2017

Forage Intercropping for Resiliency Experiment

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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 2017 data presented in this report is from the first year of four.

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, 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.

Table 1. Agronomic and trial information, 2017.

Location	Borderview Research Farm-Alburgh, VT
Soil type	Benson silt loam
Previous crop	Sunflower, no-till
Tillage operations in 2016	Moldboard plow
Tillage operations in 2017	Aerway
Field operations after planting	Cultipack
Plot size (ft.)	20 x 35
Perennial planting date	24-Aug 2016
Perennial harvest date (1st cut)	1-Jun 2017
Perennial system fertilized	8-Jun 2017 140 lb/acre K with potassium sulfate (0-0-51-18)
Perennial harvest date (2nd cut)	21-Jul 2017
Perennial system fertilized	7-Aug 2017 140 lb/acre K with potassium sulfate (0-0-51-18)
Perennial system legumes reseeded	1-Sep 2017
Annual planting date, cool season	12-Sep 2016
Annual harvest date, cool season	27-May 2017
Annual system fertilized	7-Jun 2017 1000 lbs/acre Krehers poultry litter (8-2-2) and 25.5 lbs/acre K with potassium sulfate (0-0-51-18)
Annual planting date, warm season	8-Jun 2017
Annual harvest date, warm season (1st cut)	3-Aug 2017
Annual system fertilized	7-Aug 2017 1000 lbs/acre Krehers poultry litter (8-2-2) and 25.5 lbs/acre K with potassium sulfate (0-0-51-18)
Annual harvest date, warm season (2nd cut)	6-Sep 2017

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). Treatments in the perennial system were seeded 9-Sep 2017. Annual cool season forage treatments were planted to a depth of 1.5 inches on 12-Sep 2016 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 8-Jun 2017 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. After each planting, the field was cultipacked.

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. 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. (Table 2). The annuals system was planted with cool season grasses in 2016 and followed by warm season in 2017 (Tables 3 and Table 4, respectively).

Table 2. Perennial system treatments and seeding rates, 2017.

Perennial System Treatments				
Very Low **23.5 lbs acre $^{-1}$**	**Low** **23.5 lbs acre $^{-1}$**	**High** **17.4 lbs acre $^{-1}$**	**Very High** **17.4 lbs acre $^{-1}$**	
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 cool season treatments and seeding rates, 2017.

Annual system cool season treatments				
Very Low **211.8 lbs acre $^{-1}$**	**Low** **211.8 lbs acre $^{-1}$**	**High** **154.1 lbs acre $^{-1}$**	**Very High** **154.1 lbs acre $^{-1}$**	
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*

All plots were harvested with a Carter Harvester in two passes 3x35 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 analyzed by Dairy One Forage Laboratory (Ithaca, NY) for crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF).

Table 4. Annual system warm season treatments, 2017.

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

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. Table 5 shows weather data from Aug-Dec 2016 and Table 6 shows weather data from Jan-Sep 2017. From August through December 2016, there were an accumulated 2077 growing degree days (GDDs), at a base temperature of 41° F. This is 404 more than the long-term average. From January to September 2017, there were an accumulated 3902 GDDs. This is 199 more than the long-term average.

Table 5. 2016 weather data for Alburgh, VT.

Alburgh, VT	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16
Average temperature (°F)	71.5	63.6	50.0	40.0	26.8
Departure from normal	2.68	3.03	1.80	1.82	0.89
Precipitation (inches)	3.00	2.50	5.00	3.00	1.60
Departure from normal	-0.93	-1.17	1.39	-0.13	-0.82
Growing Degree Days (base 41°F)	942	681	320	125	9
Departure from normal	80	93	97	125	9

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. 2017 weather data for Alburgh, VT.

Alburgh, VT	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17
Average temperature (°F)	27.0	27.0	25.1	47.2	55.7	65.4	68.7	67.7	64.4
Departure from normal	8.23	5.47	-6.05	2.37	-0.75	-0.39	-1.90	-1.07	3.76
Precipitation (inches)	1.00	1.50	1.60	5.20	4.10	5.60	4.90	5.50	1.80
Departure from normal	-1.05	-0.29	-0.63	2.40	0.68	1.95	0.73	1.63	-1.80
Growing Degree Days (base 41°F)	9	42	27	247	463	727	859	829	699
Departure from normal	9	42	27	133	-14	-17	-59	-33	111

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.

At the time of planting and through the end of 2016, temperatures were slightly above normal and with 1.66 inches of rain less than usual, it was also drier. Overall, January through March 2017 was warmer and drier than typical. The spring (April) of 2017 was warmer (higher temperatures and GDDs) and wetter than usual. Coming out of a relatively dry winter, these conditions were welcomed by the cool season annual forage crop. However, the 2017 summer trends (May-Aug) were cooler and wetter than usual. This stunted growth and increased susceptibility to disease and pest pressure of the forage crops. In September 2017, the weather turned warm and dry again which allowed for an extended harvest of the warm season annuals. The effects of the poor summer conditions were particularly noticeable in the perennial system. The forage was only harvested twice in order to allow the perennials ample recovery time prior to winter. The perennial system rebounded in the unusually warm fall weather. Had the fall growing conditions been known, a third cut may have been taken.

Perennial System

Harvest x Treatment Interactions

The treatments in the perennial system were harvested twice over the season. There was a significant interaction between harvests and treatments (p=0.0663). The High and Very High treatments always yielded higher than the Low and Very Low This means that the treatments responded differently to harvest timing. Overall, the yield of the first cut from Very Low treatment was higher than that of the Low treatment yield, but at the second cut and opposite trend was observed where the Low treatment yield was higher than the Very Low treatment (Figure 1). These results indicate that in a perennial forage system, stands with multiple varieties may be more resistant than forage with only one variety especially in the presence of adverse weather conditions and pest pressure. This is to be expected as different varieties have different characteristics that can compensate for other varieties. For example, one of the three alfalfa varieties was disease resistant and one was tolerant to potato leafhopper (Image 1).

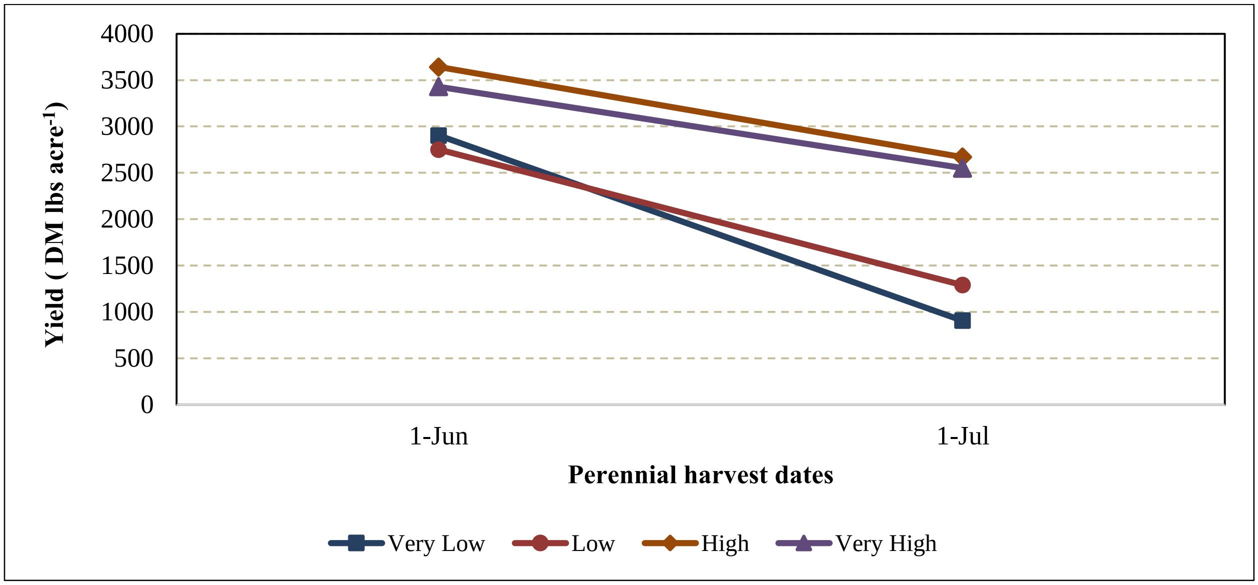

Figure 1. Perennial forage system harvest by treatment interacts (p=0.0663).

Image 1. Potato leaf hopper resistant alfalfa cultivar shown on left. Non-resistant cultivar shown on right. Picture taken 21-Jul.

Effect of Harvest Date

There was a significant difference between 1st and 2nd cut yields ($p<0.001$). Forage quality was higher in the 1st cut (higher crude protein and lower NDF). The average 1st cut (3180 lbs $acre^{-1}$) in the perennial systems was 1327 lb $acre^{-1}$ higher than the 2nd cut (1854 lbs $acre^{-1}$). Overall, weather conditions were poor leading to disease and pest outbreaks in the perennial forages. Most of the pest damage occurred following the first harvest.

Effect of Treatments

There were significant differences in yield and quality among the perennial forage system treatments (Figure 2 and Table 7). Yields were as follows: Very Low < Low < Very High < High. The High and Very High treatments yielded significantly more than the Low and Very Low treatments.

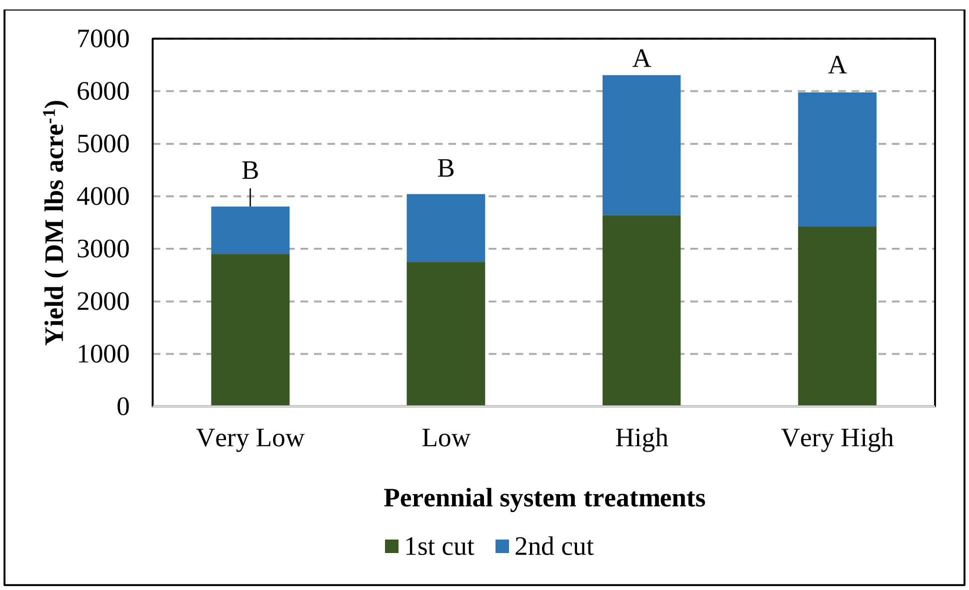

Figure 2. Perennial forage system yield by treatment.
Treatments that share a letter were not significantly different from one another ($p=0.010$).

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 (Table 7). The lower diversity treatments had lower fiber concentrations. The High and Very High treatments had the highest yields. This is indicative of the challenges presented in balancing yield with quality as diversity in forages increases.

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

Treatment	Dry matter yield	Dry matter	Crude protein	ADF	NDF
	lbs acre^{-1}	%	-------------------% of DM-------------------		
Very Low	1904	20.1	18.9*	**33.0**	**43.0**
Low	2021	19.4	**19.0**	33.2*	43.2*
High	**3155**	**22.8**	15.8	35.6	53.9
Very High	2989*	21.1	14.4	37.4	57.2
LSD (p = 0.10)	377	1.35	0.90	1.60	2.60
Trial mean	2517	20.9	17.0	34.8	49.3

Treatments indicated with an asterisk* performed similarly to the top performer in **bold.**

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 High treatment had the highest yield (Table 8). There were some significant differences between treatments in forage quality. The Low and Very Low treatments had the best forage quality. In particular, the Very Low treatment had the lowest fiber concentrations. This may indicate a timelier harvest of the single variety/species of triticale in the Very Low treatment. In other treatments, multiple species and varieties 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 may have outcompeted these legumes or they may have not survived the winter.

Table 8. Cool season annual system yield and forage quality by treatment.

Treatment	Dry matter yield	Dry matter	Crude protein	ADF	NDF
	lbs acre^{-1}	%	-------------------% of DM-------------------		
Very Low	5605	17.1	17.0*	**28.4**	**43.5**
Low	5346	16.6	**17.3**	29.2	46.6
High	**6148**	16.3	15.9	32.7	51.0
Very High	5618	**17.1**	15.0	35.7	54.1
LSD (p = 0.10)	NS	NS	1.30	0.80	1.60
Trial mean	5680	16.8	16.3	31.5	48.8

Treatments indicated with an asterisk* performed similarly to the top performer in **bold.**
NS- No significant difference.

Warm Season Treatments

Although there were no significant differences in yield, there was some significant difference in quality of warm season annual treatments. It is worth noting the High treatment had the lowest fiber concentrations (Table 9). There was a statistical difference between the first and second cut yield and forage quality of the warm season forages (Table 10). The average 1st cut of the warm season annual forages systems was 1116 lb ac^{-1} higher than the 2nd cut. However, the forage quality of the 2nd cut was better than the 1st cut. The greater forage quality of the 2nd cut may be due to greater mineralization of fertilizer due to warmer temperatures and greater uptake potential from an already established plant and root system.

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

Treatment	**Dry matter yield** lbs $acre^{-1}$	**Dry matter** %	**Crude protein**	**ADF** -------------------% of DM-------------------	**NDF**
Very Low	3147	16.4	15.1	31.2	55.4*
Low	3189	17.0	14.5	31.6	56.4
High	**3470**	**17.8**	**15.8**	**30.**	**54.1**
Very High	3304	16.1	15.3	31.2	55.2*
LSD (p = 0.10)	NS	NS	NS	0.88	1.2
Trial mean	3277.3	16.8	15.2	31.0	55.2

Treatments indicated with an asterisk* performed similarly to the top performer in **bold.**
NS- No significant difference.

Table 10. Warm season annual system by cut.

Harvest	**Dry matter yield** lbs $acre^{-1}$	**Dry matter** %	**Crude protein**	**ADF** -------------------% of DM-------------------	**NDF**
1st Cut	**3835**	16.1	12.7	34.1	59.8
2nd Cut	2719	**17.5**	**17.7**	**28.0**	**50.7**
LSD (p = 0.10)	289	0.87	0.61	0.62	0.83
Trial mean	5680	16.8	16.3	31.5	48.8

Treatments in **bold** indicate the top performer.

Systems Yield Summary

Systems Treatment Interactions

When yields of treatments are examined across both perennial and annual forage systems, there was a significant difference among treatments (p=0.002) (Table 11). This data suggests that regardless of perennial or annual system, increased species diversity produces higher yields than single species. In 2017, there was a significant difference between systems. The annual system produced an average 7200 lbs ac^{-1} more than the perennial system. This gap may have narrowed if we were able to harvest a 3rd cut of the perennial system.

Table 11. Average summed yields by treatment, irrespective of system.

Treatment	Dry matter yield lbs acre^{-1}
Very Low	7854
Low	7883
High	**9698**
Very High	9101*
LSD (p = 0.10)	690
Trial mean	8634

Treatments indicated with an asterisk* performed similarly to the top performer in **bold.**

Systems Treatment Yields

Figure 3 illustrates total yield across the entire growing season from each treatment within a system. Within the perennial system, the High and Very High treatment produced the most yield. The annual system did not differ in yield among the treatments (Table 12). This may partially be attributed to loss of species diversity from winter killed legumes.

Table 12. Treatment yields by cropping system.

Treatment	Dry matter yield Perennial	Dry matter yield Annual
Very Low	3808	11899
Low	4041	11724
High	**6310**	**13087**
Very High	5977*	12226
LSD (p = 0.10)	836	NS
Trial mean	5034	12234

Treatments indicated with an asterisk* performed similarly to the top performer in **bold.**
NS- No significant difference.

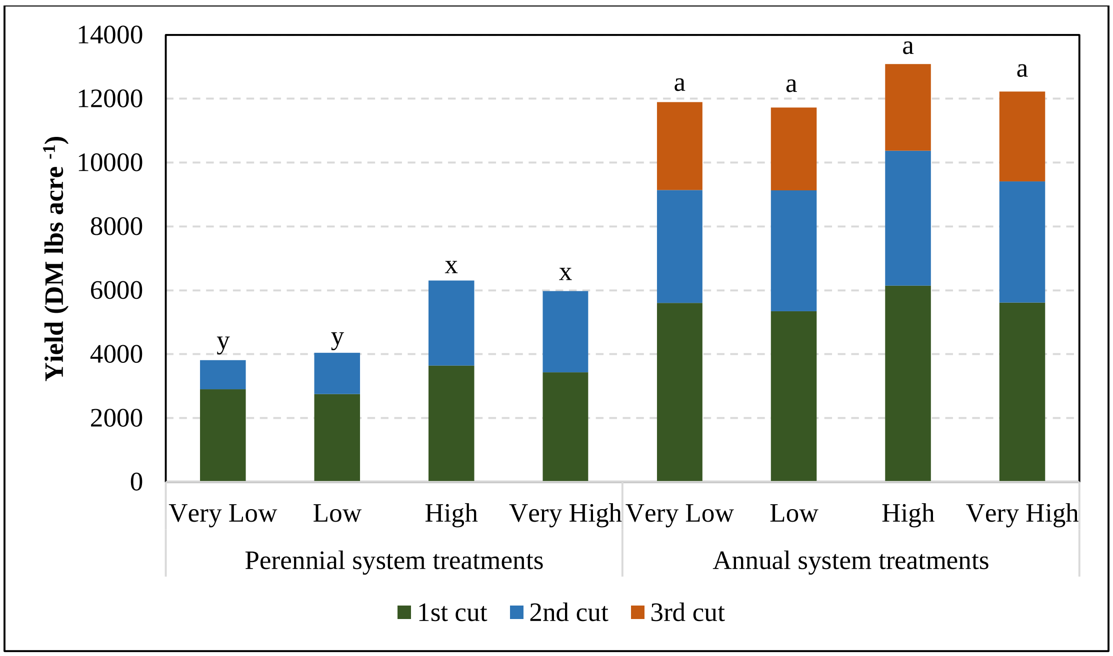

Figure 3. Total yield of treatments across the entire growing season by system (annual or perennial). *Within a system, treatments that share a letter were not significantly different from one another (p=0.010).*

CONCLUSION

Greater diversity within a forage system can increase resilience and mitigate negative impacts from extreme weather, disease and pest pressure. Overall, this trial indicates that higher species diversity can result in higher yields, but may provide challenges to maximizing forage quality. In the perennial system, it was clear that having multiple varieties of alfalfa in the stand provided protection from pests. Addition of grass into the alfalfa stands further enhanced yield but reduced CP and increased fiber concentrations. This is expected given the differences already known about the forage quality of grasses versus legumes. Clearly a more diverse stand was beneficial in the 2017 growing season. The annual system did not see the same benefits to increasing diversity in species or varieties. Overall, there were no yield differences among the treatments in the annual system. However, in the cool season annuals the quality was highest in the Very Low diversity treatments and was likely a result of being able to better gauge optimum harvest timing with fewer species and/or varieties. This study will continue for the next three years in an effort to collect long term data on forage system and treatment response to weather, disease and pest pressure on yield, forage quality, and soil health. These data only present one year of data and should not alone be used to make important management decisions.

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