2018 Forage Intercropping for Resiliency Experiment

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THE UNIVERSITY OF VERMONT EXTENSION

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Producing high quality forage crops is exceedingly challenging in Vermont as climate change progresses with more precipitation, faster rates of precipitation, and higher annual temperatures (Faulkner, 2014). Knowing which cropping systems, annual or perennial, and which forage species will grow best in this challenging environment is crucial to the success of our forage-based farm operations. Increased species and variety diversity has been shown to increase resiliency or tolerance to pests and environmental stress, however it can also make it more difficult to harvest at peak quality and yield. This project evaluates the productivity of both perennial and annual forage systems with varying levels of species complexity. The 2018 data presented in this report is from the second year of the trial.

MATERIALS AND METHODS

In 2016, a forage systems trial was initiated at Borderview Research Farm in Alburgh, VT on a Benson (loamy-skeletal, mixed, active, mesic Lithic Eutrudept) rocky silt loam, over shaly limestone, 0 to 3 percent slopes, and USDA plant hardiness zone 4b (Table 1). The experimental design was a spatially balanced, randomized complete block split-plot design where cropping systems were blocked and the diversity level of the cropping system was randomized. Plots were 20 x 35 ft and each had four replicates. Between blocks, there was 10 ft buffer around each side planted with meadow fescue. See Table 1 for a summary of agronomic and trial information.

The field was moldboard plowed to a depth of six inches on 1-Aug 2016 following the harvest of an oilseed sunflower crop. Prior to planting, 3 tons ac^{-1} of poultry manure, an amount meeting the phosphorous levels of the heaviest using crop, sorghum sudangrass, was broadcasted with a box spreader (Tebbes MS140) and then incorporated with a disc to a depth of four inches on 18-Aug 2016. The legumes were inoculated with a rhizobium mixture suitable for alfalfa and red clover prior to planting. Perennial crops were seeded to a depth of 0.25 inches on 24-Aug 2016 using a Sunflower™ 9412 grain drill with seed box attachment (Beloit, Kansas). Legumes in the perennial system were reseeded 1-Sep 2017. Annual cool season forage treatments were planted to a depth of 1.5 inches on 11-Sep 2017 using the Sunflower grain drill. Before planting the annual warm season forages, plots were fertilized and tilled twice using an Aerway™ on the most aggressive setting. Warm season annual treatments were planted on 31-May 2018 using the same methods for the annual cool season forages. Subsequent plantings of the annual systems aligned with previous treatments, i.e. warm season Very Low treatments were planted in the Very Low cool season plots.

The Very Low treatments have one species, the Low treatments have four varieties of one species, the High treatments have one variety of four species, and the Very High treatments have four varieties of four species (Table 2). The perennial system was planted initially in 2016 and replanted with legume in 2017 due to poor establishment and disease pressure which made the plants more susceptible to pest pressure. The annuals system was planted with cool season grasses in 2017 and followed by warm season in 2018 (Tables 3 and 4, respectively).

All plots were harvested with a Carter Harvester in two passes 3 x 35 feet to determine dry matter yields. See Table 1 for harvest date information. Dried vegetation was ground to 1mm using a UDY Corporation cyclone mill. Forage quality was at the University of Vermont Cereal Testing Lab (Burlington, VT) with a FOSS NIRS (near infrared reflectance spectroscopy) DS2500 Feed and Forage analyzer for crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF).

Table 1. Agronomic and trial information, 2018.

Location	Borderview Research Farm-Alburgh, VT
Soil type	Benson silt loam
Tillage operations in annuals	Aerway
Field operations after planting annuals	Cultipack
Plot size (ft.)	20 x 35
Perennial planting date	24-Aug 2016
Perennial system legumes reseeded	1-Sep 2017
Perennial harvest date (1st cut)	30-May 2018
Perennial system fertilized	6-Jun 2018 95 lb/acre K with potassium sulfate (0-0-51-18)
Perennial harvest date (2nd cut)	3-Jul 2018
Perennial system fertilized	7-Jul 2018 125 lb/acre K with potassium sulfate (0-0-51-18)
Perennial harvest date (3rd cut)	13-Aug 2018
Annual planting date, cool season	11-Sep 2017
Annual harvest date, cool season	25-May 2018
Annual system fertilized	31-May 2018 1250 lbs/acre Krehers poultry litter (8-2-2) and 75 lbs/acre K with potassium sulfate (0-0-51-18)
Annual planting date, warm season	31-May 2018
Annual harvest date, warm season (1st cut)	16-Jul 2018
Annual system fertilized	16-Jul 2018 1250 lbs/acre Krehers poultry litter (8-2-2)
Annual harvest date, warm season (2nd cut)	20-Aug 2018

Table 2. Perennial system treatments and seeding rates, 2018.

Perennial System Treatments				
Very Low **23.5 lbs ac^{-1}**	**Low** **23.5 lbs ac^{-1}**	**High** **17.4 lbs ac^{-1}**	**Very High** **17.4 lbs ac^{-1}**	
Alfalfa (100%) *Viking 370HD*	Alfalfa (25% each) *Viking 370HD* *FSG 420LH* *KF Secure BR* *Roadrunner*	Alfalfa (34%) *Viking 370HD* Orchardgrass (34%) *Extend* Timothy (25%) *Climax* White Clover (7%) *Alice*	Alfalfa (34%/each) *Viking 370HD* *FSG 420LH* *KF Secure* *Roadrunner* Orchardgrass (34%/each) *Extend* *Benchmark Plus* *Niva* *Intensiv*	Timothy (25%/each) *Climax* *Summit* *Glacier* *Promesse* White Clover (7%/each) *Alice* *Liflex* *Ladino* *KopuII*

Table 3. Annual system warm season treatments, 2018.

Annual system warm season treatments				
Very Low **52.9 lbs ac^{-1}**	**Low** **51.1 lbs ac^{-1}**	**High** **44.7 lbs ac^{-1}**	**Very High** **47.6 lbs ac^{-1}**	
Sudangrass (100%) *Hayking*	Sudangrass *Hayking* (25.9%) *Piper* (18.7%) *SSG886* (30.9%) *Promax* (24.5%)	Sudangrass (29.6%) *Hayking* Pearl millet (21.0%) *Wonderleaf* Sorghum sudangrass (32.9%) *Greengrazer* Ryegrass (16.5%) *Enhancer*	Sudangrass *Hayking* (6.9%) *Piper* (5.0%) *SSG886* (8.3%) *Promax* (6.6%) Pearl millet *Wonderleaf* (5.0%) *FSG315* (5.0%) *Exceed* (6.1%) *Trileaf* (5.2%)	Sorghum sudangrass *Greengrazer* (7.7%) *400 x 38* (9.2%) *AS6401* (9.5%) *Sweet 6* (10.2%) Ryegrass *Enhancer* (3.9%) *Tetraprime* (4.4%) *Marshall* (2.7%) *Kodiak* (4.3%)

Table 4. Annual system cool season treatments, 2018.

Annual system cool season treatments				
Very Low **211.8 lbs ac^{-1}**	**Low** **211.8 lbs ac^{-1}**	**High** **154.1 lbs ac^{-1}**	**Very High** **154.1 lbs ac^{-1}**	
Triticale (100%) *Trical 815*	Triticale (25% each) *Trical 85* *Fridge* *NE426GT* *Hy octane*	Triticale (34%) *Trical 85* Cereal rye (34%) *Wheeler* Red clover (3%) *Mammoth* Winter pea (29%) *Austrian*	Triticale (34%) *Trical 85* *Fridge* *NE426GT* *Hy octane* Cereal rye (34%) *Wheeler* *Guardian* *Aroostook* *Spooner*	Red clover (3%) *Mammoth* *Freedom* *Starfire* *Duration* Winter pea (29%) *Austrian* *Frostmaster* *Whistler* *Windham*

The bulky characteristics of forage come from fiber. High fiber is negatively associated with forage feeding values since the less digestible portions of plants 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). Chemically, this fraction includes cellulose, hemicellulose, and lignin. Because of these chemical components and their association with the bulkiness of feeds, NDF is closely related to feed intake and rumen fill in cows. Recently, forage testing laboratories have begun to evaluate forages for NDF digestibility (NDFD). Evaluation of forages and other feedstuffs for NDFD is being conducted to aid prediction of feed energy content and animal performance. Research has demonstrated that lactating dairy cows will eat more dry matter and produce more milk when fed forages with optimum NDFD. Forages with increased NDFD will result in higher energy values and, perhaps more importantly, increased forage intakes. Forage NDFD can range from 20-80% NDF.

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 cropping system and/or treatments within cropping systems were treated as fixed. Treatment mean comparisons were made using the Least Significant Difference (LSD) 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 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 the 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. The cool season annuals were established in Aug of 2017. Table 5 shows the weather data from Aug-Dec 2017 and indicates the growing conditions observed following the planting of the cool season annuals. Table 6 shows weather data from Jan-Sep 2018. From Aug through Dec 2017, there were an accumulated 2128 growing degree-days (GDDs), at a base temperature of 41° F (for cool season perennial forages). This is 455 more than the long-term average. From January to August 2018, there were an accumulated 3444 GDDs. This is 329 more than the long-term average.

Table 5. 2017 weather data for Alburgh, VT.

Alburgh, VT	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17
Average temperature (°F)	67.7	64.4	57.4	35.2	18.5
Departure from normal	-1.07	3.76	9.16	-2.96	-7.41
Precipitation (inches)	5.5	1.8	3.3	2.3	0.8
Departure from normal	1.63	-1.80	-0.31	-0.84	-1.59
Growing Degree Days (base 41°F)	829	699	516	73	12
Departure from normal	-33	111	293	73	12

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.

Table 6. 2018 weather data for Alburgh, VT.

Alburgh, VT	Jan 18	Feb 18	Mar 18	Apr 18	May 18	Jun 18	Jul 18	Aug 18
Average temperature (°F)	17.1	27.3	30.4	39.2	59.5	64.4	74.1	72.8
Departure from normal	-1.73	5.79	-0.66	-5.58	3.10	-1.38	3.51	3.96
Precipitation (inches)	0.8	1.2	1.5	4.4	1.9	3.7	2.4	3.0
Departure from normal	-1.26	-0.60	-0.70	1.61	-1.51	0.05	-1.72	-0.95
Growing Degree Days (base 41°F)	14	30	17	118	582	701	1007	974
Departure from normal	14	30	17	4	105	-43	89	112

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.

Despite an unusually wet April with 1.6 inches more rain than usual, there were an accumulated 7 inches less precipitation than usual from September 2017 to May 2018. During the summer months (May-Aug), temperatures were an average of 2° F warmer and there were 2 inches less rain then normal. Overall, conditions were drier than in 2017 and the alfalfa had more tolerable field conditions. Despite the lack of rain, three harvests from each of the systems were taken by the end of August.

Perennial System

Effect of Harvest

The treatments in the perennial system were harvested three times over the season. There were significant differences in yield among the harvests. Yield was highest in the first cut. However, overall quality was lowest in the first cut and highest in the third harvest.

Table 7. Perennial system yield and forage quality by harvest.

Harvest	Dry matter yield	Dry matter	Crude Protein	ADF	NDF
	lbs ac^{-1}	%	-------------------% of DM	-------------------	
First	**2,774^{a}**	22.7^{c}	16.8^{b}	30.1^{c}	46.6^{c}
Second	1,160^{c}	23.5^{b}	**21.1^{a}**	28.6^{b}	42.4^{b}
Third	1,551^{b}	**31.3^{a}**	**21.1^{a}**	**25.2^{a}**	**37.5^{a}**
LSD (p = 0.10)	260	0.79	0.55	0.78	1.68
Trial mean	1,828	25.8	19.6	28.1	42.3

Treatments in **bold** are top performers for that parameter.
Treatments that share a letter were not significantly different from one another (p<0.10).

Harvest x Treatment Interactions

There was no significant interaction between treatment and harvest yield or quality, except for dry matter. Dry matter was highest in the High and Very High treatments in the third harvest. This means that the treatments did not respond differently to harvest timing for forage quality parameters. However, quality overall was highest (highest protein, highest digestibility) in the last harvest.

Effect of Treatments

There were no significant differences in yield among the perennial forage system treatments (Figure 1). This year's growing conditions were less stressful for the alfalfa than the very wet spring of 2017. Overall, the alfalfa only treatments, Very Low and Low, had higher yields than the alfalfa/grass mixes and diversity in alfalfa varieties improved yield whereas the diversity of grass varieties did not. This is exemplified in the 1500 lb ac^{-1} difference between the Low and Very High treatments.

There were some differences among forage quality parameters (Table 8). Overall, the Low and Very Low treatments had the highest quality. This high protein content in the Low and Very Low treatments is likely due to the dominance of alfalfa in these treatments. The lower diversity treatments had lower fiber concentrations. This is indicative of the challenges presented in balancing yield with quality as diversity in forages increases.

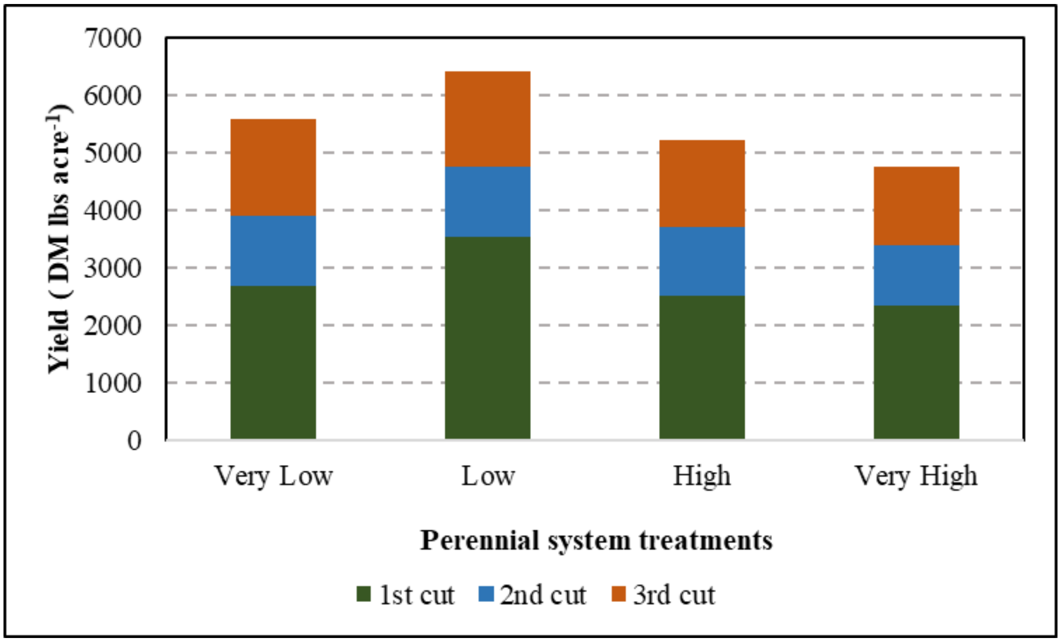

Figure 1. Perennial forage system yield by treatment.

Table 8. Perennial system yield and forage quality by treatment.

Treatment	**Dry matter yield** lbs ac^{-1}	**Dry matter** %	**Crude Protein**	**ADF** -------------------% of DM-------------------	**NDF**
Very Low	5,574	23.4^{b}	**21.8^{a}**	**24.8^{a}**	**33.8^{a}**
Low	6,398	23.9^{b}	21.3^{a}	26.1^{b}	36.8^{b}
High	5,223	27.8^{a}	17.8^{b}	30.4^{c}	48.8^{c}
Very High	4,747	**28.3^{a}**	17.5^{b}	30.7^{c}	49.6^{c}
LSD (p = 0.10)	NS	0.91	0.62	0.88	1.90
Trial mean	5,485	25.8	19.6	28.0	42.2

Treatments in **bold** are top performers for that parameter.

Treatments that share a letter were not significantly different from one another (p<0.10).

NS- No significant difference.

Annual System

Cool Season Treatments

Although there were no significant differences in yield of annual cool season treatments, it is worth noting that, like the perennial system, the Low treatment had the highest yield (Table 9). Although there was no significant difference among treatments in protein content, there were some significant differences in fiber concentrations among treatments. The Low and Very Low treatments had the lowest percent ADF and NDF. This may indicate a timelier harvest of the single variety/species of triticale in the Very Low treatment. In other treatments, multiple species may lead to differences in maturity at harvest and compromise quality. It should also be noted that clover and peas were nearly nonexistent by the time treatments were harvested. The cereal grains likely outcompeted these legumes or they may have not survived the winter.

Table 9. Cool season annual system yield and forage quality by treatment.

Treatment	Dry matter yield	Dry matter	Crude protein	ADF	NDF
	lbs ac^{-1}	%	-------------------% of DM-------------------		
Very Low	4,340	19.6	13.8	**27.5^{a}**	50.8^{a}
Low	4,535	22.1	13.7	27.6^{a}	**50.2^{a}**
High	4,079	22.0	13.5	30.7^{b}	53.6^{b}
Very High	4,320	22.5	13.4	31.9^{b}	55.3^{b}
LSD (p = 0.10)	NS	NS	NS	1.42	1.94
Trial mean	4,318	21.5	13.6	29.4	52.5

Treatments in **bold** are top performers for that parameter.
Treatments that share a letter were not significantly different from one another (p<0.10).
NS- No significant difference.

Warm Season Treatments

Effect of Harvest

There were no significant differences in the annual system in yield or crude protein among harvests. There were significant differences among other forage quality parameters. Overall, fiber concentrations were lowest in the first harvest (Table 10).

Table 10. Warm season annual system yield and forage quality by harvest.

Harvest	Dry matter yield	Dry matter	Crude Protein	ADF	NDF
	lbs ac^{-1}	%	-------------------% of DM-------------------		
First	4,593	**22.9**	15.7	**28.6**	**50.7**
Second	5,031	19.5	15.3	34.1	58.0
LSD (p = 0.10)	NS	1.03	NS	0.59	1.02
Trial mean	4,812	21.2	15.5	31.3	54.3

Treatments in **bold** are top performers for that parameter.
NS- No significant difference.

Harvest x Treatment Interactions

There were harvest by treatment interactions for ADF and NDF concentrations. Both ADF and NDF were lowest in the 1st cut of the warm season annuals and there was little difference between treatments (Figures 2 and 3). However, at the second harvest the low diversity had the highest fiber concentrations and the most diverse treatment had the lowest fiber concentrations. There were no harvest by treatment interactions for yield, dry matter, or crude protein.

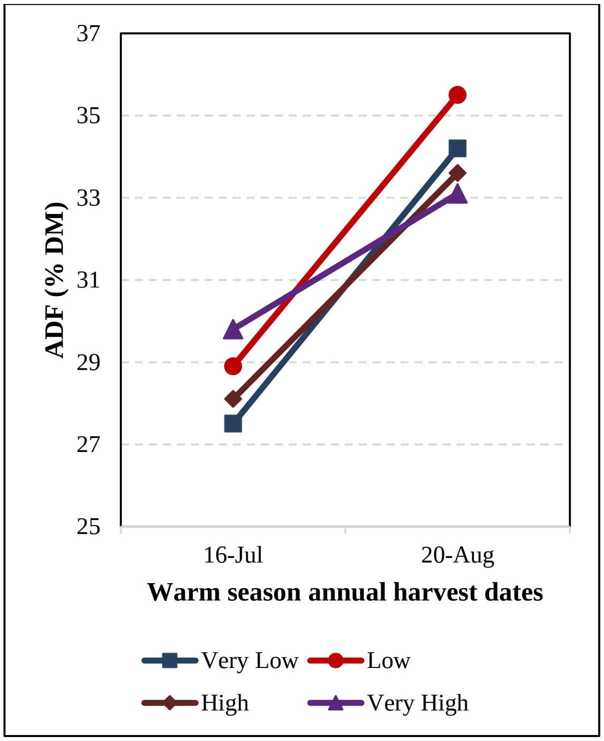

Figure 2. Warm season annual forage system harvest by ADF interaction (p<0.10).

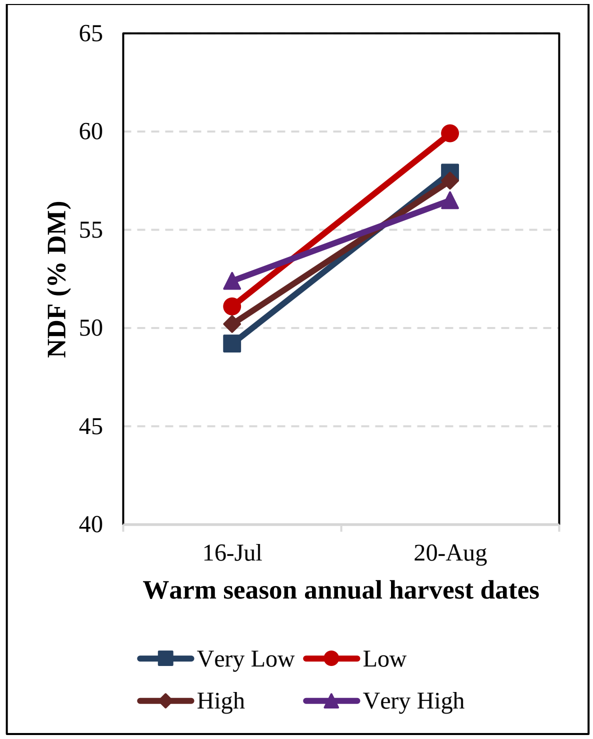

Figure 3. Warm season annual forage system harvest by NDF interaction (p<0.10).

Effect of Treatments

There were no significant differences in yield among the treatments (Table 11). However, ADF was significantly higher in the Low Treatment. This indicates that fiber concentrations can be increased even if only one variety in the mixture has high fiber concentrations.

Table 11. Warm season annual system yield and forage quality by treatment.

Treatment	Dry matter yield lbs ac^{-1}	Dry matter %	Crude protein	ADF	NDF
			-------------------% of DM-------------------		
Very Low	10,093	21.7	15.8	**30.8**[a]	53.6
Low	9,817	21.1	14.8	32.2[b]	55.5
High	9,156	21.7	15.6	**30.8**[a]	53.8
Very High	9,428	20.1	15.6	31.4[a,b]	54.4
LSD (p = 0.10)	NS	NS	NS	0.84	NS
Trial mean	9,624	21.2	15.5	31.3	54.3

Treatments in **bold** are top performers for that parameter.
Treatments that share a letter were not significantly different from one another (p<0.10).
NS- No significant difference.

Systems Yield Summary

System Treatment Yield Interactions Over Two Years

As in 2017, 2018 had a significantly higher yield in the annual system then the perennial system (Table 12, Figure 4). The annual system produced an average 8457 lbs ac^{-1} more than the perennial system. In 2017, there were only two cuts of the perennial system and the difference between the two systems was 7,200 lbs ac^{-1}.

Table 12. Treatment yields by cropping system, 2018.

Treatment	Dry matter yield	
	Perennial	Annual
Very Low	5,574	**14,433**
Low	**6,398**	14,353
High	5,223	13,235
Very High	4,747	13,942
LSD (p = 0.10)	NS	NS
Trial mean	5,485	13,942

Treatments in **bold** are top performers for that parameter.
NS- No significant difference.

Although notable, but not statistically significant, within each system, the Very Low and Low treatments had slightly higher yield than the High and Very High treatments. However, in 2017, within each system, the High and Very High treatments had slightly higher yield than the Very Low and Low treatments (Figure 5). This indicates that species diversity may mitigate forage loss when field conditions are cooler and wetter than usual. In addition, a severe potato leafhopper, a primary pest of alfalfa, was severe in 2017. This pest decimated alfalfa stands in 2017 so the stands that were mixed with grasses were able to compensate for the loss of alfalfa.

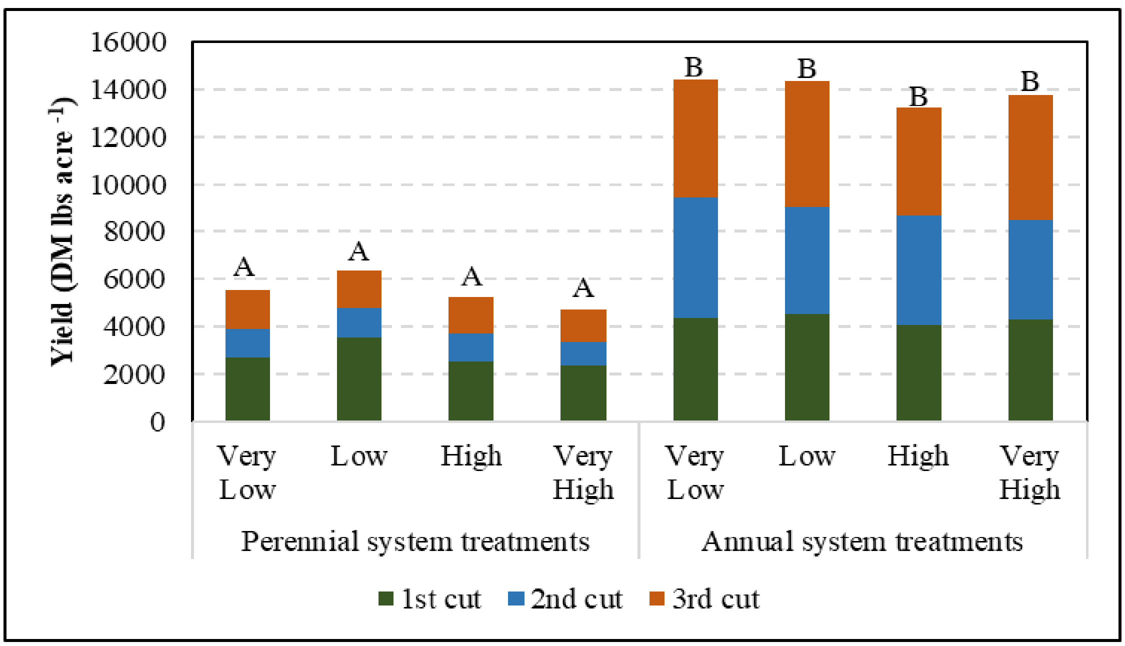

Figure 4. Total yield of treatments across the 2018 growing season by system (annual or perennial). *Within a system, treatments that share a letter were not significantly different from one another (p<0.10).*

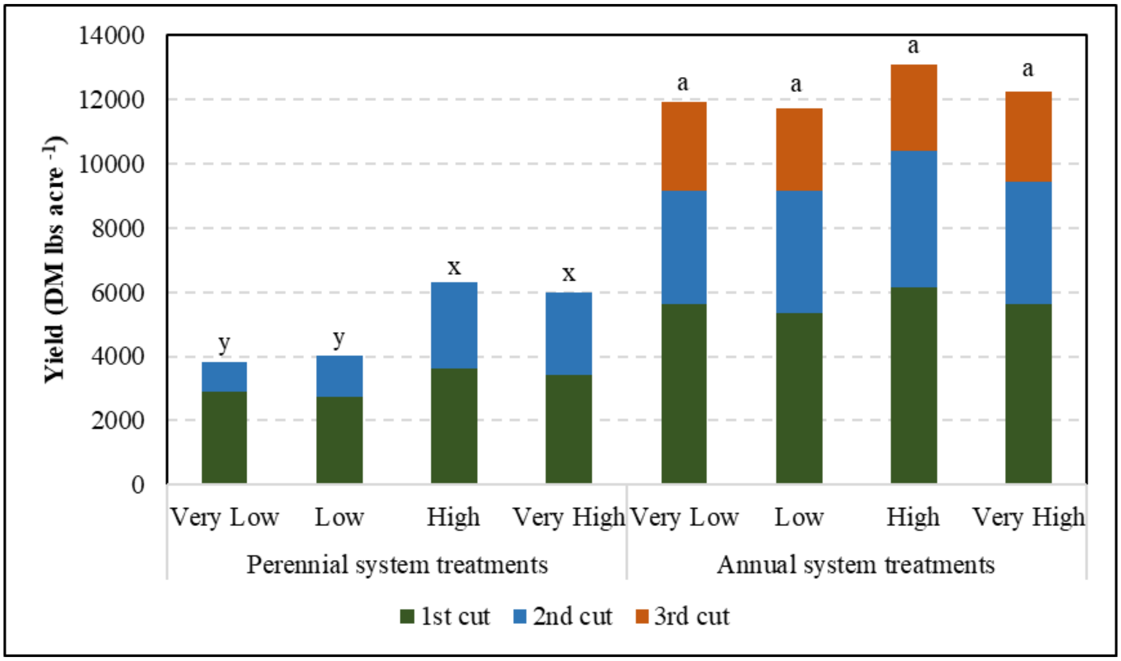

Figure 5. Total yield of treatments across the 2017 growing season by system (annual or perennial). *Within a system, treatments that share a letter were not significantly different from one another (p<0.10).*

This year, when weather conditions were more favorable, there was no significant yield difference among treatments across systems (Table 13). However, last summer was wetter and cooler than usual and yield was significantly higher in the High and Very High treatments. This data suggests that regardless of perennial or annual system, increased species diversity produces higher yields than single species when conditions were wet and cold. In 2018, the alfalfa responded better under warmer, dryer condition. Those same conditions were not as favorable to the grasses and clovers that are not as drought tolerant and prefer cooler temperatures. Due to the unpredictability of weather, forages stands comprised of mixes can mitigate the impact of adverse weather conditions.

Table 13. Average summed yields by treatment, irrespective of system.

Treatment	2017 Dry matter yield lbs ac^{-1}	2018 Dry matter yield lbs ac^{-1}
Very Low	7,854[b]	10,003
Low	7,883[b]	10,375
High	**9,698[a]**	9,229
Very High	9,101[a]	9,247
LSD (p = 0.10)	690	NS
Trial mean	8,634	9,714

Treatments in **bold** are top performers for that parameter.
Treatments that share a letter were not significantly different from one another (p<0.10).
NS- No significant difference.

CONCLUSION

Greater diversity within a forage system can increase resilience and mitigate negative impacts from extreme weather, disease and pest pressure when weather conditions are adverse. Higher species and variety diversity has less impact when weather conditions are dryer and warmer than usual. It is difficult to maximize forage quality of all species or varieties present in mixed stands. Overall, the annual system produces a higher yield. An exclusively annual system is labor intensive and may not be suitable or practical for all operations. Although there are two years of data presented, this data should not alone be used to make important management decisions.

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