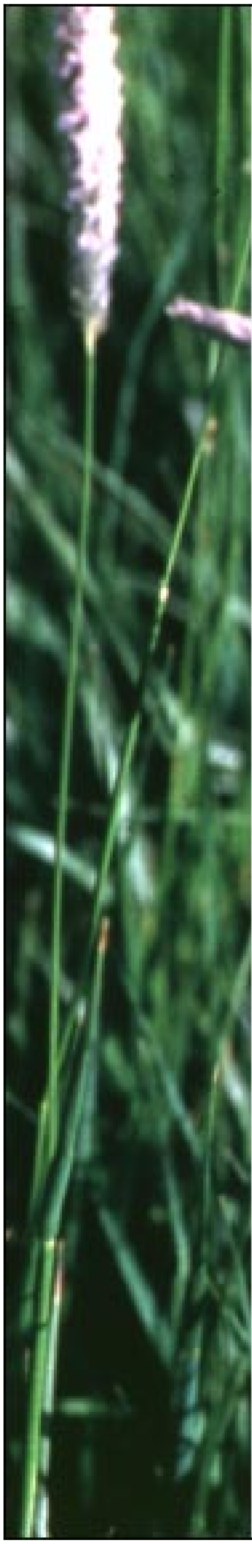

PHOSPHORUS FERTILIZATION OF GARRISON CREEPING FOXTAIL

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Abstract

Soil testing is a useful starting point in diagnosing the need for fertilizer. The Garrison creeping foxtail response to phosphorus fertilizer was similar to that previously reported for other irrigated grasses. Garrison creeping foxtail responded economically to phosphorus, in addition to nitrogen fertilizer, at one site (Kerbs) where the initial soil-test level of phosphorus was low and lime content high and also at another site (Sims) where the initial soil-test level was medium. This soil, however, was shallow. A balance of nitrogen and phosphorus was needed; the phosphorus response required nitrogen needs be met first.

Data suggest that phosphorus should be applied annually, particularly on high-lime soils. Applying phosphorus based on a soil test is an economical way to enhance hay yield on irrigated meadows containing grasses such as Garrison creeping foxtail. Although the soil test considers soil texture, lime content, and yield goal, soil depth also might be considered in determining phosphorus fertilizer needs.

One of the easiest and least expensive ways to increase meadow hay production is to apply fertilizer. Knowledge of initial soil fertility, other soil characteristics, and the relationship of fertilizer application rate and hay yield is necessary to efficiently and profitably utilize fertilizer. Irrigated cool-season grasses, including Garrison creeping foxtail (*Alopecurus arundinacea*), have shown good response to nitrogen (N) fertilizer. Averaged over 10 studies in Wyoming, unfertilized improved grass meadows yielded 1.20 tons per acre, and 80 pounds applied nitrogen per acre increased hay yield 0.80 ton per acre (4).

Several grasses, including smooth bromegrass (*Bromus inermis*), tall fescue (*Festuca arundinacea*), and a mixture of bromegrass, timothy (*Phleum pratense*), and orchardgrass (*Dactylis glomerata*), have responded positively to phosphorus (P) fertilizer on soils testing low in phosphorus (2,6,7,8,10, 11). Even on high-phosphorus soils, an increase in grass yield with phosphorus fertilizer has been shown (3). Although no studies on response to phosphate could be found, because Garrison creeping foxtail responds well to nitrogen, it might also benefit from phosphorus application.

Often, phosphorus is overlooked in a grass fertility program. Usually, phosphorus is not applied to grasses, even though approximately 32 percent of Wyoming soil tests show low and 37 percent show medium levels of available phosphorus (K. Belden, personal communication, 1999). Grasses are thought to need less phosphorus than legumes because they have a fibrous root system and are better able to extract soil phosphorus; however, like legumes, they require 8 to 12 pounds of phosphorus per ton of forage produced (6).

Forage phosphorus needs can be predicted from soil tests. Soil test recommendations for grasses, however, do not include Garrison creeping foxtail phosphorus response. The comparative phosphorus needs of Garrison creeping foxtail are not known.

Garrison creeping foxtail is well adapted to wet meadows in Wyoming.

One factor relating to phosphorus response is the nitrogen fertilizer level. Since nitrogen is usually most limiting for grass growth and phosphorus is secondary, response to phosphorus will not be expected until nitrogen fertilizer needs are met.

Garrison creeping foxtail has high yield potential with ample soil moisture and nutrients (5). Once established, it can increase hay production on wet meadows by two to threefold and improve forage quality over native species. It also tolerates moderate salinity. Garrison creeping foxtail acreage in the intermountain region has increased. This study was undertaken because there is very little information available regarding the need and response of this grass to phosphorus fertilizer.

Methods

Soil samples (0- to 6-inch depth) were collected from each plot at each study site and analyzed by the University of Wyoming Soil Testing Laboratory. The phosphorus amount was determined by the bicarbonate method (1,9).

Study 1: S&S Land Company

A 1986 study was initiated on an irrigated meadow dominated by Garrison creeping foxtail. It was located on the S&S Ranch in McFadden, Wyoming. The initial soil analysis was: pH, 7.3; organic matter, 16.1 percent; nitrate, 10.5 parts per million; phosphate, 10 parts per million; potash, 148 parts per million; and salts, 0.5 mhos per centimeter. These levels of phosphorus and potassium (K) are considered medium and high, respectively. The soil was a sandy loam (70 percent sand, 12 percent silt, and 18 percent clay). Lime content was low. The soil was shallow (less than 8 inches) and underlain with gravel. A previous study indicated that 90 to 100 pounds per acre was the most economical rate of nitrogen on this field.

Treatments included a control (nitrogen fertilizer only) and phosphorus (phosphate) at 15 and 30 pounds per acre (Table 1). Additionally, the study was designed to answer the question, “Is a phosphorus application necessary every year?” Treatments 2, 3, and 5 were intended to be alternate year applications. Ammonium nitrate at 80 pounds nitrogen per acre was applied on April 10, 1986, and at 90 pounds nitrogen per acre on April 8, 1987, and May 6, 1988. Phosphorus was applied on the same day. In 1988, the plot area was covered with snow until early May. Harvest dates were July 2, 1986; June 26, 1987; and July 6, 1988. Regrowth was measured on September 6, 1987. The experimental design was a randomized complete block and four replications were used.

Study 2: Kerbs Farm

An established meadow dominated by Garrison creeping foxtail and located on the Kerbs' Farm near Saratoga, Wyoming, was used to study response to nitrogen, phosphorus, and potassium fertilizer. The soil was a sandy loam with a pH of 7.5. Initial soil analysis was as follows: nitrates, 4.6 parts per million; phosphate, 4 parts per million; and potassium, 97 parts per million. Phosphorus and potassium levels were low and medium, respectively.

Fertilizer was applied as ammonium nitrate (34-0-0), triple superphosphate (0-46-0), and muriate of potash (0-0-62). Treatments consisted of a control (no fertilizer); nitrogen rates of 0, 50, and 100 pounds per acre applied yearly; phosphate rates of 0, 15, 30, and 45 applied yearly and a one-time rate of 135 pounds per acre applied at the beginning of the study in 1989; and potassium rates of 0 and 150 pounds per acre. Potassium was applied in 1989 only. Fertilizer was applied on April 13, 1989; April 3, 1990; and April 21, 1991. Four replications of all treatments were used.

The experimental design was a split-split plot, with nitrogen fertilizer rates as main plots, phosphorus and potassium rates as subplots. A randomized block arrangement with four replications was used.

The soil temperature on April 13, 1989, the fertilizer application date, was 46 degrees Fahrenheit at 2 inches and 40 degrees Fahrenheit at 4 inches. The field was flood irrigated for the first time on April 20. Air temperatures during May and early June 1989 were below normal, and hay yields in the area were approximately 15 to 25 percent lower than normal. In 1990 and 1991, irrigation was delayed several weeks following the fertilizer application, and there was less than optimum irrigation water applied. This resulted in lower average yields than in 1989. Plots were harvested on July 7, 1989; July 12, 1990; and July 25, 1991. Sub-samples were taken for moisture and chemical analysis. The amount of regrowth was not determined.

A 2- by 17-foot area of each plot was harvested with a flail mower to determine forage yield. Sub-samples were weighed, dried, and moisture content was determined. All yields were reported on a hay basis (12 percent moisture). Forage samples from the S&S Ranch were ground for forage analysis, and forages were analyzed at the Department of Agriculture Analytical Services Laboratory.

Return on investment in fertilizer was based on yield response of each three-year study. Cost of fertilizer and value of hay was based on five-year average prices paid and received by farmers, as reported by Wyoming Agricultural Statistics (12). Spring prices were used because fall and winter prices are sometimes lower.

Hay yields and forage quality data were analyzed based on the experimental designs used. Means were separated with Fisher's protected LSD (least significant difference) at the 5 percent level of probability.

Results

S&S Ranch Study. Hay yields increased about 1/3 ton with 15 pounds phosphate per acre per year and about 2/3 ton with 30 pounds phosphate per acre per year, when

Table 1. Yield and quality of Garrison creeping foxtail hay as influenced by phosphorus fertilization. Study 1: S & S Ranch, McFadden, WY.

Fertilizer treatment number	Amount of P_2O_5 fertilizer lb/A			Hay yield, 12% moisture[1]					1988 Forage quality[2]			1988 Soil[3] phosphate ppm
	4-10-86	4-8-87	5-6-88	7-2-86	6-26-87	7-6-88	3-year average	Regrowth 9-6-87	P content	Crude protein	TDN	
1	0	0	0	2.57	2.03	2.36	2.32	0.21	.165	10.6	53.8	10
2	0	15	0	2.51	2.72	2.31	2.51	0.32	.163	10.5	53.6	10
3	0	30	0	2.49	2.83	2.47	2.60	0.39	.164	10.3	54.1	11
4	15	15	15	2.72	2.65	2.31	2.66	0.33	.182	10.2	55.7	10
5	15	30	15	2.81	2.93	2.74	2.83	0.51	.184	10.1	56.2	11
6	30	30	30	2.95	3.33	2.84	3.04	0.58	.212	10.2	56.1	12
$LSD_{.05}$				0.16	0.22	0.20	0.19	0.16	.02	0.5	2.1	

All plots were fertilized with 80 lb N/A in 1986 and 90 lb N/A in 1987 and 1988.
[1] *Single cutting yields only; regrowth was grazed.*
[2] *Dry matter basis.*
[3] *Initial soil test level of phosphate on April 1986 was 10 ppm. Samples were taken before fertilization in 1988.*

averaged over three years (1986 to 1988, Table 1). The response was greatest in 1987. This may have been related to the fact that 90 pounds of nitrogen were applied in 1987, compared with 80 pounds in 1986, and the 1987 fertilizer application was earlier than in 1988. The response to phosphorus in 1987 was so obvious that plots receiving nitrogen and phosphorus fertilizer could be visually distinguished from those receiving nitrogen only. Regrowth in 1987 was 0.32 to 0.33 ton per acre with 15 pounds phosphate per acre, and 0.51 to 0.58 ton per acre with 30 pounds phosphate per acre (Table 1). In a previous study near Saratoga, Wyoming (treatment 5), where fertility and water were adequate, Garrison creeping foxtail regrowth following early July harvest was 0.70 to 0.90 ton per acre.

Evidently, there was no carryover of phosphorus from one year to the next at the 15 pounds per acre application rate (treatment 2 versus 1 in 1988, Table 1). At the 30 pounds per acre rate, there was a trend for carryover (treatment 3 versus 1 and 2 and treatment 5 versus 4 in 1988), although the increase was not significant with the former comparison. The other evidence for carryover was the slightly higher phospho-

Unfertilized (left) and fertilized (right) plots of Garrison creeping foxtail at the Kerbs' Farm near Saratoga. The plot on the right received 100 pounds of nitrogen and 45 pounds of phosphorus fertilizer per acre.

rus soil test level in 1988 following 30 pounds per year applications (Table 1). At the level of nitrogen applied (80 to 90 pounds per acre), 30 pounds per acre apparently provided more phosphorus than the crop needed.

Improvement in forage quality is an additional benefit of phosphorus fertilization. Mineral phosphorus content of hay increases with phosphorus fertilization (Table 1). This could reduce the need for phosphorus supplementation of livestock. Forage levels below 0.20 percent phosphorus can result in nutrient deficiency if forages comprise the bulk of the animal's diet and supplements are not used. The studies showed there was an increase in total digestible nutrients with 30 pounds phosphate per acre per year, but not with 15 pounds per acre per year, compared with no phosphorus fertilizer. Crude protein was not affected by phosphorus application.

In comparing treatments 5 and 3, the 1988 data suggest that some phosphorus fertilizer might be required each year to maintain top yields. However, more data is needed before a recommendation can be made as to the frequency of phosphorus application. On the other hand, nitrogen is required every year for best yields, and the application of phosphorus along with nitrogen in a bulk blend would be the most economical method of fertilizing. At a lower test level than with this study, the need for phosphorus fertilization each year would probably be more important.

Over the three-year period, the various phosphorus fertilizer treatments were compared for cost, hay yield, and return on the fertilizer dollar (Table 2). Greatest net increase in value, which is a measure of profitability, was $32.94 per acre per year ($98.82 for three years) at the highest phosphorus fertilization rate (30 pounds phosphate per acre per year). There were high returns (greater than $3.50 per dollar spent on fertilizer) on all levels of phosphorus application. The highest phosphorus fertilizer rate (30 pounds per acre per year) produced the greatest yield and returned $3.73 for each phosphorus fertilizer dollar. The return was slightly better than that of 15 pounds per acre per year. This study indicates the potentially high yields associated with an early, uniform application of a balanced fertilizer, avoidance of early season

Table 2. Hay yield, costs, and returns from phosphorus fertilizer. Data are summed over three years. Study 1: S & S Ranch, McFadden, WY.

A	B	C	D	E	F	G	H	I
Amount[1] of P_2O_5 applied (3-yr total)	Hay yield		Cost of increase		Value of forage increase	Net[4] increase in value	Return on fertilizer dollar	Cost of each additional ton of hay
	3-yr total	Increase over control	Fertilizer[2]	Harvest[3]				
lb/A	tons/A		$					
			(Ax0.294)	(Cx12)	(Cx70)	[F-(D+E)]	(G/D)	[(D+E)/C]
0	6.96	--	--	--	--	--	--	--
15	7.54	0.58	4.41	6.96	40.60	29.23	6.63	19.60
30	7.79	0.83	8.82	9.96	58.10	39.32	4.46	22.63
45	7.98	1.02	12.94	12.24	71.40	46.22	3.57	24.69
60	8.48	1.52	17.64	18.74	106.40	70.52	4.00	23.61
90	9.12	2.16	26.46	25.92	151.20	98.82	3.73	24.25

[1] *Treatments 1 through 6, respectively (Table 1).*
[2] *Based on cost of 0-46-0 ($270/ton), therefore, P_2O_5 at $0.294/lb. Application cost was not included, as phosphorus easily can be bulk-blended and applied with nitrogen.*
[3] *Cost of $12/ton for each additional ton of forage produced with P fertilizer.*
[4] *Value of increased forage, less increased cost of production.*

grazing, a good supply of water, and good water control.

With all levels of phosphorus fertilization, the cost of additional hay produced was less than $25 per ton. Higher fertilizer costs without a corresponding increase in hay prices reduce returns and vice-versa. For instance, increasing phosphorus costs by 20 percent and reducing the forage value of hay to $50 with the 30-pound phosphate rate reduces the return on the fertilizer dollar from $3.73 to $1.59 and increases the cost of each additional ton of hay from $24.25 to $26.70. Including regrowth yield would improve returns. These results show that even with substantial fertilizer price increases, it would still be profitable to apply phosphorus fertilizer. Good management is necessary, however, so other factors are not limiting yield.

Soil fertility specialists suggest that producers have soils tested as a first step in determining fertilizer needs. Many factors (soils, management, etc.) affect yield and, in turn, the need for fertilizer, and these factors need to be considered when tailoring a fertility program on specific fields. Based on the initial soil analysis (10 parts per million), the resulting recommendation would have been that soil phosphorus was adequate for 3 tons per acre. On this field, however, the very shallow soil underlain with gravel limited the soil's ability to supply phosphorus.

Kerbs Farm Study. Hay yield of the unfertilized meadow was only 0.89, 0.34, and 0.35 ton per acre in 1989, 1990, and 1991,

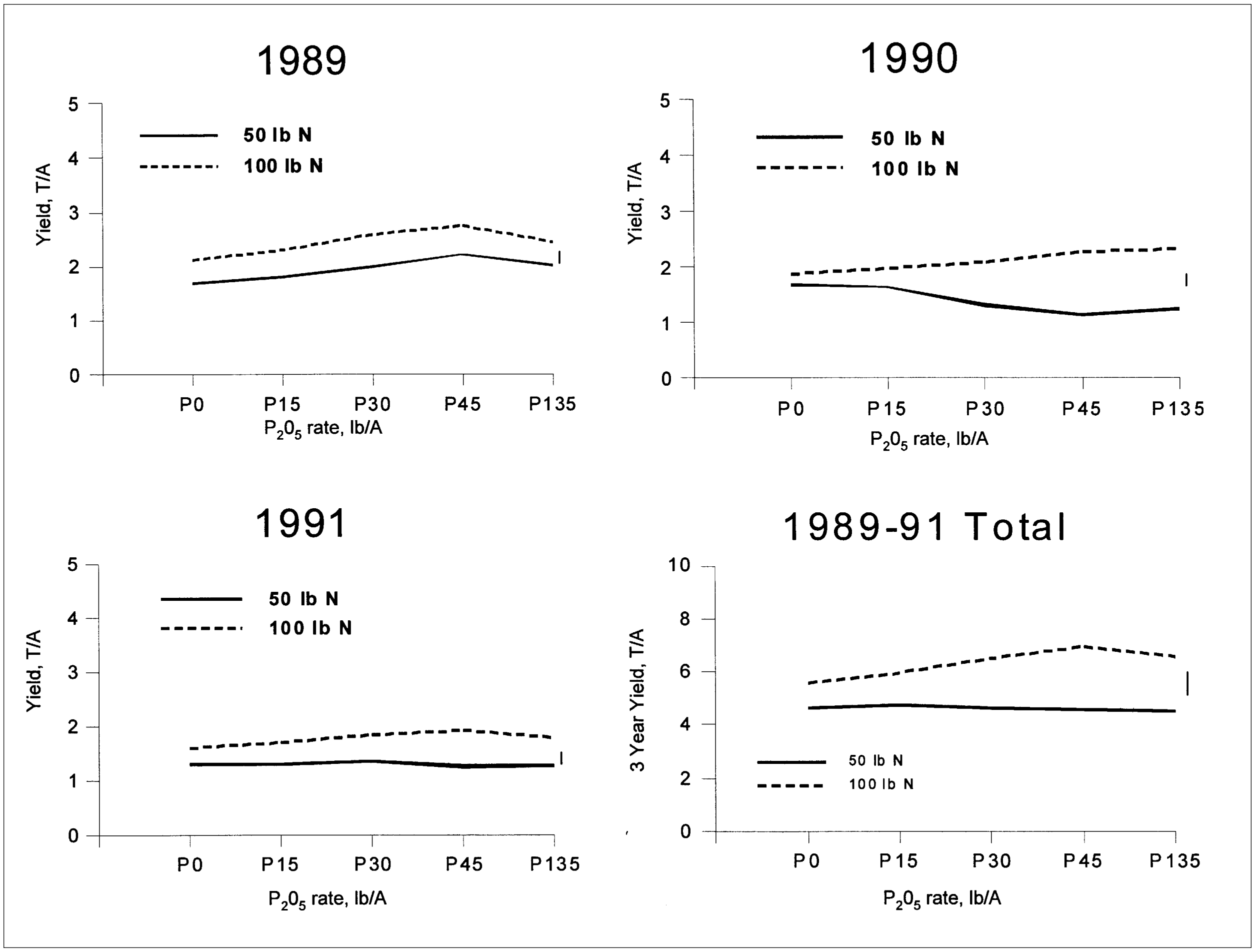

Figure 1. Yield of Garrison creeping foxtail with two nitrogen and five phosphorus fertilizer rates, 1989-91, Kerbs Farm, Saratoga, WY. The 135 lb P_20_5 per acre rate was applied in 1989 only. Vertical bars represent NxP $LSD_{.05}$.

respectively. No significant yield response to potassium was found during the three year study. Therefore, yield responses to nitrogen and phosphorus were averaged over potassium treatments.

Yield across all plots was higher in 1989 (2.19 tons per acre) than in 1990 (1.75 tons per acre) and 1991 (1.53 tons per acre), reflecting the benefit of timely application and adequate amounts of water (Fig. 1). In all three years, 100 pounds nitrogen per acre significantly increased hay yield, compared with 50 pounds nitrogen per acre; the yield increase was about ½ ton per acre in 1989 and 1991 and 0.71 ton per acre in 1990.

Averaged over nitrogen rates, phosphorus application significantly increased hay yields in 1989 (0.58 ton per acre with 45 pounds phosphate per acre). In 1990, 45 pounds phosphate per acre applied with 50 pounds nitrogen per acre reduced hay yield, while 45 pounds phosphate per acre applied with 100 pounds nitrogen per acre increased hay yield. Increasing phosphorus fertilization with 50 pounds nitrogen per acre could have created a nutrient imbalance. There was no significant response to phosphorus fertilization in 1991, the year of poorest water management.

Table 3. Hay yield (average of three years) and response to nitrogen (N), phosphorus (P), and potassium (K) fertilizer. Study 2: Kerbs Farm, Saratoga, WY, 1989-91.

Fertilizer rates[1]	Hay yield	Increased yield		
		N	P	K
(lb/A)		(tons/A)		
None	0.53			
50-0-0	1.55	1.02		
100-0-0	2.10	1.57*		
50-15-0	1.58		0.03	
50-30-0	1.54		-0.01	
50-45-0	1.53		-0.02	
50-135-0	1.51		-0.04	
100-15-0	1.99		0.14	
100-30-0	2.16		0.31	
100-45-0	2.31		0.46*	
100-135-0	2.19		0.34	
100-45-150	2.41			0.10

[1] *Fertilizer rates in pounds of N, P_2O_5, and K_2O. All were applied annually, except the 135 lb/A rate of P_2O_5, which was applied in the first year only.*
** Significant increase, $P<0.05$.*

Applying 135 pounds of phosphate at the beginning of the study (in 1989) was not as effective as applying 45 pounds of phosphate yearly. In 1989, the 135-pound phosphate rate may have caused a nutrient imbalance and reduced hay yields, compared with lower rates of phosphorus fertilizer. Less response from the high initial rate may have been due to greater fixation. The initial soil test indicated a high level of lime. The calcium in lime reacts with and reduces availability of phosphorus. Averaged over nitrogen rates, hay yields were lower, although not significantly, in two of the three years with 135 pounds phosphate applied initially, compared with 45 pounds phosphate annually.

Averaged over three years (1989 to 1991), 50 pounds nitrogen per year without phosphorus increased the three-year hay yield by about 1 ton per acre over the unfertilized control (Table 3 and Fig. 1). Over the same time period, applying 100 pounds nitrogen per acre per year increased hay yield over the unfertilized control by about 1½ tons per acre.

Table 4. Hay yield response to nitrogen and phosphorus fertilizer and costs and returns over three years. Study 2: Kerbs Farm, Saratoga, WY.

A	B	C	D	E	F	G	H	I	J
Amount[1] of fertilizer	Hay yield		Cost of increase			Value of forage increase	Net[4] increase in value	Return on fertilizer dollar	Cost of each additional ton of hay
	3-yr total	Increase over control	Fertilizer[2]	Application	Harvest[3]				
lb/A/yr	tons/A		$/A					$	$
					(Cx12)	(Cx70)	[G-(D+E+F)]	(H/D)	[(D+E+F)/C]
N_0P_0	1.59	--	--	--	--	--	--	--	--
$N_{50}P_0$	4.65	3.06	46.20	7.50	36.75	214.38	123.93	2.68	29.53
$N_{100}P_0$	5.55	3.96	92.40	7.50	47.70	278.25	130.65	1.41	37.13
$N_{50}P_{15}$	4.74	3.15	59.43	7.50	37.80	220.50	115.77	1.95	33.25
$N_{50}P_{30}$	4.62	3.03	72.66	7.50	36.60	213.50	96.74	1.33	38.28
$N_{50}P_{45}$	4.59	3.00	85.89	7.50	36.00	210.00	80.61	0.94	43.13
$N_{100}P_{15}$	5.97	4.38	105.63	7.50	52.50	306.25	140.62	1.33	37.86
$N_{100}P_{30}$	6.48	4.89	118.86	7.50	58.95	343.88	158.57	1.33	37.72
$N_{100}P_{45}$	6.93	5.34	132.09	7.50	64.50	376.25	172.16	1.30	37.97
$N_{100}P_{135}$	6.57	4.98	132.09	7.50	59.70	348.25	148.96	1.13	40.06

[1] *N and P are in pounds of N and P_2O_5/acre. P_{135} rate was applied in first year only.*
[2] *Based on $0.308/lb of N and $0.294/lb of P_2O_5.*
[3] *Cost of $12 for each additional ton of forage produced with fertilizer.*
[4] *Value of increased forage, less increased cost of production.*

Hay yield response to 100 pounds nitrogen per acre was three times greater than the response to 45 pounds phosphate per acre. Averaged over three years, there was a greater response to phosphorus fertilizer with 100 pounds versus 50 pounds nitrogen per acre (Table 3). This interaction of nitrogen and phosphorus fertilizer on hay yield can be seen in Figure 1.

Even though the initial soil test indicated a medium potassium level, there was no difference in yield with an application of 150 pounds potassium per acre, even at the high levels of nitrogen and phosphate (Fig. 1).

Applying phosphorus with 50 pounds nitrogen per acre produced limited increases in yield. This indicates that nitrogen is most limiting, and the need for nitrogen must be met before there is a response to phosphorus. Best return on the dollar for phosphorus was when phosphorus was applied with 100 pounds nitrogen per acre (2.02 to 2.15 tons per acre) (Table 4).

Greatest net return for nitrogen fertilizer ($43.55 per acre per year or $130.65 for three years) was with 100 pounds nitrogen per acre (Table 4). Adding phosphorus fertilizer to the 100 pounds nitrogen per acre

Table 5. Effect of phosphorus fertilization in 1989 and 1990 on soil test phosphorus in 1991 at the Kerbs Farm.

Phosphorous (P_2O_5) rate	Year	1991 soil test level
(lb/A)		ppm
0	1989 & 1990	2.67
15	1989 & 1990	3.00
30	1989 & 1990	3.33
45	1989 & 1990	3.67
135	1989 only	3.76

Individual plots were sampled in the spring of 1991. Each mean is the average of 16 plots.

rate increased profitability; the best return was with 100 pounds nitrogen and 45 pounds phosphate per acre per year ($57.39 per acre per year). Best return on fertilizer dollars spent was with 50 pounds nitrogen per acre ($2.68 return on the fertilizer dollar). However, returns were $1.30 to $1.33 for 15 to 45 pounds phosphorus per acre in combination with 100 pounds nitrogen per acre. Even better returns might have resulted, particularly in 1990 and 1991, if irrigation had been more timely and water more abundant. Also, there might have been an economic return from potassium fertilization under these conditions. Single harvest hay yields of 3 tons per acre have been obtained from stands similar to the Garrison creeping foxtail in this study on similar soils in the region. Cost of additional forage was generally $40 per ton or less, even with the highest fertilizer rates.

Phosphorus fertilization of 45 pounds phosphate per acre yearly was needed to maintain the soil test phosphorus level, which was 3.5 parts per million at the start of the study (Table 5). It is obvious that improvement in soil fertility with this high-lime soil is very slow. High-lime soils have great buffering capacity. Change in soil-test phosphorus often does not result, even with high phosphorus fertilizer rates. But response to applied phosphorus usually is good, as shown in this study, and residual effects of phosphorus can be observed for years, even if the soil test does not change.

The most effective fertilizer rate, 100 pounds nitrogen per acre and 45 pounds phosphate per acre averaged over three years, produced 2.3 tons hay per acre. Based on initial soil analysis, 45 pounds phosphate per acre would have been recommended for this yield level, verifying the validity of soil testing for phosphorus need determination.

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