Influence of Fertility on Pasture Species Diversity, Yield, and Quality

Project Number: 533-2

Grazing Lands Conservation Initiative (GLCI) Research Summary

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Introduction:

Extensive soil sampling on ten grazing farms in north central Wisconsin revealed a need for implementing nutrient management on farms using managed intensive rotational grazing. Numerous paddocks and hayfields contained optimum or higher soil phosphorus levels but lacked adequate potassium for maximum forage growth. While conducting preliminary surveying of these farm operators, many farm operators commented that poor performance of legume species had been observed in some pastures and mixed hayfields. Questions have arisen relating to how supplementing pastures with commercial fertilizer will influence pasture species diversity, productivity, and quality. The objective of this research is to generate data that will help address these questions.

Materials and Methods:

Research was conducted at the University of Wisconsin Marshfield Agriculture Research Station. Two locations of pasture forage mixtures were established in the spring of 2006. The high fertility location was planted and soil sampled on April 26th. The low fertility location was planted and soil sampled on May 19th. Soil samples were also collected at the end of the growing season in 2006 and 2007. Manure was analyzed for nutrient content in 2006 and 2007, and then averaged. A split plot with replicated block design was used. There were four replications of each fertility treatment at each location. All plots were planted with two pounds per acre (lbs/a) of 'Colt' white clover, eight lbs/a 'Marathon' red clover, four lbs/a 'Ginger' Kentucky bluegrass, and six lbs/a acre 'Pizza' orchardgrass. This mixture represents a typical pasture sward on grazing farms in north central Wisconsin.

Fertility treatments are based on recommendations from 'Nutrient application guidelines for field, vegetable, and fruit crops in Wisconsin', soil group D, low soil test category (Laboski et al., 2006).

Rates and cost of treatments were as follows:

2006

1. Untreated
2. Nitrogen (N) = 40 lbs/a on June 23rd and July 14th for a total of 80 lbs/a. Cost = $40 /acre.
3. Phosphorus (P) = 30 lbs/a P_2O_5 on July 14th. Cost = $14.50 /acre.
4. Potassium (K)= 120 lbs/a K_2O on July 14th. Cost = $32.80 /acre.
5. A2809 Pasture, legume-grass, seeding (N+P+K) = 15 lbs/a N, 30 lbs/a P_2O_5, and 120 lbs/a K_2O on July 14th. Cost = $50.05 /acre.
6. A2809 Pasture, legume-grass, seeding + micronutrients (K+B+Ca+S) = 15 lbs/a N, 30 lbs/a P_2O_5, and 120 lbs/a K_2O, 28 lbs/a Ca, 25 lbs/a S, 1 lb/a boron on July 14th. Cost = $69.30 /acre.
7. Manure = 2 tons/acre per cutting. 4 total tons/manure per acre. 11 lbs/a N, 10 lbs/a P_2O_5, 34 lbs/a K_2O, 2 lb/a S. Cost = $0 /acre (Equivalent purchase cost = $16.61 /acre).

2007

1. Untreated

2. Nitrogen (N) = 50 lbs/a on April 18th, 40 lbs/a on June 19th and July 23rd for a total of 130 lbs/a. Cost = $62.50 /acre.
3. Phosphorus (P) = 30 lbs/a P_2O_5 on May 21st. Cost = $14.50 /acre.
4. Potassium (K) = 210 lbs/a K_2O on May 21st. Cost = $54.40 /acre.
5. A2809 Pasture, managed grass (N+P+K) = 50 lbs/a N on April 18th, 40 lbs/a on June 19th and July 23rd for a total of 130 lbs/a. 30 lbs/a P_2O_5 and 225 lbs/a K_2O on May 21st. Cost = $127.00 /acre.
6. A2809 Pasture, managed legume/grass + micronutrients (K+B+Ca+S) = 210 lbs/a K_2O, 28 lbs/a Ca, 25 lbs/a S, and 1 lb/a boron on May 21st. Cost = $73.65 /acre.
7. Manure: 2 tons/acre after first four harvests. 8 total tons/manure per acre. 22 lbs/a N, 20 lbs/a P_2O_5, 68 lbs/a K_2O, and 4 lb/a S. Cost = $0 /acre (Equivalent purchase cost = $33.22 /acre).

Cost calculations use a price of $0.45/lb nitrogen, $0.35/lb phosphorus, $0.24/lb potassium, $4.50/lb boron, $0.10/lb gypsum (supplied calcium and sulfur), and $4 per acre dry fertilizer application.

Plots were 10 feet wide by 20 feet long. The center three feet was harvested from each plot using a flail-style plot harvester. Plots were harvested when the red clover in the untreated plots of the low fertility location was approximately eight to ten inches in height. Cutting height was two inches above the soil surface. The remaining plot area was used for collecting forage quality samples and determining the proportion of grass and clover in each plot. Once dried, the final dry matter weights were used to calculate the percentages of grass and clover in each sward. Harvest dates were July 14th, and August 21st in 2006 and May 21st, June 19th, July 23rd, August 30th, and November 1st in 2007.

Forage quality analysis was performed at the Marshfield Forage and Soil Analysis Laboratory. Crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), total digestible nutrients (TDN), net energy (NE), and Relative Feed Value (RFV) were determined using near infrared spectroscopy (NIR). Wet chemistry procedures were used to measure phosphorus, potassium, calcium, and magnesium. An Excel spreadsheet titled 'Pricer' developed by the University of Wisconsin was used to place a price per ton value on the forage (Howard and Shaver, 1998). All forage quality, yield, and forage value determinations are presented on a 100% dry matter basis.

Replicated pasture species diversity samples were collected only from the low fertility location. Because of time constraints, pasture species diversity and forage quality data were collected from replicate three only in the high fertility location at each harvest. Pasture species diversity was determined by gathering numerous sub-samples from a plot and then separating the grass component from the clover component prior to drying and weighing. Final dry matter weight of clover and grass was used the determine pasture species diversity. Due to the difficulty of separating white clover from red clover or Kentucky bluegrass from orchardgrass, data will be presented as clover or grass. At the beginning of the study, red clover and orchargrass were the dominate species. By the fall of 2007, white clover was becoming more common in plots; however there was little Kentucky bluegrass.

All data were statistically analyzed using STATISTIX 8 software. Analysis of Variance with split-split plot design was used. Fertility location was assigned the main plot; fertility treatment was assigned the sub-plot, and cutting date was assigned the sub-sub-plot.

Means comparisons were performed with Least Significant Differences (LSD) at a 95% confidence interval.

Results and Discussion:

Soil Fertility

The pH, organic matter percentage, potassium, and phosphorus were determined for all samples at the beginning and end of the study (Table 1). Additionally, boron, calcium, magnesium, sulfur, and magnesium were measured in the untreated and K+B+Ca+S treatments (Table 2). When averaged across treatments, all nutrients, except boron declined from the spring of 2006 to fall of 2007. Some of this decline may be related to seasonal fluctuations, yet the overall decline in fertility in both the low and high fertility location should represent the changes in typical pastures or hayfields.

When soil fertility of individual treatments is compared in the fall of 2007, the only nutrient demonstrating significant treatment differences was potassium. At the low fertility location, the untreated, N, P, and manure treatments had soil potassium that was less than the K+B+Ca+S treatment. The other two treatments, which contained potassium fertilizer, had soil potassium equal to K+B+Ca+S. The high fertility location had similar trends with the untreated, N, and P treatments resulting in lower potassium. Lack of potassium supplementation contributed to declines in soil potassium.

Table 1. Beginning and End Soil Nutrients

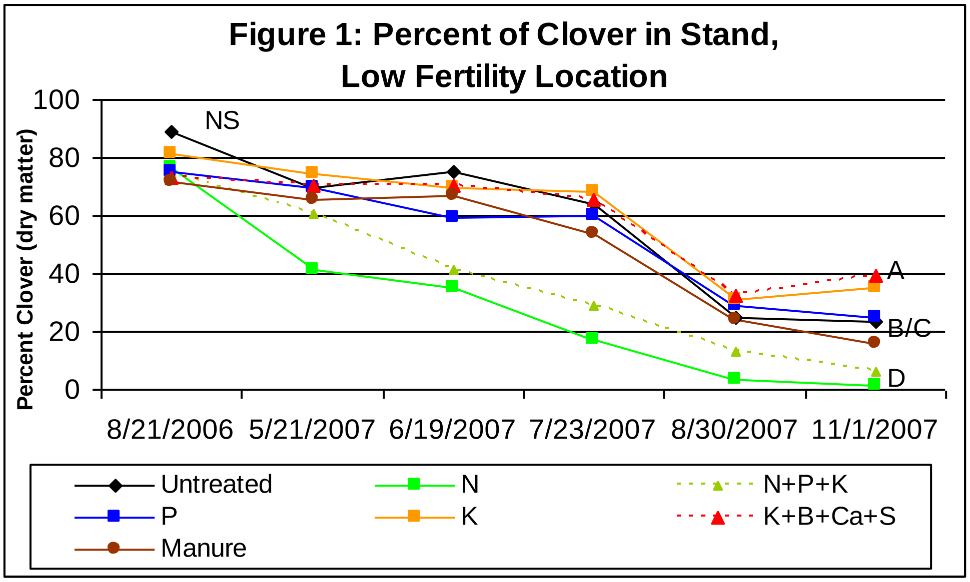
	Low Fertility Location							
	pH		Organic Matter %		Potassium ppm		Phosphorus ppm	
	S. 2006	F. 2007	S. 2006	F. 2007	S. 2006	F. 2007	S. 2006	F. 2007
Untreated	6.7	6.5	2.8	2.7	56	42 cd	31	26
N	6.5	6.5	2.9	2.9	54	33 d	33	25
N+P+K	6.9	6.6	2.9	2.9	52	55 ab	30	26
P	6.8	6.6	2.9	2.8	60	41 cd	31	28
K	6.8	6.5	2.9	2.8	53	55 ab	30	25
K+B+Ca+S	6.9	6.7	3.0	2.9	50	63 a	31	26
Manure	6.8	6.7	2.9	2.9	55	47 bc	31	27
Average	6.8	6.6	2.9	2.9	54	48	31	26
P-Value	0.0348	0.4126	0.3105	0.2171	0.8145	0.0001	0.1578	0.6209
LSD (0.05)		NS	NS	NS	NS	10	NS	NS
	High Fertility Location							
	pH		Organic Matter %		Potassium ppm		Phosphorus ppm	
	S. 2006	F. 2007	S. 2006	F. 2007	S. 2006	F. 2007	S. 2006	F. 2007
Untreated	7.0	6.8	3.1	3.1	158	115 bc	55	44
N	7.0	6.7	3.0	3.1	151	93 c	53	41
N+P+K	7.0	6.8	3.0	3.1	153	154 a	58	48
P	7.0	6.9	2.9	3.1	168	123 b	40	47
K	7.1	7.0	3.0	3.1	146	158 a	53	45
K+B+Ca+S	7.1	6.9	3.1	3.2	154	156 a	58	49
Manure	7.0	6.8	3.1	3.2	172	152 a	50	47
Average	7.0	6.8	3.0	3.1	157	136	52	46
P-Value	0.0405	0.1047	0.1682	0.3274	0.2489	<0.0001	0.741	0.3666
LSD (0.05)		NS	NS	NS	NS	23	NS	NS

Table 2. Beginning and Ending Soil Micronutrinets										
	Low Fertility Location									
	Boron ppm		Calcium ppm		Magnesium ppm		Sulfur Index		Manganese ppm	
	S. 2006	F. 2007	S. 2006	F. 2007	S. 2006	F. 2007	S. 2006	F. 2007	S. 2006	F. 2007
Untreated	0.8	0.9	1050	1095	303	248	38	27	25	17
K+B+Ca+S	0.8	1.1	1105	1155	325	270	37	31	25	19
Average	0.8	1.0	1078	1125	314	259	37	29	25	18
	High Fertility Location									
	Boron ppm		Calcium ppm		Magnesium ppm		Sulfur Index		Manganese ppm	
	S. 2006	F. 2007	S. 2006	F. 2007	S. 2006	F. 2007	S. 2006	F. 2007	S. 2006	F. 2007
Untreated	1.0	0.8	1150	1220	338	285	42	29	17	12
K+B+Ca+S	1.1	1.2	1165	1250	355	290	43	29	17	13
Average	1.0	1.0	1158	1235	346	288	42	29	17	13

Pasture Species Diversity

Fertility treatments have the ability to influence pasture species diversity. Changes in species diversity are presented as the percent of clover (from weighed dry matter) in Figure 1. In fall of 2006, the establishment year, all treatments had similar percentages of clover containing between 72 to 89% clover. Starting in the spring of 2007, then throughout 2007, there was a decline in clover percentage when commercial nitrogen fertilizer was applied. This trend supports the widespread assumption that applications of commercial sources of nitrogen can contribute to displacement of clover through robust growth of grasses. Less than 7% clover remained in the two nitrogen based treatments at the conclusion of this study.

A sharp decline in clover percentage was measured from July 23rd, 2007 to August 30th 2007 in all treatments. During this period of time, rainfall was much below normal. The untreated check, phosphorus, potassium, potassium with micronutrients, and manure had similar percentages of clover from August 2006 through August 2007. By the fall of 2007, treatment differences were more apparent. Potassium based treatments had the highest proportion of clover with 35 to 39% of the sward derived from clover. A gradual increase in white clover may have contributed to the higher percentage of clover; however, red clover and white clover were not separated. The phosphorus and untreated check treatments consisted of 25 and 24% clover, respectively. Clover in the manure only treatment dropped to 16% of the sward. It is possible the nitrogen cycling from the manure contributed to more aggressive grass growth; thereby displacing some clover. This may indicate manure on pastures may be a contributor to the decline of clover when pastures have a relatively large amount of manure. Further research is needed exploring this interaction.



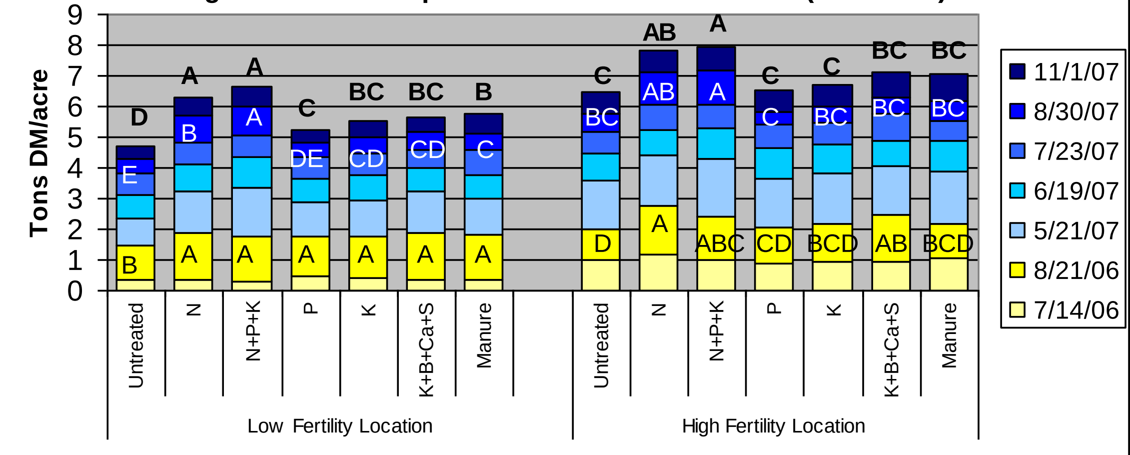
Yield Results
Background soil fertility and nutrient treatments both influenced pasture yields. The combined 2006-2007 yield ranged from 4.75 tons dry matter per acre in the untreated check of the low fertility location to a high of nearly 8 tons per acre in the N-P-K treatment of the high fertility location. This represents a yield increase of approximately 68% above the untreated. Figure 2 presents the yield response to nutrient treatments. Data from the low fertility location are separated from the high fertility location. Data from 2006 are represented by yellow bars while data from 2007 are represented by blue bars. Significant yield differences determined by LSD are denoted by letters embedded in each treatment bar. Total yield difference within a location is denoted by the letter above each bar.

Both locations shared some similar responses to nutrient applications with the two nitrogen based treatments resulting in the greatest total yields. Also, the treatments with potassium, potassium + micronutrients, and manure had similar yields at both locations.

In the low fertility location, the untreated check had the lowest yield throughout most of the harvests. Due to the low background fertility, nutrients applications have a high likelihood of yield response. The phosphorus treatment contributed to a slightly greater yield than the untreated in the seeding year and total yield. Treatments containing potassium or manure resulted in a yield increase of 0.75 to 1 ton dry matter combined over two years.

The high fertility location treatments consistently yielded 1.25 to 1.75 tons dry matter more than the same treatment in the low fertility location. It should be noted that the high fertility location was established three weeks prior to the low fertility location which contributed to an additional 0.75 ton of dry matter in the July 14th, 2006 harvest. There were fewer treatment differences at the high fertility location. This was anticipated because the background soil fertility was great enough that a yield response to potassium or phosphorus had a low probability. Treatments containing potassium, phosphorus, or manure did not have a different total yield than the untreated check in the high fertility location. Only the nitrogen based treatments clearly had a greater total yield than the untreated check in the high fertility location. A small yield increase was measured in the establishment year with some nutrient treatments.

Figure 2: Yield Response to Nutrient Treatments (2006-2007)



Forage Quality

Forage quality and mineral composition data are presented in Table 3. The data in the analysis includes the six harvest dates from August 21st, 2006 to November 1st, 2007 in the low fertility location and only the November 1st, 2007 harvest at the high fertility location. When comparing the November harvest quality results, crude protein, NDF and RFV were similar between the high and low fertility locations. Potassium and phosphorus content in the forages were greater in forage samples collected from the high fertility location; however calcium and magnesium content was less (data not shown). This result is consistent with the Focus or Forage tip sheet titled "Soil Fertility Influences on Cation Levels in Forage" (Peters and Kelling, 2002). It states, "…as soil K increased, tissue K increased and tissue Ca and Mg tended to decrease."

Similar to yield results, the two nitrogen based treatments typically were different from the other treatments for forage quality. The dominance of grass in the nitrogen treatments likely contributed to a lower crude protein, NE, TDN and RFV with greater NDF indicating nitrogen nutrient applications contributed to inferior forage quality. However, it should be noted that neutral detergent fiber digestibility (NDFd) and relative forage quality (RFQ) are now considered better tools for assessing the quality of grassy forages (Undersander, 2007). Analysis with NIR is not capable of determining NDFd and RFQ. Calcium content was also lower in nitrogen based treatments. Despite the quality difference, all treatments across all harvest dates had forage quality that is acceptable for feeding to lactating dairy cattle (Hoffman and Shaver, 2006).

Content of potassium and phosphorus in the forage samples were reflective of nutrient applications. Treatments containing potassium fertilizer had the greatest content of potassium in the forages. Similarly, the phosphorus treatment contributed to higher phosphorus content in the forage. Forage from the manure treatment had a greater potassium and phosphorus content than the untreated check. Potassium content in the forages from the high fertility location were greater than what is desirable for feeding to dry cows which can contribute to hypocalcemia (Kelling et al, 2002).

Table 2: Forage Quality Measurements

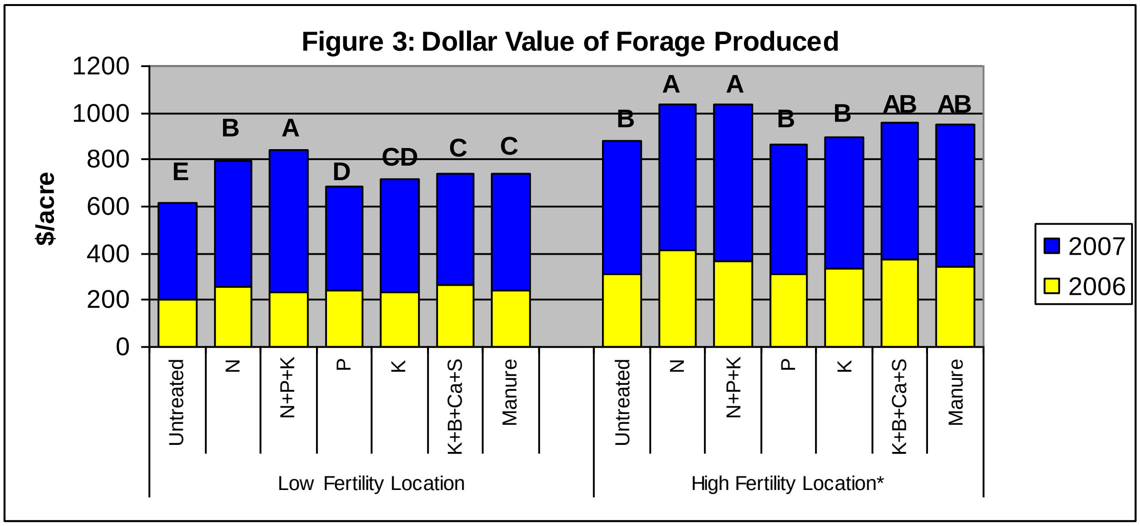
	Low Fertility Location, Harvests 8/21/06 to 11/1/07								
	C. Protein	NDF	Ne	RFV	TDN	Ca %	K %	Mg %	P %
Untreated	19.6 ab	37.0 b	0.718 a	175.7 a	69.5 a	1.05 a	1.94 c	0.43 a	0.31 c
N	18.7 c	39.5 a	0.711 b	162.8 b	68.7 bc	0.77 c	1.81 c	0.39 b	0.33 bc
N+P+K	18.5 c	39.4 a	0.705 c	163.0 b	68.3 c	0.75 c	2.64 a	0.33 c	0.31 bc
P	19.5 ab	37.4 b	0.715 ab	174.3 a	69.3 ab	1.01 ab	2.00 c	0.43 a	0.36 a
K	19.4 ab	37.7 b	0.712 b	171.8 a	68.9 b	1.02 a	2.47 ab	0.39 b	0.32 bc
K+B+Ca+S	19.8 a	37.4 b	0.713 ab	173.6 a	69.1 ab	1.01 ab	2.55 a	0.37 b	0.32 bc
Manure	19.2 b	37.8 b	0.713 ab	171.7 a	69.1 ab	0.95 b	2.25 b	0.38 b	0.34 b
Average	19.3	38.0	0.71	170.4	69.0	0.94	2.24	0.39	0.33
P-Value	0.0003	0.0001	0.0054	0.0002	0.0048	<0.0001	<0.0001	<0.0001	0.0068
LSD (0.05)	0.5	0.9	0.006	5.4	0.5	0.07	0.23	0.03	0.024

	High Fertility Location, 11/1/07 Harvest Only								
	C. Protein	NDF	Ne	RFV	TDN	Ca %	K %	Mg %	P %
Untreated	19.6 a	33.3 b	0.77 a	208.0 a	74.2 a	0.69 a	3.03 bc	0.18	0.42
N	16.6 b	37.4 a	0.75 bc	180.7 cd	72.6 bc	0.54 bc	2.90 c	0.17	0.40
N+P+K	17.2 b	38.5 a	0.76 c	174.8 d	72.3 c	0.46 c	3.33 a	0.15	0.35
P	18.8 a	34.6 b	0.76 ab	198.8 ab	73.7 a	0.74 a	2.96 c	0.18	0.39
K	18.9 a	35.2 b	0.75 ab	194.2 bc	73.5 ab	0.70 a	3.33 a	0.17	0.39
K+B+Ca+S	19.0 a	35.2 b	0.76 ab	194.4 b	73.5 ab	0.68 a	3.23 ab	0.16	0.39
Manure	19.4 a	34.4 b	0.76 ab	199.6 ab	73.6 a	0.61 ab	3.11 abc	0.16	0.40
Average	18.5	35.5	0.76	193	73.4	0.63	3.10	0.17	0.39
P-Value	<0.0001	0.0005	0.0162	0.001	0.0055	0.0042	0.0082	0.0998	0.5469
LSD (0.05)	1	2	0.01	13.6	0.9	0.14	0.25	NS	NS

Economic Return

One of the keys to success in grazing systems is the minimization of the cost of production (Kriegl and McNair, 2005). The dollar value of forage produced for each harvest was determined by multiplying the dry matter yield per acre by the price per ton derived from 'Pricer'. Additional comparison is performed by subtracting the cost of purchased fertilizer from the forage value. The dollar value of forage produced (Figure 3) is a reflection of the cost that a grazier would incur to purchase an equal amount of similar quality forage. (*Note that the forage quality data from the high fertility location is not fully replicated).

From 2006 through 2007, the range of value of forage was $615 to $845 dollars per acre in the low fertility location and $865 to $1,041 in the high fertility location. Dollar value differences were strongly related to yield. While the nitrogen based treatments encouraged more of lower quality grass growth, the quality of the forage was not a significant detriment to the dollar value of forage produced. In the low fertility location, nitrogen based treatments clearly generated more forage dollar value while the untreated check had the least forage dollar value. In the high fertility location, only the nitrogen based treatments generated a forage dollar value greater than the untreated check.



The cost of the nutrient applications was subtracted from the dollar value of forage produced to arrive at a net dollar return from nutrient applications per acre (Table 4). In both the low and high fertility location, the manure treatment resulted in the greatest net dollar return. No cost was associated with this treatment because it is assumed manure will be deposited by grazing livestock. Except for the nitrogen treatment in 2006, all applications of commercial nutrient sources resulted in a net loss of dollar return in the high fertility location. With below average precipitation during June and July, the 40 lb/acre nitrogen application did not generate a yield response during the June and July harvests in 2007. Cosgrove (2006) found similar results where a June 15th nitrogen fertilizer application encouraged less growth than a May or August application. These findings indicate it may not be profitable to apply nitrogen during mid-summer when precipitation is lacking.

The majority of commercial fertilizer applications to the low fertility location contributed to a positive net dollar return. Excluding manure, the greatest returns were generated from the nitrogen, N-P-K, and phosphorus treatments. Phosphorus is known to increase seedling vigor and data shows a $26/a net return in the seeding year. The potassium + micronutrients treatment had the least net return because soil nutrient levels of the micronutrients were not low enough to justify purchasing the added nutrient.

Table 4. Net Dollar Return from Nutrient Applications

	Low Fertility Location			High Fertility Location		
Treatment	2006	2007	Combined	2006	2007	Combined
Untreated	$203	$411	$615	$313	$566	$879
N	+$12	+$68	+$80	+$61	-$6	+$55
N+P+K	-$35	+$70	+$35	-$18	-$17	-$35
P	+$26	+$14	+$40	-$14	-$27	-$41
K	-$2	+$16	+$14	-$14	-$58	-$72
K+B+Ca+S	+$10	-$4	+$6	+$9	-$56	-$47
Manure	+$39	+$90	+129	+$26	+$49	+$75

Conclusion

Nutrient inputs influence pasture species diversity, quality, yield, and profitability. Potassium content in the soil is susceptible to rapid decline if potassium is not returned to the pasture, either through manure or commercial fertilizer application. Potassium and nitrogen have the ability to influence the ratio of clover to grass. Nitrogen promotes dominance of grasses while potassium promotes a high portion of clovers. Continuation of this research will help to reveal how long the clover longevity is extended by adequate soil potassium.

Background soil fertility is a major contributor to yield. All treatments had greater yield when the background fertility was at a 'high' level rather than 'low'. Yield was unresponsive when potassium, phosphorus and micronutrients were applied to a high fertility location; however, there was a growth response to all nutrient additions in the low fertility location. Nitrogen applications have the ability to encourage the greatest yield increase regardless of background fertility.

Forage quality is largely influenced by nitrogen application because grass growth is promoted. Over all treatments, forage quality was adequate for lactating dairy animals. The dollar value of the forage grown is directly related to the yield produced. Fertilizer expenditures have the greatest chance of a positive net dollar return when background soil fertility levels are low. Manure continues to be a vital nutrient source on grazing farms, clearly supported by the manure applications generating the greatest net dollar return. However, early data shows two tons of manure per acre per grazing event may not be enough to maintain soil fertility. Future research on fertility in pastures should focus on combinations of manure and commercial fertilizer applications.

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Appendix 1: Photographs of Sward Condition

Oct. 4 ’06: Untreated: Low Fertility Loc. (L), High Fertility Loc. (R)

May 14 ’07: Wide Location View: Low Fertility Loc. (L), High Fertility Loc. (R)

July 18 ’07: High Fertility Loc: Trt. N (L), Trt. K (R)

Appendix 1: Continued

July 23 ’07: Low Fertility Loc: Untreated (L), Trt. N (R)

July 23 ’07: Low Fertility Loc: Trt. K (L), Trt. Manure (R)