table 8). Total yields were over four tons ac^{-1} for all varieties. Some quality differences also impacted the yield of quality components on a per acre

basis. Protein yields were similar for all varieties, however, the ESC yield differed with Harmonie producing the lowest yield of 553 lbs ac^{-1} which was lower than all the other varieties which performed similarly to one another. Fiber digestibility averaged 54.2% and did not differ statistically between varieties on a percent of dry matter or per acre basis. Combining multiple yield metrics to predict milk yield, we see similar yields from all varieties averaging 160 cwt ac^{-1}.

Table 8. Total dry matter and quality component yields of red clover varieties, 2023.

Variety	Total DM yield	CP	ESC	30-hr NDFD	Milk yield
	tons ac^{-1}	lbs ac^{-1}		tons ac^{-1}	cwt ac^{-1}
Freedom	4.25	1612	672a†	0.712	159
Gallant	4.19	1661	641ab	**0.746**	161
Harmonie	4.08	1613	553b	0.671	155
Red Wing	4.60	1608	699a	0.602	163
Starfire II	**4.37**	**1704**	**707a**	0.670	**165**
LSD (p = 0.10) ‡	NS§	NS	96.5	NS	NS
Trial mean	4.30	1640	654	0.680	160

†Within a column, species with the same letter performed statistically similar to one another.
Top performing treatments are indicated in **bold.**
‡LSD; least significant difference at the p= 0.10 level.
§NS; not statistically significant.

Impact of Variety-White Clover

White clover varieties did not differ statistically in total yield or quality characteristics (Table 9). While yields at the first two harvests were similar across varieties, regrowth at the third harvest was lowest for Kakariki which averaged only 0.186 ton ac^{-1} for that harvest. Total yields over the season did not differ statistically, which may suggest differences in vigor, stature, and regrowth potential. Varieties did not differ in protein or ESC content and therefore, the yield of these components on a per acre basis did not differ statistically either. Fiber digestibility ranged from 76 to 82% but did not differ statistically. White clovers produced on average about 0.48 tons of digestible fiber per acre. With little difference in yield or quality, similar milk yields were predicted both on a per ton of forage and per acre basis.

Table 9. Forage yield and quality characteristics of white clover varieties, 2023.

Variety	Total DM yield	CP	ESC	30-hr NDFD	Milk yield
	tons ac^{-1}	lbs ac^{-1}		tons ac^{-1}	cwt ac^{-1}
Domino	1.97	1000	329	0.456	88.3
Huia	**2.13**	1013	**348**	**0.530**	**91.3**
Kakariki	1.84	969	297	0.483	83.5
Klondike	1.97	**1042**	325	0.461	89.2
Legacy	1.99	1009	312	0.487	89.4
LSD (p = 0.10) †	NS‡	NS	NS	NS	NS
Trial mean	1.98	1006	322	0.483	88.4

†LSD; least significant difference at the p= 0.10 level. Top performing treatments are indicated in **bold**.
‡NS; not statistically significant.

DISCUSSION

The last several years have presented challenging weather conditions for perennial forage species in the northeast. Prolonged periods of very cold weather and little snow cover in the winters, combined with dry conditions at various points through the 2021 and 2022 seasons followed by excessive rainfall in the 2023 season challenged legume productivity and persistence. During this first season of data collection, differences in species and varietal performance in terms of yield and quality were observed. Fewer differences were observed in the second season. While alfalfa is often thought of as the primary forage legume, red clover continues to perform very well producing similar yields with higher fiber digestibility. While the white clovers are less drought tolerant, including them in pastures and mixed grass-legume hay fields can help provide nitrogen and high-quality forage throughout the summer. As this trial matures, we will continue to evaluate these species and varieties for persistence, pest and disease resistance, yield, and forage quality in the future to better understand varietal performance and potential in this region.

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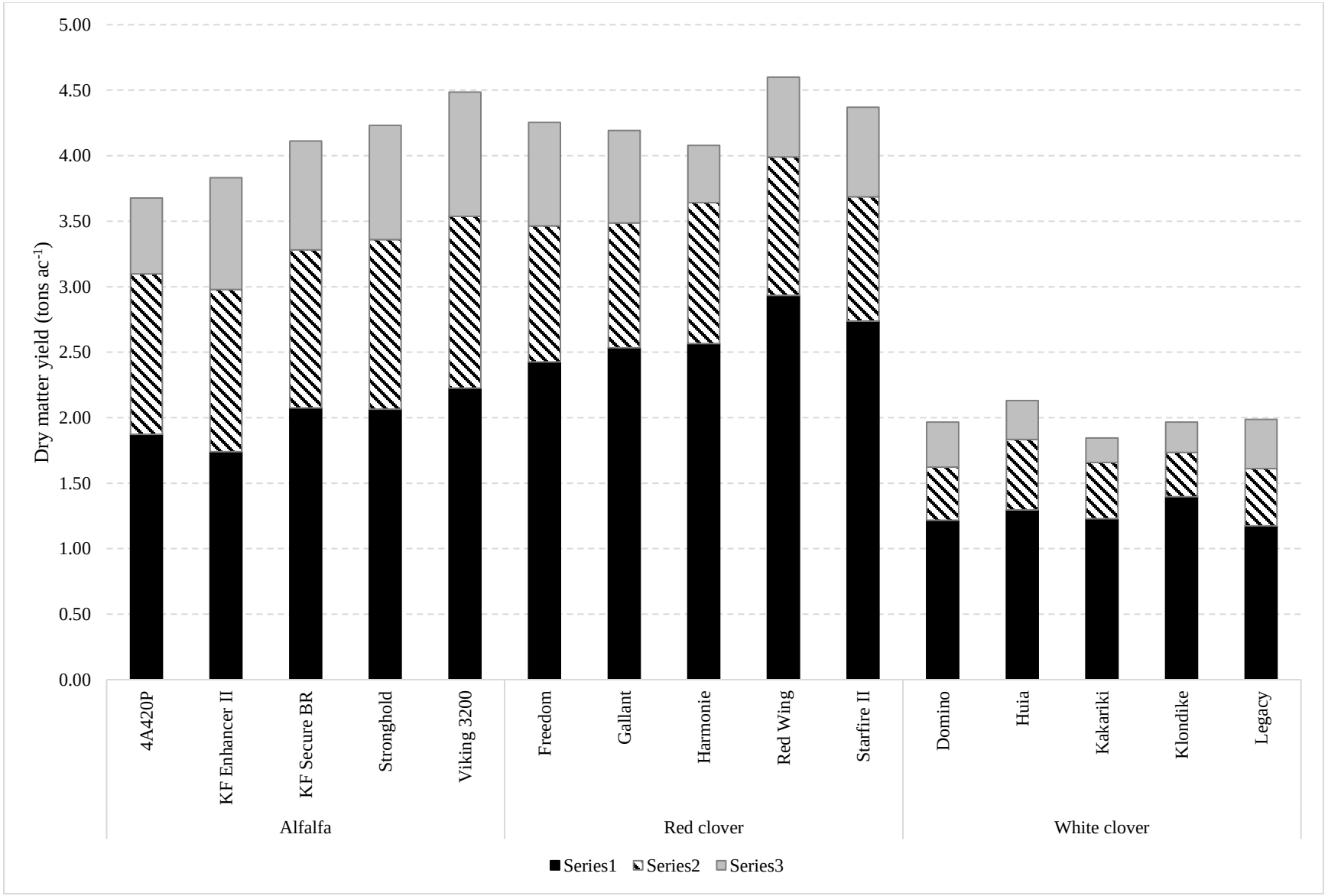

Figure 1. Dry matter yield by cutting for 15 perennial legume varieties, 2023.