West Virginia University
Extension Service

Forage Fertilization Based on Yield and Management Goals

Edward B. Rayburn, *Extension Specialist*
WVU Extension Service, Agriculture and Natural Resources
March 2008[1]

Fertilizer recommendations from a soil testing laboratory are based on the analysis of a soil sample and an expected crop yield listed on the soil test form. Sometimes it is desirable to know the fertilizer needs of the crop if the yield is different from that used by the computer. Also, the economics of fertilizer use changes as the cost of fertilizers change relative to the value of the crop. The work sheet provided with this fact sheet, outlines the calculations needed to determine the fertilization requirement of a forage crop at a specific yield level.

Expected Yield

Before a site specific fertilizer recommendation can be made, it is necessary to know the yield which can be achieved from the field. Crop yield will depend on the crop, soil type, crop management, and weather during the growing season. An estimate of a soil's potential yield is provided in the county soil survey. Average yields under two management levels are often published. Use the yield level for good management. Table 1 shows the estimated yield under good management for selected West Virginia soils. Yield levels such as these are based on research and experience in the area and are a reliable first estimate. However, with improved plant varieties and management it is possible to exceed these published levels by 25% or more. Yield records for the farm give more accurate information than general area-wide yield estimates.

Yield and Cost/Ton of Hay

Increased hay yields reduce the total cost per ton of hay produced when machinery, fertilizer, and labor charges are considered (Fig. 1). The way to minimize the cost of hay production is to manage for reasonably high yields, relative to the yield potential of the soil, and reduce

[1] Programs and activities offered by the West Virginia University Extension Service are available to all persons without regard to race, color, sex, disability, religion, age or national origin. Issued in furtherance of Cooperative Extension Work, Acts of Congress of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture.

Table 1. Estimated yield, under good management, for selected soils in West Virginia for clover-grass and alfalfa-grass hay and grass-legume pasture.

Soil	Slope	Grass-legume Hay		Pasture
		Clover	Alfalfa	
	%	tons/acre		AUD/acre
Berks shaly silt loam	3-8	3.0	3.5	200
Berks shaly silt loam	15-25	2.0	3.0	170
Dekalb channery loam	5-12	2.8	3.2	120
Dekalb channery loam	12-25	2.6	3.0	105
Ernest silt loam	8-15	3.0	3.5	140
Frankstown silt loam	3-10	3.5	4.5	165
Frankstown silt loam	10-20	3.2	4.3	160
Frederick cherty silt loam	3-8	3.5	4.5	165
Frederick cherty silt loam	8-15	3.2	4.3	155
Frederick cherty silt loam	15-25	3.0	4.0	150
Gilpin silt loam	8-15	3.0	3.5	200
Gilpin silt loam	15-25	2.5	3.0	170
Monongahela silt loam	3-8	3.0	3.5	200
Monongahela silt loam	8-15	2.5	3.0	170
Teas and Litz silt loams	3-8	3.0	3.5	130
Teas and Litz silt loams	8-15	2.8	3.2	120
Teas and Litz silt loams	15-25	2.4	3.0	100
Westmoreland silt loam	3-10	3.0	4.0	145
Westmoreland silt loam	10-20	3.0	3.8	135
Westmoreland silt loam	20-30	2.8	3.5	125

machinery costs by harvesting as few cuttings as needed to achieve the potential yield, without reducing forage quality below an acceptable level. The forage quality required depends on how the forage is to be used. If forage is sold on a quality basis or used for dairy cattle, having high quality is more important than if the forage is to be fed to dry beef cattle.

Crop Response to Soil Test

To determine a crop's fertilizer requirement, we need to know the crop's response to soil fertility and to added fertilizer. Forage crops respond to increasing soil test phosphorus (P) and potassium (K) up to a point called the critical value (Fig. 2). These response curves are based on research in Ohio and New York with the soil test values calibrated to the WVU soil test system (Sperow and Rayburn respectively, unpublished data) and show forage crop yields over a range of soil tests when no fertilizer is applied. Yields are expressed as a fraction of the maximum crop yield

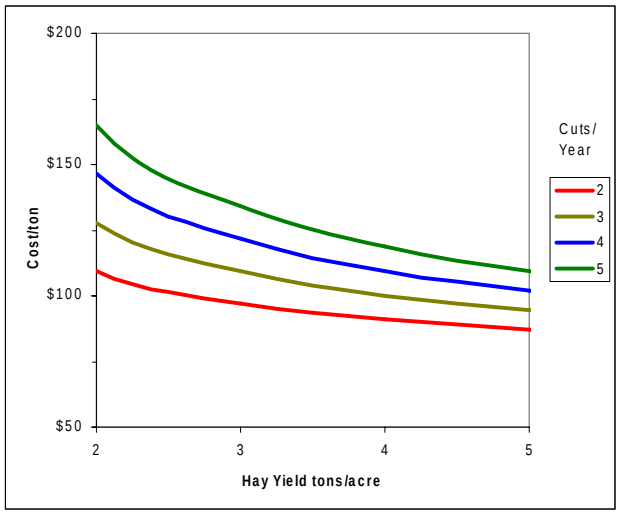


Figure 1. Harvest and fertilizer cost per ton of hay relative to the yield per acre and number of harvest cuts per year.

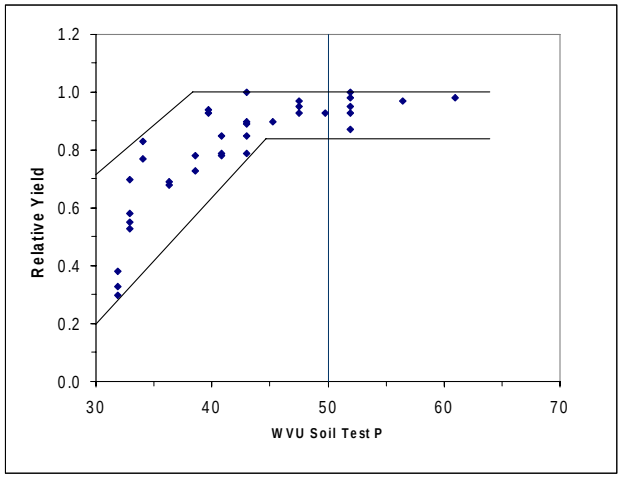
obtained with fertilization. This is called relative yield. As can be seen, if the soil test P is greater than 50, the lower end of the high P range (Fig. 2 A), or the soil test K is greater than 125, the lower end of the high K range (Fig. 2 B), the yield is not influenced by fertilization.

These are short term experiments and do not account for removal of plant nutrients by the crop. A growing crop removes plant nutrients from the soil. If no nutrients are returned to the soil the soil test will go down. Then over a period of time crop yields will go down once the soil test value goes below the critical value for any of the nutrients. The decrease in crop yields will depend on the initial soil test, the soils ability to hold reserve plant nutrients, the amount of nutrients removed in the harvested crop, the release rate of reserve nutrients, and the length of time that fertilizer is not applied. It is easy to measure soil test values and crop removal of plant nutrients and then manage return of nutrients through fertilization and manure management. First, take a good soil sample to obtain an index of the soil fertility. Second, calculate fertilizer nutrient removal by estimating crop yield and crop content of P and K by using average forage test values for the crop grown (worksheet Table 1).

Crop Response to Fertilizer

When looking at crop fertilizer response, it is helpful to express fertilizer rates as a multiple of the plant nutrients removed by the crop. If the soil test is medium or high and P is applied at 1-times the crop removal rate, crop yields are 90-100% of maximum (Fig. 3 A). If no fertilizer is applied, crop yields will drop to between 50 and 80% of the potential yield. If needed fertilizer is not applied and yields are reduced there will be an increase in the cost per ton of hay produced (Fig. 1). At medium and high soil test levels, applying more fertilizer than is removed by the crop provides no increase in yield. Soil test level will increase but will return no economic value until fertilizer inputs are reduced to draw on this reserve fertility.

A. Soil Test Phosphorus (P)



B. Soil Test Potassium (K)

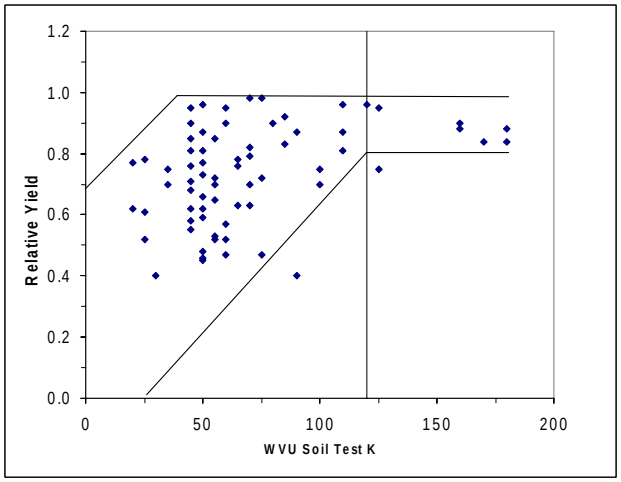


Figure 2. Effect of soil test phosphorus (A) and potassium (B) on forage crop yield without supplemental fertilizer as a fraction of the yield when adequate fertilizer is applied.

For potassium the effect is the same (Fig. 4 A). When the soil test is medium or high an application rate of 1 times crop removal, maintains crop productivity at maximum level. Again with no added K, the crop yield drops to 0.3 to 0.9 of potential over a 3 to 7-year period. The drop in yield without K fertilizer is determined by initial soil test, soil type, crop yield, and forage species.

When soil test levels are low, crop yields will be greatly reduced if fertilizers are not used. For soils testing low in P or K, when no fertilizer is applied crop yields drop to 0.1 to 0.4 of the potential yield for P (Fig. 3 B) and to 0.3 to 0.7 of potential yield for K (Fig. 4 B). For low testing soils, the cost to get near potential yield is higher than for medium and high testing soils since the fertilizer rate needed is 1.5 to 3.0-times the removal rate rather than the 1-times removal rate needed on more fertile soils. On low testing soils, fertilizing at the removal rate gives a yield between 0.40 and 1.0 for P (Fig. 3 B) and between 0.8 and 1.0 for K (Fig 4 B). The actual yield response depends on the soil's ability to fix these minerals and how low the test is at the start.

Nitrogen Fertilizer

Legumes should be used with grasses on pastures and hayfields to provide economical nitrogen (N) fixation and improved forage quality. On average well managed legumes provide hay yields equivalent to about 150 lbs N from ammonia nitrate N. Where mineral N is used in place of legumes, apply from 50 to 200 pound N per acre commercial fertilizer or available N from poultry litter or livestock manure, based on yield desired (Fig. 5). Commercial fertilizer N should be split applied at 50-60 pounds N per acre, 3 to 4 times during the growing season.

A. Medium to High Soil Test P

B. Low Soil Test P

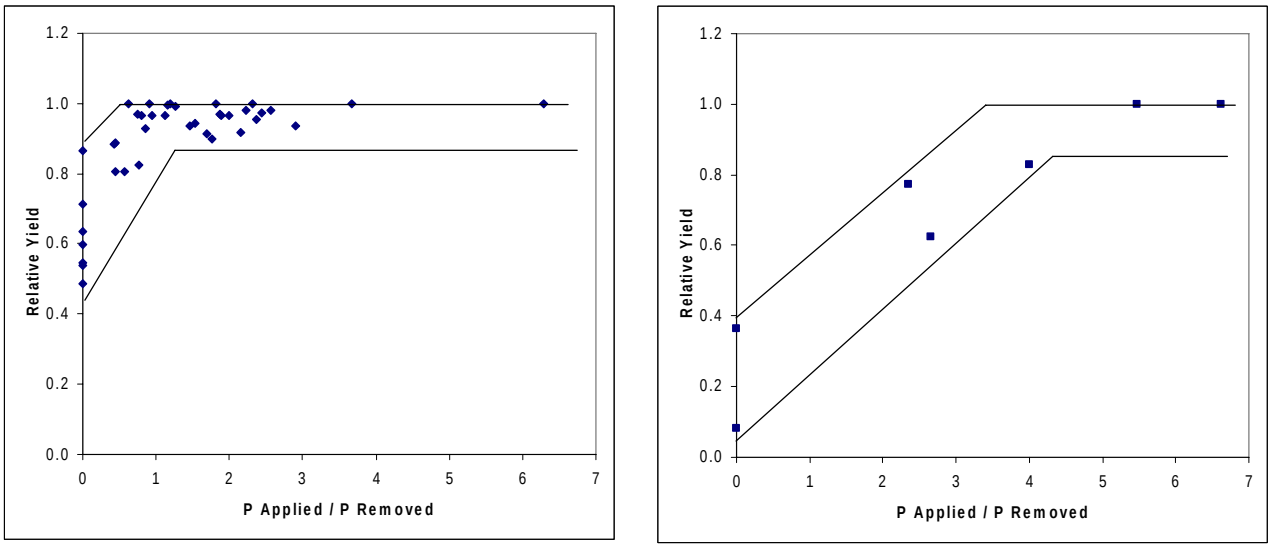


Figure 3. Forage crop response to applied fertilizer phosphorus (P) on soils having a high (A.) and low (B.) soil test P.

A. Medium to High Soil Test K

B. Low Soil Test K

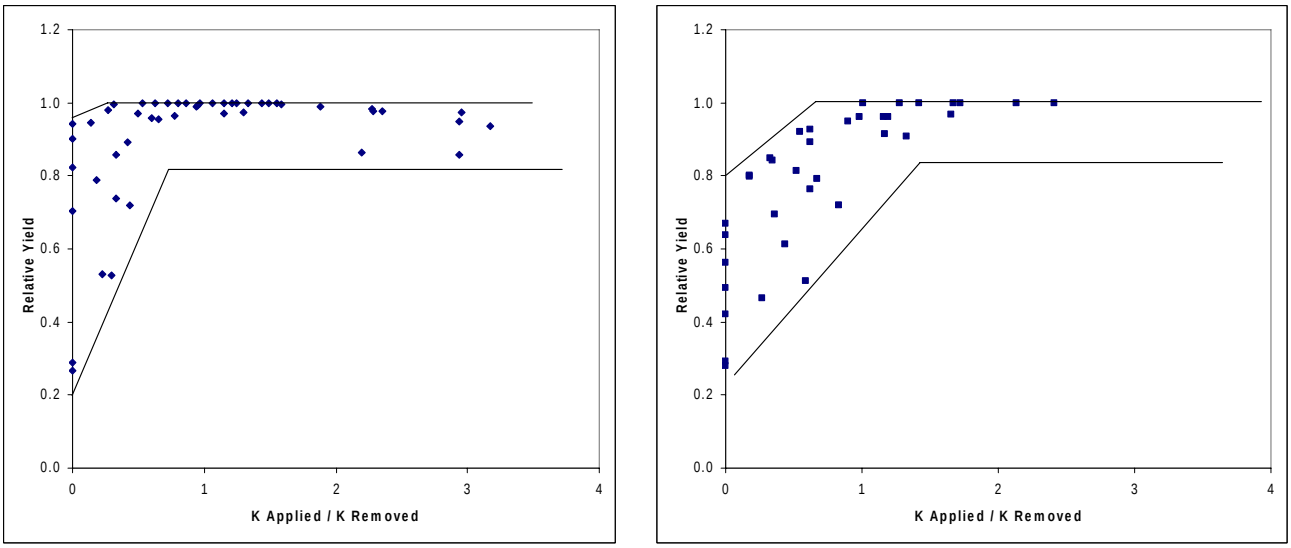


Figure 4. Forage crop response to fertilizer potassium (K) on soils having high (A) and low (B) K soil test.

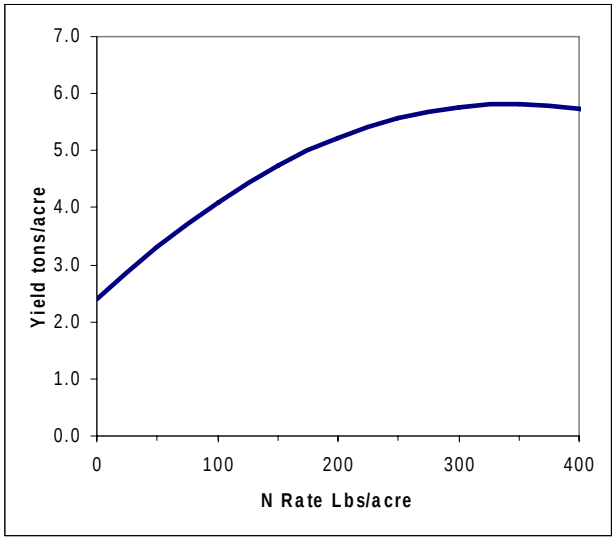


Figure 5. Orchardgrass growth response to nitrogen (N) when grown on well drained soils before accounting for harvesting losses; haylage dry yield will be 90% and dry hay yield 75% of these values after accounting for drying and harvesting losses.

Site Specific Fertilizer Requirements

Use the attached worksheet to determine the fertilizer rates needed based on the soil's expected yield, soil test, and management goals. Identify the farm, field, crop, and soil type at the top of the worksheet.

1. Soil sample each field and enter the soil test level (low, medium, high, very high) for P (P_2O_5) and K (K_2O) in the appropriate column.
2. On line 2 enter the expected crop yield in tons per acre.
3. On line 3 enter the plant nutrient removal rate/ton of forage (worksheet Table 1).
4. Multiply yield by removal rate (line 2 x line 3) and enter the result on line 4.
5. The application rate factor (line 5) is the fertilizer rate as a multiple of crop removal. This varies under different management conditions based on soil test, harvest management, and management philosophy related to economics and risk. Two application rate factors are given for each soil test level (worksheet Table 2). The lower application rate will result in the soil test moving towards the medium range. Using the higher value will move the soil test into the high range. Maintaining a high soil test will allow some insurance for improved crop growth under adverse environmental conditions such as drought, cold soils, and when diseases are present. A high soil test also allows skipping fertilization for one or two years if economic or supply conditions prevent purchase of fertilizer. Once the soil test is in either range, the cost to maintain fertility at that level is the same. Pastures require less fertilizer than harvest crops, since most of the nutrients are returned directly to the soil by the animal. Under rotational grazing the distribution of manure and urine is more uniform, so the efficiency of recycling is greater.
6. Multiply removal rate/acre by the application rate factor (line 4 x line 5) and enter the result in line 6. This is pounds of fertilizer P and K (expressed as P205 and K20) needed to meet the crop management goals.

Forage Fertilization Based on Yield and Management Goals Worksheet

Date_____/_____/_____
Farm _____ Field_____
Crop _____ Soil Series_____

Calculated Fertilizer Recommendation.

	P or P_2O_5	K or K_2O
1. Soil test level from soil test report. (L, M, H, VH)		
2. Expected yield (tons/acre)		
3. Nutrient removal rate lbs/ton (from Table 1)		
4. Nutrient removal rate/acre (multiply line 2 x line 3)		
5. Application rate factor (from Table 2)		
6. Fertilizer rate pounds/acre (multiply line 4 x line 5)		

Table 1. Nutrient removal rate in pounds per ton of material harvested at normal moisture or dry matter content.

Crop	Moisture	Dry Matter	N	P_2O_5	K_2O
	%	%		Pounds/Ton	
Pasture	0	100	60	15	60
SD[1] Pasture			16	3	18
Hay, grass	10	90	31	10	41
Hay, mixed mostly grass	10	90	35	11	42
Hay, mixed mostly legume	10	90	50	12	47
Hay, legume	10	90	61	12	52
SD[1] Hay			10	3	13

1. SD is standard deviation, +/- 1 SD gives the range within which 66% of the sample values occurred.

Table 2. Application Rate Factor. Multiply this number by the nutrient removal rate to calculate the fertilizer rate per acre. Two rate factors are given. To maintain a medium soil test or minimize cost use the smaller value. To maintain a high soil test use the higher value.

Soil Test Level	Crop[1]	
	Hay or Silage	Pasture[2]
Very High	0.0	0.0
High	0.5-1.0	0.0-0.5
Medium	1.0-1.5	0.5-1.0
Low	1.5-3.0[3]	1.5-3.0[3]

1. All fields, especially pastures, should be strategically soil sampled, tested, and fertilized.
2. Apply potash on pastures during the summer to reduce the risk of grass tetany in the spring.
3. Lower values work for potash, higher levels needed for phosphate until soil tests in the medium range.