Penn State **Extension**

Agronomy Facts 31-C

Soil Fertility Management for Forage Crops: Maintenance

Soil fertility management for forage crops is a continuous process that begins well before the forage crop is established. In the pre-establishment phase, the soil conditions are adjusted to provide optimum soil fertility when the crop is established. At the establishment phase, the fertility program should deal with any last-minute, small adjustments in soil fertility and any requirements such as a starter fertilizer for getting the plants established. If the pre-establishment soil fertility goals are met and the stand is successfully established, the goal becomes maintenance of an adequate level of fertility to meet the needs of the crop throughout the life of the stand. This soil fertility management timeline is illustrated in Figure 1.

This fact sheet will deal with the maintenance phase of soil fertility management for forages.

MAINTAINING SOIL pH

If the soil pH was near to 7.0 at seeding, there should be little need for liming at least for three years. Soil tests should be used to monitor the soil pH, and as long as it remains above 6.5, there will probably be little benefit from liming. Applying limestone to an established forage stand, where mixing is not possible, is not very effective in changing soil pH, except in the very surface layer of soil. However, if the soil pH does drop significantly below 6.5, there will usually be some benefit even from surface liming. This difficulty in changing pH in an established stand emphasizes the importance of having the pH in the optimum range before seeding.

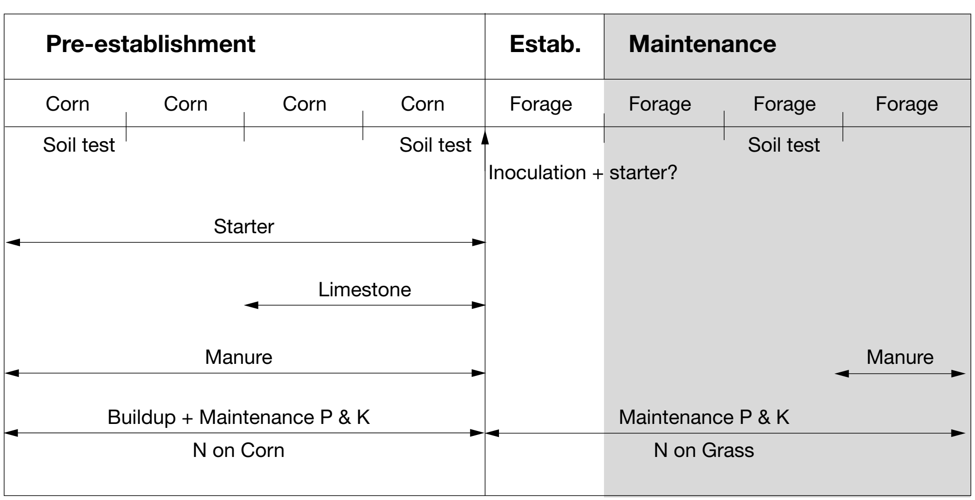
NITROGEN MANAGEMENT FOR LEGUMES

If legumes were properly inoculated at seeding and are well nodulated, they will have all of the nitrogen they need for optimum production. There is no need to apply supplementary nitrogen to them. Besides being uneconomical, adding nitrogen to a legume stand will not increase yield, and can greatly increase the competition from grass and weeds, which can shorten the life of the stand.

Even though manure is a good source of nitrogen, legumes are generally not a good crop to receive manure. The phosphorus and potassium in the manure can benefit the legume (Table 1), but the nitrogen can't be separated, and would have the potential for those problems outlined above.

There are situations, however, where it may be necessary to apply manure to a legume crop field. This often is the case on farms with a high animal density where the nutrients in manure produced on the farm meet or exceed the requirement of the corn. In this case, the emphasis of the manure management plan is to maximize the environmentally safe utilization of the manure on the farm, even if it is not the most efficient use of the manure nutrients. Spreading manure on the legumes on these farms is an example of maximizing the utilization of manure. The manure will contribute to the phosphorus and potassium needs of the legume and it will also utilize the nitrogen in the manure, even though the crop doesn't need it. The common forage legumes will remove 50 to 60 pounds of nitrogen per ton of hay harvested. Thus, these forage legumes can be an effective user of excess nitrogen on some farms. However, continuous application of manure to both corn and forages in the rotation will likely result in a buildup of

Figure 1. Soil fertility management timeline for corn-forage rotation.



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soil phosphorus into the excessive range. This increases the potential for environmental problems due to phosphorus.

If manure is spread on legumes, priority should be given to spreading it on the older stands rather than on the new stands. Also, competition must be minimized. This means that manure should be spread only on pure legume stands where weeds are controlled. Otherwise, the nonlegumes will be more competitive than the legumes and crowd the legumes out of the stand. Care must be taken to minimize any damage to the legume, such as smothering by spreading too heavily or unevenly, burning the new growth because the manure was applied after regrowth had started, physical damage to the plants, and soil compaction from manure spreading equipment.

Old legume stands (less than 30 percent legume) will probably respond to the additional nitrogen. This yield increase is mainly from the nonlegumes in the stand, and will further reduce the legumes present. But it may increase the productivity in that last year before the field is rotated out of the forage crop. This is an excellent place to apply some manure in the summer.

NITROGEN ON LEGUME/GRASS MIXTURES

A common problem is deciding whether to apply nitrogen to a legume/grass mixture. The main decision that needs to be made is whether the field is a legume field with some grass or a grass field with some legume. The economic cutoff for nitrogen fertilization is about 25 to 30 percent legume in the stand. At a greater percentage legume than this, it is probably best not to apply nitrogen. The main problem with adding nitrogen to a mixed stand is that the grass will become more competitive and further reduce the legume in the stand. However, if it is the last year that a stand will be maintained, adding nitrogen will probably be beneficial for that year. When the percentage of legume in the stand is below 25 to 30 percent, the field should be considered a grass field, and nitrogen fertilizer or manure should be applied accordingly.

NITROGEN MANAGEMENT FOR GRASSES

Grasses, unlike legumes, require regular applications of nitrogen for optimum production. The rate and timing of nitrogen application should be based on the expected

Table 1. Average total nutrient content of manure.

ANIMAL TYPE	DAILY PRODUCTION	MANURE % DRY MATTER	ANALYSIS UNITS	N	P_2O_5	K_2O	COMMENTS
Dairy cattle							
Lactating cows, liquid	13 gal/AU/day	<5	lb/1,000 gal	28	13	25	Production does not include dilution. Analysis includes dilution to approximately 5% solids.
Lactating cows, solid	111 lb/AU/day	12	lb/ton	10	4	8	No bedding included in production or analysis figures. Use these analyses for estimating nutrients deposited on pastures by dairy cows, dairy dry cattle, and dairy young cattle.
Dry cow	51 lb/AU/day		lb/ton	9	3	7	
Heifer	60 lb/AU/day		lb/ton	10	3	7	
Calf	80 lb/AU/day		lb/ton	10	3	4	
Veal	7 gal/AU/day	2	lb/1,000 gal	19	13	25	Production does not include dilution. Analysis includes dilution.
Beef cattle							
Cow and calf	90 lb/AU/day	12	lb/ton	11	7	10	No bedding included in production or analysis figures. Use these analyses for estimating nutrients deposited on pastures by a beef cow and calf, beef calves, and steers.
Calf	90 lb/AU/day	12	lb/ton	11	7	10	
Finishing cattle	65 lb/AU/day	8	lb/ton	14	5	8	
Swine							
Farrow to wean (includes sows)	11 gal/AU/day	2.5	lb/1,000 gal	18	18	11	Production includes a typical amount of in-barn dilution water but not rainfall for an outdoor storage, except for farrow to wean which also includes rainfall. Analysis includes dilution to approximately the % dry matter indicated.
Nursery	14 gal/AU/day	1.5	lb/1,000 gal	19	8	14	
Wean to finish	5.5 gal/AU/day	4	lb/1,000 gal	37	23	21	
Grow to finish	7 gal/AU/day	4	lb/1,000 gal	31	24	22	

(continued)

Table 1. Average total nutrient content of manure (continued).

ANIMAL TYPE	DAILY PRODUCTION	MANURE % DRY MATTER	ANALYSIS UNITS	N	P_2O_5	K_2O	COMMENTS
Swine, anaerobic lagoon	Figures apply only to a treatment lagoon						
Supernatant	—	0.25	lb/1,000 gal	2.9	0.6	3.2	
Sludge	—	7.6	lb/1,000 gal	25	23	63	
Sheep/Goats	40 lb/AU/day	25	lb/ton	23	8	20	No bedding included in production or analysis figures. Use these analyses for estimating nutrients deposited on pastures by sheep.
Horse	55 lb/AU/day	20	lb/ton	12	5	9	No bedding included in production or analysis figures. Use these analyses for estimating nutrients deposited on pastures by horses.
Poultry							
Layer (364 d)[1]	26 lb/AU/day	41	lb/ton	37	55	31	
Pullet (126 d)[1]	48 lb/AU/day	35	lb/ton	43	46	26	
Light broiler (44 d)[1]	22 lb/AU/day	66	lb/ton	79	62	43	Production and analysis figures include litter.
Heavy broiler (57 d)[1]	20 lb/AU/day	75	lb/ton	66	63	47	Production and analysis figures include litter.
Turkey (tom) (123 d)[1]	13 lb/AU/day	60	lb/ton	52	76	42	Production and analysis figures include litter.
Turkey (hen) (88 d)[1]	11 lb/AU/day	65	lb/ton	73	88	46	Production and analysis figures include litter.
Duck (dry)	110 lb/AU/day	27	lb/ton	21	26	15	No bedding included in production or analysis figures.
Duck (wet)	13 gal/AU/day	5	lb/1,000 gal	33	23	16	Production does not include dilution. Analysis includes dilution to approximately 5% solids.

SOURCE: *Penn State Agronomy Guide*, Table 1.2-13.
Note: When possible, have manure analyzed. Actual values may vary over 100 percent from averages in the table.
[1] Typical production days.

yield through the season. The general recommendation is 50 pounds of nitrogen per ton of expected yield per acre. The best approach to nitrogen management for grasses is to apply the nitrogen in the spring and after each cutting, based on the expected yield for the next cutting. Applying all of the nitrogen at one time is very inefficient and increases the risk that the nitrogen can be lost before the full needs of the crop are met. An example of nitrogen management program for intensively managed grass hay is illustrated in Table 2.

Nearly all the common nitrogen fertilizer sources and manure work well for fertilizing grasses. Anhydrous ammonia is an exception because it must be injected into the soil. Urea, UAN (solution nitrogen), and manure will be most effective if applied immediately before rainfall. One-half inch of rain will incorporate the nitrogen and reduce potential nitrogen volatilization losses from these materials. Rain will also reduce plant burning caused by the fertilizer or manure.

MANURE NITROGEN ON GRASSES

Grasses are especially well suited to manure application because they have a high demand for all of the major nutrients in manure (Table 1). Some of the precautions for manure use, discussed earlier for legumes, are also relevant for the grasses. Care must be taken to minimize damage to the grass. Damage can include smothering by spreading too heavily or unevenly, burns to new growth caused by waiting until regrowth has started before applying the manure, simple physical damage to the plants, and soil compaction from manure spreading equipment. Rates of manure application to grasses should be based on the annual nitrogen requirements of the grass and on balancing the phosphorus and potas-

Table 2. An example of a nitrogen program for intensively managed grass hay.

CUTTING	EXPECTED YIELD (TON/ACRE)	NITROGEN RATE (LB N/ACRE)
1 (spring)	2	100
2 (summer)	1	50
3 (fall)	1.5	75
Total	**4.5**	**225**

Table 3 Nitrogen availability factors for manure applied to grass.

PLANNED MANURE APPLICATION SEASON	RAINFALL	NITROGEN AVAILABILITY FACTOR[1] POULTRY MANURE	SWINE MANURE	OTHER MANURE
Spring or summer	Rainfall the same day	0.75	0.70	0.50
	Rainfall within 1 day	0.50	0.60	0.40
	Rainfall within 2–4 days	0.45	0.40	0.35
	Rainfall within 5–7 days	0.30	0.30	0.30
	Rainfall after 7 days or no incorporation	0.15	0.20	0.20
Early fall[2]	Rainfall within 2 days	0.50	0.45	0.40
	Rainfall within 3–7 days	0.30	0.30	0.30
	Rainfall after 7 days or no incorporation	0.15	0.20	0.20
Late fall or winter[3]	All situations	0.50	0.45	0.40

[1]Multiply this factor times the manure N content to estimate the manure N available for the planning conditions.
[2]Early fall would be when it is still warm enough for plant growth and microbial activity to continue (soil temperature >50ºF @ 2").
[3]Late Fall and winter is when it is so cold that there is no plant growth or microbial activity (soil temperature <50ºF @ 2").

sium needs of the entire crop rotation. The rate must also be low enough so that the stand is not physically damaged by the application. When calculating the manure application rate based on the nitrogen, the nitrogen availability of the manure must be considered. Table 3 gives the nitrogen availability factors for manure. The amount of available nitrogen will depend on the type of manure and how long it will be exposed on the surface before it receives ½ inch of rainfall.

For example, if your dairy manure has an analysis of 11 pounds of nitrogen per ton and you expect a ½ inch of rain within four days of application, the available nitrogen would be 3.85 pounds of nitrogen per ton of manure (11 x 0.35 = 3.85 lb/ton). Thus, to supply the requirement for 1 ton of grass hay (50 pounds of nitrogen), you would need to apply a little over 13 tons of manure per acre (50 ÷ 3.85 = 13 tons/acre). More information on manure use and calculations is provided in the *Penn State Agronomy Guide*.

PHOSPHORUS AND POTASSIUM FOR MAINTAINING ESTABLISHED FORAGES

Phosphorus and potassium management for forages should be based on a regular soil testing program. The goal is to maintain the soil test levels in the optimum to high range. Soil test recommendations are designed to achieve this goal by estimating rates of crop removal from the field and recommending an equivalent amount of nutrients be applied. Because crop removal is determined from the expected yield, it is critical that good estimates of the expected yield be included when a soil sample is submitted. Too high or too low an estimate of expected yield can result in large errors in fertilizer recommendations. Most forage crops remove between 15 and 20 pounds of phosphorus per ton of hay equivalent and between 45 and 60 pounds of potash per ton of hay equivalent. See Table 4 for the amount of phosphate and potash removal per ton of hay equivalent per acre with same common perennial forage crops.

If the soil test does not give a recommendation for phosphorus and/or potassium, this means that there is enough of these nutrients in the soil to provide the needs of the crop and still maintain the soil test in the optimum range or higher. For example, consider a field with a soil test level of 200 ppm K and an expected crop yield of 5 tons of alfalfa hay per acre. This crop will remove approximately 250 pounds of K_2O per acre. When the crop has removed this amount of potash, this would leave 250 pounds of K_2O per acre in the soil. This is above the optimum soil test level of 100 ppm K in a typical Pennsylvania soil. Thus, the potash recommendation on this field would be zero. The details for these calculations are given in ST-4 "Interpreting Soil Tests for Agronomic Crops," which is sent out with each soil test run by the Penn State Soil Testing Laboratory and in the *Penn State Agronomy Guide*.

Table 4. Crop removal of phosphorus and potassium for common perennial forage crops.

CROP	P_2O_5	K_2O
	(LB/TON HAY EQUIVALENT/ACRE)	
Alfalfa	15	50
Birdsfoot trefoil	15	40
Red clover	15	40
Cool-season grass	15	50

The timing of phosphorus and potassium applications for forages depends on the situation. When the soil test levels are in the optimum range and the recommendations are low, the timing of fertilizer application is not critical. It can be applied after one of the cuttings or in the fall. There will be no advantage to splitting the fertilizer application in this situation. These low recommendations on an optimum testing soil are only to replace what the crop will remove so that the test level is still in the optimum range going into the following season. When high rates of fertilizer are recommended, there may be an advantage to splitting the application, some after first cutting and the balance in the fall. Many plants will take up potassium whether they need it or not. This is called luxury consumption. If all of the fertilizer is applied at one time, the next cutting may take up more than it needs and leave the crop deficient later on. Splitting the application improves the efficiency of potassium use because there will be less luxury consumption. Also, if the soil test levels are low enough to result in a large recommendation, particularly for potassium, applying some of the fertilizer in the fall before the plants are dormant may improve winter survival.

Triple superphosphate (0-46-0), diammonium phosphate (18-46-0), monoammonium phosphate (11-55-0), and ammonium polyphosphate (10-34-0) are the more common fertilizer sources of phosphorus. Triple superphosphate is the best source for use on legumes because it does not contain nitrogen. A fertilizer based on one of the ammonium phosphates is best on grasses. All of these materials contain readily available phosphorus.

The most common source of potassium fertilizer is muriate of potash or potassium chloride (0-0-60). Muriate of potash is a readily available source of potassium. It does have a relatively high salt index, which can, at very high rates, cause some salt injury to the crop. This is another reason for splitting high rates of potassium fertilizer into several applications.

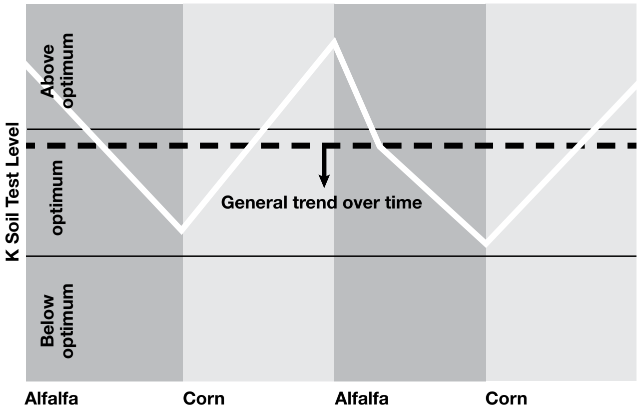
Manure is an excellent source of phosphorus and potassium (see Table 1). The phosphorus and potassium in manure can be considered equivalent to commercial phosphorus and potassium for building soil fertility. However, as was discussed before, the potential problems must be considered in applying manure directly to legumes. The best time to apply manure phosphorus and potassium to a legume is when the field is in corn. Remember that when manure is applied to corn to meet nitrogen needs of the corn, excess phosphorus and potassium will be applied. This excess phosphorus and potassium will accumulate in the soil and can be used by the forage crops later in the crop rotation (Figure 2).

SULFUR

Sulfur deficiency is not a common problem in Pennsylvania. Conditions where sulfur deficiency might occur include low organic matter soils, coarse-textured soils such as sandy soils, areas of high rainfall, and fields that do not have a history of manure application. Acid rain is a major contributor of sulfur in Pennsylvania. Current soil tests for sulfur are not very reliable. The best approach to diagnosing a sulfur problem is to use plant tissue analysis, taking care to get a proper sample at the appropriate stage of growth. For alfalfa, as an example, the top one-third of the plant should be sampled between bud and one-tenth bloom stage. If sulfur is sufficient, the sulfur analysis of this alfalfa sample should be between 0.25 and 0.50 percent (Table 5). The ratio of nitrogen to sulfur in plant tissue is a good indicator of whether sulfur is adequate or deficient. For example, a nitrogen-to-sulfur ratio greater than 11 to 1 is an indication of sulfur deficiency in alfalfa.

Elemental sulfur, gypsum, and Sul-Po-Mag are materials commonly used to correct a sulfur deficiency. Ammonium sulfate, which is 24 percent sulfur, can be used as the nitrogen source on grasses. Grass crops require around 8 to 12 pounds of sulfur per acre and legume crops 20 to 25 pounds of sulfur per acre. These requirements can be used as guides in determining the application rate when a sulfur deficiency is suspected.

Figure 2. Soil test trends in a corn-forage rotation.



BORON

Alfalfa has a high boron requirement and grasses have a low boron requirement. Other legumes are somewhere in between in their boron requirements. Alfalfa will remove about 0.05 pounds of boron per ton of hay equivalent. A soil test recommendation for boron greater than 1 ppm is considered adequate for alfalfa and greater than 0.5 is considered adequate for the other forage crops. The sufficiency level for plant analysis for boron in the top one-third of the alfalfa plant, sampled between bud and one-tenth bloom stage, is 30 ppm (Table 5). This can be compared to the sufficiency level for clover, which is 20 ppm boron in the tissue, and the grasses that require 5 to 10 ppm in the tissue. The common symptom of boron deficiency in alfalfa is "alfalfa yellows," or stunted yellow alfalfa plants. This is usually associated with drought conditions. A routine recommendation in Pennsylvania is 2 pounds of boron applied when alfalfa is topdressed with fertilizer. If a serious boron deficiency is suspected, based on soil tests or plant analysis, the rate may be increased up to 4 pounds of boron per acre. Because corn is somewhat sensitive to boron toxicity, do not apply excessive boron on fields that will be rotated to corn.

PLANT ANALYSIS FOR MANAGING ESTABLISHED FORAGES

Plant tissue analysis can be a very useful tool for managing the nutritional status of an established perennial forage crop. Plant analysis is usually a post-mortem program for annual crops. It can provide information on what was wrong with a crop but often it is too late to do anything about it. With perennial crops, such as most forages, plant analysis can provide very timely information that can be used to adjust the fertility management of the established crop. Plant analysis has several roles in improved forage management. Since a soil test only determines the nutrient status in the surface soil, a plant analysis can complement the soil test because it monitors the nutrient status throughout the rooting zone. Plant analysis can detect problems where the soil may be optimum but where some other factor, such as compaction-limited root growth, inhibits the plant's ability to take up the available nutrients. Finally, plant analysis is currently better than a soil test for determining the micronutrient status of a crop.

Table 5. Plant part to be sampled, sampling time, and sufficiency levels for plant tissue analysis for common forage crops. At least 10 subsamples of the indicated plant part(s) should be taken to make a complete sample for submission to the lab.

CROP	ALFALFA	RED CLOVER	TREFOIL	GRASSES
Plant part	Leaves from top ⅓ of plant	Leaves from top ⅓ of plant	Leaves from top ⅓ of plant	Uppermost leaves
Stage	Bud to 10% bloom	Bud to 10% bloom	Bud to 10% bloom	Before heading
ELEMENT	SUFFICIENCY RANGE[1] (%)			
Nitrogen	3.75–5.50	3.00–4.50	4.00–4.50	3.20–4.20
Phosphorus	0.25–0.70	0.28–0.60	0.28–0.36	0.23–0.35
Potassium	2.00–3.50	1.80–3.00	1.60–2.60	2.60–3.50
Calcium	1.75–3.00	2.00–2.60	1.70–2.00	0.50–0.90
Magnesium	0.30–1.00	0.21–0.60	0.40–0.60	0.10–0.30
Sulfur	0.25–0.50	0.26–0.30	—	0.20–0.25
	PPM			
Manganese	30–100	30–120	50–80	50–150
Iron	30–250	30–250	—	50–200
Boron	30–250	30–80	30–75	8–12
Copper	10–30	8–15	6–10	3–5
Zinc	20–70	18–80	30–50	20–50

[1]Sufficiency range is valid only for the crop, plant part, and sampling time indicated.

Plant analysis results for forage crops are commonly used in two ways. They are most often used to diagnose production problems. In this case, samples are collected from the problem area and from a nearby area where the problem is not evident. Comparison of the results from these two samples will usually lead to a straight-forward diagnosis of a nutritionally related problem. When plant analysis is used in this way it is very important that the samples be taken consistently. The same plant part must be sampled at the same stage of growth for the comparison to be valid. The second common use of plant analysis is to routinely monitor the nutritional status of the crop. In this type of program the nutrient levels in the plant are compared to established norms for optimum production of the crop. The sufficiency levels for plant analysis for some of the forage crops are given in Table 5. As noted above, when comparing plant analysis values to these sufficiency levels, the correct plant part must be sampled at the proper stage of growth.

SUMMARY

Once the crop is established, the fertility program will focus on maintenance of good fertility levels in the soil for the life of the forage stand. The most important part of the maintenance program is regular soil testing to determine the need for lime, phosphorus, or potassium to replace the large amount of nutrients removed in the forage. On grasses, nitrogen will also be an important part of the maintenance fertility program. Manure is best applied to corn. It can also be effectively used on grass forage, but it is not as well suited to use on legumes. Micronutrient deficiencies are rare in Pennsylvania. There may be a few situations where sulfur or especially boron may be required. Plant analysis, when properly used, is an excellent tool for improving the fertility management of perennial forage crops.

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