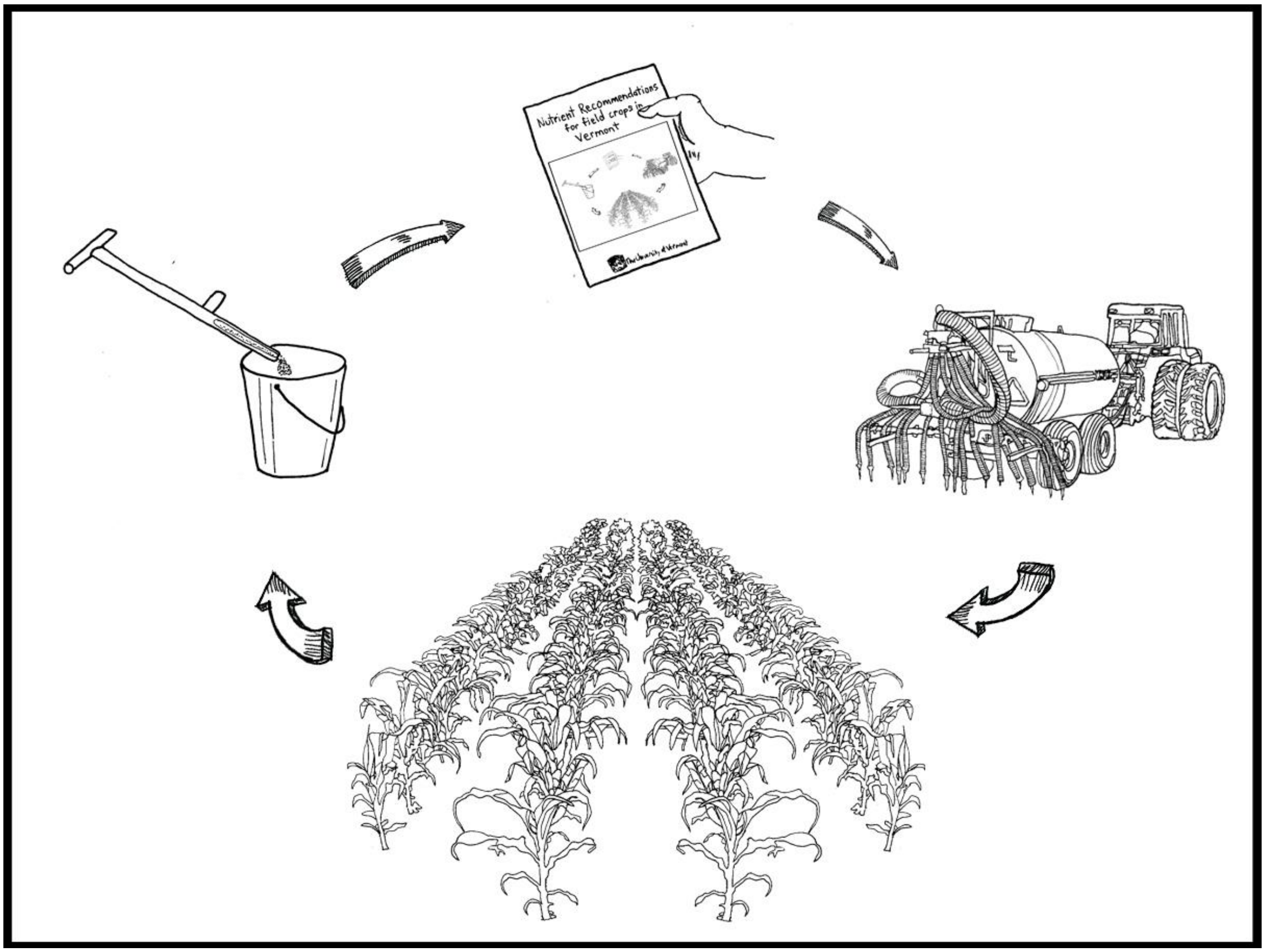
Nutrient Recommendations for Field Crops in Vermont



THE UNIVERSITY OF VERMONT EXTENSION

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This 2018 publication, of *Nutrient Recommendations for Fields Crops in Vermont* (BR 1390.2), is a revision of the 2004 publication, *Nutrient Recommendations for Field Crops in Vermont* (BR 1390).

This 2018 publication is updated to accommodate recommendations for additional crops, changes to some nutrient application recommendations, and a revised Vermont Phosphorus Index.

Nutrient Recommendations for Fields Crops in Vermont is intended to be used as a guidebook to complement nutrient recommendations for field and forage crops provided on UVM soil test reports.

This guidebook reflects the current (and past) authors' best effort to interpret a complex body of scientific research and to translate this into practical management options. Following the guidance provided in this guidebook does not assure compliance with any applicable law, rule, regulation or standard, or the achievement of particular discharge levels from agricultural land.

To find out more about state and federal nutrient and water quality regulations and programs for Vermont farms, contact the Vermont Agency of Agriculture or your local NRCS office.

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Nutrient Recommendations for Field Crops in Vermont

Introduction

Nutrient recommendations for field and forage crops based on soil testing and other soil and crop information are the basis for manure and fertilizer management which optimizes economic return while protecting water quality and the environment. This publication documents the approach and specific soil test and crop data used to generate those recommendations at the University of Vermont.

The soil testing program at the University of Vermont is an effort of the Agricultural and Environmental Testing Laboratory (AETL), which oversees laboratory analysis of the soils, and UVM Extension, which interprets and develops nutrient recommendations that are presented in the UVM Soil Test Report.

Information provided by the farmer on the soil test submission forms is combined with laboratory results to create a computerized soil test report that shows soil test results, nutrient recommendations, and other information about fertilizer application. See Appendix for a sample form and report.

There are a variety of tools available to assess nutrient needs of crops. This guidebook primarily refers to the routine soil test, as well as the pre-sidedress soil nitrate test (PSNT) for corn. For the routine soil test, the routine soil test, the University of Vermont uses the Modified Morgan's solution (1.25 *M* ammonium acetate, pH 4.8) to analyze most nutrients. Research in Vermont, New York, and other New England states has shown this extract to be a good indicator of plant availability nutrients. (For more details about laboratory methods, refer to the Appendix.)

Frequency of Soil Sampling and Time Period

Frequency of Sampling for the Routine Soil Test – We recommend soil sampling for routine nutrient analysis every one to three years and/or when crop rotation occurs (Figure 1). Situations where annual soil sampling is especially recommended include:

1) intensively managed production of high potassium (K) demanding crops (e.g., alfalfa or silage corn), particularly when these crops are on sandy soils;
2) low testing fields where severe deficiency is possible and raising soil test level is critical; and
3) following an extreme climate event such as flooding that might exacerbate nutrient leaching.

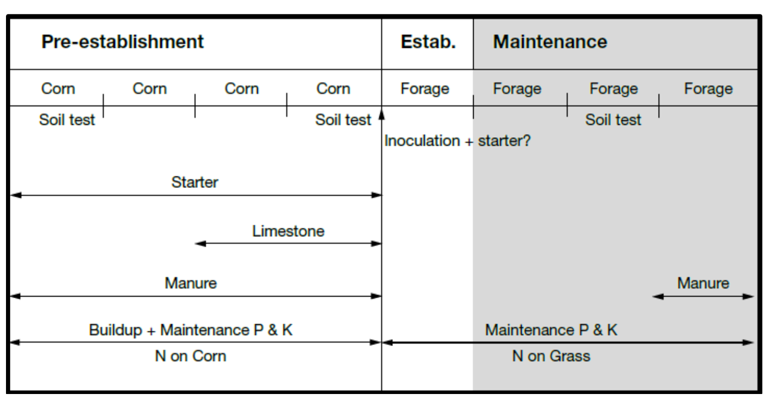


Figure 1. Example of the time of soil testing in a corn/hay crop rotation. (Source: Penn State University Extension)

Sampling in the fall after crop harvest can be more convenient from a practical perspective. This allows ample time to get the analysis back and make nutrient management and fertilizer decisions for the upcoming year.

The routine soil test laboratory analysis does not measure soil nitrogen (N), but other methods can be employed to assist with developing N recommendations for field crops. Two common methods for assessing N need for corn at sidedress time are the pre-sidedress nitrate test (PSNT) and software tool Adapt-N. Soil sampling for nitrogen is time-sensitive. For more information on the PSNT go to section *Pre-sidedress Soil Nitrate Test* on page 9. For more information on Adapt-N visit: http://blogs.cornell.edu/newadaptn/.

Interpreting Soil Test Levels

Laboratory analysis of a soil sample only has value if it can be interpreted for a meaningful purpose, such as to indicate the availability of essential elements to a crop. To aid in this effort, we place soil test results into categories that are indicative of their relative deficiency or sufficiency in terms of crop growth (Table 1). The interpretation of soil analysis may vary somewhat by crop types. For example, the levels of soil phosphorus (P) and K that define optimum for vegetable crops are higher than that for field crops.

Interpretation of the categories in terms of probability of crop response is explained in Table 2. In the UVM soil testing program, results are expressed as parts per million (ppm) of elemental P, K, magnesium (Mg), etc. (Note that milligram/kilogram—mg/kg—is equivalent to ppm.) For categories expressed in other units, see Table 20 – Vermont Soil Test Categories Expressed as Pounds Per Acre in Elemental Form in the Appendix.

Soil Test Nutrient Recommendations

Nutrient recommendations are based on soil analysis, interpretation, and estimated crop removal rates. Estimated crop removal rates are determined by the amount of nutrient needed per unit of crop growth. Refer to Table 21 – Typical Crop Nutrient Removal in the Appendix for more information on estimated nutrient removal by crop.

The objectives of the recommendations are to meet crop needs as well as to maintain or meet soil test P or K levels at an Optimum level. If soil test P or K is Low or Excessive, then recommendations are adjusted to gradually build or lower soil nutrient levels, respectively (see Table 2 for definitions).

The recommended nutrient rates given on the UVM Soil Test Report are designed to provide annual application rates, good for up to three years, unless soil sampling is done more frequently due to mitigating circumstances that necessitate more frequent sampling. Using a soil test report that is over three years old may not be as accurate since the assumptions above are designed for resampling every three years or less.

Table 1. General soil test categories used for all field and forage crops.[1]

	Low	Medium	Optimum[2]	High	Excessive
	ppm				
Available P	0.0-2.0	2.1-4.0	4.1-7.0	7.1-20.0	>20
K	0-50	51-100	101-130	131-160	>160
Mg	0-35	36-50.0	51-100.0	>100	—

[1] Soil test extractant is Modified Morgan (1.25 *M* NH_4 acetate, pH 4.8).
[2] UVM's AETL soil test reports will show greater ranges for P, K, and Mg than in the table above in order to reflect nutrient requirements for vegetable crops.

Note that the actual recommendations found on the UVM Soil Test Report are always given in “fertilizer equivalent values” that would match the fertilizer formula you find on a fertilizer bag. For example, “P_2O_5” refers to the “fertilizer equivalent,” whereas “P” refers to elemental phosphorus that you would see in the “analysis” part of the test report. The UVM Soil Test Report no longer shows nutrient credits from manure; these must be estimated by the farmer, crop consultant, or nutrient management planner. See section Nutrient Credits from Manure beginning on page 18.

Aglime

Most soils in Vermont need periodic applications of aglime to maintain pH in a range optimum for crop production. Aglime neutralizes acidity in soils and, in humid eastern climates such as Vermont, there is a tendency for most soils to become naturally acidic. In addition, ammonium-based fertilizers can acidify the soil over time.

Liming, or otherwise raising the soil pH, in an acidic soil can increase soil phosphorus plant availability. Raising the pH lowers aluminum (Al) solubility and its ability to fix phosphorus. See Figure 2.

Table 2. Interpretation of soil test categories.

Low (L)	• High probability of crop response to addition of nutrient. • Substantial amounts of additional nutrients needed to achieve optimum yields. • In the case of phosphorus, the amount of P needed will vary with the level of reactive aluminum (Al)—more P needed with high Al.
Medium (M)	• Moderate probability of crop response to addition of nutrient. • Moderate amounts of additional nutrients needed to achieve optimum yields.
Optimum (OPT)	• Most desirable soil test range on economic and environmental basis. • Low probability of crop response to addition of nutrient, but to maintain in this range for successive years, a portion of crop removal needs to be replaced. • If crop planning is done on short-term basis (e.g., one-year land rental) recommended broadcast fertilizer can be eliminated with low probability of yield reduction. However, in this case soil testing should be done annually to assure that soil test does not drop below Optimum level.
High (H)	• Higher soil test nutrient values than needed for optimizing yields of most crops. • Very low probability of crop response to addition of nutrient. • No additional nutrients needed except K for high K-demanding crops on high-yielding sites. • Low rate of starter fertilizer may be needed.
Excessive (EX)	• Soil test higher than desirable for economic and/or environmental reasons. • No fertilizer recommended. • Addition of nutrients may cause nutrient imbalance.

Maintaining an optimum pH level is important for maximizing availability of plant nutrients, for encouraging activity of beneficial soil microorganisms, and for maintaining soil conditions that will support good root growth and crop production (Figure 2). Generally, crop productivity can be optimized within a wide pH range and the average is considered the target. Crops in the region can be grown on soil with the following pH ranges: clover 6.0-6.8, soybeans 6.0-7.0, grasses 5.6-6.8, corn 5.8-7.5, alfalfa 6.2-7.4. A pH of 6.8 is recommended for barley and alfalfa or if alfalfa is to be seeded into a field within two years. A minimum pH of 6.2 is recommended for all other field crop situations. Refer to your soil test report and Table 3 to make any necessary liming adjustments to meet target pH.

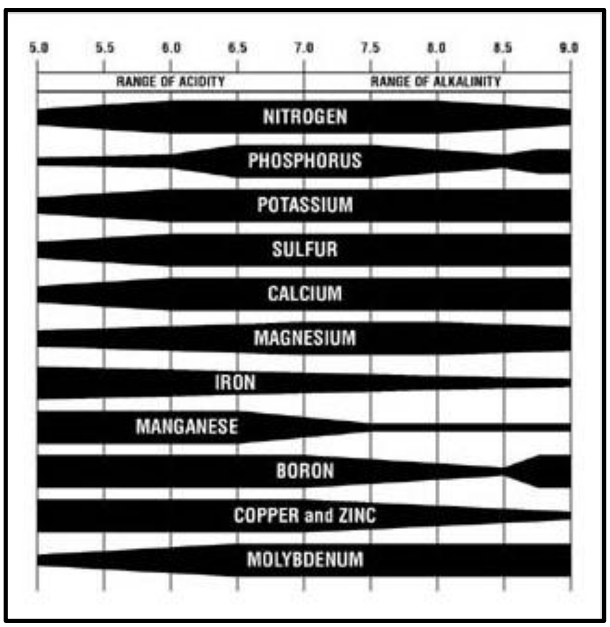


Figure 2. Relationship between pH and availability of nutrients essential for plant growth. (Source: Ohio State University Extension)

The UVM soil test aglime recommendation is based on a combination of soil pH and reactive Al soil content, and a target soil pH to meet crop needs (Table 3). The pH tells us whether or not aglime is needed. However, different soils with the same pH may require very different amounts of aglime to reach the optimum pH. The reactive Al level is an indicator of the amount of reserve soil acidity that needs to be neutralized in order to change the pH and is used to determine the application rate of lime (Table 3).

Recommendations are given in tons of aglime per acre, assuming a calcium carbonate equivalent (CCE) of 90% or higher. Most aglime sold in Vermont is within this range, but if your liming material has a CCE less than 90%, application rate should be increased accordingly. Alternative liming materials used in Vermont are wood ash and an aglime-wood ash blend (typically 80% aglime, 20% wood ash). These alternative materials usually have a CCE lower than pure aglime and application rates should be adjusted accordingly. See Appendix for the Equation to Determine Application Rate of Alternative Liming Materials.

Table 3. Aglime requirement based on soil pH, reactive Al, and target pH.

Soil pH[1]	Reactive Al[2]	Target pH	
		6.2	6.8
	ppm	tons/acre	
>6.7		0	0
6.2-6.7	0-40	0	1
	>40	0	2
5.6-6.1	0-40	1	2
	41-70	1.5	2.5
	71-100	1.5	3
	101-150	2	3.5
	151-200	2.5	4
	>200	3	5
<5.6	0-40	1.5	3
	41-70	2	3.5
	71-100	2	4
	101-150	2.5	4.5
	151-200	3	5
	201-250	3.5	5.5
	251-300	4	6
	>300	5	7
	>300	5	7

[1] Soil pH is reported as the equivalent of pH measured in water (approximately 0.6 higher than pH measured in 0.01 M $CaCl_2$).
[2] The UVM Soil Test Report refers to *reactive aluminum* as just *aluminum*.

Nitrogen

Nitrogen for Annual Crops

Most annual non-legume crops are very responsive to applications of N. However, N is not stable enough in the soil to be quantified reliably for all crops at any time of the year, and therefore, is not included in the analysis of a routine UVM soil test, even though recommendations are still given in the routine UVM Soil Test Report. There are special soil nitrate-N tests available for some crops (such as the Pre-sidedress Nitrate Test for corn) but they have to be taken at specific times during the crop's growth to be useful as a decision making tool.

Table 4 shows recommended N application rates for annual crops (without credit for manure or previous crop). Aside from the basic N recommendation found in Table 4, it is also important to estimate and account for N contributions from manure and the previous crop. If the previous crop was a perennial forage crop or other legume crop, adjust values by subtracting previous crop N credits found in Table 5. If manure has been applied in the past two years, subtract manure N credits calculated from Tables 15 to 19.

Nitrogen rates should be adjusted based on soil drainage class. The UVM Soil Test Report only gives a N recommendation for annual field crops for well-drained to moderately well drained soils (the middle column in Table 4). Soils with poor or excessive drainage require an additional 10-20 N lb/acre, as indicated in Table 4, because of the higher potential for gaseous N loss (denitrification) or nitrate leaching and/or slower N release via mineralization.

The adjustments for previous crop, applied manure, and soil drainage are attempts to make N recommendations more site-specific, but they are estimates based on average weather and soil conditions. For a more reliable recommendation for corn, take a soil sample for the Pre-sidedress Soil Nitrate Test (PSNT) when the corn is 8 to 12 inches tall to determine available nitrates and use the PSNT results for sidedress N rates when corn is 12 to 24inches tall (Table 6). Alternatively, Adapt-N can be used to make nitrogen recommendations.

Nitrogen rates for corn are also adjusted for yield level. This is a well-established practiced, based on the fact that a higher yielding crop takes up more N than a low yielding one. However, evaluation of long-term N response trials on corn in Wisconsin, Iowa, and Pennsylvania has shown poor correlation between yield level and optimum fertilizer N rate. It appears that soil and weather conditions conducive to producing high crop yields are the same conditions that support greater N supply from soils and more efficient use of that N by plants. There is evidence for some variation in optimum N rate based on soil type and climate, resulting in soil yield potential differences.

Credit for Previous Crop and Past Manure Applications

Nitrogen released from the previous years' plowed-down crop residue and past manure applications can supply a significant portion of a crop's N need (or even all the N needs in some situations).

Nitrogen tied up in the roots and above-ground regrowth of perennial forages, especially legumes, is released over an extended period of time as soil microorganisms break down the plant tissues and release N in inorganic forms that plants can use. Although the UVM Soil Test Report does not give a N recommendation that includes previous crop N credits, it is important to account for N from plowed pasture, hay, or bean fields. Nitrogen credits for the first and second year after plow down (Table 5) should be subtracted from the N rates given in Table 4. Because the amount of N released varies with temperature and moisture conditions, as well as the amount and type of initial plant material, the values in Table 5 are estimates and will vary for the specific situation. Use of the PSNT (Table 6) or Adapt-N is the best way to reduce this uncertainty when corn is the current crop.

Manure applied within the past two years can also contribute to current soil N and can be subtracted from the crop N recommendation. This N comes from the organic fraction of the manure (that you can be obtained from manure analysis reports) and only a certain percentage of it becomes available over time. Refer to Table 19 to determine the percentage of available N.

Following are several suggestions or adjustments that may be made to the recommended N rates for annual crops (corn, small grains, soybeans, etc.):

- Nitrogen rates in Table 4 are total amount of N to apply to meet the crop requirements. This would include application of N from manure and fertilizer applied as broadcast, starter, or topdress applications and N from plow down credits.
- Apply a portion of the recommended N as a starter fertilizer banded with the planter (10-30 lb/acre for corn, 10-20 lb/acre for winter small grains, 10-30 lb/acre for spring small grains). Use the higher rates where no pre-plant N or manure has been applied. Subtract starter N rate to determine application rate for broadcast or sidedressing.
- The salts in fertilizer—primarily N and K compounds—can cause poor germination and seedling injury if excessive rates are applied near the seed. To prevent these problems, limit the rate of starter fertilizer. For corn, limit combined N + K_2O banded with planter (2" to the side and 2" below the seed) to 80 lb/acre. For "pop-up" fertilizer in which low rates are applied directly to the seed, limit N + K_2O rate to 10 lb/acre.
- For small grains, limit combined N + K_2O applied with the grain drill to 40 lb/acre.
- For no-till corn, add 30 lb/acre to the recommended rates in Table 4 to account for slower N mineralization and/or greater N losses under no-till conditions.
- For corn grown on sandy, excessively drained soils without manure, split N into pre-plant and/or starter with the remainder applied as sidedress.
- For small grains on fields where lodging tends to be a problem, reduce N rates by 20 lb/acre.
- Soybeans properly inoculated with N-fixing bacteria seldom respond to N fertilizer. However, a low rate of nitrogen at planting can be beneficial to early growth before nitrogen fixation begins. Inoculate with fresh, viable bacteria just before planting. If soybeans have not been grown on the field previously, triple the rate of inoculant.

Table 4. Recommended nitrogen rates for annual crops (without credit for manure or previous crop).

			Soil drainage class		
			Somewhat poorly to poorly drained	Well drained to moderately well drained	Excessively drained
Corn	Expected yield[1]				
	Silage[2] ton/acre	Grain bu/acre	N to apply, lb/acre		
	15	90	110	90	110
	20	120	140	120	140
	25	150	170	150	170
	30	180	n/a[3]	180	190
	35	210	n/a[3]	210	210
Small grains (oats, wheat, barley, rye, millet)					
	Expected yield				
		bu/acre			
		45	65	45	65
		60	80	60	80
		90	110	90	110
Sorghum, sorghum-sudan, sudangrass, sunflower			90	70	90
Dry beans, peas, buckwheat			40	30	40
Soybeans			0[4]	0[4]	0[4]

Note: Adjust N rates for previous crop credits (Table 5) and manure application (Tables 15-19).
[1] Basing a nitrogen application on realistic yield goals is extremely important in order to avoid over applications of N.
[2] Silage yields are wet tons/acre (30-35% dry matter (DM)).
[3] n/a-30 ton/acre or greater (180 bu/acre) yield not considered realistic on these soils. Recommendation for 25 ton/acre yield is provided.
[4] A low rate of N may be applied at a rate of 20 lb/acre broadcast or 5-10 lb/acre applied in a 2" x 2" placed starter band, but do not apply in direct contact with the seed.

Table 5. Nitrogen credits for previous crops.

Previous Crop		Fertilizer N credit	
		Previous year	Two years ago
		lb/acre	
Alfalfa	>60% legume	120	80
	30-60%	80	40
Red clover, trefoil	>60% legume	90	40
	30-60%	70	30
Grass	Moderate high level mgmt. (>2 ton/acre yield)	70	30
	Low level mgmt. (2 ton/acre or less)	40	20
Soybeans, dry beans/peas		30	0

Note: Subtract N credit from soil test report recommended N rates in Table 4.

Average Yield Verses "Maximum" Yield – Using long-term average yield on a particular soil or field is a better way to estimate soil yield potential and optimum N rate compared to "maximum attainable yield" which could lead to over-fertilization in most years. An approach to determine a realistic yield goal is by adding 10% to a multi-year moving average that takes into account yields from the most recent years. This is considered a moving average because the average can change from year to year as the yields from different years are considered e.g. yields from 2011-2016 would generate the yield average for 2017; yields from 2012-2017 would generate the yield average for 2018. For an example on calculating a moving average, see *Determining a Realistic Yield Goal Example* in the box below. It is best to use three or four years but ignore extreme outliers such as years that have extremely high pest pressure, are droughty, or excessively wet.

<u>Determining a Realistic Yield Goal Example</u>

Corn Silage Harvest Records for Field 1B:

Year	Ton/Acre
2011	20
2012	21
2013	22
2014[1]	12 (army worm damage)
2015	21
2016[1]	16 (abnormally dry year)

Multi-Year Moving Average: 21.0

2017 Harvest Goal: 21.0 + 10%[2] = **23.1 tons/acre**

[1] Yields from 2014 and 2016 were determined to be outliers and thus omitted from determining the average as the yields were from atypical years due to pest or weather extremes.

[2] 10% of 21 = 2.1.

Pre-sidedress Soil Nitrate Test (PSNT) for Corn
Applying fertilizer N at sidedress time is also a more efficient use of N, especially under conditions for high leaching potential, because it avoids loss of N between spring and the start of the period of maximum crop N demand in late June and July. The PSNT is a site and time specific soil test for assessing N needs of field corn. The PSNT requires a soil sample (0-12 inch depth) taken when corn plants are 8 to 12 inches tall. Soil nitrate-N measured at that time is a good indicator of the N-supplying capacity of the soil, accounting for soil differences among fields and year-to-year weather differences in the same field. Fertilizer N is then recommended to supply adequate N to the corn crop (Table 6).

Table 6. Recommended nitrogen rates for corn based on the PSNT.

PSNT	Expected corn yield[1]				
	15 ton/acre or 90 bu/acre	20 ton/acre or 120 bu/acre	25 ton/acre or 150 bu/acre	30 ton/acre or 180 bu/acre	35+ ton/acre or 210+ bu/acre
ppm	N to apply, lb/acre[2,3]				
<5	80	110	140	170	200
6	80	105	140	165	190
8	75	100	125	150	175
10	70	90	115	135	160
12	65	80	100	120	140
14	60	75	90	110	125
16	55	65	80	95	110
18	50	60	70	80	90
20	45	50	60	65	75
22	40	40	45	50	55
24	35	35	35	40	40
25	30	30	30	30	30
>25	0	0	0	0	0

[1] Silage yields are wet tons/acre (30-35% DM) or bushels/acre (bu/acre) and should be a realistic yield goal for the site.
[2] If starter application rates are greater than 20 lb/acre, subtract the amount greater than 20 from the PSNT recommendations e.g. if the starter rate was 30 lb/acre, subtract 10 lb/acre.
[3] If previous crop was well-managed stand of grass, legume, or mixed forage, subtract 30 lb/acre from above N rates.

Recommendations in Table 6 are based on the following formulas, depending on expected yield and rounded to nearest five:

15 ton/acre yield: N Rate = 80 - [2.5 x (PSNT-5)];
except if PSNT <5, then N Rate = 80 lb/acre.

20 ton/acre yield: N Rate = 110 - [4 x (PSNT-5)];
except if PSNT <5, then N Rate = 110 lb/acre.

25 ton/acre yield: N Rate = 140 - [5.5 x (PSNT-5)];
except if PSNT <5, then N Rate = 140 lb/acre.

30 ton/acre yield: N Rate = 170 - [7.0 x (PSNT-5)];
except if PSNT <5, then N Rate = 170 lb/acre.

35 ton/acre yield: N Rate = 200 - [8.5 x (PSNT-5)];
except if PSNT <5, then N Rate = 200 lb/acre.

Soil samples for PSNT are taken between corn rows to avoid starter fertilizer. Because these are sidedress N application rates, they do not include N applied in the starter, assuming a 10-20 lb/acre rate. Consequently, starter N rates greater than 20 lb/acre should be subtracted from the recommended sidedress rates. Recommended N rates are reduced by 30 lb/acre where the previous crop was a well-managed stand of grass, legume, or mixed forage. Research results have shown less yield response to N fertilizer where corn followed a good sod or cover crop plow down. The PSNT does not always capture the mineralized nitrogen from these plowed down crops. This is likely due to increased N mineralization rates of the plowed down perennial forage after PSNT sampling.

With uncertain climate predictability, weather can often be extreme (e.g., very wet spring and droughts in the summer). Exceptionally dry or wet conditions can increase N volatility or otherwise decrease N uptake by the plant and more N may be needed to compensate for these losses or uptake inefficiency.

Adapt-N – Cornell's Adapt-N program is a relatively new way to fine tune site specific N recommendations. It does not require sampling and takes longitude, latitude, soil type, past manure applications, applied fertilizer, crop, and other factors into consideration. To find out more about this web-based nitrogen recommendation tool, go to: http://blogs.cornell.edu/newadaptn/.

Nitrogen for Perennial Forages

Establishment (Seeding Down)

Nitrogen fertility is not recommended for establishment of legumes or legume-dominant mixtures without a companion crop because N will favor the grasses and weeds and it may delay development of N-fixing capacity of legumes (Table 7). Some N is needed to support adequate growth when the perennial forage species are established with a small grain companion crop, or when grasses are direct seeded (i.e., without a companion crop). The higher N rate for direct-seeded grasses is recommended for spring seeding in order to support a grass harvest later in the season. For late-summer grass establishment, reduce N application rates to 30 lb/acre. When a companion crop is grown, the N rate must be limited to avoid excessive competition, or even lodging, from the small grain. Once the small grain companion crop is harvested, a second application of N can be applied if a second hay crop is anticipated.

Table 7. Recommended nitrogen rates for establishment of perennial legume or grass forages.

Companion (nurse) crop	Legumes, legume-grass	Grasses
	—— N to apply, lb/acre ——	
None	0	50[1,2]
Small grain	30	30[1]

[1] If a second grass harvest is expected, make a second application of 40-50 lb N/acre after first harvest.
[2] For late-summer seeding, reduce to 30 lb/acre.

Topdressing

Established grass forage species generally show consistent and large yield increases from application of N fertility. Economic responses can be obtained from application rates as high as 200 lb N/acre on well-managed, high-yielding stands (three or four cut system, adequate P and K fertility, etc.) (See Table 8). For lower level management or yield potential situations, less N is recommended. Because of the potential for leaching and other losses, N should be split into multiple applications of 40 to 75 lb N/acre each. An optimum schedule is to apply N before significant regrowth occurs—in early spring and after first, second, and (if a fourth cut will be made) third harvest. The higher rate should be applied in early spring when growth (and N response) potential is the greatest.

If manure is to be applied (or has been applied), reduce fertilizer amounts to account for nutrient contributions from manure (Tables 15 to 19). Nitrogen loss can occur due to volatilization, the extent of which depends on application method, nitrogen source, time of year, soil and weather conditions.

Mixed stands of hay crops with less than 30% legume should be fertilized in a similar manner as

Table 8. Recommended nitrogen rates for perennial grass and grass-legume forages.

	Nitrogen to apply[1]	
	Per application	Total per year
	—— N to apply, lb/acre ——	
Grass (<30 legume)[2]		
Hay, high level management (5+ ton/acre)	50-75	200 - 240
Hay, medium level management (3-4 ton/acre)	50	120 - 160
Hay, low level management (2 ton/acre)	40-50	80
Pasture[3]	50	50 - 100
Conservation planting	40	40
Legume-grass mix (30-60% legume)		
Hay harvest	40	40 - 80[4]
Pasture	0	0
Conservation planting	0	0
Legume (>60% legume)	0	0

[1] Basing a nitrogen application on realistic yield goals is extremely important in order to avoid over applications of N.
[2] Yields are dry hay equivalent (12-15% moisture). One ton dry hay is equivalent to 2.5 tons haylage (65% moisture).
[3] Avoid N applications to pasture if over-seeding legumes or to encourage legume growth.
[4] If a spring nitrogen application is made, in some cases, a second application later in the season may benefit mixed hay stands.

a pure grass stand. Hay crop stands with higher legume amounts (30 to 60%) may benefit from an early spring topdress of about 40 lb/acre, and in some cases from a second application later in the season. This practice will encourage the grasses and cause a decline in legume content; therefore, it is often reserved for older stands that need additional N fertility. No N is recommended for hay stands where legumes are dominant (>60%), because N is supplied by N-fixing bacteria.

Pasture production can be increased with additional N when legume content is less than 30%. However, if legumes are being encouraged, it is best to eliminate or limit N applications. No additional N is recommended for pastures if legume content is greater than 30%.

Phosphorus

Phosphorus recommendations for agronomic crops in Vermont are based on a combination of the available P soil test (P extracted with Modified Morgan's solution) and reactive Al (Al in the same extractant). Research results from Vermont, New York, and other states support an available P soil test critical level of approximately 4 ppm, which means that economic yield increases from the addition of P fertilizer are unlikely on soils testing above that level. Little P fertilizer is recommended for a soil testing higher than 4 ppm (Table 9). No fertilizer containing phosphorus is recommended for a soil testing higher than 7.0 ppm. Reactive Al is an indicator of a soil's ability to fix, or tie up, added phosphorus. Thus, low P-testing soils with high aluminum levels require greater amounts of added P to provide an adequate P supply to the crop and to raise soil test P. The recommended P fertilizer rates are expected to raise soil test P to the critical level in 4 to 6 years. *The available P soil test categories may be different on your soil test analysis report. The extended ranges, especially in the optimum category, are to accommodate vegetable crops on the same report.*

The adjustments in Table 10 are based on crop management factors and relative crop needs. For example, more P is recommended for seeding down a perennial forage than for topdressing because the tillage in preparation for establishment gives an opportunity to mix P fertilizer throughout the plow layer. Phosphorus that is tilled in is more efficiently taken up by the plant root system than P topdressed on the surface. It is also less susceptible to loss in surface runoff.

Table 9. Recommended base phosphorus rates for selected available P and Al test values. (Adjust for specific crop based on Table 10.)

Reactive Al	Available P soil test: Low		Medium		Optimum[1]	High[2]	Excessive
	ppm						
	0.5	1.5	2.5	3.5	4.1-7	7.1-20	>20
ppm	P_2O_5 to apply, lb/acre						
10	60	60	40	40	20	0	0
20	65	60	40	40	20	0	0
30	75	55	40	40	20	0	0
40	90	65	40	40	20	0	0
50	100	70	45	40	20	0	0
60	110	80	50	40	20	0	0
70	120	90	55	40	30	0	0
80	120	95	60	40	30	0	0
90	120	105	65	40	30	0	0
100	120	115	70	40	30	0	0
110	120	120	75	40	30	0	0
120	120	120	80	40	30	0	0
130	120	120	85	40	30	0	0
140	120	120	90	40	30	0	0
150	120	120	95	40	30	0	0
160	120	120	100	40	30	0	0
170	120	120	105	40	30	0	0
180	120	120	110	40	30	0	0
190	120	120	115	40	30	0	0
200	120	120	120	40	30	0	0

Note: Table shows selected values within each category. Recommended P application rates are based on the equation in the text below.

[1] The recommended rate (20-30 lb P_2O_5/acre) is best applied as starter/row fertilizer at planting for corn or broadcast as a blend with other nutrients as a topdress on perennial hay forages.

[2] A low rate of starter fertilizer (10-20 lb P_2O_5/acre) is recommended, especially under conditions of early planting, limited drainage, or conservation tillage.

Recommended P application rates for soils testing Low or Medium (4 ppm or less) are determined as follows:

1) Determine base P rate from available P and reactive aluminum (Al) soil tests using the following equation: P_2O_5 to apply (lb/acre) = [(Al+36) x (4 - Avail P)]/3. (See Table 9 for P rates for selected soil test levels.)
2) Adjust these phosphorus rates for specific crops by adding or subtracting amounts given in Table 10. Results are rounded to nearest 5 lb/acre.
3) Apply maximum and minimum limits, as follows: Maximum recommended rate = 120 lb P_2O_5/acre. If available P test = Low, then minimum = 60 lb P_2O_5/acre. If available P test = Medium, then minimum = 40 lb P_2O_5/acre.

Minimum and maximum limits are placed on recommended P rates even though the P test- reactive Al combination may indicate a higher or lower rate (see shaded areas in Table 9). A minimum of 60 or 40 lb/acre is recommended for soils testing low or medium because lower rates are sometimes impractical to spread as a broadcast application.

A maximum of 120 lb/acre is recommended because higher rates are considered economically prohibitive and the 120 lb/acre rate will adequately meet the current crop need. However, a longer-than-expected time may be required to raise the P test to the optimum range on those soils.

Soils testing in the optimum range receive a recommendation of 20 lb P_2O_5/acre or (if Al > 60 ppm) 30 lb P_2O_5/acre. Applying these low rates will help maintain test levels within the optimum range until the next soil testing is done. Except for topdressing of perennials, this P is best applied as a band at planting. Band application of low rates of P near the seed (e.g. starter fertilizer) with the planter or drill is a very efficient method for supplying P to the young plant. This method is especially important with low soil temperatures that occur with early planting, limited drainage, or conservation tillage or with low soil test P. When lower rates of P are recommended (20-60 lb P_2O_5/acre), all the P can be applied in a band at planting. When high rates are recommended, a combination of starter and broadcast fertilizer or manure should be used. The probability of an economic yield increase from the use of starter P decreases as soil test P reaches the high category; and if P test is excessive, none is recommended.

If manure will be applied, recommended P rates should be reduced based on manure rate and nutrient content (from manure analysis or typical values, Tables 15 and 16).

Table 10. Phosphorus (P_2O_5) rate adjustments for different crops.

Crop	Available P soil test level	
	Low medium (0-4 ppm)	Optimum (4.1-7 ppm)
	lb P_2O_5/acre	
Corn	No change	No change
Small grains, soybeans, dry beans/peas, buckwheat, sorghum, sorghum-sudan, sudangrass, sunflower	Subtract 20	No change
Establishment of perennial forages	Add 40	Add 20
Topdress of alfalfa (>60%)	No change	No change
Topdress or other perennial forages	Subtract 20	No change
Conservation planting	Subtract 30	Subtract 20 or 30

Note: Add or subtract from values in Table 9, but note minimum rates for Low and Medium P test.

Example Calculations for Phosphorus Recommendations

(See formula and procedure p. 12, and Table 10 above.)

Soil with available P test = 2.2 ppm and reactive Al test = 62 ppm

Scenario 1:

Recommended P rate for corn = [(62 + 36) x (4 - 2.2)]/3
= (98 x 1.8)/3
= 58.8 or 60 lb P_2O_5/acre.

Scenario 2:

Recommended P rate for establishment of perennial forage = 60 + 40
= 100 lb P_2O_5/acre.

Phosphorus Index to Assess Runoff Potential

Increasing concern in recent years about the contribution of nutrients in surface runoff to lake eutrophication makes it important to avoid excessive application of P in fertilizers and manure. For both environmental and economic reasons, application of P is not recommended when soil test P is above the level at which an economic yield response is likely (Table 9). However, assessment of the potential for P runoff loss from an agricultural field requires evaluation of a number of factors, of which soil test P is only one. The Phosphorus Index was developed as a tool to combine various soil and management factors into an index that can serve as a management tool as part of the nutrient management planning process, taking into account the following factors to estimate the potential for runoff of phosphorus from a given field:

- soil hydrologic group
- P soil test
- rate and method of P application
- buffer characteristics
- sub-surface drainage
- P availability coefficients for biosolids, crops, and manure injection

The results of the P Index calculation for each field are expressed as an index (0 to 100+) and are assigned a low, medium, high, or very high rating. Recommended management practices for each category can then be used as a guide to prioritize fields and to determine those on which P application should be limited or additional conservation practices implemented. The 2017 version of the Vermont P Index can be downloaded online at *go.uvm.edu/vtpindex*.

Potassium

Plant-available soil K is primarily in the exchangeable form. That is, it is adsorbed to organic matter and clay surfaces but can be readily exchanged with ions in soil solution and taken up by plants. It is exchangeable K that is measured by the Modified Morgan's extractant (NH_4 acetate, pH 4.8). The rate of potash recommended is based on soil test K level and on crop need, as determined by crop type and yield level (Table 11). Recommended K rates for low-testing soils are quite high, especially for corn silage and perennial forages in which the whole plant is harvested. Even for soils in the optimum range, a substantial amount of potash is recommended because soils can be more quickly depleted of K than of P.

> *In a mixed stand forage system, an adequate supply of potassium is important to maintain the competitiveness of the legumes relative to grasses.*

Potassium rates for corn silage and hay forages are adjusted based on yield level and on whether corn is harvested for silage or grain because these factors affect plant uptake and removal of K. Less potash is recommended for grass forage than for legumes because the fibrous rooting system of grasses is more efficient at scavenging for K than is the tap root system of legumes. In the case of a legume-grass mix, an adequate K supply is important to maintain the competitiveness of the legumes relative to the grasses. Less potash is recommended for establishment of perennial forage than for topdressing to minimize any possible fertilizer injury to seedlings. Lower establishment-year yields mean lower K uptake, as well.

A portion of the K recommended for corn (10-20 lb K_2O/acre) should be banded with the planter, especially on low- and medium-testing soils. For "popup" fertilizer that is applied directly to the seed, limit N + K_2O rate to 10 lb/acre.

If manure will be applied, recommended K rates should be reduced based on manure rate and nutrient content (from manure analysis or typical values, see Tables 15 and 16).

Table 11. Recommended potassium rates for field crops.

	K soil test						
	Low		Medium		Optimum	High	Excessive
K, ppm	<25	26-50	51-75	76-100	101-130	131-160	>160
	K_2O to apply (lb/acre)						
Corn for silage[1]							
15-20 ton/acre	180	140	100	60	40	20[2]	0
20-25 ton/acre	200	160	120	80	60	20[2]	0
25+ ton/acre	240	200	160	120	80	30	0
Corn for grain							
90-120 bu/acre	120	80	40	30	20	20	
120-150 bu/acre	140	100	60	40	30	20	0
150+ bu/acre	180	140	100	60	30	20	0
Alfalfa (>60%)[3]							
Topdress							
2-4 tons/acre	280	240	200	160	100	40	0
5 tons/acre	320	280	240	200	140	60	0
6+ tons/acre	360	320	280	240	180	80	0
Establishment	240	200	160	120	80	40	0
Clover, trefoil, grass, alfalfa (30-60%)[3]							
Topdress							
2-4 tons/acre	220	180	140	100	60	0	0
5 tons/acre	240	200	160	120	80	40	0
6+ tons/acre	260	220	180	140	100	60	0
Establishment	180	140	100	80	60	0	0
Small grains, soybeans, buckwheat, dry beans, peas, millet	120	100	80	60	40	0	0
Conservation Planting	80	60	40	0	0	0	0

[1] Corn silage yields are wet tons/acre (30-35% DM).
[2] 10-20 lb K_2O/acre is recommended as row-applied starter under conditions of early planting, limited drainage, or conservation tillage.
[3] Yields are dry hay equivalent (12-15% moisture). One ton dry hay is equivalent to 2.5 tons haylage (65% moisture).

Secondary and Micronutrients

Magnesium Recommendation - All Crops

Magnesium (Mg) can be deficient in some Vermont soils. Because the available form of both Mg and K is a cation (positively charged ion), there is competition between the two for plant uptake. As a result, Mg deficiency is more likely to occur on high K-testing soils. Therefore, we have different recommendations for two situations—those with K test lower and higher than 200 ppm. For the higher K-testing soils, Mg critical level and recommended rate are adjusted for the K test level.

Examples:
Situation 1: K soil test is 200 ppm or less.
Mg soil test of 50 ppm is considered adequate. Mg recommendation, lb/acre = 100 - (2 x Mg soil test)

Situation 2: K soil test is greater than 200 ppm.
Mg recommendation, lb/acre = (0.6 x K test) – (2 x Mg soil test)

Mg deficiency is more likely when the soils are very high in potassium, >200 ppm.

If soil magnesium is less than 50 ppm and no limestone is recommended, add magnesium fertilizer at a rate of 20-50 lb Mg/acre as magnesium sulfate or other fertilizer. If soil magnesium is less than 50 ppm and there is a lime recommendation, a good combination of both is dolomitic limestone with at least 10% of the calcium carbonate ($CaCO_3$) equivalence as magnesium carbonate.

Sulfur – All Crops

Although sulfur (S) deficiency has not been widely documented in Vermont field crops, several nearby states, including New York and Pennsylvania, are reporting crop response when S fertilizer is added to the soil. Reduced S levels in soil are a result of reduced atmospheric deposition of S following implementation of the 1970's Clean Air Act, applications of more concentrated fertilizers with less or no S, and reduced use of sprays with S compounds. Sulfur deficiency displays as yellowing of the new leaves at the top of the plant and is more likely to show up in patches and on sandy soils or soils with low organic matter. If S deficiency is suspected, a tissue analysis of the crop is suggested to determine if it is meeting an S sufficiency level (refer to Table 12).

Zinc for Corn

Zinc (Zn) deficiency is not a consistent problem in Vermont, but it has caused serious production problems, primarily in corn, in some fields in some years. The Zn soil test provides a guide for Zn fertilizer need, but is best combined with field observations (Table 13). Zinc deficiency is more likely on fields with no recent manure application or on soils with very high soil test P (or excessive P application), low organic matter, or relatively high pH (approaching 7 or higher). Weather conditions are also a factor—with problems more likely under cool spring conditions. Zinc

Table 12. Most definitive way to diagnose sulfur deficiency.

Crop	Sufficiency range	Growth stage	Plant part
Corn	0.20 – 0.50%	Silking	Ear leaf
Alfalfa	0.25 – 0.50%	10% flowering	Top 1/3 of plant
Small Grains	0.20 – 0.40%	Before heading	Most recently mature leaf
Soybean	0.30 – 0.50%	Early flowering	Most recent mature leaf

(Source: Beegle & Spargo, Evaluation of Sulfur Needs for Corn in PA) deficiency symptoms generally appear in young corn (6-12 inches tall) as interveinal chlorosis (light color between veins) or wide bands on either side of the midrib of younger (upper) leaves. The chlorotic bands do not extend to the tip of the leaf (as they do in Mg-deficient plants). Plants are often stunted in growth. Zinc deficiency usually occurs in spotty, irregularly shaped areas in the field.

Zn deficiency is more likely when the soils are very high in phosphorus, have low organic matter, relatively high pH, or have not received recent manure applications.

Where Zn test is low or deficiency symptoms have been observed in the past, a broadcast application of Zn incorporated with tillage has been more effective than starter Zn and is generally sufficient for five or more years. Zinc sulfate (36% zinc) is the most common fertilizer material and should be applied at a rate to supply 8 to 10 lb/acre of actual Zn (25 lb/acre of $ZnSO_4$). Under less immediate deficiency situations, a low rate (about 2 lb/acre) can be applied annually with starter fertilizer.

Boron on Perennial Legume Forages

Boron (B) deficiency has historically been a problem in Vermont on alfalfa, and to a lesser extent, red clover and birdsfoot trefoil. In fact, some of the early research that showed that serious alfalfa production problems were caused by B deficiency was done by Professor Midgley at the University of Vermont in the 1930's and 1940's. Unfortunately, a soil test is not reliable for diagnosing the need for B, so B is routinely recommended for topdressing and seeding down alfalfa, trefoil, and red clover—except where B was applied the previous year (Table 14). Care should be taken to avoid excessive rates, especially on legume-grass combinations, because of the potential for B toxicity.

Table 13. Zinc recommendations for corn.

Zn test	Zn level	Deficiency symptoms?	Zn recommendation
ppm			
<0.5	Low	yes/no	8-10 lb/acre, broadcast and incorporated[1]
0.5-0.9	Medium	yes	8-10 lb/acre, broadcast and incorporated[1]
0.5-0.9	Medium	no	8-10 lb/acre, broadcast and incorporated[1] *or* 2 lb/acre in starter annually for 2-3 years, then retest
1.0+	Optimum/High	no	None

[1] Adequate for five or more years.

Table 14. Boron recommendations for perennial forages.

Species	Seeding year[1]	Topdress
	—— lb/acre ——	
Alfalfa (>90% legume)	2	1-2
Alfalfa/grass mix (30-90% legume)	1	1
Red clover (>90% legume)	2	1-2
Red clover/grass mix (>30% legume)	1	1
Birdsfoot trefoil alone	2	1
Birdsfoot trefoil/grass mix (>30% legume)	1	1
Grass (<30% legume)	0	0

[1] If B was applied within past year, none is needed at seeding. For late summer legume seedings, only apply one lb of B the next year.

Other Micronutrients

Micronutrients are essential for plant growth, but are required in much smaller quantities than N, P, and K. Maintaining soil pH between 6 and 7 will optimize micronutrient availability. Furthermore, manure is often a major source of micronutrients and often provides enough to meet crop demands. Currently, there are little data on micronutrient sufficiency levels and recommendations are not provided in this publication or on soil test analysis reports. However, the UVM AETL Soil Test Report provides "average" levels found in Vermont to provide a baseline of typical micronutrient levels for this state.

Nutrient Credits from Manure

Nutrient Content

Manure is a very important source of nutrients for crop production in Vermont, supplying more nutrients than purchased fertilizer on most dairy farms in the state. Proper application of manure can result in substantial reductions in fertilizer costs. As with fertilizer, however, careful management is necessary to minimize any adverse effects on water quality. For both economic and environmental objectives, it is important to know the content of nutrients in the manure so that the quantity applied matches crop need. Because the nutrient content of manure is highly variable, sampling and lab analysis are strongly recommended. Table 15 displays average typical nutrient content values for dairy manure, delineated by DM content. Table 16 displayed average typical nutrient content for non-dairy livestock manure.

Not all nitrogen in manure is readily available for immediate crop uptake. In terms of availability, N in manure consists of two fractions—the ammonium portion which is potentially equivalent to fertilizer N but is also susceptible to large losses, and the more stable organic fraction which releases N in an available form over a longer time period (Figure 3).

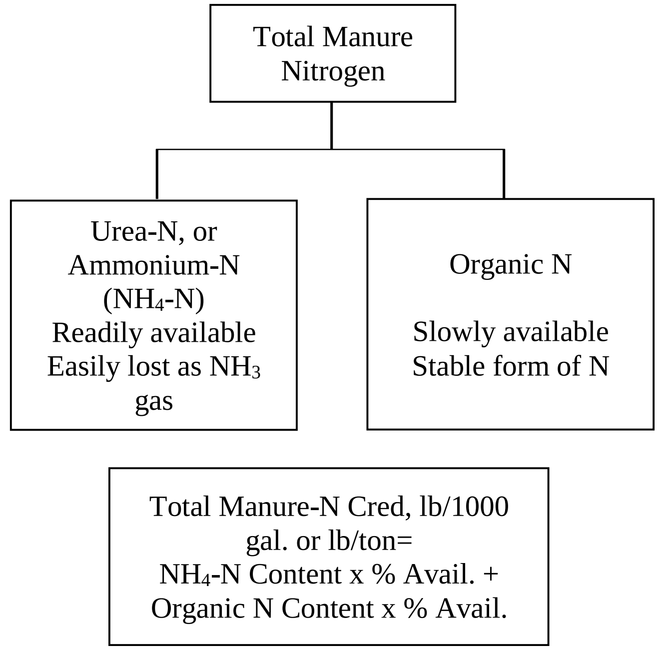


Figure 3. Forms of manure nitrogen.

Availability of Ammonium Nitrogen

The ammonium N (NH_4^+-N) fraction of manure N (or urea or uric acid, which quickly converts to ammonium) represents a form of N that is essentially equivalent to fertilizer N if managed properly. However, it can volatilize quite quickly as ammonia (NH_3) gas if left on the surface after spreading. This gaseous loss of N can be prevented by incorporating manure into the soil, either by tillage or by significant rainfall (about 1/2 inch). Incorporation brings NH_4^+ in manure into direct contact with soil organic matter and clay, which can adsorb NH_4^+. Loss of ammonium via volatilization is also a function of manure dry matter content. Manure or slurry that is more liquid infiltrates the soil more readily so that more of the ammonium N is conserved. These phenomena are illustrated in Figure 4, which is based on an approach developed by researchers in England (K. Smith, 1997, personal communication) and modified to better fit Vermont research results.

Values for NH_4^+-N availability of spring-applied non-poultry manures based on the following formulas:

- Liquid (or slurry) manure: % N availability = 100 - [(20 + 5xDM) x (days /(days + 0.3))], where DM ranges from 4% to 12%.
- Semi-solid manure: same as liquid manure, using 12% DM in formula.
- Solid manure: % N availability = 100 - 90 [days ⁄ (days + 1.2)].
- If time to incorporation is >7 days (or not incorporated), % N availability = 60, 40, 20, and 10% for thin, medium, thick (or semi-solid), and solid manure (See Table 17).

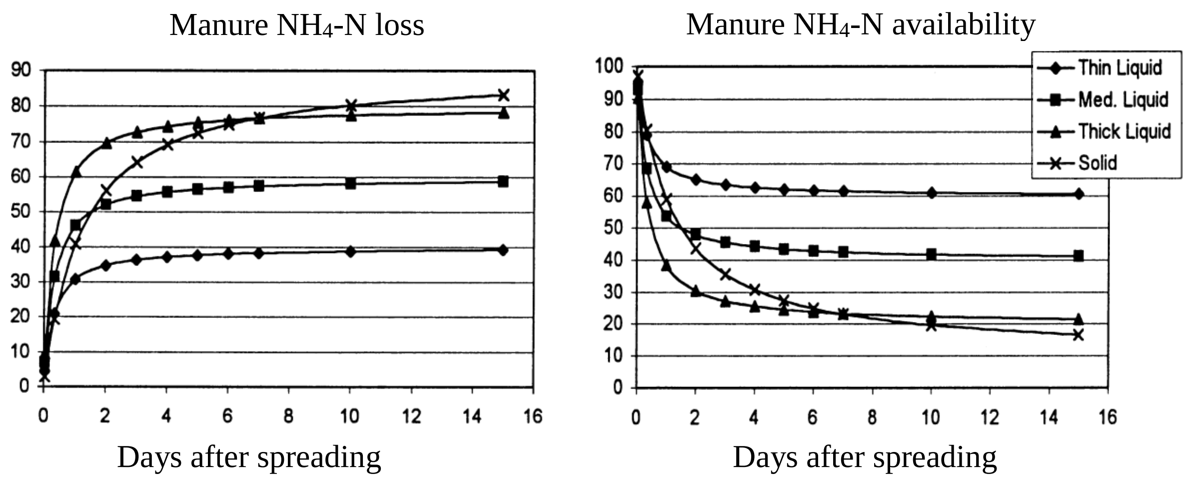


Figure 4. Loss (left) and resultant availability relative to fertilizer N (right) of ammonium N from manure as a function of manure dry matter content and time after spreading.

If the farmer provides a value for % DM (same as % solids) of manure (from analysis or reliable estimate), then an estimate of N availability will be given based on the above formulas and the specific DM content. If a DM content is not given, then availability of ammonium-N in manure will be based on approximate values from different categories of DM content—thin (0-5%), medium (5-10%), and thick (>10%) liquid manure, semi-solid manure, or solid (>20% DM) manure (Tables 15 or 16). Availability for the three liquid manure categories are calculated using DM percentages of 4, 8, and 12. Semi-solid is treated as "thick liquid" using a DM value of 12%. If manure is applied in the fall, estimates of NH_4^+-N availability are reduced to 40% of spring-applied manure to account for overwintering losses due to leaching, denitrification, and runoff (Table 18). Values in Tables 17 and 18 have been rounded to the nearest 5%.

Availability of Organic Nitrogen

Organic N is the manure N fraction that is part of large organic compounds, a form that cannot be taken up directly by crop plants. But as microorganisms utilize these carbon compounds to derive energy, some of the N is mineralized, or released, as ammonium and is available for plants. While the greatest portion is mineralized in the first season, the process continues at a slower rate for one or more additional years and is affected by several factors (Table 19). Because mineralization is carried out primarily by aerobic bacteria, the rate is reduced in poorly drained soils compared to well-drained (well-aerated) soils. Large amounts of high-carbon bedding material (as indicated by high DM content, greater than 20%) decrease the net release of N because more of the inorganic N mineralized is immobilized, or utilized directly by the soil microbes to supply their N needs. Available N values for manure left on the soil surface, as in perennial forages and no-till corn, are reduced (by approximately a third) to account for slower mineralization of organic N that is not mixed with the soil (Table 19).

Availability of N from composted manure has not been well researched in Vermont or the region. It is expected to be less than uncomposted manure because most of the available N has been either lost to volatilization or immobilized during the composting process. Penn State (*Agronomy Guide*, 2016) uses a first-year availability of 10% of the total N, with 5% and 2% availability in the second and third years after application.

Other Nutrients

The approach for estimating the availability of other nutrients in manure is much less complex. Potassium in the plant cell (and, thus, in manure) is not tied up in complex organic compounds but exists in the K^+ ionic form. Therefore, it is equivalent in availability to K in fertilizers. Phosphorus in manure is a combination of organic and inorganic compounds and is sometimes considered less plant-available than fertilizer P. However, manure P is not as readily tied up in unavailable forms in the soil as soluble P fertilizers. Consequently, manure and fertilizer are very similar in building soil P and supplying crop needs. In the current Vermont program, the manure P is considered equivalent to the fertilizer P content. Manure also contributes significant amounts of magnesium, calcium, sulfur, and various micronutrients for crop growth.

Table 15. Typical values for total nutrient content of dairy manure.

Type	Dry matter	Total N	NH_4-N	Organic N	P_2O_5	K_2O	Mg	Ca
	%	lb/1,000 gal.						
Dairy, liquid (<5% DM)	3.0	12.2	4.9	7.3	4.8	15.1	2.8	6.1
Dairy, slurry (5-10% DM)	7.0	22.3	7.6	14.7	8.9	22.0	5.0	14.3
	%	lb/ton						
Dairy, semi-solid (10-20% DM)	14.7	8.5	1.8	6.7	4.1	6.1	2.1	5.6
Dairy, solid (>20%DM)	30.8	12.3	1.4	10.9	8.1	10.0	4.3	19.5

Note: Dairy manure values are from Vermont samples analyzed by University of Maine, 2012-2016.

Table 16. Typical values for total nutrient content of non-dairy livestock manure.

Species	Dry Matter	Total N	NH_4-N	Organic N	P_2O_5	K_2O
	%	lb/ton				
Beef (paved lot)	29	14	5	9	9	13
Swine (hoop barns)	40	26	6	20	15	18
Sheep	25	23			8	20
Poultry, layer	41	37	18	19	55	32
Poultry, broiler	69	75	15	60	27	33
Horse	20	12			5	9

Note. Adapted from University of Nebraska-Lincoln NebGuide G 1335 and Penn State Agronomy Guide (2016). Values do not include bedded pack. It is best practice to use a recent manure analysis. Actual values may vary considerably from averages in the table.

Table 17. Availability of ammonium nitrogen from spring- or summer-applied manure (% fertilizer N equivalent).

Time to incorporation by tillage or rain	Dairy cattle or other livestock				Poultry
	Liquid or slurry			Solid	
	Thin (<5% DM)	Medium (5-10% DM)	Thick or semi-solid (>10%DM)	(>20% DM)	
	% available				
Immediate/1 hr.	95	95	90	95	95
<8 hr.	80	70	60	80	90
1 day	70	55	40	60	85
2 days	65	50	30	45	80
3-4 days	65	45	25	35	70
5-7 days	60	40	25	25	60
>7 days (or non-incorporated)	60	40	20	10	50

Table 18. Availability of ammonium nitrogen from fall-applied manure (% fertilizer N equivalent).

Time to incorporation by tillage or rain	Dairy cattle or other livestock				Poultry
	Liquid or slurry			**Solid**	
	Thin (<5% DM)	Medium (5-10% DM)	Thick or semi-solid (>10%DM)	(>20% DM)	
	% available				
Immediate/1 hr.	40	35	35	40	40
<8 hr.	30	25	25	30	35
1 day	30	25	15	25	35
2 days	25	20	10	20	30
3-4 days	25	20	10	15	25
5-7 days	25	14	10	10	25
>7 days (or non-incorporated)	25	15	10	0	20

Table 19. Availability (% fertilizer N equivalent) of organic N from manure applied in current and past years.

Dry matter (%)	Soil drainage	Current Year		1 Year Ago	2 Years Ago
		Tilled	Surface		
		% available			
20 or less	Well to moderately well drained	36	24	12	5
	Somewhat poorly to poorly drained	24	16	10	4
>20	Well to moderately well drained	30	20	12	5
	Somewhat poorly to poorly drained	20	14	10	4

Appendix

Soil Testing Lab Methods

Soil samples that come to UVM are assigned a lab number and forwarded to the University of Maine where a subsample is air-dried before analysis. The soil is then put through a 2 mm sieve to remove coarse fragments. All of the available nutrients are measured in an extract of this sample. Four milliliters (mL) of soil (about 1 tsp.) is shaken for 15 minutes with 20 mL of Modified Morgan's solution (1.25 *M* ammonium acetate at pH 4.8). The original Morgan's extract was developed at the Connecticut Agricultural Experiment Station in the 1940s. The Modified Morgan's solution, which improves the extract's ability to remove potassium from fine textured soils, was developed in the 1960s by Dr. J. McIntosh at the University of Vermont. While the extraction process is similar to these early methods, more modern methods are used for the determination of the nutrients in the extract. Phosphorus, Ca, K, Mg, Zn, Al, and micronutrients are measured with spectroscopy technology following standard protocols. For more information, refer to Recommended Soil Testing Procedures for the Northeastern United States posted University of Delaware's website: http://extension.udel.edu/lawngarden/soil-health-composting/recommended-soil-testing-procedures-for-the-northeastern-united-states/.

Soil pH is measured in 10 mL of a weak calcium chloride "salt" solution (0.01 *M*), using 5 mL of soil. Using a weak salt ensures a more accurate reading with less seasonal fluctuation. This pH reading averages 0.6 pH units less than a pH measured in water and we adjust our "salt" pH readings upwards to be comparable with results from other labs. Organic matter is determined by "weight-loss-on-ignition." A dry, weighed sample of soil is brought to 700 degrees F until all the soil organic matter is burned off. After reweighing, percent organic matter is calculated from the weight loss.

Soil Test Categories Expressed in Alternate Units

Soil test results can be expressed in different units. The UVM lab reports results as parts per million (ppm), but some labs use units of pounds per acre (lb/acre). The UVM Soil Test Report uses ppm for soil nutrient analysis in order to avoid confusion with our recommendations which are in lb/acre. To convert, multiply ppm by 2 to get lb/acre, assuming the soil plow layer (to 6 inches in depth) weighs 2 million pounds. See Table 20 for UVM soil test categories expressed as lb/acre.

Table 20. Vermont soil test categories expressed as pounds per acre (lb/acre, or parts per two million) in elemental form.

	Low	Medium	Optimum	High	Excessive
			lb/acre		
Available P	0-4	4.1-8	8.1-14	14.1-40	>40
K	0-100	101-200	201-260	261-325	>325
Mg	0-70	71-100	101-200	>200	--

Conversion Factors for Soil Test Units

- ppm x 2 = lb/acre in plow layer
- P_2O_5 x 0.44 = P (phosphorus, elemental form)
- P x 2.27 = P_2O_5
- lb P_2O_5/acre x 0.22 = ppm P
- ppm P x 4.6 = lb P_2O_5/acre
- K_2O x 0.83 = K (potassium, elemental form)
- K x 1.2 = K_2O
- lb K_2O/acre x 0.42 = ppm K
- ppm K x 2.4 = lb K_2O/acre

Crop Nutrient Removal

While nutrient removal does not enter directly into UVM nutrient recommendations, it is an important consideration in some cases. For example, the potassium recommendation for corn harvested for silage, in which the entire above-ground plant is removed, is much greater than for grain corn. Also, crops that remove a large amount of potassium such as corn silage or high yielding hay crops, can cause quick changes in soil test K for soils with a low CEC.

It is important to recognize that nutrient removal does not necessarily equate to nutrient recommendations for nutrient applications since soil and organic matter can provide a significant supply of most nutrients. Also, nutrient removal is only accounting for the harvested portions of the crop.

Although typical nutrient removal rates for common field crops are shown in Table 21, it is best for farmers to keep good records of their own crop yields to have a more accurate account of nutrient removal. For forage crops such as corn silage, haylage or hay crops, using forage tests can be a useful way to calculate your "unit per yield" of each of your crops. It is best to take an average of two or more forage tests especially for hay crops with multiple cuts.

Fertilizer Nutrient Sources

Crop nutrient need not met by manure and/or previous crop residue can be supplied by various fertilizer materials (Table 22). Most local fertilizer suppliers can provide blends of these materials to accommodate a range of N, P, K, and other nutrient requirements.

Table 21. Typical Crop Nutrient Removal.

	Per unit of yield				Removal for given yield		
Crop (units)	N	P_2O_5	K_2O	Typical yield/A	N	P_2O_5	K_2O
Corn (bu)	0.75	0.4	0.3	120 (bu)	90	50	35
Corn Silage (T)[4]	9	4	11	20 (T)	180	80	220
Grain sorghum (bu)	0.5	0.6	0.8	120 (bu)	60	70	95
Forage sorghum (T)[4]	9	3	10	15 (T)	135	45	150
Sorghum/sudangrass[4]	8	7	7	15 (T)	120	105	105
Alfalfa (T)[2,5]	50[1]	15	50	5 (T)	250	75	250
Red Clover (T)[2,5]	40[1]	15	40	3.5 (T)	140	55	140
Trefoil (T)[2,5]	50[1]	15	40	3.5 (T)	175	55	140
Cool-season grass (T)[2,5]	40	15	50	4 (T)	150	60	200
Bluegrass (T)[2,5]	30	10	30	2.5 (T)	75	25	75
Wheat/rye (bu)[3]	1.5	1	1.8	60 (bu)	90	60	110
Oats (bu)[3]	1.1	0.9	1.5	80 (bu)	90	70	120
Barley (bu)[3]	1.4	0.6	1.5	75 (bu)	105	45	110
Soybeans (bu)	3.2[1]	1	1.4	40 (bu)	130	40	56
Small grain silage (T)[4]	17	7	26	6 (T)	100	40	160

Note: Adapted from Beegle, 2017. This table does not imply any UVM recommendation for fertilizer rates.
[1] Legumes fix all their required nitrogen. However, they also are able to use nitrogen as indicated.
[2] For legume-grass mixtures, use the predominant species in the mixture.
[3] Includes straw.
[4] 65% moisture.
[5] 10% moisture.

Table 22. Nutrient content and other properties of fertilizer materials.

Fertilizer Material	Chemical formula[1]	%N	$\%P_2O_5$	$\%K_2O$	Other nutrient, %[2]	Equiv. acidity[3]	Salt index[4]
Nitrogen Sources							
Anhydrous ammonia	NH_3	82	0	0		148	47
Urea	$(NH_2)_2CO$	46	0	0		84	75
Ammonium nitrate	NH_4NO_3	33-34	0	0		63	105
Urea-ammonium nitrate (UAN)	$(NH_2)_2CO + NH_4NO_3$	28-32	0	0		54	74
Ammonium sulfate	$(NH_2)_2 + SO_4$	21	0	0	24 S	112	69
Phosphorus Sources							
Diammonium phosphate (DAP)	$(NH_4)_2HPO_4$	18-21	46-53	0		74	34
Monoammonium phosphate (MAP)	$NH_4H_2PO_4$	11-13	48-52	0		65	30
Ammonium polyphosphate		10	34	0		53	--
Ordinary superphosphate	$Ca(H_2PO_4)_2 + CaSO_4$	0	20	0	14 S, 20 Ca	0	8
Triple superphosphate	$Ca(H_2PO_4)_2$	0	46	0	1.5 S, 14 Ca	0	10
Potassium, Magnesium, sulfur sources							
Muriate of potash	KCl	0	0	60-62		0	116
Potassium sulfate	K_2SO_4	0	0	50	18 S	0	46
Potassium nitrate	KNO_3	13	0	45		-26	74
Potassium hydroxide	KOH	0	0	70		-89	--
Magnesium sulfate	$MgSO_4$	0	0	0	10-16 Mg, 14-21 S	0	
Magnesium oxide	MgO	0	0	0	45 Mg		
Sulfate of potash magnesia (Sul-Po-Mag or K-Mag)	K_2SO_4 $MgSO_4$	0	0	22	11 Mg, 22 S	0	43
Calcium sulfate (gypsum)	$CaSO_4$	0	0	0	15-18 S, 19-22 Ca	0	
Micronutrient Sources							
Borate	Na_2BO_4				20 B		
Solubor	Na_2BO_4				21 B		
Iron (ferrous) sulfate	$FeSo_4$				20 Fe, 12 S		
Manganous sulfate	$MnSo_4$				28 Mn, 16 S		
Zinc sulfate	$ZnSo_4$				36 Zn, 18 S		
Zinc Oxide	ZnO				50-80 Zn		
Zinc chelate	Zn chelate				6-14 Zn		

Note: Adapted from Beegle, 2017, Cornell Guide for Integrated Field Crop Management, 2003, and other sources.
[1]Water of hydration (HO_2) not included in formula.
[2] Actual analysis varies with specific product formulation: B = boron, Ca = calcium, Fe = iron, Mg = manganese, Zn = zinc.
[3] Pounds of calcium carbonate equivalent/100 lb of fertilizer material. Positive numbers indicate that the material increases soil. acidity, that is, lowers soil pH. Negative numbers indicate that the material reduces acidity, that is, raises soil pH.
[4] Salt index of equal weights of the fertilizer material compared to sodium nitrate which equals 100. Useful for comparing the salt effect of different fertilizer materials.

Equation to Determine Application Rate of Alternative Liming Materials

Application Rate (tons/acre) = Recommended Lime Rate (tons/acre) / (CCE% of material/100).

Example Calculation to Determine Application Rate of Alternative Liming Materials

The CCE of wood ash is 60% and soil test recommends 2 tons of lime/acre:
Application rate = 2 / (60 / 100) = 3.33 tons per acre

Soil Test Submission Form

For forage and grain crops
(see crop list on back)

The University of Vermont

Agricultural & Environmental Testing Laboratory
and UVM Extension

Main Contact (mailing address)	Send copy to (Extension, NRCS, consultant, etc.), or Billing Name and Address (if different than Main)
Name:	Name:
Farm/Company:	Company/Agency:
Address:	Address:
City, State, Zip:	City, State, Zip:
Phone:	Phone:
E-mail:	E-mail:
Send results by: Mail ___ **or** E-mail ____	Send results by: Mail ___ **or** E-mail ____

Vermont county where samples were taken: ____________________

The basic nutrient test costs $14 per sample (1 bag of soil = 1 sample), and includes pH, available P, K, Ca, Mg, S, micronutrients, CEC, organic matter, and fertilizer recommendations for **one** crop. Recommendations for additional crops **on the same sample** are $2 each. **Add** $10 for heavy metal analysis (**in addition to basic analysis, for a total fee of $24**). Metals only **analysis** (no nutrient test or fertilizer recommendations) is $15 per sample (Code Z2). **One-half cup to one cup of sample required for all tests; any clean plastic bag may be used.** Use additional sheets if needed.

Lab ID (For lab use only)	Field or Sample Name (You may list up to 10 samples on one page; use any clean plastic bag for samples)	Approx. area of field	Crop Codes (see back of form; 1 crop included in $14 fee; add'l crops $2 each)	Expected yield (see back of form)	Check here for metals test	Fee
1		acres				$
2		acres				$
3		acres				$
4		acres				$
5		acres				$
6		acres				$
7		acres				$
8		acres				$
9		acres				$
10		acres				$

Use additional sheets for more than 10 samples. Please print clearly.

Please include payment, unless prior arrangements have been made. **Checks only**, payable to **UVM**. **Total fee $______**

If this form came in a pre-addressed mailer, one sample can fit in it. Otherwise, use a box or large envelope.

Send to: AETL, Univ. of Vermont, 262 Jeffords Hall, 63 Carrigan Drive, Burlington, VT 05405-1737

Other tests available on request. Email us at: agtesting@uvm.edu 802-656-3030 pss.uvm.edu/ag_testing

Test results are normally ready to mail/e-mail on the 2nd Monday after samples arrive at the lab.

Revised 9/07/2017

Forage and Grain Crop Codes

(use Garden/Hort form for vegetables, fruits, lawn/turf, trees, shrubs, and flowers)

Lime and nutrient recommendations are provided on your test report specifically for the crop code(s) you identify when you submit your soil sample. Select the crop code below that best describes your management objectives. Nutrient recommendations (e.g., N and K_2O) for several forage and grain crops are adjusted based on expected yield to account for difference in nutrient demand and removal. For these crops the yield range and default are indicated below. Providing information about your expected yield, where appropriate, will improve your recommendations. If you do not supply an expected yield value, the **default** will be used.

Crop Code	Crop Description	Expected yield range (default), units
Annual Crops		
3A	Corn for Silage	15 to 30 (**default 25**), tons/ac
3A2	Corn for Silage (planting alfalfa within next 2 yr)	15 to 30 (**default 25**), tons/ac
3B	Corn for Grain	100 to 225 (**default 150**), bu/ac
VSWE	Sweet Corn, Early	N/A
VSWF	Sweet Corn, Full Season	N/A
3C	Sorghum-sudan, Sudangrass, Sunflower	N/A
3D	Oats, Barley, Rye, Wheat, Triticale, Millet	45 to 90 (**default 60**), bu/ac
3E	Dry Beans, Peas, Buckwheat	N/A
3F	Soybeans	N/A
Hay Crops and Pasture: New seeding		
1AE	Alfalfa / Grass mix; **30-60% legume**	N/A
1BE	Alfalfa / Grass mix; **60-100% legume**	N/A
1CE	Clover or Trefoil / Grass mix; **30-60% legume**	N/A
1DE	Clover or Trefoil / Grass mix; **60-100% legume**	N/A
1EE	Grass Hay **(less than 30% legume)**	N/A
2AE	Pasture, Grass (**less than 30% legume**)	N/A
2BE	Pasture, Horse	N/A
2CE	Pasture, Mixed (**more than 30% legume**)	N/A
Hay Crops and Pasture: Maintain existing stand		
1AM	Alfalfa / Grass mix; **30-60% legume**	2 to 6 (**default 4**), tons/ac
1BM	Alfalfa / Grass mix; **60-100% legume**	2 to 6 (**default 4**), tons/ac
1CM	Clover or Trefoil / Grass mix; **30-60% legume**	2 to 6 (**default 4**), tons/ac
1DM	Clover or Trefoil / Grass mix; **60-100% legume**	2 to 6 (**default 4**), tons/ac
1EM	Grass Hay (**less than 30% leg.**) 3 or 4 cuts / yr	3 to 6 (**default 4**), tons/ac
1FM	Grass Hay (**less than 30% leg.**) 1 or 2 cuts / yr	2 to 3 (**default 3**), tons/ac
2AM	Pasture, Grass (**less than 30% legume**)	N/A
2BM	Pasture, Horse	N/A
2CM	Pasture, Mixed (**more than 30% legume**)	N/A
Conservation Planting		
4AE	Warm Season Grasses - Establishment	N/A
4AM	Warm Season Grasses - Maintenance	N/A
4BM	Wildlife Food Plot - Brassica/Rapeseed/Canola	N/A
4CE	Wildlife Food Plot – Clover - Establishment	N/A
4CM	Wildlife Food Plot – Clover - Maintenance	N/A

Y1.................Nutrient data only (no fertilizer recommendations)
Z2.................Heavy metals only (no nutrient test) $15

Soil Test Report

Agricultural & Environmental Testing Laboratory and UVM Extension

The University of Vermont

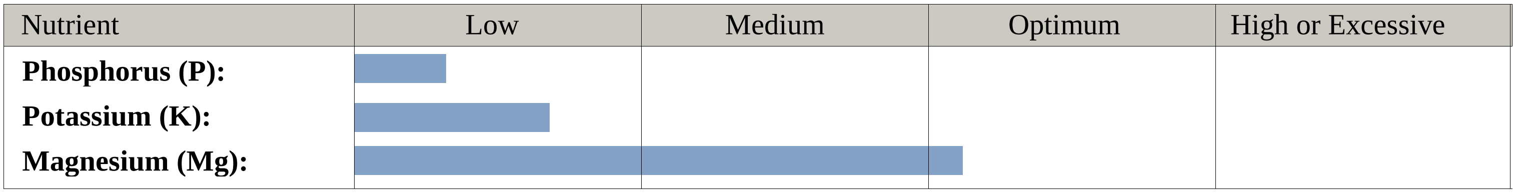
Prepared For:

Consultant:

Sample Information:
Order #: **451**
Lab ID: **S17-02**

Received: 6/26/2017
Reported: 7/10/2017
VT County:

Results



Analysis	*Value Found*	*Optimum Range (or Average *)*	*Analysis*	*Value Found*	*Optimum Range (or Average *)*
Soil pH (2:1, water)	5.8		Boron (B)	0.2	0.3*
Modified Morgan extractable, ppm			Copper (Cu)	0.2	0.3*
Macronutrients			Zinc (Zn)	0.8	2.0*
Phosphorus (P)	0.7	4-10	Sodium (Na)	52.0	20*
Potassium (K)	34	100-160	Aluminum (Al)	51	35*
Calcium (Ca)	1630	**	**Soil Organic Matter %**	5.8	**
Magnesium (Mg)	58	50-120	**Effective CEC, meq/100g**	8.7	**
Sulfur (S)	6.0	11*	**Base Saturation, %**		
Micronutrients			Calcium Saturation	69.2	40-80
Iron (Fe)	13.1	7.0*	Potassium Saturation	0.7	2.0-7.0
Manganese (Mn)	12.2	8.0*	Magnesium Saturation	4.1	10-30

** Micronutrient and S deficiencies are rare in Vermont and optimum ranges are not defined; thus average values in Vermont soils are shown instead.*
*** Ranges for Calcium, Organic Matter, and Effective CEC vary with soil type and crop.*

Recommendations for Corn for Silage (3A)

Limestone (Target pH of 6.2)	Nitrogen, N	Phosphate, P_2O_5	Potash, K_2O
tons / Acre	**lbs / Acre**	**lbs / Acre**	**lbs / Acre**
1.5	**120**	**95**	**140**

Comments: **Default Yield Goal: 20. tons / Acre**

Estimate nutrients supplied by manure - consult UVM Extension or Nutrient Recommendations for Field Crops in Vermont.
Add 10-20 lb/acre extra N in excessively drained (droughty) soils OR in somewhat poorly to poorly drained soils. Consult Extension Agronomists or References to estimate N credits from a grass or legume crop plowed down within the past 2 years.
Band most if not all phosphorus at planting. Do not band more than 60-80 lbs per acre combined N plus K2O.
See the 2016 Addendum to Nutrient Recommendations for updated information on nitrogen recommendations.

References:

2016 Addendum to Nutrient Recommendations http://pss.uvm.edu/vtcrops/articles/2016_Soil_Test_addendum_UVMExt.pdf

Manure
Sample Submission Form

The University of Vermont

Agricultural & Environmental Testing Laboratory
and UVM Extension

Main contact (mailing address)	Send copy to (Extension, NRCS, consultant, etc.). OR Billing name and address (if different than Main)
Name:	Name:
Farm/Company:	Company:
Address:	Address:
City, State, Zip:	City, State, Zip:
Phone:	Phone:
E-mail:	E-mail:
Send results by: Mail ___ or E-mail ____	Send results by: Mail ___ or E-mail ____

Manure (**Basic test $35**, includes % dry matter, total N, ammonium-N, P, K, Ca, Mg, Mn, Fe, Zn, Cu, and B)

Place sample in wide-mouth plastic quart jar (available from AETL)—**Do NOT use glass.** Fill no more than 2/3 full. Freeze if possible; seal jar in plastic bag before shipping. It is best to not ship samples on a Thursday or Friday, as they will sit in a truck or Post Office over the weekend.

You may list up to 5 samples on this sheet

Lab ID (For lab use only)	Sample Name	Indicate manure type if other than dairy (e.g., chicken, goat)	Fee
1			$
2			$
3			$
4			$
5			$

Please include payment, unless prior arrangements have been made. **Checks only**, payable to **UVM. Total fee $_______**

Send samples & payment to: **University of Vermont, AETL**
262 Jeffords Hall
63 Carrigan Dr
Burlington, VT 05405-1737

Other tests available on request. Email us at: agtesting@uvm.edu 802-656-3030 www.uvm.edu/pss/ag_testing
Test normally take 2 to 3 weeks after samples arrive at the lab.

NOTE: Compost and Saturated Media Extract (Greenhouse media) tests are no longer offered through UVM. See our website for a list of labs offering these tests.

Revised 08/31/2015

The University of Vermont

Manure Test Report

Agricultural & Environmental Testing Laboratory
and UVM Extension

Prepared For:

Consultant:

Sample Information:

Order #: **45**

Lab ID: **M17-0008**

Received: 6/23/2017

Reported: 8/1/2017

VT County:

6.28 % Dry Matter

8.34 Density (lbs per gallon)

Description	*lbs/wet ton*	*lbs/1,000 gal*	*Dry Wt. Basis*
			(%)
Total Nitrogen	6.0	24.9	4.75
Ammonium Nitrogen (NH_4-N, part of total)	2.4	10.0	1.92
Organic Nitrogen (part of total)	3.6	14.8	2.84
Phosphorus as P_2O_5	1.5	6.3	1.20
Potassium as K_2O	5.1	21.4	4.09
Calcium	2.1	8.8	1.69
Magnesium	0.9	3.7	0.70
Sodium	1.0	4.4	0.83
Micronutrients			*(ppm or mg/kg)*
Copper	0.07	0.3	583
Zinc	0.02	0.1	169
Iron	0.18	0.7	1,398
Manganese	0.02	0.1	150
Boron	<0.01	< 0.05	20

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