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Effective Nitrogen Fixation by Legumes in Cool Season Grass Mixtures

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Contents

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Introduction

The topography and attendant soils, coupled with climatic conditions, make pastures and meadows the predominant cover on more than 50% of the total land area of Missouri. The value of forage produced on this area increased with the introduction of Kentucky 31 tall fescue in the 1940s, the availability of inexpensive fertilizers (especially nitrogen) and the development of large feed lots in the 1950s and 1960s.

These incentives resulted in rapid growth of beef cattle numbers in Missouri. The record number of beef cows that had calved was 2.76 million in 1975 (Kroth and Meinke, 1981; Kroth and Mattas, 1981). The embargo on crude oil exports by the Organization of Petroleum Exporting Countries (OPEC), in 1973, resulted in immediate increase of fertilizer prices especially nitrogen (Fig. 1). Consequently, cattle prices fell, cattle numbers began to decline and producers became interested in legumes as a source of nitrogen for their pastures and hay meadows.

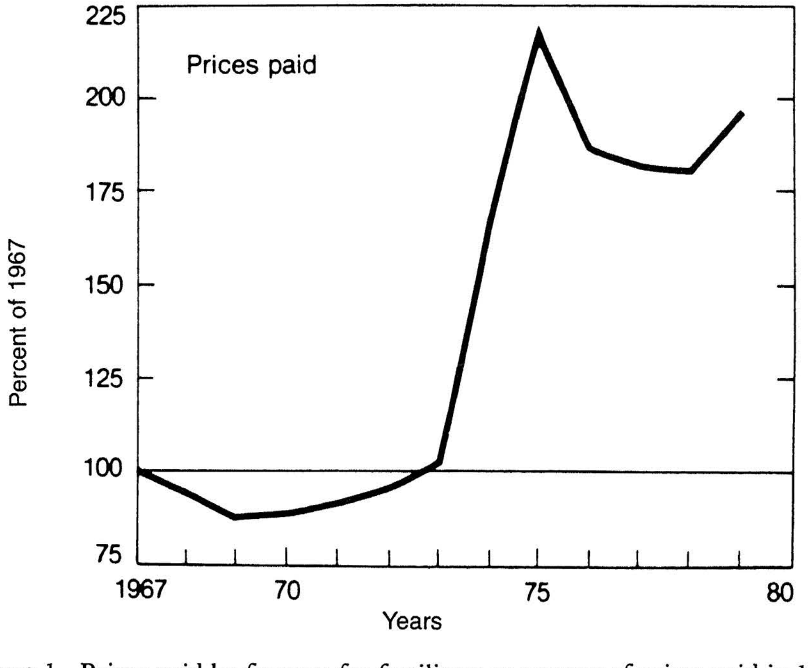

Figure 1. Prices paid by farmers for fertilizers as percent of prices paid in 1967 (USDA 1980).

Pasture renovation with limestone, fertilizers, and legumes had been promoted by several states in the 1960s. The need for similar data as a guide to Missouri cattlemen stimulated the establishment of the studies, the results of which are given in this report. Part I summarizes the studies with reed canarygrass at the North Missouri Center, Spickard, Grundy County. Part II summarizes the study with tall fescue at the Southwest Center, Mount Vernon, Lawrence County.

Objectives

The objectives of these studies were to determine: (1) the effective nitrogen (N) fixation by creeping alfalfa, red clover and birdsfoot trefoil growing with reed canarygrass, (2) the effective nitrogen fixation by birdsfoot trefoil growing with tall fescue, (3) the phosphorus (P) and potassium (K) needs of these mixtures and (4) the estimated limestone necessary for growth of these legumes in pasture mixtures.

Summaries and Conclusions

1. Creeping alfalfa-reed canarygrass mixture produces a four-year average yield of 4.6 tons/acre. The forage N content of this mixture ranges from 3.0-3.8%. Under North Missouri conditions, Victoria creeping alfalfa, and this study's method of evaluation fixes 178 lbs N annually.
2. Dawn birdsfoot trefoil-reed canarygrass mixture produces a four-year average yield of 3.6 tons/acre. The forage N content ranges from 2.7 to 3.7%, and under conditions of this study, fixes 115 lbs N annually.
3. Red clover (common 2 yrs, Kenstar 1 yr)-reed canarygrass mixture produces a three-year average yield of 3.5 tons/acre. The forage N content ranges from 2.6 to 3.3%, and under conditions of this study fixes 115 lbs N annually.
4. Dawn birdsfoot trefoil-tall fescue mixture under a tall fescue seed-forage management system produces 2.6 tons/acre forage, 323 lbs fescue seed, and fixes 45 lbs N as four-year averages. Fifty lbs N topdressed in March on the trefoil fescue mixture does not increase forage yields, but increases fescue seed production by a four-year average of 160 lbs. The 50 lbs N in March reduce the N fixed by the trefoil to 28 lbs/yr.
5. Three tons/acre calcitic limestone disked into the plowed surface during seed bed preparation, in 1972, plus an additional 3 tons/acre topdressed, in 1977, supplies adequate limestone for alfalfa, red clover and birdsfoot trefoil. The final 0-3 in. depth pHs was 6.4 under the alfalfa-reed canarygrass mixture.
6. The amount of N fixed by birdsfoot trefoil growing with tall fescue in Southwest Missouri may have been low due to the low pHs of 5.2 in the 0-3 in. depth.
7. The most efficient 0-3 in. depth P_2O_5 and exchangeable K soil test values apparently were not reached during this study. Values from other studies indicate (P_2) P_2O_5 and exchangeable K soil test values of 45 and 200 lbs/2 million lbs of soil are optimum values to maintain for the 0-3 in. depth of soil supporting legume cool season grass mixtures on highly weathered soils.

Part 1

Effective Nitrogen Fixation by Creeping Alfalfa, Red Clover and Birdsfoot Trefoil Growing with Reed Canarygrass

Procedure

An excellent, uniform stand of Rise reed canarygrass resulting from the April, 1972, planting of a Reed Canarygrass Establishment Study (Kroth *et al.*, 1976) was used. The area soil was a Lagonda silt loam (Aquic Argiudoll; fine, montmorillonitic, mesic) which had three tons of calcitic limestone disked into the plowed surface during seed bed preparation in April, 1972. An additional 3 tons/acre of limestone were topdressed in March, 1977. In April, 1974, the soil of the experimental area was divided into thirds. Each third was sampled 0-3 and 4-6 in. depths by taking 20 cores, cutting them into the selected depths, and placing them in the appropriate sample bags. The average results of tests on these samples are given in table 1.

The area was disked and harrowed in April, 1974, to kill half the reed canarygrass. Nine blocks were delineated in a randomized block design. Every third block was seeded to Victoria alfalfa, Dawn birdsfoot trefoil and common red clover (Kenstar cultivar not available). Each legume area was large enough to include four P K topdressed blocks. Each block was large enough to contain four N plots. These plots were 8 x 30 ft, separated at the ends by five-foot borders to permit harvesting with a modified 5-foot flail-type forage harvester and over-sized burlap bags. The annually topdressed P K blocks were:

A - 30 lbs P_2O_5, 100 lbs K_2O.
B - 30 lbs P_2O_5, 200 lbs K_2O.
C - 60 lbs P_2O_5, 100 lbs K_2O.
D - 60 lbs P_2O_5, 200 lbs K_2O.

The N treatments on each P K block of each legume were:

1. Reed canarygrass alone.
2. Reed canarygrass alone + 50 lbs N after cutting 1.
3. Reed canarygrass + legume.
4. Reed canarygrass + legume + 50 lbs N after cutting 1.

The legumes were removed from the plots to be grass alone by 2-4D. The annual P K topdressings were made in March. The 50 lb N topdressings were applied after the first cutting using this cutting to evaluate the amount of N released from soil organic matter or residual N from legume fixation the previous year. Plots were harvested when the legumes were in the early blossom stage. The times of cutting averaged the first week of May, the second week of July, and the second week of August. If a rare fourth cutting occurred in September, the yield was included with the third cutting for yield analysis. Yields were reported in tons of hay, 15% moisture.

Forage samples taken from each plot at harvest time to evaluate dry matter yield were kept and ground for total N determinations. These total N values were used to calculate effective N fixation by the legumes. All forage samples for 1975 were inadvertantly destroyed before total N was determined; however, averages of other appropriate data were used for calculating amounts of N fixed.

To assure adequate lime for legume growth 3 tons/acre calcilic limestone were topdressed in March 1977 (Table 1). Soil samples by one-inch depths to a depth of six inches were taken at the close of the study only from the alfalfa-reed canarygrass plots due to financial constraints. The alfalfa-reed canarygrass mixtures produced the highest yields and would have the greatest effects on the terminal soil test values. Ten cores were taken from each plot, cut into one-inch lengths and each piece placed in the appropriate sample bag. The chemical tests were made according to Brown *et al.* (1977).

Rainfall amounts and distribution by months during the period of the study are given in table 2.

Table 1. Soil Test Values of the Reed Canarygrass Area, April 1974.

Depths Inches	pHs*	Neutralizable Acidity me/100 g	OM %	P_2O_5** P_1	P_2	K***	Ca	Mg	CEC me/100 g
			lbs/2,000,000 lbs soil						
0-3	6.1	3.3	3.2	29	38	239	6600	930	24.0
4-6	4.9	7.8	3.1	20	26	177	4500	910	23.0

*Measured in 1:1 soil 0.01 M $CaCl_2$ suspension.

**P_1, P_2 indicates Bray's weak and strong extractants respectively.

***Exchangeable K determined by ammonium acetate extraction.

Results and Discussion

Victoria Alfalfa-Reed Canarygrass

Forage Yields

Yield results by cuttings and total production of the alfalfa-reed canarygrass mixture are given in table 3.

Comparison of yield data with monthly rainfall (Table 2) showed low July rainfall, in 1975, limited production of the pure grass plots (cuttings 2 and 3). In 1976, low July rainfall reduced forage yields on all plots. In contrast, rainfall distribution in 1977 and 1978 was better because relatively high yields occurred at each cutting. The percentage of alfalfa in the forage mixture of treatments 3 and 4 was higher during dry periods because the deeper rooting alfalfa had more available soil moisture. Observation of the block yields for 1978, indicated that P could be a limiting nutrient under the conditions of the 1978 season because the yield of block A was significantly below that of block B.

Table 2. Precipitation North Missouri Center 1970-1978.

Months	Precipitation in Inches								
	1970	1971	1972	1973	1974	1975	1976	1977	1978
January	0.10	1.88	0.37	3.05	1.53	0.70	0.24	0.62	0.29
February	0.22	1.07	0.55	1.73	1.03	1.26	0.90	0.53	1.24
March	1.60	0.98	1.43	8.35	1.26	1.65	4.75	3.84	1.47
April	3.91	2.43	3.21	4.57	1.95	3.31	4.79	2.37	5.48
May	4.99	2.83	5.29	6.16	4.23	4.85	3.67	4.49	6.47
June	3.67	2.77	4.19	3.69	4.46	3.05	2.35	1.78	3.39
July	0.92	3.75	2.84	8.68	1.72	1.32	0.94	1.33	3.60
August	8.61	0.56	2.30	2.25	3.87	3.38	1.91	8.79	6.52
September	9.12	2.40	4.52	7.14	3.39	5.05	3.03	7.19	5.36
October	3.74	2.88	1.67	3.89	5.87	0.26	2.81	6.15	0.57
November	1.17	3.90	3.87	1.61	1.29	3.30	0.12	0.92	3.95
December	1.56	2.88	1.57	2.22	1.34	1.32	0.20	1.06	0.52
Total	39.61	28.33	31.81	53.34	31.94	29.45	25.71	39.07	38.86
Departure from long Term Mean	2.18	-9.87	-6.39	15.14	-6.26	-5.72	-9.46	3.90	3.69

Nitrogen Content

Total N was determined (Table 4) on forage samples from all cuttings from all plots in 1976, '77, and '78. Values for each cutting were subjected individually to statistical analysis. Averages of these determinations were used as values for the three cuttings in 1975.

The data for treatment 1 of all cuttings of all blocks resulted from the N derived by mineralization of soil organic matter. The average N content of this grass forage (3 cuttings, 3 years) was 2.50%.

The data for cutting 1, treatment 2 (50 lbs N after cutting 1) are the same as for cutting 1, treatment 1. However, the 50 lbs N after cutting 1 increased the N content of cutting 2 with some influence on cutting 3 in all years (Table 4).

Forages of cutting 1 containing alfalfa had an average N content of 3.11%; when 50 lbs N were topdressed after cutting 1, treatment 4, the N content increased to 3.77% with no significant increase in total yield (Table 3).

Total Nitrogen Removed

The calculated amounts of N removed in the forage of the alfalfa-reed canarygrass portion of the study are given in table 9.

These data (Table 9) showed the average annual N removal for reed canarygrass alone was 46 lbs/acre. When 50 lbs N were topdressed, the N removal increased to 133 lbs/acre. The 50 lbs N increased plant growth by sending roots deeper into the soil thereby getting mineralized N not available to the shallower roots produced by mineralized N in the upper soil.

Table 3. Victoria Alfalfa—Reed Canarygrass Forage Yields, T/A.

Treatment		1975				1976				1977			
N	PK	Cut 1	Cut 2	Cut 3	Total	Cut 1	Cut 2	Cut 3	Total	Cut 1	Cut 2	Cut 3	Total
1	A	.97	.44	.27	1.68eg*	.17	.13	.01	.31e	.13	.42	.63	1.17c
2	A	.70	.34	.79	1.83eg	.20	.71	.02	.93de	.24	1.13	1.63	3.01b
3	A	1.63	1.12	.82	3.57abc	2.60	1.15	.21	3.96bc	1.77	2.07	1.33	5.17a
4	A	1.70	1.35	1.14	4.19a	3.22	1.50	.27	4.98a	1.84	2.09	1.43	5.37a
1	B	.80	.24	.32	1.36g	.15	.11	.02	.28e	.11	.31	.64	1.06c
2	B	1.00	.43	.63	2.06eg	.21	.69	.05	.95de	.23	1.41	1.78	3.41b
3	B	1.40	.81	.74	2.95cd	2.15	1.30	.24	3.70c	1.79	2.07	1.19	5.05a
4	B	1.40	.82	.85	3.07bcd	2.43	1.38	.20	4.01bc	1.69	2.02	1.71	5.42a
1	C	.90	.45	.36	1.70eg	.19	.13	.02	.34e	.11	.41	.62	1.13c
2	C	.83	.45	.78	2.06eg	.21	.75	.04	1.03d	.24	.97	1.44	2.65b
3	C	1.83	1.25	.82	3.91ab	2.87	1.31	.30	4.48b	1.88	2.26	1.35	5.48a
4	C	1.47	.96	1.07	3.49abc	2.94	1.56	.28	4.78a	1.87	2.27	1.88	6.02a
1	D	.87	.43	.34	1.64eg	.18	.15	.02	.35e	.14	.35	.85	1.34c
2	D	1.03	.66	.64	2.34de	.32	.83	.03	1.18d	.29	1.37	1.66	3.31b
3	D	1.80	1.26	.96	4.02a	3.02	1.52	.27	4.81a	1.91	2.14	1.43	5.17a
4	D	1.87	1.13	1.12	4.12a	3.13	1.52	.29	4.94a	1.94	2.29	1.56	5.79a

	Avg. of Total Block Yields (1975)				Avg. of Total Block Yields (1976)				Avg. of Total Block Yields (1977)			
	A	B	C	D	A	B	C	D	A	B	C	D
	2.82a	2.36b	2.79a	3.03a	2.55a	2.24b	2.66a	2.82a	3.68a	3.74a	3.82a	3.90a

*Yields followed by the same letter are not significantly different Duncan's New Multiple Range Test .05 level. The same letter identification applies to all data in this report.
**Mean of 4 year totals.

Table 4. Victoria Alfalfa—Reed Canarygrass, Percent Total Nitrogen of Forage Mixture.

Treatment		1976			1977			1978		
N	PK	Cut 1	Cut 2	Cut 3	Cut 1	Cut 2	Cut 3	Cut 1	Cut 2	Cut 3
		%								
1	A	2.26b	2.83c	3.12e	2.53b	2.36g	2.35gh	2.08b	2.58g	2.35cde
2	A	2.16b	3.80ab	3.33d	2.68b	4.03b	2.78ef	1.87b	3.58bcde	2.55bcd
3	A	2.90a	3.71ab	3.76bc	3.06a	3.41cdef	3.78ab	3.08a	3.53de	3.73a
4	A	3.01a	3.83ab	3.71bc	3.17a	3.38def	3.88a	2.88a	3.80abcd	3.53a
1	B	2.20b	2.90c	2.80g	2.61b	2.28g	2.16h	2.10b	2.45g	1.98e
2	B	2.02bc	3.62ab	3.22de	2.47b	4.17ab	2.88de	1.80c	3.87abcd	2.63bc
3	B	3.02a	3.64ab	3.74bc	3.43a	3.33ef	3.70ab	3.13a	3.55cde	3.73a
4	B	2.96a	3.82ab	3.77abc	3.12a	3.65c	3.62abc	3.12a	4.00a	3.72a
1	C	2.18b	2.99c	2.95fg	2.55b	2.46g	2.51fg	1.97b	2.55g	2.38cde
2	C	2.05bc	3.86ab	3.32d	2.53b	4.29a	2.99de	2.00b	3.15f	2.68bc
3	C	2.99a	3.61b	3.68c	3.40a	3.27f	3.78ab	3.10a	3.35ef	3.63a
4	C	2.88a	3.84ab	3.67c	3.25a	3.62cd	3.83ab	3.12a	3.97ab	3.60a
1	D	2.14b	2.92c	3.07ef	2.48b	2.41g	2.53fg	2.07b	2.53g	2.08de
2	D	1.89c	3.79ab	3.37d	2.54b	4.06ab	3.08d	2.15b	3.95abc	3.02b
3	D	2.93a	3.75ab	3.87ab	3.21a	3.39cdef	3.37c	3.05a	3.57bcde	3.77a
4	D	2.83a	3.87a	3.93a	3.17a	3.56cde	3.56bc	3.12a	3.85abcd	3.72a

*Values used to calculate amount of N fixed in 1975.

Table 3. (continued)

1978 Cut 1	Cut 2	Cut 3	Total
.49	.37	.69	1.55f
.86	1.50	1.05	3.41e
1.84	1.43	1.61	4.88bc
2.12	1.81	1.62	5.55ab
.27	.29	.58	1.17f
.82	1.79	1.26	3.88de
2.14	1.62	1.57	5.33ab
2.03	1.89	1.84	5.76a
.61	.35	.52	1.47f
.70	2.13	.94	3.77de
2.17	1.50	1.53	5.19abc
2.02	1.96	1.61	5.60ab
.60	.38	.63	1.62f
1.44	1.94	1.10	4.48cd
1.91	1.56	1.72	5.19abc
1.86	1.87	1.94	5.67a

Avg. of Total Block Yields

A	B	C	D
3.84b	4.03a	4.01a	4.24a

Treatment N	PK	Study Averages Cut 1	Cut 2	Cut 3	Total**
1	A	.44	.34	.40	1.18
2	A	.50	.92	.87	2.29
3	A	1.96	1.44	.99	4.39
4	A	2.28	1.69	1.12	5.09
1	B	.33	.24	.39	.96
2	B	.57	1.08	1.01	2.66
3	B	1.87	1.45	.94	4.26
4	B	1.89	1.53	1.15	4.57
1	C	.45	.34	.46	1.16
2	C	.50	1.08	.80	2.38
3	C	2.19	1.58	1.00	4.77
4	C	2.18	1.69	1.21	4.97
1	D	.45	.33	.46	1.24
2	D	.77	1.20	.86	2.83
3	D	2.16	1.62	1.10	4.80
4	D	2.20	1.70	1.23	5.13

Total Yield Averages by Treatments

1	2	3	4
1.14	2.54	4.56	4.94

Cut 4	Averages of 1976, 77, 78* Cut 1	Cut 2	Cut 3
1.40f	2.29	2.59	2.61
1.50f	2.24	3.80	2.89
2.73ab	3.01	3.55	3.76
2.22cd	3.02	3.67	3.71
1.36f	2.30	2.54	2.31
1.73ef	2.10	3.89	2.91
3.10ab	3.19	3.51	3.72
3.05ab	3.07	3.82	3.70
1.58ef	2.23	2.67	2.61
1.63ef	2.16	3.77	3.00
2.63bc	3.16	3.41	3.70
2.63bc	3.08	3.81	3.70
1.53ef	2.23	2.62	2.56
2.03de	2.16	3.93	3.16
3.22a	3.06	3.57	3.67
3.00ab	3.04	3.76	3.74

Table 5. Birdsfoot Trefoil—Reed Canarygrass Forage Yields T/A.

Treatment		1975				1976			1977		
N	PK	Cut 1	Cut 2	Cut 3	Total	Cut 1	Cut 2	Total	Cut 1	Cut 2	Total
1	A	.53	.23	.36	1.13bcd	.19	.16	.35cd	.28	.67	.95c
2	A	.60	.22	.70	1.41bcd	.30	.65	.96b	.66	2.40	3.06ab
3	A	1.90	.62	.62	3.14a	2.66	.64	3.30a	1.53	1.53	3.06ab
4	A	1.93	.62	.82	3.37a	2.53	.90	3.43a	1.62	1.68	3.29ab
1	B	.40	.22	.32	.95d	.14	.14	.28d	.27	.74	1.01c
2	B	.60	.22	.49	1.31bcd	.18	.63	.81bc	.60	2.46	3.06ab
3	B	1.77	.94	.56	3.26a	2.83	.64	3.47a	1.74	1.21	2.95b
4	B	1.30	.83	.87	2.99a	2.39	1.03	3.42a	1.58	1.91	3.49ab
1	C	.53	.30	.29	1.12bcd	.17	.13	.30cd	.29	.76	1.04c
2	C	.57	.26	.82	1.64bc	.30	.74	1.04b	.59	2.34	2.93b
3	C	1.97	.83	.61	3.40a	2.84	.57	3.41a	1.81	1.40	3.21ab
4	C	1.90	.81	.81	3.52a	2.37	.93	3.30a	1.76	1.83	3.58ab
1	D	.47	.29	.27	1.03cd	.16	.15	.32cd	.32	.65	.97c
2	D	.57	.28	.92	1.74b	.31	.68	.99b	.60	2.36	2.95b
3	D	1.73	1.19	.57	3.49a	3.03	.63	3.67a	1.74	1.27	3.01b
4	D	1.67	.79	.78	3.23a	2.70	.96	3.66a	1.69	2.21	3.90a

1975 Total Block Yields				1976 Total Block Yields				1977 Total Block Yields			
A	B	C	D	A	B	C	D	A	B	C	D
2.26a	2.13a	2.42a	2.37a	2.01a	1.99a	2.01a	2.15a	2.59a	2.63a	2.69a	2.71a

*Mean of 1975, 1978.

**Mean of 4 year totals.

Table 6. Birdsfoot Trefoil—Reed Canarygrass, Total Nitrogen of Forage Mixture.

Treatment		1976		1977		1978		
N**	PK*	Cut 1	Cut 2	Cut 1	Cut 2	Cut 1	Cut 2	Cut 3
		%						
1	A	2.17c	2.97d	2.30d	2.17ef	2.40abc	2.65c	1.88bcd
2	A	1.99c	3.95abc	1.97e	2.57de	1.88ef	3.57ab	1.55d
3	A	2.86b	3.73c	3.05a	3.15abc	2.25bcd	3.10bc	2.28abc
4	A	3.05ab	4.10ab	2.83b	3.56a	2.23bcd	3.92a	2.30abc
1	B	2.21c	2.91d	2.32d	1.95f	2.20cde	2.43c	1.67cd
2	B	2.21c	3.85bc	2.04e	2.81bcd	1.82f	4.03a	1.62d
3	B	3.10ab	3.89abc	3.02ab	3.27ab	2.55ab	3.58ab	2.33ab
4	B	3.11ab	3.91abc	2.90ab	3.52a	2.30abc	3.68ab	1.85bcd
1	C	2.15c	2.93d	2.34d	2.20ef	2.11cdef	2.60c	2.02bcd
2	C	1.98c	3.89abc	2.04e	2.67cde	1.92def	3.47ab	1.58d
3	C	3.05	3.93abc	2.93ab	3.22abc	2.38abc	3.07bc	2.47ab
4	C	3.06ab	4.12a	2.61c	2.82bcd	2.20cde	4.05a	2.17bcd
1	D	2.19c	3.07d	2.30d	2.13ef	2.20cde	2.52c	1.83bcd
2	D	2.00c	3.77c	2.01e	2.67cde	1.83f	4.00a	1.87bcd
3	D	3.20a	3.80c	3.06a	3.13abcd	2.60a	3.05bc	2.87a
4	D	3.16a	4.10ab	2.91ab	3.46a	2.18cde	4.13a	2.43ab

*Used to calculate N fixed in 1975, value for cutting 3 1978 used for value of cutting 3, 1975.

Table 5. (continued)

1978 Cut 1	1978 Cut 2	1978 Cut 3	1978 Total
.48	.50	1.27	2.25ef
.77	1.41	1.53	3.71cd
1.18	.74	1.34	3.26d
1.25	1.61	1.39	4.25bc
.27	.33	1.12	1.72f
.82	1.56	1.82	4.20bc
1.28	.88	1.47	3.63cd
1.25	1.45	1.85	4.55ab
.44	.54	1.48	2.47e
.75	1.87	1.69	4.31abc
1.41	.76	1.26	3.43d
1.32	1.90	1.60	4.82ab
.47	.49	1.22	2.19ef
.83	1.79	1.69	4.31abc
1.24	.98	1.57	3.79cd
1.22	1.99	1.76	4.97a

Total Block Yields			
A	B	C	D
3.37b	3.53ab	3.76a	3.81a

Treatment N	Treatment PK	Study Averages Cut 1	Cut 2	Cut 3*	Total**
1	A	.37	.39	.82	1.17
2	A	.58	1.17	1.12	2.29
3	A	1.82	.88	.98	3.19
4	A	1.83	1.20	1.11	3.59
1	B	.27	.36	.86	.99
2	B	.55	1.22	1.11	2.35
3	B	1.91	.92	1.01	3.33
4	B	1.63	1.31	1.36	3.61
1	C	.36	.43	.89	1.23
2	C	.55	1.30	1.26	2.48
3	C	2.01	.89	.94	3.36
4	C	1.84	1.37	1.21	3.81
1	D	.36	.40	.75	1.13
2	D	.58	1.28	1.31	2.50
3	D	1.94	1.17	1.07	3.49
4	D	1.82	1.49	1.27	3.94

Total Yield Averages by Treatments			
1	2	3	4
1.13	2.41	3.34	3.74

Averages of 1976, 77, 78* Cut 1	Cut 2
2.29	2.60
1.95	3.36
2.72	3.33
2.70	3.86
2.24	2.43
2.02	3.56
2.89	3.58
2.77	3.70
2.20	2.58
1.98	3.34
2.79	3.41
2.62	3.66
2.23	2.57
1.95	3.48
2.95	3.33
2.75	3.89

The quantity of N fixed by Victoria alfalfa and removed in its forage was calculated from making the following assumptions:

1. The alfalfa-reed canarygrass mixture would have the same amount soil N at its disposal as the reed canarygrass of treatment 1, i.e. 46 lbs/acre annually.
2. The reed canarygrass in the alfalfa-reed canarygrass mixture would perform equally well from the N fixed by the alfalfa as from the 50 lbs N of treatment 2.
3. The 50 lbs N of treatment 2 is recovered in the forage of treatment 2, consequently:

N of treatment 2	133 lbs	
less N treatment 1	46 lbs	
	87 lbs	due to treatment 2
less N topdressed treatment 2	50 lbs	
	37 lbs	N from soil due to extra root growth of reed canarygrass
N of treatment 3	261 lbs	
less N treatment	46 lbs	
	215 lbs	N from legume and extra N from soil
less extra N from soil	37	
	178 lbs	N fixed by Victoria alfalfa per/A/yr

Table 7. Red Clover—Reed Canarygrass Forage Yields, T/A.

Treatment N	Treatment PK	1975 Cut 1	1975 Cut 2	1975 Cut 3	1975 Total	1976 Cut 1	1976 Cut 2	1976 Total
1	A	.70	.44	.34	1.48c	.18	.15	.33bc
2	A	.63	.30	.87	1.80c	.19	.58	.77bc
3	A	2.43	1.63	.38	4.45ab	1.46	.54	2.00a
4	A	2.67	1.64	.70	5.04ab	1.55	.92	2.47a
1	B	.50	.42	.36	1.28c	.10	.10	.20c
2	B	.40	.29	.60	1.28c	.15	.52	.66bc
3	B	2.53	1.63	.58	4.75ab	1.32	.65	1.97a
4	B	2.27	1.66	.71	4.64ab	1.08	1.03	2.11a
1	C	.50	.40	.47	1.36c	.17	.10	.27bc
2	C	.50	.33	.85	1.68c	.19	.67	.86bc
3	C	3.03	1.85	.52	5.40a	1.41	.57	1.98a
4	C	2.90	1.71	.65	5.26a	1.68	.97	2.65a
1	D	.43	.34	.27	1.05c	.11	.10	.21c
2	D	.67	.41	.77	1.85c	.21	.72	.93b
3	D	2.60	1.16	.57	4.32b	1.59	.55	2.01a
4	D	2.93	1.70	.70	5.34a	1.46	.93	2.39a

	1975 Total Block Yields				1976 Total Block Yields			
	A	B	C	D	A	B	C	D
	3.19a	2.99a	3.43a	3.14a	1.39a	1.24a	1.44a	1.38a

*Mean of 1975, 1978.

**Mean of 3 year totals.

Soil N was not measured in this study. Lyon and Bizzell (1934) in a ten-year study found alfalfa removed an annual average of 180 lbs N in the forage with 61 lbs of fixed N remaining in the soil. In their study, the alfalfa was alternated each year with a cereal (barley or rye), each crop grown each year on a pair of plots. The alfalfa was planted the spring of each year so the N was fixed by young plants.

Heichel *et al.* (1981) reports 172 lbs N was fixed by a pure stand of alfalfa the first production year. The quantity of N fixed by the alfalfa and removed in the forage was believed to be a reasonable amount to expect for alfalfa in a half-and-half cool season grass mixture under Missouri conditions, i.e. 178 lbs N/acre per yr. The quantity probably would be less under grazing management. The 50 lbs N of treatment 4 did not increase yields and resulted in an apparent loss of 27 lbs N to the soil.

Birdsfoot Trefoil-Reed Canarygrass

Forage Yields

Forage yields produced by the birdsfoot trefoil-reed canarygrass study are given in table 5.

Yields of treatment 3 were surprisingly good, averaging about one ton less than the same treatment with alfalfa (Table 3). This forage generally had a higher percentage of reed canarygrass than the alfalfa-canarygrass mixture. As with the other legumes, the

1978				Study Averages			
Cut 1	Cut 2	Cut 3	Total	Cut 1	Cut 2	Cut 3*	Total**
.45	.42	.93	1.83f	.44	.34	.64	1.21
.45	1.51	1.81	3.76bcde	.42	.80	1.34	2.11
.85	1.22	1.45	3.52de	1.58	1.13	.92	3.32
.89	1.76	1.70	4.35abc	1.70	1.44	1.23	3.95
.23	.28	.79	1.30f	.28	.27	.58	.93
.31	1.50	2.43	4.25abcd	.29	.77	1.52	2.06
.92	1.09	1.63	3.64cde	1.59	1.12	1.11	3.45
.96	1.75	1.95	4.67a	1.44	1.48	1.33	3.81
.39	.45	.73	1.57f	.35	.32	.60	1.07
.42	1.81	1.46	3.69bcde	.37	.93	1.16	2.08
.73	1.15	1.54	3.42e	1.72	1.19	1.03	3.60
.76	1.95	1.45	4.16abcde	1.78	1.54	1.05	4.02
.31	.47	1.06	1.84f	.28	.30	.67	1.03
.47	1.66	1.71	3.84bcde	.45	.93	1.24	2.21
.98	1.25	1.79	4.03abcde	1.72	.99	1.18	3.45
.88	1.99	1.63	4.49ab	1.76	1.54	1.17	4.07

Total Block Yields				Total Yields by Treatments			
A	B	C	D	1	2	3	4
3.36a	3.46a	3.21a	3.55a	1.06	2.12	3.46	3.97

yields of treatments 1 and 2 were about the same and showed the effect of the 50 lbs N of treatment 2. The 50 lbs N of treatment 4 had some effect on yields, in 1978, when rainfall was more evenly distributed during the growing season.

Nitrogen Content

The nitrogen content of the forage produced by the different N treatments are given in table 6.

These data showed the 50 lbs N of treatment 2 had an effect on the N content of the reed canarygrass forage of cutting 2, and added to the N content of the trefoil-reed canarygrass mixture of treatment 4, cutting 2.

Nitrogen Removed

The quantities of N removed by the treatments by the birdsfoot trefoil-reed canarygrass mixture during the four years of the study are given in table 9.

The apparent N fixation by birdsfoot trefoil of 115 lbs/acre per yr was determined by the same calculations as Victoria alfalfa. Heichel *et al.* (1981) reports 52 lbs N were fixed the first production year of a four-year study with a pure stand of birdsfoot trefoil. However, the rainfall for the first production year was below normal for the growing season, and one could assume greater fixation under more favorable conditions. Birdsfoot trefoil was not included in the study of Lyon and Bizzell (1934). It is believed that 115 lbs N/acre per yr fixed by birdsfoot trefoil in a cool season grass mixture would be a reasonable expectation under North Missouri conditions.

Table 8. Red Clover—Reed Canarygrass, Total Nitrogen of Forage Mixture.

Treatment		1976		1978			Averages of 1976, 1978 Values*	
N	PK	Cut 1	Cut 2	Cut 1	Cut 2	Cut 3	Cut 1	Cut 2
		%						
1	A	2.13bc	2.92c	2.13def	2.53d	1.73cd	2.13	2.73
2	A	2.03cd	3.83a	2.08ef	3.48b	1.45de	2.05	3.66
3	A	2.60a	2.91c	2.55ab	3.18c	2.30ab	2.58	3.05
4	A	2.56a	3.94a	2.33abcde	3.97a	2.07bc	2.44	3.96
1	B	2.59b	2.87c	2.16cdef	2.42d	1.42de	2.38	2.65
2	B	2.24bc	3.88a	2.17cdef	3.78a	1.02e	2.21	3.83
3	B	2.62a	3.42b	2.48abcd	3.13c	2.32ab	2.55	3.28
4	B	2.54a	3.93a	2.33abcde	3.87a	2.05bc	2.44	3.90
1	C	2.16bc	3.46b	2.02ef	2.50d	1.40de	2.09	2.98
2	C	2.13bc	3.90a	2.00ef	3.75a	1.38de	2.07	3.83
3	C	2.58a	3.48b	2.65a	3.20c	2.50ab	2.62	3.34
4	C	2.57a	3.93a	2.23bcdef	3.92a	2.60a	2.40	3.93
1	D	2.18bc	2.83c	2.15cdef	2.65d	1.65cd	2.17	2.74
2	D	1.87d	3.84a	1.92f	3.88a	1.38de	1.90	3.86
3	D	2.50a	3.52b	2.52abc	3.02c	2.35ab	2.51	3.27
4	D	2.52a	4.01a	2.35abcde	3.97a	2.30ab	2.44	3.99

*Used to calculate N fixed in 1975. Value for cutting 3, 1978 was used for value for cutting 3, 1975.

Red Clover-Reed Canarygrass

Forage Yields

The common red clover-reed canarygrass mixture produced good yields in 1975 and again in 1978 due to full stands of red clover (Table 7). The stand was reduced, in 1976, due to death of plants. Those plants remaining produced low yields due to inadequate rainfall in July and August (Table 2). Kenstar cultivar was drilled into the plots in August, but seed did not germinate until late September rains and seedlings did not survive the winter of 1976-77. An additional attempt to establish a red clover stand, in 1977, was not successful. A stand was obtained in the spring, of 1978, resulting in low yields in cutting 1, but produced good yields in cuttings 2 and 3. The forage of cutting 1 was primarily reed canarygrass. The data in tables 3 and 7 show red clover-reed canarygrass produced about 1 ton more for 1975 than the alfalfa-reed canarygrass mixture, but for 1978 the reverse was true.

The experience with getting seedlings of red clover to survive in this study indicates the need for cattlemen to have alternate methods of establishing legumes in grass pastures. Broadcasting seed in February with freezing and thawing doing the covering is one alternative. Securing a grain drill with small grass and legume seeding attachment, that can be used in March or April when the soil is firm but moist, or in mid August after a good rain, is another good alternative. Special drills for planting in sods are available. Brillion seeders are questionable because they do not cover the seed adequately under most Missouri conditions. For best results, seed should be covered ¼-½ in. in either spring or late summer sod plantings.

Nitrogen Content

The total N content of the red clover-reed canarygrass forage mixtures at different cuttings are given in table 8.

The data for cutting 1 showed red clover had a lower N content than alfalfa in treatments 3 and 4 (Tables 3 and 7). The data for cutting 2 also showed the effect of the 50 lbs N of treatment 4 on the N content of the forage produced by this treatment.

Nitrogen Removed

The calculated amounts of N removed in the forage of the red clover-reed canarygrass portion in this study are given in table 9.

The average differences between N treatments 1 and 2 indicated the 50 lbs N of treatment 2 were recovered by the reed canarygrass. The differences between treatments 3 and 4 indicated that the red clover-canarygrass mixture of treatment 4 recovered the 50 lbs of N of treatment 4. This contrasted with the alfalfa-reed canarygrass results that indicated only 27 lbs of the 50 lbs N applied were recovered by the alfalfa-reed canarygrass mixture getting treatment 4.

The N fixed by red clover during three years of the study were calculated the same way as alfalfa (the quantity was 115 lbs/acre per yr). The work of Lyon and Bizzell (1934) reported 87 lbs/acre were removed by red clover forage the seeding year. Heichel *et al.* (1981) reported a pure stand of red clover fixed 74 lbs N the first production year. Again, the first production year experienced subnormal rainfall conditions. As with alfalfa and birdsfoot trefoil, the data for N fixation in this study were the average of several years' production, three for red clover and four for alfalfa and trefoil. These data were believed to be of practical value for North Missouri conditions when these legumes were grown in approximate half-and-half legume-cool season grass mixtures.

Reed Canarygrass Yields

The average reed canarygrass yields growing alone, treatments 1 and 2, are given in table 10.

The average yield of 1.11 ton/acre was produced by mineralization of soil organic matter, treatment 1. A total of 4.44 tons of reed canarygrass hay was produced by treatment 1, removing 184 lbs N during the three years when stands of red clover-reed canarygrass were harvested.

Final Soil Test Values Under Alfalfa-Reed Canarygrass

The results of P_1 and P_2 exchangeable K and pHs tests on soil samples taken by one-inch depths to a depth of six inches are given in table 11.

Previous work by Kroth and Mattas (1974) showed the seventh depth was the same as the sixth depth so the seventh depth was not tested as an economy measure. (The results of tests for Ca, Mg, and organic matter are given in appendix table 1). Nutrient extractants were calibrated to give lbs of nutrient/acre seven ins. or 2 million lbs of soil.

Table 9. Amounts of Nitrogen Removed by Legume—Reed Canarygrass Mixtures.

Treatment N	Treatment PK	Victoria Alfalfa-Reed Canarygrass 1975	1976	1977	1978	4-Year Avg.	Birdsfoot Trefoil-Reed Canarygrass 1975	1976	1977	1978	4-Year Avg.
		lbs/A									
1	A	69	13	48	61	48	42	15	36	83	44
2	A	88	54	165	164	118	51	54	127	150	96
3	A	203	214	298	284	250	147	171	161	136	154
4	A	243	280	314	318	289	161	182	180	209	183
1	B	54	12	40	41	37	33	12	35	56	34
2	B	96	52	197	199	136	47	48	138	182	104
3	B	171	206	297	311	246	166	190	157	167	170
4	B	180	225	320	353	270	141	195	192	198	182
1	C	71	15	48	57	48	43	12	40	91	47
2	C	99	59	154	181	123	56	59	127	180	106
3	C	222	245	321	294	271	167	184	167	150	167
4	C	208	263	365	338	294	165	188	166	239	190
1	D	67	15	57	60	50	39	14	36	77	42
2	D	116	66	194	239	154	65	50	128	201	111
3	D	230	265	309	303	277	182	215	158	182	184
4	D	240	270	338	344	298	163	205	214	258	210

Victoria Alfalfa-Reed Canarygrass — Treatment Averages

N		Blocks	
1.	46	A.	176
2.	133	B.	172
3.	261	C.	184
4.	288	D.	195

Birdsfoot Trefoil-Reed Canarygrass — Treatment Averages

N		Blocks	
1.	42	A.	119
2.	104	B.	123
3.	169	C.	128
4.	191	D.	137

To get the value of a nutrient for each inch, the test result was divided by seven, i.e. the test results were concentrations/2 million lbs per acre seven in. of soil (conventional plow layer).

The array of P_1 and P_2 soil test values given in table 11 showed the results of different P_2O_5 and K_2O topdressing rates mainly in the first in., and to some extent in the second in. Values for the third in. in most instances were not different from the lower three ins. The same distribution was shown for exchangeable K. These distributions would be expected from other work reported by Kroth and Meinke (1981, Kroth and Mattas (1974, 1981).

The array of pHs values, (Table 11) showed the effect of the 3 tons/acre limestone topdressed in March, 1977, especially in the upper three ins (Table 1). These values and the high alfalfa-reed canarygrass forage yields (Table 3) indicated that alfalfa, as well as the other legumes of the study, grew well with the limestone located in the surface ins. Kroth and Mattas (1981) reported the same results with red clover growing in a tall fescue mixture.

The soil test values for P_1 and P_2 exchangeable K and pHs for the 0-3 in. depth and the alfalfa-reed canarygrass forage yields for 1978 are given in table 12.

The forage yields for block A (30 lbs P_2O_5, 100 lbs K_2O annually) were not significantly different than those from plots getting the other P K topdressed treatments.

Red Clover-Reed Canarygrass			
1975	1976	1978	3-Year Avg.
56	14	62	44
62	44	150	85
206	91	160	114
246	129	214	196
48	9	39	32
44	40	150	78
224	97	161	161
229	115	221	188
49	12	50	37
59	51	164	91
262	96	161	173
261	138	222	207
39	9	62	37
67	54	165	95
198	101	178	159
264	126	233	208

Treatment Averages

N		Blocks	
1.	38	A.	110
2.	87	B.	108
3.	152	C.	127
4.	200	D.	126

Table 11. Final Soil Test Values Victoria Alfalfa—Reed Canarygrass Renovation Study (Block, N Treatment, Depth Relationships).*

Treatment		P_1							
		Depths							
N	PK	1	2	3	4	5	6	1	2
		lbs P_2O_5/2,000,000 lbs soil							
1	A	378 c	89 ijklm	46 lm	27 m	22 m	21 m	478 efg	119 opqr
2	A	185 fg	113 hijk	28 m	24 m	21 m	19 m	250 jklm	151 nop
3	A	242 ef	55 klm	35 lm	22 m	21 m	20 m	309 ij	79 pqr
4	A	203 gf	52 klm	27 m	25 m	24 m	20 m	283 jk	88 pqr
1	B	368 c	138 ghij	48 lm	24 m	21 m	22 m	464 fg	176 mno
2	B	282 de	118 hijk	39 lm	25 m	19 m	18 m	363 hi	180 lmno
3	B	160 gh	36 lm	25 m	19 m	20 m	18 m	240 jklm	55 qr
4	B	163 gh	43 lm	23 m	17 m	19 m	20 m	253 jklm	65 qr
1	C	464 b	169 gh	65 klm	28 m	27 m	23 m	613 bc	220 klmn
2	C	474 b	118 hijk	54 klm	31 m	22 m	23 m	659 b	209 klmn
3	C	371 c	77 jklm	36 lm	26 m	27 m	24 m	459 fg	99 opqr
4	C	419 bc	88 ijklm	38 lm	24 m	27 m	31 m	536 cdef	125 opq
1	D	583 a	302 d	106 hijkl	45 lm	36 lm	41 lm	765 a	432 gh
2	D	473 b	200 fg	68 klm	45 lm	34 m	28 m	590 bcd	265 jkl
3	D	456 b	118 hijk	74 jklm	47 lm	27 m	34 m	549 cde	211 klmn
4	D	422 bc	79 jklm	46 lm	41 lm	31 m	31 m	518 def	119 opqr

*Values followed by same letter not statistically significant. Duncan's New Multiple Range Test .05 level. Not all letters given for exchangeable K and pHs values because of large numbers of letters given in the analyses.

Table 11. (continued)

Treatment		Exchangeable K							
		Depths							
N	PK	1	2	3	4	5	6	1	2
		lbs/2,000,000 lbs soil							
1	A	614 def	419	239	183	159	162	6.78 abc	6.37 def
2	A	327 klmnopq	332	193	172	161	166	6.23 fgh	6.73 abc
3	A	425 ij	209	160	156	147	150	6.80 ab	6.40 bcd
4	A	363 jklmno	190	158	145	140	145	6.57 abc	6.33 def
1	B	767 ab	547	403	280	161	202	6.98 a	6.57 abc
2	B	549 fg	380	287	208	172	174	6.77 abc	6.63 abc
3	B	531 gh	308	224	174	162	155	6.80 ab	6.00 jkl
4	B	563 efg	300	217	175	158	159	6.67 abc	6.07 jkl
1	C	546 fg	368	257	205	200	202	6.67 abc	6.60 abc
2	C	525 gh	335	250	201	183	198	6.53 bde	6.47 bcd
3	C	438 ij	259	224	223	217	201	6.80 ab	6.50 bcd
4	C	431 ij	222	181	170	166	162	6.27 efg	6.30 def
1	D	830 a	582	462	318	257	232	6.70 abc	6.57 abc
2	D	718 bc	513	355	253	210	192	6.57 abc	6.53 bcd
3	D	635 de	354	252	222	207	195	6.57 abc	6.20 ghi
4	D	660 cd	396	272	225	207	212	6.57 abc	6.47 bcd

P_2			
Depths			
3	4	5	6
— lbs/2,000,000 lbs soil —			
63 qr	38 qr	31 r	28 r
42 qr	30 r	29 r	30 r
56 qr	33 qr	32 qr	32 qr
44 qr	32 qr	30 r	29 r
63 qr	33 qr	32 qr	33 qr
56 qr	44 qr	32 qr	28 r
41 qr	28 r	30 r	30 r
36 qr	30 r	32 qr	36 qr
89 pqr	49 qr	42 qr	35 qr
69 pqr	45 qr	32 qr	35 qr
56 qr	41 qr	32 qr	32 qr
62 qr	44 qr	42 qr	45 qr
154 nop	67 pqr	54 qr	61 qr
108 opqr	67 pqr	52 qr	46 qr
108 opqr	63 qr	51 qr	53 qr
61 qr	54 qr	54 qr	53 qr

pHs			
Depths			
3	4	5	6
6.00 klm	5.37 xyz	5.03	4.90
6.43 bcd	5.80 nop	5.23	5.05
6.07 jkl	5.60 rst	5.20	4.90
6.27 fgh	5.67 qrs	5.13	5.00
6.27 fgh	5.50 stu	5.23	4.90
6.40 bcd	5.83 mno	5.40	5.13
5.80 nop	5.33 uvw	5.03	4.97
6.10 ijk	5.83 mno	5.40	5.33
6.57 abc	5.97 lmn	5.33	5.03
6.13 hij	5.53 stu	5.10	5.03
6.23 fgh	5.83 mno	5.27	4.97
6.27 fgh	5.97 lmn	5.43	5.30
6.13 hij	5.80 nop	5.40	5.23
6.27 efg	5.67 qrs	5.37	5.17
6.00 klm	5.70 qrs	5.37	5.00
6.30 efg	6.00 klm	5.73	5.17

These results indicated that 0-3 in. soil test values of 94 (P_1), 138 (P_2) lbs P_2O_5 and 237 lbs exchangeable K/2 million lbs per soil were not limiting forage yields when the 30 lbs P_2O_5 and 100 lbs K_2O were topdressed annually. The P_1, P_2 and exchangeable K soil test values of the 0-1 in. depth for block A (Table 11) indicated the values for the 0-3 in. depth were higher than necessary to produce the highest yields permitted by available soil moisture, Kroth and Mattas (1974).

The array of Mg soil test values given in appendix table 1 indicated that the Mg level had declined in the plow layer during the period of the study. This was especially noticeable in the surface two ins. The array of exchangeable K soil test values given in table 11 showed high exchangeable K values in the surface in., as well as in the second in. where 200 lbs K_2O were topdressed annually. No explanation of the lower Mg values in the surface two ins. was made in this report.

Table 10. Summary of Legume-Reed Canarygrass Forage Yields by Treatments, Compiled from Tables 3, 5, and 7.

"N" Treatment	Alfalfa-Reed Canarygrass*	Trefoil-Reed Canarygrass*	Red Clover Reed Canarygrass**	Average Treatment 1 and 2
1	1.14	1.13	1.06	1.11
2	2.54	2.41	2.12	2.36
3	4.56	3.34	3.46	--
4	4.94	3.74	3.97	--

*4 year averages.

**3 year averages.

Table 12. Victoria Alfalfa—Reed Canarygrass Final 0-3 Inch Soil Test Values and Forage yields, 1978.

N Treatment	Block	P_2O_5 (P_1)	P_2O_5 (P_2)	Exchangeable K	pHs	Yields 1978
		lbs/2,000,000 lbs soil				T/A
1	A	171de	220c	424cd	6.38cde	1.55f
2	A	111f	151d	286hi	6.53abc	3.41e
3	A	111f	148d	265hijkl	6.42abcd	4.88bc
4	A	94fg	138d	237ijklm	6.39bcde	5.55ab
1	B	185cd	234c	572b	6.60ab	1.17f
2	B	146e	200c	405cdef	6.60ab	3.88de
3	B	74g	112d	356fg	6.20e	5.33ab
4	B	76fg	118d	360efg	6.28de	5.76a
1	C	233b	308b	390cdef	6.61a	1.47f
2	C	227b	312b	370def	6.38cde	3.77de
3	C	161de	205c	307gh	6.51abc	5.19abc
4	C	182de	241c	278hij	6.28de	5.60ab
1	D	330a	450a	624a	6.47abcd	1.62f
2	D	247b	321b	529b	6.46abcd	4.48cd
3	D	216bc	289b	414cde	6.26de	5.19abc
4	D	182cde	232c	442c	6.44abcd	5.67a

Part II

Effective Nitrogen Fixation by Birdsfoot Trefoil Growing with Tall Fescue

The results of Kroth *et al.* (1977) showed the benefits of forage management and nitrogen fertilizer on forage quality and seed production of Kentucky 31 tall fescue. Interest in the nitrogen fixing ability of legumes as an aid to fescue seed production and forage quality caused the establishment of this study at the Southwest Center, Mount Vernon, MO.

Procedure

A good stand of Dawn birdsfoot trefoil established, in 1968, for a fertility experiment was used for the study. The soil was a Lebanon silt loam (typic fragiudalf, fine, mixed, mesic). Kentucky 31 tall fescue at 15 lbs/acre was planted into the trefoil with a grain drill on 2 October 1972. During the 1973 season, the area was managed to favor the fescue. Twelve P K blocks were delineated to include three N blocks. The P K blocks to be topdressed annually in March were as follows:

Block A	30 lbs P_2O_5 + 100 lbs K_2O
Block B	30 lbs P_2O_5 + 200 lbs K_2O
Block C	60 lbs P_2O_5 + 100 lbs K_2O
Block D	60 lbs P_2O_5 + 200 lbs K_2O

The N treatments on each block were:

1. tall fescue alone
2. tall fescue + birdsfoot trefoil
3. tall fescue + birdsfoot trefoil + 50 lbs N in March.

The trefoil in the treatment 1 plots was eliminated by spraying with 2 4-D. Because hard trefoil seed had accumulated in this soil, these plots required additional spraying in following seasons. These N plots were 8′ x 50′ separated by three-foot borders. The soil of these plots was sampled 0-7 ins. on 27 March 1974 (Table 13). The first N P K treatments were applied 2 April 1974 with forage and seed yield data taken in 1982.

The forage was harvested by a five-foot flail-type forage harvester and oversized burlap bags. Fescue seed was harvested with a five-foot grain binder with canvasses removed, the seed of each plot caught on a canvas on the binder platform and transferred to a large burlap bag for drying in a greenhouse. The seed was later threshed by an Almaco[1] plot thresher. The first forage harvest was made immediately after seed harvest, the second week of June. Other forage was harvested the third week of July, 1976, 1977, and in November all five years of the study.

[1]Specialized Agricultural Research Equipment, 222 Duff Ave., Ames, Iowa 50010.

The forage moisture samples taken for yield determinations were ground and kept for total N evaluation. Evaluations were not made on all cuttings. Final soil samples from each N plot were taken by one-in. depths to a depth of five ins. by the method described in the spring, of 1979. The last forage yield was taken in early December, 1978.

Rainfall for the study period is given in table 14.

Table 13. Soil Test Values Birdsfoot Trefoil—Tall Fescue Forage and Seed Production Area 1973.

Depth Inches	pHs*	Neutralizable Acidity me/100 g	OM %	P_2O_5** P_1	P_2	K***	Ca	Mg	CEC me/100 g
				– lbs/2,000,000 lbs soil –					
0-7	5.9	1.8	2.3	46	85	98	2500	360	9.5

*Measured in 1:1 soil 0.01 M $CaCl_2$ suspension.

**P_1, P_2 indicates Bray's weak and strong extractants respectively.

***Exchangeable K determined by ammonium acetate extraction.

Results and Discussion

Forage and Seed Yields

Forage and tall fescue seed yields are given in table 15.

The forage yield data shows no significant total yield differences occur between treatments 2 and 3. The 50 lbs N applied in March, treatment 3, stimulates the growth of tall fescue resulting in higher fescue seed yields, but the 5-year average forage yields are the same; 2.56 vs 2.49 tons/acre for treatments 2 and 3, respectively. However, the 50 lbs N applied in March increases fescue seed yields by a five-year average of 161 lbs/acre.

Nitrogen Content

The N content of trefoil-fescue forage is given in table 16.

The N content of the trefoil-fescue forage of treatment 2 is higher than treatment 3 resulting in a greater N removal in this forage. The forage produced by treatments 2 and 3 after fescue seed harvest would make nutritious grazing in addition to the seed produced by the fescue in the mixture.

Nitrogen Removal

The amount of nitrogen removed by the trefoil-fescue forage are given in table 17.

These data show the effects of 50 lbs N on tall fescue growth results in lower trefoil growth, and consequently less N fixed, treatment 2 vs treatment 3. The N fixed by birdsfoot trefoil in a mixture with tall fescue is the difference between treatment 2 and treatment 1, or 45 lbs/acre per yr. The assumption is made that increased root growth of tall fescue by N fixation of trefoil is negliable in this fragipan soil, and the difference between treatment 2 and 1 is a valid method to estimate the amount of N fixed by trefoil under South Missouri conditions. Applying the 50 lbs N in March to produce fescue seed reduces the quantity of N fixed to 28 lbs/acre per yr; the difference between treatment 3 and treatment 1.

The N removed by fescue alone (treatment 1, Table 17) is 37 lbs/acr per yr. The N removed by reed canarygrass (Part I Table 9) is 42 lbs/acre per yr. The organic matter is 3.3% where the reed canarygrass grows compared to 2.3% for soil producing the tall fescue. It is apparent that the cooler, wetter soil of the North Missouri has a lower rate of soil organic matter mineralization in comparison to the rate of decomposition in the Southwest Missouri soil, and only 5 lbs N more from the much larger quantity of organic matter in the Lagonda soil.

The estimated quantity of N fixed by birdsfoot trefoil growing with tall fescue in this study is 45 lbs/acre per yr. This is 70 lbs less than the estimated quantity of N fixed by birdsfoot trefoil when growing with reed canarygrass (Table 9). However, it is only 7 lbs less than the quantity fixed the first production year reported by Heichel *et al.* (1981).

The pHs of the Lebanon silt loam concerns the relation to N fixation by birdsfoot trefoil. The pHs of this soil at the beginning of the study is 5.9. The final pHs values of the 0-1 and 1-2 in. depths are 5.11 and 5.12, respectively. The average for the 0-5 in. depth sample is 5.45. Beuselinck[1] indicates a pH (water) of 6.3 as an optimum value for birdsfoot trefoil. It is apparent limestone should have been topdressed at the initiation of this study. This oversight leaves the amount of N fixed by birdsfoot trefoil under Southwest Missouri conditions unfortunately a matter of conjecture.

Table 14. Precipitation Southwest Center 1972-1978.

Precipitation In Inches	1972	1973	1974	1975	1976	1977	1978	19-Year Average
January	.46	3.85	1.97	3.32	.50	1.46	1.52	1.55
February	.83	1.06	1.76	3.66	.91	1.74	1.34	1.66
March	1.24	9.64	5.55	7.10	3.56	3.49	4.88	3.64
April	4.01	6.26	3.02	3.42	5.78	3.78	4.31	4.05
May	2.16	4.07	5.70	2.58	4.12	3.53	7.11	4.67
June	1.27	5.23	7.57	5.49	4.62	8.11	5.34	5.13
July	3.24	1.72	1.98	.68	5.20	2.84	3.68	2.94
August	3.96	.90	6.77	6.05	3.29	7.12	2.80	3.64
September	9.07	9.29	4.52	5.29	2.25	9.90	4.10	5.15
October	4.91	4.16	4.53	1.51	3.60	1.52	.58	3.22
November	7.91	7.86	5.07	2.92	.65	2.24	5.88	3.40
December	2.10	4.34	2.67	2.78	.71	2.41	2.48	2.51
Total Inches	41.19	58.38	51.11	44.80	35.09	48.14	44.02	41.56

[1]Personal communication from Dr. P. R. Beuselinck, USDA Research Geneticist, Department of Agronomy, University of Missouri-Columbia, Columbia, Missouri 65211.

Table 15. Tall Fescue—Birdsfoot Trefoil Forage and Seed Yields.

Treatment		1974				1975			
		Forage T/A			Seed	Forage T/A			Seed
N	PK	Cut 1	Cut 2	Total*	lbs/A	Cut 1	Cut 2	Total*	lbs/A
1	A	.56c	.53abc	1.30cd	152d	.90d	.47cd	1.36c	622bc
2	A	.78bc	.50bc	1.49bcd	205cd	.81d	.63ab	1.86b	553c
3	A	1.41a	.55abc	2.36a	324ab	1.50ab	.56abcd	2.07ab	819a
1	B	.82bc	.45c	1.51bcd	241bcd	.81d	.43cd	1.24c	594e
2	B	.85b	.64a	1.75b	202cd	1.55a	.68a	2.24a	499c
3	B	1.40a	.63a	2.45a	223cd	1.47ab	.65ab	2.12ab	819a
1	C	.56bc	.46cb	1.23d	177cd	.80d	.42d	1.22d	537c
2	C	.83bc	.52abc	1.56bcd	242bcd	1.32bc	.58abc	1.90b	538c
3	C	1.45a	.56abc	2.47a	271abc	1.45ab	.52bcd	1.96ab	722ab
1	D	.65bc	.48bc	1.39bcd	251abc	.79d	.46cd	1.24c	570c
2	D	.79bc	.58ab	1.63bc	252abc	1.44ab	.70a	2.16ab	533c
3	D	1.37a	.54abc	2.42a	340a	1.49ab	.51bcd	2.00ab	751a
Block Mean									
A		.91a	.53a	1.72a	227b	1.21ab	.55a	1.76a	664a
B		1.02a	.57a	1.90a	222b	1.28a	.59a	1.86a	637a
C		.95a	.52a	1.75a	230b	1.19b	.50a	1.69a	599a
D		.94a	.53a	1.81a	281a	1.24ab	.55a	1.80a	618a

Table 15. (continued)

Treatment		1977					1978			
		Forage T/A				Seed	Forage T/A			Seed
N	PK	Cut 1	Cut 2	Cut 3	Total*	lbs/A	Cut 1	Cut 2	Total*	lbs/A
1	A	.61d	.41c	.77cde	1.80d	270cd	2.05bc	.43bc	2.48bc	336b
2	A	1.33ab	1.16a	.99ab	3.48a	277cd	2.27abc	.47bc	2.73abc	343b
3	A	1.07bc	.68b	.84bcde	2.59bc	498ab	2.29abc	.40bc	2.69abc	522a
1	B	.55d	.36c	.71e	1.62d	247d	1.72c	.33c	2.05c	322b
2	B	1.49a	1.19a	1.08a	3.76a	303c	2.74a	.54ab	3.28a	344b
3	B	1.22abc	.97a	.95abc	3.14ab	474ab	2.50ab	.51ab	3.01ab	531a
1	C	.50d	.33c	.72de	1.56d	247d	2.10abc	.33c	2.43bc	330b
2	C	1.35ab	1.10a	.93abcd	3.38a	318c	2.61ab	.42bc	3.03ab	347b
3	C	.95c	.70b	.75cde	2.39c	467b	2.38ab	.32c	2.70abc	524a
1	D	.55d	.34c	.79bcde	1.69d	243d	2.04bc	.44bc	2.48bc	339b
2	D	1.35ab	1.19a	1.09a	3.63a	309c	2.73a	.63a	3.35a	320b
3	D	1.17bc	.69b	.81bcde	2.67bc	523a	2.68ab	.40bc	3.08ab	520a
Block Mean										
A		1.00a	.75a	.86a	2.62a	3.48a	2.20a	.43ab	2.63a	401a
B		1.09a	.84a	.91a	2.84a	3.41a	2.32a	.46a	2.78a	399a
C		.93a	.71a	.80a	2.44a	3.44a	2.36a	.36b	2.72a	400a
D		1.02a	.74a	.90a	2.67a	3.58a	2.48a	.49a	2.97a	393a

*Includes straw from seed harvest.

**Includes 1/5 of cutting 3, 1977.

1976			
Forage T/A			Seed
Cut 1	Cut 2	Total*	lbs/A
1.01b	.38a	1.51b	179c
1.61a	.61a	2.35a	195bc
1.70a	.40a	2.40a	324a
.98b	.38a	1.47a	147c
1.95a	.65a	2.76a	168c
1.84a	.36a	2.38a	363a
.79b	.43a	1.32b	161c
1.64a	.49a	2.26a	153c
1.72a	.36a	2.38a	246b
.99b	.36a	1.46b	142c
1.80a	.62a	2.58a	148c
1.70a	.41a	2.46b	325a
1.44a	.46a	2.09a	233a
1.59a	.51a	2.34a	226ab
1.38a	.43a	1.99a	187b
1.50a	.46a	2.17a	205ab

5 yr Avg. Yields			
Forage T/A			Seed
Cut 1	Cut 2	Total**	lbs/A
1.03	.56	1.69	312
1.36	.67	2.38	315
1.59	.51	2.42	517
.98	.39	1.58	266
1.72	.74	2.76	303
1.69	.62	2.62	482
.95	.39	1.55	290
1.55	.62	2.43	320
1.59	.49	2.38	446
1.00	.42	1.65	309
1.62	.74	2.67	352
1.68	.51	2.53	492
Treatment Means			Seed
Forage T/A			lbs/A
No. 1	1.62		294
No. 2	2.56		323
No. 3	2.49		484

Final Soil Test Values Under Birdsfoot Trefoil-Tall Fescue

The final soil test values by one-in. depths to a depth of five ins. are given in table 19. The 0-1 in. depths especially reflect the effect of the N treatments on forage yields which in turn relate to the P_2O_5 and exchangeable K soil test values of this surface in. Where average yields are low, as produced by treatment 1, the P_2O_5 values tend to be high. The same is true of exchangeable K test values although the range between treatments is not as high due to the greater luxury consumption capacity of tall fescue for K than for P.

Blocks A and C (Table 19) would be expected to have the lower P_2O_5 test values in the first in. than blocks B and D which receive 30 and 60 lbs P_2O_5 topdressed, respectively. Observation of data for treatments 1 and 3, block B, indicate these soil sample numbers must have been reversed at time of sampling, see 5-year average yields for these treatments (Table 15).

Comparison of yield data of table 15 with soil test data of tables 19 and 20 indicate that 30 lbs P_2O_5 and 100 lbs K_2O topdressed annually supply all the P and K necessary for the birdsfoot trefoil-tall fescue mixture under conditions of the study. The P_1 and P_2 soil test values of the 0-3 in. depths of treatments 2 and 3 block A, and treatment 2 block B

Table 16. Nitrogen Content of Tall Fescue—Birdsfoot Trefoil Forage Mixtures.

Treatment N	PK	1975 Cut 1*	1975 Cut 2	1976 Cut 2	1977 Cut 3**	Mean Cut 2 1975, 1976***
		%				
1	A	.84e	1.65cd	1.59bcde	1.69gh	1.62
2	A	1.70ab	1.77bc	1.87abc	1.63h	1.82
3	A	1.15de	1.67cd	1.19e	1.70bcd	1.43
1	B	.82e	1.59d	1.64abcde	2.04a	1.62
2	B	1.84a	1.97a	2.05a	1.88bcde	2.01
3	B	1.27d	1.87ab	1.27de	1.68gh	1.57
1	C	.78e	1.64cd	1.54cde	1.75efgh	1.59
2	C	1.66abc	1.87ab	2.03ab	2.00ab	1.95
3	C	1.39bcd	1.79bc	1.40de	1.80defg	1.60
1	D	.84e	1.57d	1.66abcd	1.95bc	1.62
2	D	1.68abc	1.75bc	1.94abc	1.85cdef	1.85
3	D	1.39bcd	1.64cd	1.25de	1.73fgh	1.45
Blocks						
A		1.23a	1.70ab	1.55a	1.74b	
B		1.31a	1.73a	1.65a	1.86a	
C		1.28a	1.77a	1.66a	1.85a	
D		1.27a	1.65b	1.62a	1.84a	

*% N used for estimating lbs N fixed cutting 1 all years.

**% N used for estimating lbs N fixed cutting 3 1977 only.

***% N used for estimating lbs N fixed cutting 2 1974, 1977, 1978.

Note: N content of tall fescue seed used to calculate N in harvested seed was 2.09%.

Table 17. Pounds Nitrogen Removed by Tall Fescue—Birdsfoot Trefoil Forage and Tall Fescue Seed.

Treatment N	Treatment PK	1974	1975	1976	1977	1978	5-Year Means
		lbs/A					
1	A	26	39	28	48	48	38
2	A	42	54	70	108	87	72
3	A	48	62	48	72	65	59
1	B	29	35	27	47	40	36
2	B	53	82	87	128	111	92
3	B	52	70	55	79	79	67
1	C	24	34	25	42	44	34
2	C	46	67	76	113	95	79
3	C	55	65	54	74	76	65
1	D	28	36	27	49	48	38
2	D	45	73	75	117	104	83
3	D	53	65	56	79	84	67

5-Year Treatment Means	
Treatment 1	37
Treatment 2	82
Treatment 3	65

Table 18. Summary of Tall Fescue—Birdsfoot Trefoil Forage and Tall Fescue Seed Yields Compiled from Table 15.

Block	Forage T/A Treatments 1	2	3	Seed lbs/A Treatments 1	2	3
A	1.69	2.38	2.42	312	315	517
B	1.58	2.76	2.62	266	303	482
C	1.55	2.43	2.38	290	320	446
D	1.65	2.67	2.53	309	352	492
Average	1.62	2.56	2.49	294	323	484

(Table 20) do not differ significantly; the averages of these three values are 71 and 87 lbs P_2O_5/2 million lbs of soil for the P_1 and P_2 extractants, respectively. The average 0-3 in. exchangeable K soil test value of treatments 2 and 3 of blocks A and C is 220 lbs/2 million lbs of soil. No increase in forage yield would be expected when P_2O_5 and K_2O are topdressed to soils having these test values for the 0-3 in. depth.

Kroth and Mattas (1974) report results of a P_2O_5-K_2O topdressing study on yields of alfalfa-orchard grass and final soil test values. The treatment of 25 lbs P_2O_5 and 100 lbs K_2O topdressed annually produced the last four years of the eight-year study a four average yield of 2.25 tons/acre with 0-3 in. P_2O_5 (P_2) and exchangeable K soil test values of 56 and 280 lbs/2 million lbs of soil, respectively. Soil water limited yields these last

Table 19. Final Soil Test Values Birdsfoot Trefoil—Tall Fescue Forage and Fescue Seed Production Study.

Treatments		P_1					P_2		
		Depths					Depths		
N	PK	1	2	3	4	5	1	2	3
		lbs/2,000,000 lbs soil							
1	A	71hij	32lmnop	21nop	15op	12p	76ijklmn	35no	29o
2	A	101fg	40klmnop	30lmnop	28lmnop	38klmnop	109efghi	55klmno	55klmno
3	A	131de	56ijkl	26lmnop	21nop	19nop	153de	67ijklmn	50lmno
1	B	82ghi	37klmnop	22nop	24mnop	20nop	87ghijklm	39lmno	39lmno
2	B	143d	64ijk	45jklmno	38klmnop	33lmnop	158d	79hijklm	58jklmn
3	B	265a	44jklmno	20nop	28lmnop	24mnop	367a	52klmno	47lmno
1	C	265a	115ef	56ijkl	35klmnop	36klmnop	307b	135def	79hijklm
2	C	188c	72hij	26lmnop	21nop	24mnop	235c	82ghijkl	49lmno
3	C	223b	83ghi	40klmnop	31lmnop	29lmnop	263c	101fghijk	61ijklmn
1	D	230b	109efg	50jklmn	48jklmn	47jklmn	270bc	122defg	77hijklm
2	D	230b	115ef	55ijklm	37klmnop	29lmnop	279bc	129defg	76hijkl
3	D	215b	95fgh	34klmnop	25lmnop	20nop	252c	107efghij	54klmno

Table 19. (continued)

Treatments		Ex K						
		Depths						
N	PK	1	2	3	4	5	1	2
		lbs/2,000,000 lbs soil						
1	A	345gh	155opqrs	133rstuv	91yz	80z	310cdef	270ijklm
2	A	335ghi	147qrstu	103wxyz	85z	79z	283fghij	263klmno
3	A	415e	281kl	198mno	151qrstu	110wxyz	303defg	273hijkl
1	B	480bc	327hij	228m	161pqrs	121stuvw	243nopqr	200st
2	B	555a	424de	367fg	299ijkl	219m	317bcde	263klmno
3	B	414e	341gh	225m	165opqr	117tuvwx	323abcd	237pqr
1	C	414e	2671	175nopq	126rstuv	104wxyz	323abcd	303defg
2	C	341gh	143qrstu	95yz	81z	77z	340ab	270ijklm
3	C	317hijk	151qrstu	103wxyz	89yz	83z	283fghij	263klmno
1	D	455cd	295jkl	214m	154pqrst	117tuvwx	233qr	197t
2	D	504b	391ef	327hij	2671	203mn	250mnopq	223rs
3	D	492b	291jkl	190mnop	143qrstu	113uvwxy	260lmnop	193t

four years of the study on the Lebanon silt loam (Typic Fragiudalf, fine, mixed, messic). The results of the same study on Gerald silt loam (Umbric Fragiudalf, fine, mixed, messic) were 3.41 tons/acre and 0-3 in. P_2O_5 (P_2) and exchangeable K soil test values of 43 and 239 lbs/2 million lbs of soil, respectively. It is apparent that the 0-3 in. P_2O_5 soil test values under the birdsfoot trefoil-tall fescue mixture are higher than necessary for optimum legume-grass forage production. The 0-3 in. exchangeable K soil test value of 220 lbs/2 million lbs of soil also is above the optimum for soils low in K containing minerals as was pointed out by Kroth and Mattas (1974) in a fertility study with warm season grasses.

4	5
29o	30o
51klmno	72ijklmn
44n	44lmno
36mno	45lmno
63ijklmn	72ijklmn
52klmno	60ijklmn
68ijklmn	63ijklmn
43lmno	48lmno
55klmno	59ijklmn
88ghijkl	73ijkl
56klmno	55klmno
46lmno	40lmno

Table 19. (continued)

Treatments		pHs				
		Depths				
N	PK	1	2	3	4	5
1	A	5.20stu	5.27qrst	5.60ijklm	5.83bcdef	5.97abc
2	A	4.97vwxy	5.13tuv	5.53klmno	5.80cdefg	5.97abc
3	A	5.43nopq	5.40opqr	5.67ghijk	5.87bcdef	6.10a
1	B	4.97vwxy	4.93wxy	5.33pqrs	5.63hijkl	5.73efghi
2	B	5.23rstu	5.33pqrs	5.57jklmn	5.87bcdef	6.00ab
3	B	5.23rstu	4.93wxy	5.27qrst	5.50lmnop	5.73efghi
1	C	5.23rstu	5.33pqrs	5.60ijklm	5.83bcdef	5.93bcd
2	C	5.20stu	5.13tuv	5.50lmnop	5.67ghijk	5.83bcdef
3	C	4.87y	5.07uvwx	5.47mnop	5.63hijkl	5.77defgh
1	D	4.83y	4.83y	5.27qrst	5.50lmnop	5.73efghi
2	D	5.10tuvw	5.13tuv	5.43nopq	5.70fghij	5.90bcde
3	D	5.07uvwx	4.90xy	5.40opqr	5.47mnop	5.77defgh
Avg.		5.11	5.12	5.47	5.69	5.87

Averages by depths for pHs only.

Mg		
Depths		
3	4	5
300defgh	313bcde	317bcde
290fghij	303defg	303defg
283fghij	300defgh	290efghi
237pqr	260lmnop	273hijkl
317abcd	313bcde	350a
280ghijk	313bcde	333abc
333abc	317bcde	323abcd
293efghi	307cdefg	307cdefg
297efghi	300defgh	300defgh
240opqr	270ijklm	267jklmn
240opqr	283fghij	280ghijk
233qr	250mnopq	263klmno

The evidence indicates that 30 lbs P_2O_5 and 100 lbs K_2O/acre per yr would be adequate for a birdsfoot trefoil-tall fescue mixture when the forage is removed as hay. When such a mixture is grazed these nutrients would be recycled and the 0-3 in. depth should be monitored to determine when additional P_2O_5 or K_2O should be topdressed. An increase in the 0-3 in. P_2O_5 and exchangeable K soil test values would indicate more P_2O_5 and K_2O fertilizer was being applied than necessary.

Table 20. Birdsfoot Trefoil—Tall Fescue Forage and Seed Production Final 0-3 Inch Soil Test Values.

Treatments N	PK	P_2O_5 P_1	P_2	Ex K	Mg	pHs	5 Year Avg. Yields* Total Forage T/A	Seed lbs
		lbs/2,000,000 lbs soil						
1	A	41f	47f	211d	293b	5.36abc	1.69	312
2	A	57ef	73def	195d	279b	5.21bcd	2.38	315
3	A	71def	90cde	298bc	287b	5.50a	2.42	517
1	B	47f	55ef	345b	227c	5.08de	1.58	266
2	B	84cde	98cd	449a	299ab	5.38ab	2.76	303
3	B	110bc	155ab	326bc	280b	5.14cde	2.62	482
1	C	145a	174a	285c	320a	5.38ab	1.55	290
2	C	95cd	122bc	193d	301ab	5.28bcd	2.43	320
3	C	115abc	142ab	190d	281b	5.13de	2.38	446
1	D	130ab	156ab	321bc	223c	4.98e	1.65	309
2	D	133ab	161ab	407a	238c	5.22bcd	2.67	352
3	D	115abc	138ab	324bc	229c	5.12de	2.53	492

*From Table 15.

Appendix Table 1. Final Soil Test Values Victoria Alfalfa—Reed Canarygrass Renovation Study (Block, N Treatment, Depth Relationships).

Treatment N	PK	Organic Matter Depths 1	2	3	4	5	6	Avg.	Ca Depths 1	2	3	4	5	6
		%							lbs/2,000,000 lbs soil					
1	A	3.13	2.83	2.90	2.73	2.80	2.83	2.87	6640	5620	5320	4620	4070	3990
2	A	3.53	3.42	2.73	3.37	3.03	3.30	3.23	5790	6310	5620	4880	4370	4300
3	A	3.47	2.67	2.43	2.53	2.80	2.63	2.76	7080	6083	5580	5150	4530	4310
4	A	3.53	2.57	2.60	2.97	2.60	2.63	2.82	6970	6190	5880	5070	4500	4350
1	B	4.17	3.67	3.10	3.27	3.50	3.40	3.52	7500	5920	5550	4650	4080	4270
2	B	4.90	3.90	3.57	4.30	3.93	3.93	4.09	7140	5770	5680	5070	4450	4260
3	B	4.80	3.90	3.43	3.40	3.77	3.93	3.87	7180	5360	5010	4530	4180	3930
4	B	3.83	3.50	3.30	3.53	3.50	3.20	3.48	6520	5330	5220	4760	4420	4620
1	C	4.27	3.63	3.77	3.67	3.33	3.70	3.73	6770	6070	6030	5300	4760	4370
2	C	4.50	3.77	3.07	3.03	2.93	2.97	3.38	6930	5830	5580	4900	4420	4200
3	C	4.30	3.13	2.83	2.70	3.17	3.57	3.28	7480	6130	5480	5300	4580	4320
4	C	4.47	3.60	3.50	3.23	3.17	3.40	3.56	6670	5800	5650	5280	4830	4400
1	D	4.17	3.53	3.30	3.23	3.43	3.40	3.51	6800	6120	5550	4950	4620	4470
2	D	4.47	3.93	3.60	3.37	3.43	3.47	3.71	6640	5983	5610	5170	4670	4300
3	D	4.12	3.70	3.40	3.20	3.07	3.13	3.44	6520	5480	5310	4830	4590	4310
4	D	4.57	3.53	3.33	3.23	3.13	2.83	3.44	6230	5750	5480	5130	4560	4380

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Mg					
Depths					
1	2	3	4	5	6
—— lbs/2,000,000 lbs soil ——					
590	680	730	720	700	760
590	610	720	740	760	810
540	660	720	770	760	790
500	670	760	760	770	820
580	670	760	730	720	850
530	640	720	770	770	800
530	670	740	750	750	760
430	590	700	720	740	770
560	660	730	710	750	790
520	610	710	710	720	750
550	670	730	790	800	770
460	570	680	720	760	750
560	680	720	720	750	770
530	660	720	750	770	790
530	610	670	700	740	730
490	600	710	760	740	740