SOIL TESTING HANDBOOK

FOR PROFESSIONALS IN

AGRICULTURE, HORTICULTURE, NUTRIENT AND RESIDUALS MANAGEMENT

THIRD EDITION

Formerly "Soil Testing Handbook for Professional Agriculturalists"

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TABLE OF CONTENTS

SOIL TESTING CONVENTIONS IN THE U.S.

Soil testing is far from a uniform practice across the United States. Soil fertility testing is really the combination of *three* discrete but interrelated processes: analysis, interpretation, and recommendation (Eckert,1987). Many differences in these three processes exist between labs in different parts of the country and can be the source of great confusion. To help understand why these differences exist, an examination of each of the three processes is useful.

In sample analysis, the important components of soil fertility which may limit crop production are evaluated in the laboratory according to standardized methods. Since the early 1900's, laboratory procedures have been developed in each region which work well with soils and crops in the area and address those factors which are *most commonly limiting* to production. If a nutrient or other soil component does not usually limit crop production in the area, it is often not evaluated in order to limit the cost of the service to customers. Laboratory testing procedures are designed to provide consistent year to year results, as quickly and economically as possible.

Specific procedures often vary from one region to another, depending on climate, soil parent material, soil nutrient chemistry, and the types of crops grown in each region. Phosphorus testing can be used as a good example.

The University of Maine uses a (Modified) Morgan nutrient extraction procedure, which was developed at the University of Connecticut in the 1930's for use on acidic New England soils (Morgan,1941;Lunt et.al.,1950) Indeed, almost all New England State Universities and Cornell University still use a Morgan extract. The Morgan extract is a "universal" extractant, meaning all major nutrients (including phosphorus) and many micronutrients can all be measured in the one extract. The Bray phosphorus test was originally developed in Illinois for use on slightly acidic to neutral, high organic matter prairie soils (Bray,1942;Bray & Kurtz,1945). The Olsen phosphorus test was originally developed for use on arid alkaline soils (Olsen et. al., 1954;Olsen & Sommers, 1982). Three different Mehlich (universal) soil extractants were developed in North Carolina for use on sandy coastal soils (Mehlich: 1953, 1978, 1984). These different phosphorus extraction procedures, originally developed in different physiographic regions of the country, give quite different numerical results for available phosphorus level. But, numerical results are only the first step in the overall process.

Once the analytical results are obtained, the second process is to interpret these results relative to the soil's suitability to support plant growth and to maximize yield and quality from the crop to be grown. Interpretation is, of course, specific to the procedures used in the laboratory and the requirements of the crop being grown. Each individual testing system has been calibrated over several decades on soils and crops grown in each respective region, through greenhouse and field calibration trials. Soil test calibration information is also commonly shared within a region between states with common soils, crops, and testing systems.

The key to soil test calibration is to determine the "critical" test level for each major nutrient for each crop. The critical level is the minimum test level which statistically correlates to maximum yield. In other words, it is the lowest test value necessary to support the highest yields attainable in the area (Dahnke,1993;Cate & Nelson,1971). Adding a nutrient to raise the soil test level above this critical value will not produce an economic return on the cost of that addition. Once the critical soil test level for a nutrient is reached, crop yield will be limited by some other factor such as soil moisture, length of growing season, weed pressure, an insect or disease problem, or another nutrient level.

After the critical test level has been established for a nutrient for a given crop, the interpretation scale can be set up to divide test results into general categories. The University of Maine uses the categories "Low-Medium-Optimum-Excessive". Other category names and numbers of categories are used in other states (Beegle,1995). Each category is defined by the probability of a yield increase from the addition of a nutrient already present at a given test level for the crop being grown (Olson et.al.,1987; Beegle,1995). One of the keys to understanding any interpretation system and its categories is that it is not absolute, but is tied to statistical probability.

The third discrete process, after testing and interpretation, is to make a recommendation for the addition of nutrients. The recommendation process first must determine whether an additional quantity of a nutrient is actually needed at all, usually by whether the test level is above or below the critical level. If the test level is below the critical level for a soil component for the crop being grown, then the recommendation process also determines *how much* should be added. There are several different philosophies used in making recommendations for soil amendments. For most crop systems, the University of Maine uses the "soil buildup plus crop removal" method. Other states and labs may use differing philosophies, such as the "sufficiency level" method (Eckert,1987;Olson et.al.,1987). For some crop systems, such as vegetable gardens and ornamentals, UMaine also uses a sufficiency level-type system. Each is a legitimate way to manage soil nutrient levels to maximize crop yield, but can result in different recommendations from the same test results.

Interpretation and recommendation both depend on the specific analytical procedures used and on the state or region of the country in which they are used. It is important to note that a sample sent to a laboratory outside the region from which it was taken may not be tested according to the methods developed for use on soils from the region of origin. The interpretation of the test results also may not be appropriate for a soil and/or cropping system in another region of the country. That is not to say that different testing systems should not be used within any given region, provided that each has been appropriately calibrated for soils and crop management systems in that region. Some laboratories can even provide, on request, different regional testing methods and appropriate interpretations for samples from outside their own region. In any case, it is important to be sure that the testing methods and interpretations used by a prospective lab are appropriate for the region from which the soil sample was taken.

The remainder of this Handbook will address the three parts of the soil testing process as practiced at the University of Maine in more detail, along with some of the underlying and associated concepts of soils and soil fertility.

OVERVIEW OF MAINE SOIL TESTING SERVICE KITS AND FORMS

Soil Test Sampling Kits

Soil sampling kits are available at no charge at all County Extension offices. Most county Soil & Water Conservation Districts (SWCD), Natural Resources Conservation Service (NRCS), and Farm Services Agency (FSA) offices also have kits available. They can also be obtained directly from the Soil Testing laboratory at the address and phone number on the title page.

A Soil Sampling Kit consists of a collapsible paper box and a Field and Soil Sample Information Form. A composite soil sample should be taken according to instructions on the back page of the form. The user should identify each sample with a reasonably short, but descriptive name or number (15 letters and/or numbers maximum). Also record the sample identity on the front of page 1 of the Field form. Applicable questions on the first page should be answered where appropriate for each sample. Not all questions apply to all crop or management situations. The form has space for ten individual samples, so it is not necessary to use a separate form for each sample.

The completed Information Form should be included in the shipping container when mailed to the laboratory. Please do *not* put the Field form or check inside the box with the soil sample. Please do not send cash.

The Field and Soil Sample Information Form

Following is a partial description of important information requested from the user on the Field form.

Recommendation Crop Code

The crop code is the key to translating the test results into recommendations for the crop of interest. Common crops grown in Maine are coded under eight crop groups on page 3 of the Field form. The crop groups for which codes are provided are as follows:

Agronomic Crops: corn, cereal grains, forage crops.

Turf: lawns, athletic fields, golf courses.

Commercial Vegetables: more than one acre of any vegetable crop.

General Garden Crops (Conventional or Organic): less than one acre of mixed vegetable or small fruit crops grown using chemical or organic fertilizers.

Commercial Fruits: highbush blueberries, cranberries, or more than one acre of apples, stone fruit, strawberries, or raspberries.

Forestry: general forestry (plantations), Christmas trees, tree nurseries.

Commercial Potatoes: more than one acre of processing, table stock, or seed potatoes.

Ornamentals: annuals, perennials, shrubs, broadleaf and evergreen shade trees.

Select the code number which best fits the crop to be grown. Please note that there are separate codes for seeding and for topdressing of several different crops. Please be sure you have the correct crop code for your particular situation. If no match can be found, you may write the name of the crop for which a recommendation is needed in the crop code space on the form. The laboratory will assign an appropriate code number to the crop so that a recommendation can be computed. It is not practical to list all possible crops on the code sheet. If an unlisted crop comes up frequently enough, it will be assigned a code number when the Field form is revised.

More than one crop code may be chosen if more than one recommendation is needed. Separate Report/Recommendation forms will be sent for each crop code chosen.

Yield Goal

Assumed yield goals for all forage crops are listed in the Agronomic Crops section of this Handbook. If you wish to manage for a yield which is significantly higher or lower than the yield listed, write in the expected yield in the Yield Goal column. Recommendations or nitrogen, phosphate, and potash application rates will be adjusted accordingly.

Potato Rotation Crops

In situations where recommendations are being requested for crops grown in rotation with commercial potatoes (ex. oats, corn, or clover) and where potatoes will be grown in the same field within the next 2 to 3 years, the potato rotation column labeled "yes" should be checked. Lime will be recommended to maintain soil pH in the proper range for potato production.

The potato rotation column should also be checked for home gardens (conventional or organic) where potatoes are being grown. Additional pH management information will then be included for garden potatoes.

Special pH Management Level

The pH level of the soil is typically adjusted to provide for optimum nutrient availability while taking into account the pH tolerance of the particular crop being grown. However, other considerations may be included in determining the pH management level of your soil, such as biosolids or ash application regulations or plant species/variety requirements not covered under the crop code options listed. Unless otherwise indicated by the user, the lime recommendations and the CEC and nutrient balance calculations on the Report form will be based on the target pH management level listed on the back of page 3 of the Field form. If you wish to manage the soil pH at some other level than that shown on the list, please choose the code (1-7) on page 1 which most closely matches the pH you wish to maintain.

A pH management code 2 will report CEC and nutrient balance at the current pH level of the soil, showing all conditions as they *currently* exist in the field rather than at a projected target pH. No lime will be recommended if this pH management code is chosen.

You may choose more than one pH management level for any one sample. An extra Report/Recommendation form will be generated for each additional pH management code chosen.

Request for Confidentiality

Unless otherwise requested, a copy of your Report/Recommendation form will automatically be forwarded to your county Extension office. A copy of all reports with recommendations for forage seedings will also be forwarded to your county FSA office, to meet requirements for USDA cost-sharing programs. If you do *not* want a copy of your report sent to these agencies, check the box in the lower left corner of page 1 of the Field form.

Problems

If specific problems are being experienced or if a special analysis is required, the problem should be explained in writing on the back of page 1 of the Field Form. The laboratory staff will determine if additional analyses are needed and forward a copy of test results to an Extension specialist or county Educator for more intensive help with the problem. The laboratory will notify the user if additional charges are incurred.

Available Tests and Test Fees

The routine Standard Soil Test includes pH, lime requirement, organic matter, available phosphorus (P), potassium (K), calcium (Ca), and Magnesium (Mg). Available zinc (Zn)

is also reported for commercial corn and potato crops. All homeowner samples (gardens, turf, and ornamentals) are also screened for unusually high lead (Pb) levels. These tests are provided at a charge of $12.00 per sample (eventually subject to change).

Non-routine or special tests can be performed either for free or for a small additional cost. The most commonly requested additional analyses and their prices are listed on the back of the Field form. Several of these can be requested by checking the appropriate column on the front of page 1. To obtain prices and availability of other analytical services not shown on the Field form, consult your local county Extension office or contact the Analytical lab at the above address and phone number.

The Soil Test Report/Recommendation Form

Laboratory test results are reported on a standardized computer form. An example Report form is presented as the first appendix in this handbook. A copy is mailed directly to the user from the laboratory. A second copy is sent to the local county Cooperative Extension office or to an Extension crop specialist for use in responding to questions the user might have about results and recommendations or specific problems. A third copy, for forage seedings only, is sent to the county FSA office for use in cost-sharing conservation programs. A fourth copy is retained by the laboratory for reference. The user may request that copies *not* be sent to Extension or FSA (see Request for Confidentiality, above), in which case only copies for the user and the laboratory will be generated.

Test results are also permanently stored on computer database for future summarization and retrieval. Copies of the original report can be reprinted if lost or recommendations for additional crops or pH management levels may be requested, all free of charge.

Relative Nutrient Levels

The bar graphs at the center of the Report form translate the test results into relative soil fertility ratings. This enables the user to visually determine the general fertility status of the soil. Each bar of X's provides a continuous rating for each nutrient, the soil pH, and soil organic matter relative to the optimum range for the specific crop requested. Definitions of interpretive levels appear later on.

Lime and Fertilizer Recommendations

Calculated lime and nutrient requirements are given in the middle of the Report form along with specific management statements designed to maximize efficiency of applied nutrients. The calculated nutrient requirements represent the amount of each nutrient needed to supplement the present level in the soil in order to maximize yield under Maine conditions, if there are no other factors limiting production.

For commercial growers the nutrient requirements are stated in terms of pounds of lime, nitrogen, phosphate (P_2O_5), and potash (K_2O) per acre. Since commercial growers use relatively large amounts of fertilizer, it is often cheaper to purchase nutrients as bulk blends developed on the basis of the calculated nutrient requirements. Recommending each nutrient separately also gives the commercial operator more flexibility in filling nutrient requirements from a variety of sources. An operator may choose, for instance, to fill the calculated requirements with a combination of animal manure, boiler ash, and chemical fertilizer rather than blended fertilizer alone.

The recommendations for turf, home gardens, and ornamentals are translated into pounds of ready-mixed N-P_2O_5-K_2O fertilizer per 100 or 1000 square feet, since the small total amount of fertilizer required dictates use of commonly available blends. A typical management statement in these cases advises the user to substitute a grade of similar N-P_2O_5-K_2O ratio (and to adjust the application rate) if the listed analysis is not available.

Lime and fertilizer recommendations will be dealt with in more detail in later sections.

Laboratory Results

Laboratory test results and customer/sample information are all permanently stored in a soil sample database. A PC-base program converts the laboratory data into numerical results that appear on the Report form. If numerical data is maintained on a given field and accumulated over a period of years, the user can determine the effectiveness of an applied fertility program. The laboratory results at the bottom of the form give the following specific soil properties:

Soil pH

Lime index (lime buffer capacity)

Available P, K, Mg, and Ca as pounds/acre

Estimated soil cation exchange capacity (CEC) at the target pH management level

Percent saturation of the soil CEC with K, Mg, Ca, and acidity (nutrient balance)

Percent organic matter

Available Zn as parts per million on applicable crops

Exchangeable Na, total soluble salts, nitrate-N where requested

Lead scan results for gardens, turf, and ornamentals

Where applicable, the optimum range of numerical values for these results are given for the specific crop/management situation for which recommendations are requested. The optimum range appears directly underneath the test results for each nutrient or other component.

A statement appears just above the first row of numerical results which lists the pH management level requested by the customer or chosen by the lab. This is important in understanding the estimation of CEC, the calculation of nutrient balance, and the calculation of lime and fertilizer recommendations.

An explanation of the numerical results and sample calculations appear later on.

Billing Information

At the very bottom of the Report form is a billing statement which shows the current status of the customer's account with the lab, with respect to this one sample. Any payments received will be listed here as well as any remaining balance due for the analytical services provided on this sample. The billing statement line should be treated as a billing invoice. If an invoice number is required, the printed number in the upper right corner of the Report form should be used.

EVALUATING COMPONENTS OF SOIL FERTILITY

The discussion and example calculations which follow will help to explain the significance of the laboratory data on the Report form.

Soil pH

The soil pH appears on the left end of the laboratory results line. It is defined as the negative log of the hydrogen ion activity in the soil solution:

$$pH = - \log [H^+]$$

The pH value (also called "soil reaction") tells whether or not the soil is acid or alkaline and to what degree. A value between 6.5 and 7.5 is considered neutral, whereas values below 6.5 are acidic and values above 7.5 are alkaline. Relative ratings of degree of acidity and alkalinity are as follows:

Soil Reaction Description	pH Range	Normal Crop Response
Extremely acid	Below 4.5	Very Poor*
Very strongly acid	4.5-5.0	Poor*
Strongly acid	5.1-5.5	Moderately good
Medium acid	5.6-6.0	Good
Slightly acid	6.1-6.5	Very good
Neutral	6.6-7.3	Very good
Mildly alkaline	7.4-7.8	Moderately good**
Moderately alkaline	7.9-8.4	Poor**
Strongly alkaline	8.5-9.0	Very good**
Very strongly alkaline	Above 9.0	Few grow

*Blueberry, Cranberry, Azalea, Rhododendron, and other acid-loving plants are exceptions.

**Micronutrients become the major limiting factor.

The optimum soil pH range for the crop requested is listed directly underneath the level found. The ideal range typically covers a full pH unit, usually from 0.5 units below to 0.5 units above the target pH chosen by the lab or requested by the user.

The bar graph which interprets the soil pH on the Report form is calibrated to reflect the optimum pH of the crop for which recommendations were requested and/or the pH management level requested. This graph will typically show "above optimum" if the soil pH exceeds the target pH management level by 0.5 units.

Lime Index: Buffer pH and Exchangeable Acidity

The soil is a highly buffered system. The amount of hydrogen ions in the soil solution (soil water) is small and can usually can be neutralized with about a pound of lime per acre. Hydrogen ions in soil solution are in equilibrium with and are replenished by the reserve acidity adsorbed on exchange sites in the soil. The acid ions adsorbed on the soil particles act as a reserve pool which continuously supplies hydrogen ions to the soil solution as they are neutralized. The soil pH cannot be raised to the desired level until this reserve acidity is neutralized. The size of this pool of reserve acidity, also called exchangeable acidity, is what actually determines the lime requirement of the soil.

The soil *lime index* value is the key to measuring the pool of reserve acidity. A buffer solution of standardized pH and strength is reacted with the soil. Acid-forming ions (primarily aluminum) held in reserve on exchange sites are forced into solution by mass exchange and are neutralized by the buffer. This results in a depression in the pH of the buffer solution, which is measured after a 30 minute reaction time. It is this ending pH which appears on the Report form as the "Lime Index 2" value. The final pH of the buffer solution along with the current pH of the soil are used to quantify the soil acidity to be neutralized and to calculate the pounds of lime needed to raise the soil pH to the desired level.

Prior to April, 2001 the lime buffer test used was the Shoemaker, McLean, Pratt or SMP buffer method (Shoemaker, McLean, Pratt, 1962), which was designated "Lime Index". The SMP method was discontinued due to concerns over toxicity to lab personnel and the volume of hazardous waste generated. Starting in April, 2001 the lime buffer test was changed to the Mehlich buffer method (Mehlich, 1976). The Mehlich buffer is designated as "Lime Index 2" on the Report form. The benefits of the Mehlich method include its greater analytical stability (greater precision) and no toxic reagents. Both lime buffer tests were calibrated from lime incubations run during 2000 on representative soils from Maine (Hoskins, 2001 currently unpublished). The two methods gave comparable results in side by side comparisons on several hundred routine samples, using regression equations derived from this incubation data.

Calculating Exchangeable Acidity

For any combination of current soil pH and lime index, the following calculations are used to predict the milliequivalents of base (as calcium carbonate) which must be added to 100 gm of soil to achieve the target pH listed (Hoskins, 2001 unpublished data). These equations are actually *lime response* equations, but in practice they are also used as a reasonable approximation of the exchangeable acidity neutralized to achieve the same target pH:

pH 7.0 target: 62.6-(2.33 x soil pH)-(7.13 x lime index 2)

pH 6.5 target: 51.8-(2.77 x soil pH)-(5.38 x lime index 2)

pH 6.0 target: 39.3-(3.69 x soil pH)-(2.83 x lime index 2)

Since these equations are statistically derived from experiments, they are only predictors of lime response and exchangeable acidity, not exact measurements. If the current pH of the soil is at or near the target pH of interest, a negative acidity value may result from the calculation. Any negative values should be rounded to zero. See "Soil pH Effect" in the lime section for other considerations on the calculation of exchangeable acidity.

The reserve acidity occupies the same sites in the soil used to hold many of the essential nutrients. When this reserve acidity is neutralized, these sites are free to hold essential plant nutrients and the effective nutrient-holding capacity of the soil is increased. This increase in nutrient-holding capacity with an increase in soil pH is termed "pH-dependent cation exchange capacity".

 Readily exchangeable acidity at current soil pH is traditionally measured by titrating a potassium chloride extract of the soil (USDA, 1996). This measure of exchangeable acidity can also be approximated from the lime buffer test. To estimate readily exchangeable acidity at the *current* soil pH, rather than at a target pH, use the following equation (Hoskins, 2001 unpublished data):

20.14-(0.88 x soil pH)-(2.46 x lime index 2)

This calculated value should be near zero if the soil pH is 5.6 or higher. Again, this is a statistically derived equation which should be rounded to zero if a negative value results.

Indexing Nutrient Availability

To the right of the pH results are the currently available soil nutrient levels expressed on a pounds per acre basis. These are really projections of the available nutrient levels found in the soil, as it is processed in the lab, expanded to a per acre basis. These projections are based on the rough conversion factor of 2 million pounds of soil in an acre plow layer (6 2/3 inches deep). In other words, the pounds per acre values listed are actually pounds per 2 million pounds of soil.

Pounds per acre values are often presented as the quantity of nutrients available for plant uptake, though in reality they are not *exact* measures of plant nutrient intake for the growing season. More precisely, these values serve as an availability "index", a scale which is closely related to actual plant uptake and/or yield (if no other factors limit yield). As long as this close relationship exists for each nutrient, the availability index can be accurately interpreted to determine relative nutrient level and quantity of nutrient (if any) to be amended to the soil to raise that nutrient level to "optimum". The optimum level or

range is the index level which correlates to maximum yield (Dahnke,1993). In soil testing calibration, this test level which statistically corresponds to maximum yield is called the "critical" soil test level (Cate & Nelson,1971).

Phosphorus (P) test results are reported on a pounds per acre basis only. The optimum phosphorus level varies from crop to crop and is listed in the "optimum range" section directly underneath the level found. The P bar graph is calibrated to display any value within this range as "optimum".

The plant available forms of potassium (K), magnesium (Mg), and calcium (Ca) are held in the soil as positively charged ions called cations. The optimum level of these three nutrients depends on the soil's ability to hold cations. This is called cation exchange capacity (CEC). The interpretation of K, Mg, and Ca levels is not done using pounds per acre values, but only after further calculations involving CEC. This calculation procedure is explained below.

Soil CEC

The cation exchange capacity (CEC) is an estimate of the total quantity of (+) charged nutrient ions (cations) a soil contains or can hold against leaching. CEC is essentially the total (-) charge in the soil which can attract and hold the (+) charge cations. Values of CEC are expressed in electrostatic charge units called milliequivalents per 100 grams of soil (me/100gm). In strongly acid soils the CEC is occupied primarily with exchangeable acidity (mostly aluminum). In slightly acid and neutral soils the CEC holds basic cations like Ca, K, and Mg, and relatively little acidity. Soils vary in CEC because of differences in texture, mineralogy, pH, and organic matter content.

For the purposes of our reporting system, the soil CEC is calculated by adding up the milliequivalents (me/100gm) of acidity, Ca, Mg, and K, since the CEC in most soils is occupied with just these four components. Acidity saturation is the portion of the potential CEC holding acid-forming ions (primarily aluminum) which must be neutralized with a lime application. *Base saturation* is the remaining portion of the CEC holding the nutrient cations Ca, Mg, and K.

The following equations are used to estimate soil CEC:

$$CEC = acidity + Ca + Mg + K \text{ (all in me/100gm soil)}$$

$$me \text{ of acidity/100gm} = me \text{ acidity at target pH}$$

$$me \text{ of Ca/100gm} = lb \text{ Ca per acre/401}$$

$$me \text{ of Mg/100gm} = lb \text{ Mg per acre/243}$$

$$me \text{ of K /100gm} = lb \text{ K per acre/782}$$

Using the data from the example Report form in appendix EX, the following CEC calculations can be done:

acidity(neutralized to reach pH 6.5) = 51.8-(2.77 x 6.2)-(5.38 x 5.97)= 2.51 me/100gm

$$Ca = 2555/401 = 6.37 \text{ me/100gm}$$

$$Mg = 229/243 = 0.94 \text{ me/100gm}$$

$$K = 253/782 = 0.32 \text{ me/100gm}$$

$$\text{Soil CEC} = \text{acidity} + Ca + Mg + K$$

$$= 2.51 + 6.37 + 0.94 + 0.32$$

$$= 10.14 \text{ me/100gm}$$

Hand calculations may give slightly different results from the computer, due to differences in rounding.

The difference between CEC calculated at current soil pH and CEC calculated at a target pH depends on how far the current pH is below the target and how much reserve acidity must be neutralized to reach the target pH. This illustrates the difference between *effective CEC* (calculated at the current pH of the soil) and *potential CEC* (calculated at a target pH) (Thomas,1982; Ross,1995). The type of CEC (effective or potential) appearing on the Report form can be determined by whether the pH management statement in the Laboratory Results section specifies current pH or a target pH. In most cases, the CEC appearing on the Report form will be a potential CEC at a target pH.

pH Effect on CEC

The difference between potential and effective CEC is termed "pH-dependent cation exchange capacity" and is determined by the relative amount of neutralizable acidity present at any given soil pH. In highly acidic soils, most of the *potential* CEC will be pH dependent. This will be reflected in a high percentage of acidity.

Research has shown that the CEC of the average Maine agricultural soil varies by 5.3 me/100gm for each 1.0 pH unit change (Bourgoin,1981). This means that the *effective* CEC (active at the current soil pH) increases as pH rises and decreases as pH falls. A drop in pH means a loss of effective CEC and that some cationic nutrients will lose their retention sites. These cations will leach away if no other mechanism of retention is available, such as plant uptake or precipitation in an insoluble form.

This same research has also shown that the *effective* CEC of Maine soils is essentially 100% saturated with the basic cations above a pH of 5.6 and remains 100% base saturated as pH rises. So as pH rises above 5.6, total base saturation remains near 100 %

and acidity (as a percent of effective CEC) remains near 0, even as the CEC continues to increase. This increase in effective CEC comes from the neutralization of reserve acidity and the activation of exchange sites formerly occupied by it.

Other Properties Affecting CEC

Effective and potential CEC are also determined by soil organic matter and clay content. Since (-) charged exchange sites in soils exist almost exclusively on clay and organic matter particles, the relative levels of each of these components is very important in determining the soil CEC. Soils high in clay content have a naturally high CEC. The types of clays present in the soil can also affect the magnitude of soil CEC, as well as the soil's relative ability to hold and release specific nutrient cations. Similarly, soils with a high organic matter content also have a relatively high CEC. Since clay content cannot be easily changed, the easiest way to enhance soil CEC is to increase organic matter content through additions of animal manure, compost, or crop residues (including green manure crops).

Percent Saturation

Percent saturation is a good means of evaluating nutrient balance because it shows the relative level at which various nutrients and reserve acidity occupy the soil CEC. Percent saturation is calculated by dividing milliequivalents of each cation by the calculated CEC and multiplying by 100. In the previous sample CEC calculation, the soil contains 2.51 me acidity/100gm, 6.37 me Ca/100gm, 0.94 me Mg/100gm, 0.32 me K/100gm and a CEC of 10.16 me/100gm. Percent saturations would be calculated as follows:

$$\% \text{ Acidity} = 2.51 / 10.14 \times 100 = 24.8 \%$$

$$\% \text{ Ca} = 6.37 / 10.14 \times 100 = 62.8 \%$$

$$\% \text{ Mg} = 0.94 / 10.14 \times 100 = 9.3 \%$$

$$\% \text{ K} = 0.32 / 10.14 \times 100 = 3.2 \%$$

After saturation percentages are calculated, the remaining nutrient levels are interpreted.

Ideal cation saturation levels were first proposed by Bear & Toth (1948) and later modified to saturation ranges by Graham (1959) (Eckert,1987). Graham's original saturation ranges have been modified to some extent to compensate for Maine crops, soils, and growing conditions.

The ideal range of Ca saturation is 60-80% of the soil CEC. When Ca exceeds 80% of the soil CEC, it is rated excessive. The range of 1 to 50 X's in the Ca bar graph corresponds to 20 to 80 % Ca saturation.

The ideal range of Mg saturation is 10-25% of the CEC. Magnesium is recommended when the Mg saturation drops below 15%, or the ratio of % Mg to % K is less than 2:1. Magnesium is rated excessive when it exceeds 25% of the CEC.

The ideal range of K saturation varies by crop, but is typically 3-5%. Potassium is rated as excessive when it exceeds the optimum range for the crop. High levels of K can compete with Mg for uptake. The optimum percent saturation range for the crop specified is listed in the optimum range section directly below the level found and the bar graph is calibrated to display any value within this range as "optimum".

CEC Adjustment

When a soil sample is taken after a recent lime application or within a year after a heavy lime application, there will still be a certain amount of unreacted lime in the soil. In these situations, the amounts of Ca and Mg extracted from the soil will be partially from exchange sites and partially from dissolved lime. A CEC calculated using these cation levels will be erroneously high, since the Ca and Mg are not derived entirely from exchange sites.

To correct for this situation, an additional barium adsorption test is performed on all high pH soils which isolates and corrects these samples (Analytical lab, unpublished data). The correction is made by adjusting the milliequivalent levels of Ca and Mg downward on a proportional basis until the CEC equals that calculated from the additional test. In those cases where an adjustment has been made, this symbol will appear next to the CEC: (A). The pounds per acre levels reported on the Report form are not adjusted. Only the CEC and percent saturation calculations will be affected.

Hand calculation of CEC on adjusted samples will result in a higher CEC than what appears on the Report form. To calculate adjusted milliequivalent levels of Ca and Mg, simply calculate backward from the percent saturation levels:

me/100gm Ca (adjusted) = CEC(adjusted) x % Ca saturation / 100

me/100gm Mg (adjusted) = CEC(adjusted) x % Mg saturation / 100

Nutrient Balance

There is usually an inverse (and adverse) relationship between a very high concentration of one cation in the soil and the availability and uptake of other cations by the plant. Excessive Ca can induce Mg deficiency, especially when Mg is below 5% saturation. Excessive K also suppresses Mg uptake. Excessive Mg can limit Ca availability. Therefore, balance between the three nutrient cations is important.

In figuring the proper balance it is assumed that the soil is 100% base saturated within the ideal pH range. If the three base cations are also within the respective optimum ranges listed, they are considered to be in proper balance with each other. Balance should result

in optimum availability for plant uptake of all three nutrient cations. An imbalance would occur if one or more cations is present at an excessive level while another is present at a low level. Because of the inherent competition between cations, an excess of one in this case could cause or worsen a deficiency of the nutrient present at a low level. A deficiency caused by a gross imbalance is called an "induced deficiency".

The emphasis on nutrient balance in this interpretation/recommendation system should not be misunderstood as an attempt to adjust cations to some set of ideal ratios. Instead, the goal is to ensure a sufficient supply of each nutrient by adjusting its saturation level to fall within the optimum range listed and to avoid imbalances which may induce deficiencies (Eckert,1987). A few simple calculations can demonstrate that the actual ratio of one nutrient cation to another can cover a wide range of values, even with each being within its respective optimum range. For example, the optimum ranges for Ca (60 - 80 %) and Mg (10 - 25 %) result in Ca:Mg ratios ranging from 2.4:1 to 8:1.

Important limitation: Percent saturation is (with few exceptions) the primary means of interpreting the K, Mg, and Ca levels in this testing system. The Relative Soil Nutrient Level graphs are always calibrated based on percent saturation values for these nutrients. In some unusual cases where the soil has a very low CEC, the nutrients may be present within the optimum percent saturation ranges and be interpreted as optimum, but still not be present in sufficient quantity to support crop growth for the entire season (Bear & Toth,1948). This could occur in soils with a CEC of less than 5 me/100gm where a heavy K-demand crop such as potatoes or corn is being grown. In a situation such as this, it may be necessary to add nutrients more than once during the growing season, since the soil's supply of exchangeable K will be depleted rapidly.

Phosphorus does not exist as a cation in soils and so is not included in cation balance calculations. If the soil P level is maintained within the ideal range listed for the crop and if the soil pH is also in the ideal range, an adequate P-supplying capacity should be assured.

Soil Organic Matter

Organic matter is decayed or humified organic material (crop residues, compost, manures, etc) in the soil. There are actually several techniques used to measure soil organic matter level. There is a simple ignition technique where the soil is heated to a very high temperature to burn off the organic matter (Ball,1964). The other major technique is to chemically digest or oxidize the organic carbon in the soil, using the method of Walkley & Black (1934), which is then used to estimate organic matter. Both are valid monitoring techniques, but give different numerical results. It is possible to establish a statistical relationship between these two methods, so that the ignition method can be used to estimate Walkley-Black organic matter and vice-versa. Most soil management books, reference manuals, and pesticide labels reference organic matter on the Walkley-Black scale.

In the past, the Maine Soil Testing Service has reported organic matter in terms of "loss on ignition". The faster and less hazardous ignition method is still used in the lab, but since 1995 the ignition value has been converted to Walkley-Black equivalence. Reporting organic matter on this basis makes test results compatible with current reference manuals and labels.

Using the Walkley-Black scale, the ideal soil organic matter level from the nutrient cycling and fertility standpoint is generally considered to be 5 - 8 %. If organic matter level falls below 2 - 3 %, the nutrient and water holding capacity of the soil becomes very limited and may not be sufficient to support normal plant growth during some growing seasons.

Additional Components

Available Zinc

Available zinc is reported and interpreted only for field corn, sweet corn, and commercial potato crops. Zinc is a micronutrient which is rarely limiting to plant growth in Maine. It is reported for corn and potatoes, since a response to added zinc has been shown in some cases for these two crops only.

The optimum level for both crops is 1 ppm (parts per million) of available zinc. If the available zinc level is less than 1 ppm, there is a reasonable probability of a yield response to added zinc. If the available zinc level is greater than 1 ppm, there is very little chance of a yield increase from added zinc.

If the zinc level is above 2 ppm, zinc should not be used in a banded fertilizer, which would be concentrated in the root zone. As with most micronutrients, if too much is applied, the resulting soil level may actually be toxic to plants growing in it. The exact level where toxicity will occur depends on soil texture, pH, organic matter, and the plant species and variety. To be safe, it is best not to purposely apply zinc where a need is not indicated.

When zinc is needed, a typical application rate is only 1 to 2 pounds actual zinc per acre if it is banded and 4 to 8 pounds per acre when broadcast. Specific application rates will be suggested when zinc is recommended.

Exchangeable Sodium

In cases where contamination from road salt or seawater is suspected, an exchangeable sodium test may be requested at no extra cost. Sodium (Na) is present in soils as an exchangeable cation and can compete with essential nutrient cations for exchange sites. It is easily extracted and measured with the nutrients.

When Na is present at very high levels (above 15 % saturation of the CEC) soil aggregates may be dispersed (also called soil puddling), causing a loss of soil structure,

drainage, and aeration. More moderate levels of sodium can interfere with the availability of the nutrient cations. Excess sodium can also cause salt-effect desiccation damage to plant roots.

Since water soluble salt content of soil will decrease as the season progresses and since sodium is retained by soil after a salt contamination event, exchangeable sodium content is often a more reliable long-term indicator of salt contamination than is a total soluble salt test.

Lead Scan

All home/grounds soil samples are scanned for possible lead contamination. Lead is a naturally occurring trace element present in *all* soils at a normal background level of less than 50 parts per million (ppm)(Pendias&Pendias). Lead "enrichment" or contamination of soils is a problem almost exclusively around older buildings or building sites. The usual source of this contamination is lead paint chips flaking, scraped, or sand blasted from these buildings over several decades. Lead paint was not banned until the 1970's.

The lead scan is NOT a complete test for the presence of lead contamination. It is an initial screening for the presence of lead at a level higher than the normal background level. The lead scan report will indicate either a normal background level, a moderate contamination level, or a heavy contamination level. The normal background level would not pose any health risk due to lead in the soil. A moderate to heavy contamination could, under the right circumstances, significantly add to the total daily intake of lead for those people working or playing in that area. Any vegetable garden or flower bed soil, in which there is an indication of moderate to heavy lead contamination, will automatically be tested for total lead content. Any lawn area with an indication of heavy contamination will also be tested for total lead content. A *separate* report with suggested guidelines and actions will be sent at a later date, usually within 2 to 4 weeks.

Lead is primarily a concern with growing children, who are much more sensitive to it than are adults. To be harmful, lead must be ingested by eating it or breathing the dust. Plants do not typically accumulate significant quantities of lead internally. Surface contamination of edible parts from dust, rain spatter or direct soil contact (as with root crops) is usually the most significant source of plant contamination. Additional information on lead contamination is available through your county Cooperative Extension office or through the Maine Soil Testing Service.

INTERPRETATION OF RELATIVE SOIL FERTILITY LEVELS

The test results for your soil are first presented as a series of bar graphs meant to help you visually interpret the actual numerical results which appear at the bottom of the report. Each graph is calibrated so that the optimum range listed for pH, organic matter, and each of the nutrients falls in the area under the "OPTIMUM" label. This rating system is based on the statistical probability of a positive crop yield response to the addition of a nutrient or to a higher soil pH or organic matter level (Olson, et.al., 1987; Beegle,1995).

Notes on environmental interpretation: There is no intent with this system to make any interpretation as to the potential environmental impact of sensitive nutrients, such as phosphorus. This interpretation system is meant strictly for the determination of current soil suitability for agronomic or horticultural crop production. While nutrient availability can be important in gauging the potential for adverse environmental effects, it is only one factor in the overall picture. Slope, ground cover, incorporation of nutrient sources, timing of application, and other considerations all affect the potential movement of nutrients off-site and their potential for adverse environmental impact on surface and ground water (Lemunyon & Gilbert,1993; Beegle,1995).

The formal agronomic/horticultural definition of each interpretation level follows:

LOW

A nutrient or other component interpreted as "low" will likely limit plant growth and yield. There is a high probability of improved yield from an addition of and/or higher level of this component. A recommendation will be made to substantially increase the soil level. If the level is very low, several years of corrective fertilizing or liming may be necessary to achieve an optimum soil level. Close monitoring by yearly soil testing is suggested in this case. Banding of fertilizer near the row becomes critical at this test level to ensure efficient use and maximum nutrient availability within the rooting zone of the crop.

MEDIUM

A nutrient or pH level listed as "medium" has a moderate probability of an improved crop yield with a higher level. A medium nutrient level may limit plant growth or yield by the end of the growing season or in years of very good growing conditions, though it may be adequate for some low-demand crops in some cases. Corrective fertilizing or liming is usually recommended in moderate amounts to result in a slight increase in soil level after the crop has been removed or to support an exceptional yield in a very good year.

OPTIMUM

A soil component listed as "optimum" is in the theoretical ideal range to support growth and maximize yield. There is a low probability of an improved yield from a higher level of this component. Corrective fertilizing is not recommended. Any amendments

recommended for a component listed as "optimum" are to compensate for crop removal, so that this optimum level can be maintained from year to year. Even crop removal additions are not needed if the soil is tested yearly. A small amount of a starter fertilizer containing this nutrient may also be recommended.

ABOVE OPTIMUM

An "above optimum" level of a soil component indicates a level higher than needed to support normal plant growth. The probability of an improved yield from a higher level is very low. In fact, growth and yield could be inhibited in some cases, either because of direct toxic effects to plants or because the overabundance of one nutrient may interfere with the uptake or availability of others. Additional application of something already at an above optimum level will only increase the likelihood of reduced yield. There will be no recommendation for further additions of this component under ordinary circumstances. Crop removal and other natural losses over time should eventually reduce the nutrient, pH, or organic matter level to optimum after a few years.

On sites receiving regulated materials, it is allowable to "load" the soil with strictly limited amounts of lime, P, and K to raise soil levels over and above that needed for maximum yield. In these cases, soil levels are not to exceed safe loading limits established by the Maine Department of Environmental Protection. In some of these cases, the current test level of P, K, or pH may be interpreted as above optimum from the standpoint of crop production, but still qualify for further application, provided they do not exceed safe loading limits.

RECOMMENDATIONS

Factors Influencing Recommendations

Soil Buildup: The quantities of additional Ca, Mg, P and K required to supplement the present soil content in order to achieve theoretical optimum nutrient levels. Soil buildup is also called *corrective fertilization* or *fertilizing the soil* (Olson et.al., 1987). For most crops, the Maine recommendation system typically emphasizes the soil's ability to store and release phosphorus and potassium over more than one growing season. In this way, the soil is treated as a nutrient repository. Soil buildup can be a gradual or all-at-once practice. Practicality must be considered in corrective fertilization. Where insufficiency is small, crop removal plus corrective additions can be done at one time. When large insufficiencies exist, a gradual approach (several years) is more practical. Therefore, there is a maximum application limit for any one year.

Crop Removal: A certain uptake quantity of each nutrient into the plant is critical in maximizing yield. Normal harvest removal of nutrients must be replaced in order to maintain an optimum fertility status in the soil. Once an optimum soil level is attained, only crop removal quantities need be applied to maintain this level. Crop removal quantity is also called *maintenance level* application.

Sufficiency Level: In a sufficiency level system, a nutrient is applied only if the test level is below the critical or no-response level (the absolute minimum necessary to support maximum yield). There is no overt attempt to maintain optimum level from year to year by factoring in crop removal (Olson et.al.,1987; Eckert,1987). The emphasis is to maintain a sufficient level of each nutrient to support yield and no more. Sufficiency level is also called *fertilizing the crop*. This is the concept used for home gardens, organic crops, and ornamental crops in the Maine system. For smaller-scale mixed cropping systems such as these, the sufficiency levels are high enough (to cover the requirements of heavy feeders) and soil test monitoring frequent enough that crop removal need not be factored in.

Minimum Recommendations: Practicality in being able to apply small amounts of fertilizer or lime evenly with available equipment is used in determining minimum recommendation. This limit is invoked when a nutrient tests near optimum and only crop removal quantity or starter recommendations are made.

Maximum Recommendations: Nutrient inputs typically have an associated cost which must be taken into account when making recommendations. At very low test levels, the total amount of a nutrient needed to cover crop removal *plus* soil buildup to the optimum level may exceed the income from several years of any attainable yield. Because of this, a maximum limit is placed on all phosphate and potash recommendations, depending on the relative value of the crop. Limiting maximum recommended application also lessens the possibility of temporary nutrient imbalance and fertilizer salt burn, especially with potash.

Excessive Levels: When a soil contains an available nutrient at an excessive level, there is the potential for uptake competition with other essential nutrients. For certain nutrients, there may be a direct toxicity effect from excess availability. The normal breakdown of excess organic matter can result in an overabundant supply of available nitrogen during the growing season, resulting in excess foliar and height growth and delayed blossoming or ripening of fruiting crops. In these cases a zero recommendation is usually applied to the nutrient or other component in excess. In time, cropping and normal loss to leaching should reduce the level to the optimum range.

Starter Fertilizer: In Maine's cold climate, rapid root development early in the season is important. To encourage this, a small amount of starter fertilizer may be recommended for some crops even though the available level in the soil may be rated optimum or even excessive. This applies primarily to phosphate (P_2O_5) recommendations, since an adequate available P level is critical in promoting early root growth. Starter fertilizer nutrient quantity is typically less than normal crop removal.

Calculating the Lime Requirement

The lime requirement to reach a target pH is calculated simply by multiplying the milliequivalents of exchangeable acidity to reach the target by 1000 and rounding to the nearest 500 pounds per acre:

$$LR \text{ (target pH)} = \text{exchangeable acidity (me/100gm)} \times 1000$$

If the soil pH is already within 0.1-0.2 units of the target pH, no lime is recommended since a negligible amount would be needed. Also, no lime is recommended if the Ca saturation is already above 80 %, since a nutrient imbalance would result from forcing the Ca level further into the excessive range.

The exchangeable acidity neutralized to reach the target pH of interest is calculated using the appropriate equation from p.8. These equations, as stated on that page, predict the quantity of acidity which must be neutralized in order to achieve the desired pH level. The multiplier of 1000 (above) converts the milliequivalents of acidity per 100 gm of soil to the pounds per acre of calcium carbonate necessary to neutralize it.

From the sample Report, the exchangeable acidity to be neutralized to reach a pH of 6.5 is 2.51 me/100gm. The lime requirement is calculated as follows:

$$2.51 \times 1000 = 2510 \text{ lb/A (2500 lb/A rounded)}$$

To calculate lime requirement on a 1000 sq. ft. basis, divide the pounds per acre rounded value by 43.56 and round to the nearest 10 lb/1000 sq. ft. The above lime requirement on a 1000 sq. ft. basis would be:

$$2500 / 43.56 = 57 \text{ lb/1000 sq. ft. (60 lb rounded)}$$

To calculate lime requirement on a 100 sq. ft. basis, divide the pounds per acre rounded value by 435.6 and round to the nearest whole pound per 100 sq. ft. The above lime requirement would be 6 lb/100 sq. ft.

All lime requirement equations calculate pounds per acre of <u>pure</u> calcium carbonate (or 100% calcium carbonate equivalent liming material) needed to reach the specified target pH after complete reaction. See "Selecting Liming Material" below for other liming considerations.

Even though there is an equation to predict exchangeable acidity at the current pH of the soil, this should not be used to calculate a lime requirement. Obviously, no lime is necessary to reach the current pH. This equation is used <u>only</u> to calculate the readily exchangeable acidity portion of the effective CEC (CEC at the *current* soil pH).

Reasons for Liming Soils (from Brady,1974)

1. To achieve a pH most favorable to plants in terms of their tolerance to soil acidity.

2. To reduce the availability and chemical activity in the soil of elements toxic to plants (primarily aluminum, occasionally manganese).

3. To maximize and maintain availability of nutrients, either applied or already available from the soil.

4. To achieve a favorable balance between Ca, Mg, and other cations.

5. To favor growth of beneficial microorganisms.

Selecting Liming Materials

Lime is defined as any alkaline material which is applied to soil for the purpose of neutralizing acidity. It does not refer exclusively to ground limestone. A wide variety of materials can be recommended for use as lime. These can be either natural materials or waste products from home or industry. Two important factors to consider are: (1) The purity, and (2) The particle size.

The calculated lime requirement on the Report form assumes a lime with a neutralizing value of 100% pure calcium carbonate, to be incorporated into the soil to a depth of 6 2/3 inches (2 million pounds of soil per acre plow layer). Rates need to be adjusted when the calcium carbonate equivalence (CCE) of the selected material differs greatly (at least 10%) from the 100% value. Waste materials and marl are generally of lower neutralizing value than hard rock lime, so recommended application rate will need to be adjusted. Also, the recommendation should be reduced 15% for each inch shallower than six inches and increased 15% for each inch deeper than seven inches incorporation.

Lime Sources

Following are some important characteristics of various lime sources:

Hard Rock Carbonates: The salts of weak acids and strong bases are the best materials for lime because of their high neutralizing value and relatively low cost. Calcitic lime ($CaCO_3$) and Magnesium or Dolomitic lime ($CaCO_3.MgCO_3$) are the principal minerals available and usually the least costly. They occur naturally at high purity in limestone areas, and require only crushing to fine size before use. Fineness of grind is important in speed of reaction. Magnesium lime is preferred when both pH and Mg adjustments are needed. Several different grades of magnesium lime are commercially available, ranging from a minimum of 6 % Mg (required by law to be called a magnesium lime), to purer forms of true Dolomite at 12-14 % Mg content. Calcitic lime is most appropriate where the soil Mg level is already sufficient (usually from previous magnesium lime applications).

Calcium Oxide, Calcium Hydroxide and Magnesium Oxide: These are manufactured limes from the burning of calcite, dolomite and magnesite. For example: calcite ($CaCO_3$) when burned liberates CO_2 and forms calcium oxide (CaO), which is called burned lime or quick lime. When water is added to calcium oxide the reaction yields calcium hydroxide, $Ca(OH)_2$, which is called slaked or hydrated lime. When exposed to atmospheric CO_2, it gradually converts back to calcium carbonate. Since both calcium oxide and calcium hydroxide are quite caustic and manufacturing adds to the cost, they are not normally used for agricultural lime. Magnesium oxide (Mag-Ox) may be used as a high quality, though expensive, source of magnesium for low magnesium, acid soils.

Marl: This is calcitic lime that has been biologically precipitated by algae, shellfish, etc. Because it contains silt, clay, and water the purity is usually lower than hard rock limes. It will react rapidly, but requires pulverizing to get uniform spreading quality.

Wood Ash or Bioash: This lime source covers a variety of materials, from home woodstove ash to ash from wood-burning electrical or steam plants. Many people visualize wood ash as a source of potash only. It is, however, a potentially potent source of lime, as well as a source of Ca, Mg and even P. The calcium carbonate equivalence (CCE) of wood ash is highly variable, depending on the fuel used and the efficiency of combustion. If significant tonnage is to be used, the CCE as well as nutrient content should be tested. If the CCE of the ash is not known, the potential exists to over or under-lime the soil, resulting in a soil pH well outside the intended range.

Waste lime: Pulp and paper companies use calcium oxide and calcium hydroxide limes to recausticize and recycle digestion liquor. Calcium hydroxide is also used in controlled atmosphere storage of fruit, particularly apples. When the lime is spent, it is discarded as waste and can usually be obtained at considerable cost savings over conventional lime. These materials are generally mixtures of calcium oxide, calcium hydroxide, and calcium carbonate and may occasionally contain some calcium silicate and calcium sulfate. Their

CCE is usually quite high, however water content and physical condition can be a problem in handling and spreading.

Mollusk Shells: The Maine seafood industry generates a sizeable tonnage of clam and mussel shells each year. The shells are quite pure, with a calcium carbonate equivalence of 95 to 100 %. When crushed to sand size, shells make an excellent lime. Since shells are soft compared to steel, they can be easily ground with farm equipment like farm feed hammer mills. The spreading quality of crushed shells should be good. Mollusk shells are almost entirely $CaCO_3$, with very little $MgCO_3$, and so is most appropriate where calcitic lime is needed.

Other Waste Materials: Other waste materials, because of treatment or content, may also be significant sources of lime equivalence if used in quantity and/or over a number of years.

Waste water treatment plant sludge or biosolids are required to be lime stabilized before being applied to agricultural land. Hydrated lime is typically used to raise the pH of the sludge over 12 for the purpose of reducing or eliminating pathogenic organisms. Because of the high pH and residual lime content of biosolids, after only a few years' application they will significantly raise the pH and Ca content of soils to which they are applied. If a magnesium hydrated lime is used in the stabilization process, soil Mg level will also be raised. Most biosolids applications sites eventually become ineligible for further applications due to soil pH and/or Ca content limits.

Poultry manure is another significant source of lime equivalence. This is especially true with manure from layer operations, since ground limestone and mollusk shells are included in the diet to enhance eggshell thickness. The lime and mollusk shells are both calcitic, so poultry manure typically has a low Mg content. It is not unusual to see very high or excessive soil pH and calcium levels in areas of regular poultry manure application.

Particle Size Effect

Particle size affects time of reaction and ability to get uniform spread and incorporation. Since most liming materials are relatively insoluble, reactive surface area becomes extremely important to the speed of reaction; that is, the greater the surface area the quicker the material reacts in the soil. Hard rock limestone lacks reactive surface area and must be ground to a fine size to increase reactivity. In general, a decrease in particle size by a factor of 10 increases reactivity by a factor of 10. Hard rock lime should meet state of Maine laws on purity and particle size (100% finer than 10 mesh; 98% finer than 20 mesh; 40% finer than 100 mesh). Because ground limestone has a range of particle sizes, the coarser material may take two or more years to complete reaction. Marl, woodash, and lime wastes are usually quite fine in particle size and react quickly, but may be lumpy and require pulverizing to achieve spreading ability.

Soil pH Effect

The reaction rate of lime is affected by the existing pH of the soil. A given lime application will react much more quickly and completely in strongly acid soils than in slightly acid to neutral soils. Even though the amount of neutralizable acidity decreases rapidly as soil pH increases, each extra unit increase in soil pH requires greater quantities of lime to achieve that increase. This is partly due to the fact that lime reaction rate falls off quickly at higher soil pH, especially above pH 6.0.

To achieve a target pH in a reasonable amount of time (one to two years for example), requires more total milliequivalents of alkaline material (as hard rock lime) be applied than milliequivalents of acidity to be neutralized. In effect, this could be viewed as "over-liming" to compensate for reduced lime reaction efficiency at higher soil pH's. A side-effect of this phenomenon is that once a high target pH (6.5 or 7.0 for example) has been achieved, there will still be a substantial amount of unreacted lime remaining in the soil. This unreacted lime will remain in equilibrium with the soil and can maintain soil pH at or near the target level for a number of years in some cases.

Degree of Incorporation

Lime is not very mobile in soils, therefore neutralization of acidity depends on direct contact between the lime and soil. If the soil pH is to be increased throughout the plow layer or root zone, it is essential that lime be thoroughly mixed with the soil to the desired depth. In well drained acid soils, the deeper the lime is incorporated, the deeper the effective root zone becomes. Yields are expected to increase, not only because of improved soil pH, Ca and Mg content, but also because plants can utilize the available water and nutrients to greater soil depths. For liming rates of 3 tons per acre or more, a good method of incorporation is to apply one-half the lime recommended and plow the limed soil down, then apply the other half and disk it in. This procedure assures that the lime is distributed throughout the entire plow layer.

Time of Lime Application

The crop response to lime is so great on strongly acid soils that any time of application can be justified and recommended. The best rule of thumb is to apply at a time of convenience when the soil is firm enough to support the spreading equipment. During the average year, Maine soils tend to be firmer in late summer and fall. This fact, as well as the fact that some reaction can take place before the next crop is seeded, favors fall application, even though lime reaction is slower over the winter than during the summer.

When semi-permanent and permanent crops are to be established, such as conservation plantings, hay, turf, asparagus, small fruit, or tree crops, it is *critical* that lime be applied and incorporated prior to planting while the soil can still be tilled and the lime thoroughly incorporated.

Calcium Requirement

For the purposes of this testing system, there is usually no explicit calculation of a Ca requirement. It is assumed that lime applied at the recommended rate will automatically adjust the soil Ca level to the optimum range of 60-80 % of the projected CEC, though it is not uncommon for Ca saturation to exceed 80 % for a year or two after a heavy lime application. As mentioned in the lime requirement section, if the soil Ca level is presently at 80 % or more of the projected CEC, there is no lime recommended, even if the soil pH is substantially below the target pH.

For commercial apple crops and commercial highbush blueberry crops, a Ca recommendation is occasionally calculated in the form of gypsum. Gypsum is a neutral salt consisting of calcium sulfate and has *no neutralizing value*; therefore it is not a lime as many believe. It is, however, an excellent source of both Ca and sulfur (S). Its principal use is where soil Ca level needs to be increased without changing the soil pH. It is also used to counteract the effects of excess sodium from road salt or seawater contamination.

See the Commercial Fruit section for more details on gypsum requirement calculations.

Magnesium Requirement

Method 1 (for most soils)

$$\text{Mg requirement} = (15 - \% \text{ Mg saturation}) \times \text{CEC} \times 2.4 = \text{pounds per acre}$$

Method 2 (used when K saturation level is between 7.5 - 10%)

$$\text{Mg requirement} = (2 \times \% \text{ K saturation} - \% \text{ Mg saturation}) \times \text{CEC} \times 2.4 = \text{pounds per acre}$$

Method 3 (used when K saturation exceeds 10 %)

$$\text{Mg requirement} = (20 - \% \text{ Mg saturation}) \times \text{CEC} \times 2.4 = \text{pounds per acre}$$

Example (Method 1): If the soil CEC is 12 me/100 gm and Mg saturation is 10% and K saturation < 7.5 %, then

$$\text{Mg requirement} = (15 - 10) \times 12 \times 2.4 = 144 \text{ pounds per acre}$$

Example (Method 2): If the soil CEC is 12 me/100 gm, the Mg saturation is 10% and the K saturation is 10%, then

$$\text{Mg requirement} = (20 - 10) \times 12 \times 2.4 = 288 \text{ pounds per acre}$$

In practice, if Mg is needed, an actual recommendation is made only if lime is also needed. A magnesium or dolomitic lime is by far the least expensive and most available source of Mg in Maine.

If Mg is needed and lime is <u>not</u> needed, most other sources of Mg either raise pH as lime does or are prohibitively expensive for use on commercial acreage. Other, more expensive sources of Mg may be economically feasible for small-scale applications such as lawns or gardens. For instance, blended fertilizers with trace levels of Mg may be available from some suppliers. An alternative source, if K is also needed, is Sul-Po-Mag (sold as 0-0-22-11). Because of expense, Sul-Po-Mag is an economically feasible source of Mg only for gardens or high-value commercial crops. Sources of Mg, other than lime, are intended to serve a stop-gap role until such time as lime is needed again and a magnesium lime can be applied.

Actual cases of Mg deficiency are quite rare in Maine. The current consensus is that if Mg is low and lime cannot be applied, correcting the soil Mg level can wait until such time as lime is needed again. If soil Ca or K are excessive and soil Mg is *very* low (< 5 % saturation) or if deficiency symptoms are appearing on crops in the sampling area, other more expensive options including foliar sprays should be investigated.

Magnesium Sources

Dolomitic limestone, Magnesium limestone: variable Mg (up to 14%). Use when lime and Mg are both needed. Supplies 20 lb Mg/ton for each percent Mg or 12 lb Mg/ton for each percent Mg0.

Sul-Po-Mag, K-Mag, Langbeinite, Sulfate of Potash-Magnesia (all same natural mineral): 10-12% Mg, 18% K (22% K_2O), 23% S. Use at any soil pH. Use when *both* Mg and K are needed.

Epsom salts ($MgSO_4.7H_2O$): 10-12% Mg. Use at any soil pH. Also can be dissolved in water and used as a foliar spray.

Mag-ox (MgO, burned magnesite): 53-55% Mg. Use when soil pH is below optimum.

Burned Dolomite (CaO.MgO): 20-28% Mg. Use on acid soils.

High-magnesium hydrated lime ($Ca(OH)_2.Mg(OH)_2$): up to 19% Mg. Use on acid soils. Do not use on living plants, to avoid caustic burn.

Potash (K_2O) Requirement

The interpretation of soil potassium level and the calculation of potash requirement are based on the same general model used at Penn State (Penn State, 1997). The potash requirement is figured on the basis of crop removal, plus the difference between the current percent K saturation and the optimum percent K saturation for the crop:

K$_2$0 requirement = crop removal + (optimum % K saturation - current % K saturation)

x CEC x 9.36 = pounds per acre

Example: if crop removal is 160 lb K$_2$O/acre, the optimum % K saturation is 4%, the reported K saturation is 2%, and the soil CEC is 12 me/100 gm, then:

K$_2$0 requirement = 160 + (4 - 2%) x 12 x 9.36 = 385 pounds per acre

The calculated requirement is rounded to the nearest 10 pounds, in this case 390 pounds per acre. Practical minimum and maximum rates are also imposed because of economics, machinery limitations, or nutrient balance considerations. Crop removal and optimum % K saturation levels are different for each crop. See individual crop sections for more specifics on assumed crop removal and optimum levels.

Phosphate (P$_2$O$_5$)Requirement

The following equation is used to determine the P$_2$0$_5$ requirement:

P$_2$0$_5$ requirement = crop removal + (50 - no. PX's) x multiplier = pounds per acre

The number of PX's is taken from the phosphorus bar graph, which is derived from the pounds per acre P test level. Maine's interpretation of the phosphorus soil test is based on the interpretation used at Cornell University for agricultural and horticultural crops (Cornell University, 1994). Cornell uses a Morgan phosphorus test, as does Maine. The reason phosphate requirement equations are based on the number of X's rather than directly on the pounds per acre of available P is that the interpretation of phosphorus test results is not a constant function of pounds per acre. For a crop with an optimum range of 10 - 40 pounds per acre, for instance, the number of X's in the bar graph is determined using a separate function for each of the interpretation ranges as follows:

0 to 5.0 lb P/A = 1 to 25 X's (low)

5.1 to 10.0 lb P/A = 25 to 33 X's (medium)

10.1 to 40.0 lb P/A = 33 to 50 X's (optimum)

> 40.0 lb P/A = 55 X's (excessive)

Example calculation: If the crop removal is 40 lb P$_2$O$_5$/acre, the efficiency/conversion multiplier is 2.5, and the number of X's in the P soil test interpretation graph is 15, then:

P$_2$0$_5$ requirement = 40 + (50 - 15) x 2.5 = 127.5 pounds per acre (130 pounds per acre rounded)

Phosphate requirements are also rounded to the nearest 10 pounds per acre. Minimum and maximum limits are also imposed, as with potash requirements. Crop removal values are different for each crop. The multiplier is derived from two factors: 1) The conversion from elemental phosphorus (P) to fertilizer phosphate (P_2O_5) - [roughly a factor of 2] and 2) The average efficiency or effectiveness of added phosphate for each crop. Efficiency is the percentage of fertilizer applied which is actually taken up or which remains plant available in the soil. Phosphate efficiency is a function of several factors including soil pH, soil organic matter level, whether the fertilizer is banded or broadcast, and how thoroughly the crop rooting system exploits the plow layer. See individual crop sections for assumed efficiency and crop removal factors.

Nitrogen Requirement

Since there is no good spring or fall soil test to predict nitrogen availability over an entire growing season, this nutrient recommendation is actually the estimated total seasonal crop requirement. It is assumed that an average soil will supply a modest quantity of nitrogen during the growing season, some of which will be lost to leaching and denitrification. The estimated nitrogen requirement assumes an optimum yield under Maine conditions for the crop requested. The recommendation also compensates for loss of added chemical fertilizer nitrogen to leaching and denitrification over the growing season.

Allowances are made in commercial potatoes when a green manure or legume has been turned under from the previous year in the rotation. Some nitrogen is recommended for legumes in the seeding year but not in succeeding years, since they fix their own nitrogen after they are established.

In the case of home gardens and organically grown crops, allowance is made for the organic matter level found. In gardens, it is quite common for manure, compost, or other nutrient-rich organic matter sources to be added every year or two. The normal breakdown and release of nutrients from organic matter is more likely to supply a significant amount of nitrogen in these situations. A soil with an organic matter level of 5 to 8 % should supply half or more of the seasonal nitrogen requirement of general garden crops. An application of about a quarter of the recommended nitrogen at planting time should be sufficient for the entire season in this case, unless rainfall is unusually heavy. This assumes the regular use of manure or compost. If peat moss, wood chips, or sawdust have been used, apply the quarter rate at planting time and the remainder of the full rate at early mid-season, regardless of the organic matter level.

For field corn, an extra mid-season soil test is available and highly recommended. In this test, available nitrate-nitrogen in the soil at mid-season is used to determine whether additional nitrogen sidedress is necessary and if so, how much (Magdoff, 1984). Currently, interpretation of this test is only available for field corn and sweet corn crops. (See example Report form).

A mid-season nitrate test is also available for commercial potatoes. This test monitors nitrate level in leaf petiole, rather than in the soil. Research has shown leaf petiole nitrate in potato to be a better indicator of nitrogen fertility status than is the soil level at mid-season (Porter, 1991).

Contact your county Extension office for information on either mid-season nitrogen test.

DETERMINING FERTILIZER BLEND AND APPLICATION RATE

It is important to note that even though soil test results for P and K are reported in terms of the pure element, the recommendations for additions of these two nutrients are in terms of phosphate (P_2O_5) and potash (K_2O). The P and K content of all commercial fertilizer must be reported in these terms by law. By generating recommendations in these same terms, it is easier to compare the specific requirements of a field with the fertilizer blends available.

As was stated earlier, the calculated nutrient requirements can be met with any variety and/or combination of nutrient sources: organic or chemical, residual or commercial. If the N-P_2O_5-K_2O content of the potential nutrient source(s) is known, the best choice of source and the proper application rate can be calculated. The following example will illustrate how to choose among available fertilizer blends and how to figure the application rate of the best choice. The recommendations and the available fertilizer grades are not necessarily average or typical for any crop or vendor:

Example

Recommended nutrient application rates as follows:

150 pounds nitrogen per acre

100 pounds phosphate per acre

150 pounds potash per acre

1) Determine the *ratio* of N-P_2O_5-K_2O recommendations in the simplest form by dividing all three rates by the smallest. In this case dividing all three by 100 results in the ratio: 1.5-1-1.5

2) Determine the *ratio* of the fertilizer grades available from your vendor by the same method as above:

Grade	Ratio
10-10-10	1 - 1 - 1
5-10-10	1 - 2 - 2
15-8-12	1.9 - 1 - 1.5

3) Find the closest match in ratio between the recommended application rates and the blended fertilizers available. In this case the closest match in ratio is the 15-8-12.

4) Calculate the application rate based on the most critical nutrient requirement, usually nitrogen:

150 lb nitrogen per acre / 0.15 (15% N in 15-8-12) = 1000 lb 15-8-12

Actual nutrient application from 1000 lb 15-8-12 per acre:

150 pounds nitrogen per acre

80 pounds phosphate per acre

120 pounds potash per acre

As you can see, common pre-blended fertilizer grades often do not exactly match the specific nutrient requirements of a field for a given crop. However, a 10 to 20 pound per acre overapplication or underapplication in any one year will not be a critical problem in most cases. Ideally, a custom blended fertilizer should be obtained where possible to more precisely meet specific requirements. As illustrated in the next section, a similar process is used to calculate the application rate of a manure or residual material to best match the nutrient requirements given on the Report form.

NUTRIENT CONTENT OF MANURES AND RESIDUAL MATERIALS

Animal manures and various residual materials such as bioash, municipal treatment plant sludge (biosolids), and processing wastes are all potentially rich sources of one or more of the nutrients or lime recommended on the Report/Recommendation form. The problem with these materials, as compared with commercially available fertilizers or nutrient sources, is that their content is not guaranteed. In fact, their contents are often quite variable from source to source or even over time from any one source. The key to the sensible use of any of these materials is to have the nutrient content and/or lime equivalence tested if an analysis has not already been done by the supplier.

Regulated materials *must* be analyzed by the supplier before they can be used on agricultural land. For non-regulated materials, like animal manures, it is usually well worth the cost of analysis to determine the nutrient content. When the content or nutrient equivalence of a material is known, the application can be calibrated to best match the specific requirements of each field. In this way, over or under-application of nutrients and/or lime can be avoided and the most economic use can be made of the materials at hand.

Following is a very general rating of manures and residual materials as to their nutrient and lime content:

material	lime	nitrogen	phosphate	potash
cow manure	poor-moderate	good	moderate	good
poultry manure	good	good	good	moderate
boiler ash/bioash	good	(none)	moderate	good
sludge/biosolids	good*	good	good	poor

*sludge and septage are required to be lime stabilized

To calculate the most efficient application rate of a manure or residual material for which the N-P_2O_5-K_2O (and lime) equivalence is known, calculate the application rate necessary to meet each of the individual nutrient and lime recommendations on the Report form. If overapplication of any one nutrient is to be avoided, limit the application to the *lowest* application rate calculated. The following example uses a liquid manure analysis to illustrate. The recommendations and the manure analysis results are not necessarily average or typical for any crop or manure:

<u>Example</u>

Recommended nutrient application rates as follows:

150 pounds nitrogen per acre

100 pounds phosphate per acre

150 pounds potash per acre

Analysis of a liquid manure indicates the following nutrient content (per 1000 gallons):

12 lb total N

6 lb NH_4-N

3 lb P_2O_5

12 lb K_2O

1) If the manure is immediately incorporated, all the ammonia-N, 40 % of the remaining N, and most of the P_2O_5 and K_2O will be available during the first year. The actual available nitrogen supplied by this manure would be calculated as follows:

available N = NH_4-N + [(total N - NH_4-N) x .40]

6 + [(12 - 6) x 0.4] = 6 + 2.4 = 8.4 lb available N per 1000 gal.

The phosphate and potash values for the manure should be taken at face value.

2) Now calculate the application rate needed to supply each of the recommended nutrient additions:

To meet the nitrogen recommendation:

150 lb N per acre / 8.4 lb available N/1000 gal. = 17,900 gal./A

To meet the P_2O_5 recommendation:

$$100 \text{ lb phosphate per acre} / 3 \text{ lb } P_2O_5/1000 \text{ gal.} = 33,300 \text{ gal./A}$$

To meet the K_2O recommendation:

$$150 \text{ lb potash per acre} / 12 \text{ lb } K_2O/1000 \text{ gal.} = 12,500 \text{ gal./A}$$

The actual nutrients suppied from the lowest calculated rate of 12,500 gal./A would be:

105 lb nitrogen per acre

35 lb phosphate per acre

150 lb potash per acre

This rate will avoid overapplication of any of the nutrients, while supplying the entire potash recommendation. The remaining deficit of nitrogen and phosphate would have to be supplied from some other source or sources, such as chemical fertilizer.

The manure application rate could be adjusted to supply all the recommended nitrogen or phosphate recommended, but with an over-application of potash. Since K is not an environmentally sensitive nutrient, a limited over-application could be justified. Repeated over-application of K or any other nutrient can lead to a buildup in soil level and could eventually result in nutrient balance problems.

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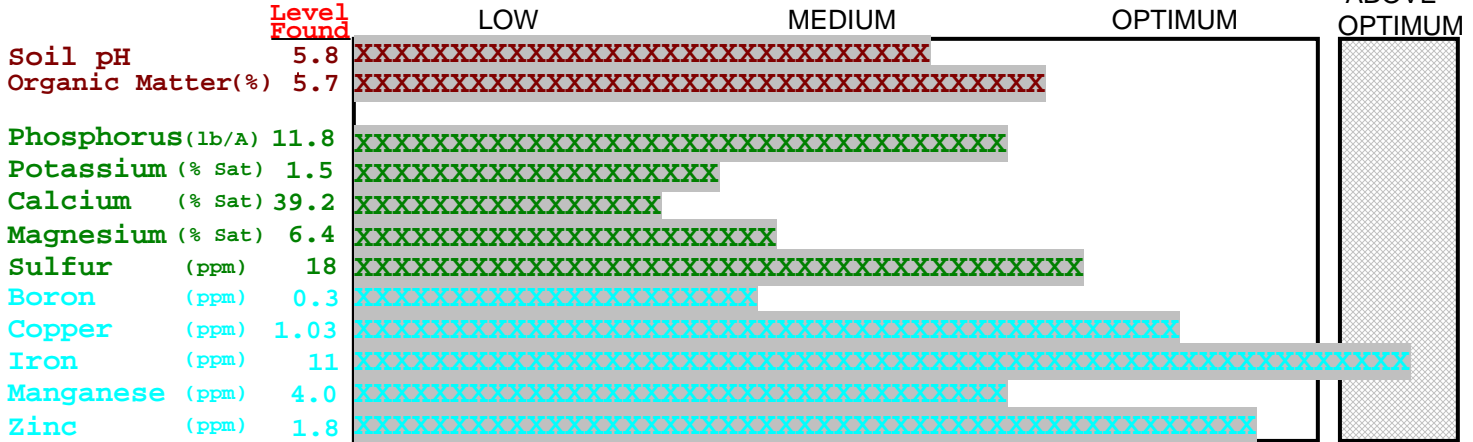| 08/18/2010	17	ROAD FIELD 1	PISCATAQUIS	
PRINT DATE	LAB NO.	SAMPLE IDENTIFICATION	COUNTY	ACRES OR SQ. FT.

● SOIL TEST REPORT FOR:

EXAMPLE AGRONOMIC CROP

Standard Soil Test

MAINE SOIL TESTING SERVICE
UNIVERSITY OF MAINE 1865
5722 DEERING HALL
ORONO,MAINE 04469-5722

● **SOIL TEST SUMMARY & INTERPRETATION**
(see Numerical Results section for more information)

	Level Found	LOW	MEDIUM	OPTIMUM	ABOVE OPTIMUM
Soil pH	5.8				
Organic Matter(%)	5.7				
Phosphorus (lb/A)	11.8				
Potassium (% Sat)	1.5				
Calcium (% Sat)	39.2				
Magnesium (% Sat)	6.4				
Sulfur (ppm)	18				
Boron (ppm)	0.3				
Copper (ppm)	1.03				
Iron (ppm)	11				
Manganese (ppm)	4.0				
Zinc (ppm)	1.8				

● **RECOMMENDED ADDITIONS FOR**   CORN - Crop Code # 164

To raise soil pH to 6.0, apply 1500 pounds of lime per acre.
To raise soil pH to 6.5, apply 4500 pounds of lime per acre.
Lime recommendation assumes a calcium carbonate equivalence (neutralizing value) of 100 %.
To meet crop magnesium requirement, use a magnesium lime.
Recommended major nutrient application rates as follows:
 Nitrogen: See management statements below.
        100 pounds phosphate per acre
        240 pounds potash per acre

Apply up to 40 lb/A each of nitrogen, phosphate, and potash through the planter.
Remaining P & K should be broadcast preplant.
              *******Nitrogen Management*******
*Best mgt: Sample soil for nitrate analysis when corn 8-12 inches tall.
Exact recommendations for N sidedress will be made at that time.
*Next best option: With no nitrate soiltest,
sidedress 80 lb N/acre when corn is 8-12 inches tall.
Note: for organic sources of nitrogen, calculate application rate to
supply 150 pounds of available N for a 20 ton/acre yield goal.

Soil zinc level is adequate. No extra yield expected from additional zinc.

For information on micronutrient management and recommendations, see enclosed form.

● **NUMERICAL RESULTS** (Test methodology: pH in water and Mehlich buffer, available nutrients by modified Morgan extract)
(Organic matter measured by LOI, P determined colorimetrically, all others measured by ICP-OES)

CEC and nutrient balance calculations assume the pH will be raised to 6.5

Level Found	5.8	5.84	11.8	91	126	1280	8.1	1.5	6.4	39.2	52.9
	Soil pH	Lime Index 2	Phosphorus (lb/A)	Potassium (lb/A)	Magnesium (lb/A)	Calcium (lb/A)	CEC (me/100 g)	K	Mg (% Saturation)	Ca	Acidity
Optimum Range	6.0-7.0	N/A	10-40	see % Saturation levels			> 5	2.8-4.0	10-20	60-80	< 10

Level Found	5.7	18	1.03	10.5	4.0	1.8	
	Organic Matter(%)	Sulfur (ppm)	Copper (ppm)	Iron (ppm)	Manganese (ppm)	Zinc (ppm)	Additional Results or Comments:
Normal Range	5 - 8	> 15	0.8-1.2	6 - 10	4 - 8	1 - 2	

Level Found	0.3	N/A	N/A	N/A	N/A	
(Extras)	Boron (ppm)	Sodium (ppm)	Soluble Salts (mmhos/cm)	Nitrate-N (ppm)	Ammonium-N (ppm)	Full payment received for this sample. Thank you.
Normal Range	0.5-1.2					

AGRONOMIC CROPS

Crop Codes 101 to 106

Topdress of Established Stands

For all crops:

* Nutrient requirements rounded to nearest 10 pounds per acre.

* Optimum P range = 10 - 40 pounds P per acre

* Optimum K range = 2.8 - 4.0 % K saturation

For crop codes 101 and 102:

* CEC and nutrient balance calculations assume a target pH of 6.5 (current pH if higher), unless otherwise requested.

* Lime is recommended to raise soil pH to both 6.0 and 6.5, unless otherwise requested.

Crop Code 101, Alfalfa (over 50% stand). For 4-5 tons hay (12-15 tons haylage) per acre.

Nitrogen requirement = 0 pounds per acre

Calc. P_2O_5 requirement = 70 + (50 - no. PX's) = pounds per acre

    Recommend 0 when P test exceeds 40 pounds per acre

Calc. K_2O requirement = 250 + (3 - % K sat.) * CEC * 9.36 = pounds per acre

    Maximum = 320 pounds per acre

    Minimum = 120 pounds per acre

    Recommend 0 when K saturation exceeds 4% and K test exceeds 250 pounds per acre

Crop Code 102, Clover (over 50% stand). For 3-4 tons hay (9-12 tons haylage) per acre.

Nitrogen requirement = 0 pounds per acre

Calc. P_2O_5 requirement = 50 + (50 - no. PX's) = pounds per acre

    Recommend 0 when P test exceeds 40 pounds per acre

Calc. K_2O requirement = $140 + (3 - \%\ K\ sat.) * CEC * 9.36$ = pounds per acre

    Maximum = 210 pounds per acre

    Minimum = 70 pounds per acre

    Recommend 0 when K saturation is above 4% and K test exceeds 250 pounds per acre

For crop codes 104, 105, and 106:

* CEC and nutrient balance calculations assume a target pH of 6.0 (current pH if higher), unless otherwise requested.

* Lime is recommended to raise soil pH to 6.0, unless otherwise requested.

Crop Code 104, Grass Hay (up to 50% legume)-one crop.
For 1-2 tons hay (3-6 tons haylage) per acre.

Nitrogen requirement = 60 pounds per acre

Calc. P_2O_5 requirement = $25 + (50 - no.\ PX's)$ = pounds per acre

    Maximum = 40 pounds per acre

    Recommend 0 when P test exceeds 40 pounds per acre

Calc. K_2O requirement = $80 + (3 - \%\ K\ sat.) * CEC * 9.36$ = pounds per acre

    Maximum = 120 pounds per acre

    Minimum = 40 pounds per acre

    Recommend 0 when K saturation exceeds 4% and K test exceeds 250 pounds per acre

Crop Code 105, Grass Hay (up to 50% legume)-two crops.
For 3-4 tons hay (9-12 tons haylage) per acre.

Nitrogen requirement = 120 pounds per acre

Crop Code 106, Pasture.

Nitrogen requirement = 100 pounds per acre

Crop Codes 105, 106:

Calc. P_2O_5 requirement = 50 + (50 - no. PX's) = pounds per acre

   Maximum = 80 pounds per acre

  Recommend 0 when P test exceeds 40 pounds per acre

Calc. K_2O requirement = 170 + (3 - % K sat.) * CEC * 9.36 = pounds per acre

   Maximum = 260 pounds per acre

   Minimum = 80 pounds per acre

   Recommend 0 when K saturation exceeds 4% and K test exceeds 250 pounds per acre

MANAGEMENT STATEMENTS:

Crop Code 101:
Apply fertilizer at any convenient time, although fall application may aid winter survival.

If B test < 0.5 ppm: For best results, use a borated fertilizer every other year.
If B test >= 0.5 ppm: Current boron level is sufficient. Apply no boron this year.

Crop Code 102:
Apply fertilizer at any convenient time, although fall application may aid winter survival.

Crop Code 104:
Apply fertilizer as soon as possible in early spring.

Crop Code 105:
Apply 80 pounds of N in early spring and 40 pounds of N for each additional cut or grazing. P_2O_5 and K_2O can be split or applied all at once.

Crop Code 106:
Apply one half of N in early spring and remainder in late August or early September. P_2O_5 and K_2O can be split or applied all at once.

For All Topdressed Crops:
Limit lime topdress to 4000 pounds per acre in any one year.

New Seedings

For all crops

* Lime is recommended to raise soil pH to both pH 6.0 and 6.5, unless otherwise requested or noted below.

* CEC and nutrient balance are calculated assuming a target pH of 6.5 (current pH if higher) unless otherwise requested or noted below.

* Nutrient requirements rounded to nearest 10 pounds per acre.

Crop Code 151, Alfalfa/Grass.

Nitrogen requirement = 50 pounds per acre

Calc. P_2O_5 requirement = 25 + (50 - no. PX's) * 3 = pounds per acre

   Maximum = 170 pounds per acre

   Minimum = 50 pounds per acre when P test exceeds 14 pounds per acre

   Recommend 0 when P test exceeds 40 pounds per acre

   Optimum range = 10 - 40 pounds P per acre

Calc. K_2O requirement = 80 + (4 - % K sat.) * CEC * 9.36 = pounds per acre

   Maximum = 200 pounds per acre

   Minimum = 80 pounds per acre

   Recommend 0 when K saturation exceeds 5%

   Optimum range = 3.5 - 5.0 % K saturation

Crop Code 152, Clover/Grass, and
Crop Code 170, Conservation seedings/steep slopes/ditches.

For crop code 170 only:

* Lime recommended to raise soil pH to 6.0 only.

* CEC and nutrient balance calculations assume a target pH of 6.0 or current pH if higher.

Nitrogen requirement = 40 pounds per acre

Calc. P_2O_5 requirement = 20 + (50 - no. PX's) * 2 = pounds per acre

   Maximum = 100 pounds per acre

Minimum = 40 pounds per acre when P test exceeds 14 pounds per acre

Recommend 0 when P test exceeds 40 pounds per acre

Optimum range = 10 - 40 pounds P per acre

Calc. K_2O requirement = 50 + (4 - % K sat.) * CEC * 9.36 = pounds per acre

Maximum = 150 pounds per acre

Minimum = 50 pounds per acre

Recommend 0 when K saturation exceeds 5%

Optimum range = 3.5 - 5.0 % K saturation

Crop Code 154, Grass only (no legumes)

Nitrogen requirement = 60 pounds per acre

Calc. P_2O_5 requirement = (50 - no. PX's) * 2 = pounds per acre

Maximum = 100 pounds per acre

Minimum = 40 pounds per acre

Recommend 0 when P test exceeds 30 pounds per acre

Optimum range = 10 - 30 pounds P per acre

Calc. K_2O requirement = (3 - % K sat.) * CEC * 9.36 = pounds per acre

Maximum = 100 pounds per acre

Minimum = 40 pounds per acre

Recommend 0 when K saturation exceeds 4%

Optimum range = 2.8 - 4.0 % K saturation

* For all small grains (crop codes 155, 156, 157, 158, 167):

Optimum P range = 10 - 23 pounds P per acre

Optimum K range = 2.8 - 4.0 % K saturation

Crop Code 155, Oats. For a 75 - 100 bushel yield per acre.

Nitrogen requirement = 50 pounds per acre

Calc. P_2O_5 requirement = 60 + (50 - no. PX's) = pounds per acre

Maximum = 90 pounds per acre

Recommend 0 when P test exceeds 23 pounds per acre

Calc. K_2O requirement = 110 + (3 - % K sat.) * CEC * 9.36 = pounds per acre

    Maximum = 160 pounds per acre

    Minimum = 50 pounds per acre

    Recommend 0 when K saturation exceeds 4%

Crop Code 156, Barley. For a 60 - 80 bushel yield per acre.

Nitrogen requirement = 60 pounds per acre

P_2O_5 and K_2O requirements same as 155 (oats).

Crop Code 157, Spring Wheat. For a 50 - 60 bushel yield per acre.

Nitrogen requirement = 60 pounds per acre

P_2O_5 and K_2O requirements same as 155 (oats).

Crop Code 167, Winter Wheat. For a 50 - 80 bushel yield per acre.

Nitrogen requirement = 30 pounds per acre

P_2O_5 and K_2O requirements same as 155 (oats).

Crop Code 158, Winter Rye. For a 25 bushel yield per acre.

Nitrogen requirement = 30 pounds per acre

P_2O_5 and K_2O requirements same as 155 (oats).

Crop Code 159, Buckwheat. For a 25 bushel yield per acre.

Nitrogen requirement = 20 pounds per acre

Calc. P_2O_5 requirement = 20 + (50 - no. PX's) * 0.5 = pounds per acre

    Maximum = 40 pounds per acre

    Recommend 0 when P test exceeds 8 pounds per acre

    Optimum range = 5.5 - 8.0 pounds P per acre

Calc. K_2O requirement = 20 + (3 - % K sat.) * CEC * 9.36 = pounds per acre

    Maximum = 40 pounds per acre

    Recommend 0 when K saturation exceeds 3%

    Optimum range = 2.1 - 3.0 % K saturation

Crop Code 160: Soybean, Lupin. For a 40 bushel yield per acre.

Nitrogen requirement = 30 pounds per acre

Calc. P_2O_5 requirement = 40 + (50 - no. PX's) = pounds per acre

    Maximum = 60 pounds per acre

    Recommend 0 when P test exceeds 40 pounds per acre

    Optimum range = 10 - 40 pounds P per acre

Calc. K_2O requirement = 60 + (3 - % K sat.) * CEC * 9.36 = pounds per acre

    Maximum = 90 pounds per acre

    Minimum = 30 pounds per acre

    Recommend 0 when K saturation exceeds 4%

    Optimum range = 2.8 - 4.0 % K saturation

**Crop Code 161, Sudan Grass/Sorghum-Sudan hybrids and
Crop Code 163, Millet.** For a 5 ton dry matter (15 ton green) yield per acre.

Nitrogen requirement = 40 pounds per acre

Calc. P_2O_5 requirement = 50 + (50 - no. PX's) = pounds per acre

    Maximum = 80 pounds per acre

    Recommend 0 when P test exceeds 30 pounds per acre

    Optimum range = 10 - 30 pounds P per acre

Calc. K_2O requirement = 150 + (3 - % K sat.) * CEC * 9.36 = pounds per acre

    Maximum = 220 pounds per acre

    Minimum = 80 pounds per acre

    Recommend 0 when K saturation exceeds 4% and K test exceeds 250 pounds per acre

Optimum range = 2.8 - 4.0 % K saturation

Crop Code 164, Silage Corn. For a 6 ton dry matter (20 ton green) yield per acre.

Nitrogen requirement = 150 pounds per acre

Calc. P_2O_5 requirement = 80 + (50 - no. PX's) = pounds per acre

    Maximum = 120 pounds per acre

    Recommend 0 when P test exceeds 40 pounds per acre

    Optimum range = 10 - 40 pounds P per acre

Calc. K_2O requirement = 180 + (3 - % K sat.) * CEC * 9.36 = pounds per acre

Maximum = 240 pounds per acre

Minimum = 90 pounds per acre

Recommend 0 when K saturation exceeds 4% and K test exceeds 250 pounds per acre

Optimum range = 2.8 - 4.0 % K saturation

See management statements for zinc recommendations

Crop Code 166, Corn Grain. For a 200 bushel yield per acre.

Nitrogen requirement = 200 pounds per acre

Calc. P_2O_5 requirement = 80 + (50 - no. PX's) = pounds per acre

Maximum = 120 pounds per acre

Recommend 0 when P test exceeds 40 pounds per acre

Optimum range = 10 - 40 pounds P per acre

Calc. K_2O requirement = 65 + (3 - % K sat.) * CEC * 9.36 = pounds per acre

Maximum = 100 pounds per acre

Minimum = 50 pounds per acre

Recommend 0 when K saturation exceeds 4% and K test exceeds 250 pounds per acre

Optimum range = 2.8 - 4.0 % K saturation

See management statements for zinc recommendations

Crop Code 175, Brassica Forages.

Nitrogen requirement = 100 pounds per acre

Calc. P_2O_5 requirement = 50 + (50 - no. PX's) = pounds per acre

Maximum = 80 pounds per acre

Recommend 0 when P test exceeds 40 pounds per acre

Optimum range = 10 - 40 pounds P per acre

Calc. K_2O requirement = 150 + (3 - % K sat.) * CEC * 9.36 = pounds per acre

Maximum = 220 pounds per acre

Minimum = 70 pounds per acre

Recommend 0 when K saturation is above 4 % and K test exceeds 250 pounds per acre

Optimum range = 2.8 - 4.0 % K saturation

Crop Code 177, Canola.

Nitrogen requirement = 90 pounds per acre following corn or grain

Nitrogen requirement = 70 pounds per acre following potatoes

Nitrogen requirement = 50 pounds per acre following a legume cover crop

Calc. P_2O_5 requirement = 50 + (50 - no. PX's) = pounds per acre

    Maximum = 80 pounds per acre

    Recommend 0 when P test exceeds 30 pounds per acre

    Optimum range = 10 - 30 pounds P per acre

Calc. K_2O requirement = 70 + (3 - % K sat.) * CEC * 9.36 = pounds per acre

    Maximum = 110 pounds per acre

    Minimum = 40 pounds per acre

    Recommend 0 when K saturation is above 4 %

    Optimum range = 2.8 - 4.0 % K saturation

MANAGEMENT STATEMENTS:

Crop Codes 151, 152, 154 - for no till seeding:
If lime requirement is over 2 tons per acre, apply 2 tons per acre 6 months before seeding, the remainder (up to 2 tons per acre) at seeding time.

Crop Code 151:
If B test < 0.5 ppm: Fertilizer should contain enough boron to supply 3-4 pounds of actual boron per acre.

Crop Codes 155, 156, and 157:
Topdressing 30 - 40 pounds per acre additional nitrogen in spring after tillering (growth stage 30) can result in yield response under good growing conditions and when lodging resistant varieties are being grown.

Crop Code 158:
If grain is to be harvested, topdress 30 - 40 pounds per acre nitrogen in spring after tillering (growth stage 30).

Crop Codes 161, 163 (as forage, NOT green manure):
If no manure has been used, apply an additional 40 pounds nitrogen at planting time. Apply an additional 40 pounds per acre of nitrogen after first harvest to increase growth of second crop.

Crop Code 164, 166:
Apply up to 40 pounds per acre each of N, P_2O_5 and K_2O through the planter. Remaining P_2O_5 and K_2O should be broadcast and tilled in preplant.

Ideally, the remaining nitrogen application will be determined by using a mid-season nitrate soil test when corn is 8 - 10 in. tall (instructions are available). Specific recommendations for nitrogen sidedress will be made at that time.

If you can't take a mid-season nitrate soil test, subtract nitrogen applied as starter from total pounds per acre N recommended. Apply 80% of this remainder when corn is 8 - 10 in. tall.

For organic sources of nitrogen, calculate application rate to supply 150 pounds of available N/acre for a 20 ton silage yield or 200 lb available N/acre for 200 bushel grain yield.

Zinc recommendations (crop code 164 and 166):
If zinc test < 1.0 ppm: Apply 2 pounds actual zinc per acre in starter fertilizer (banded) for 2 to 3 years, then retest before applying more. An alternative is to broadcast and till in 8 - 10 pounds actual zinc per acre once every 3 to 5 years.
If zinc test = 1.0-2.0 ppm: Soil zinc level is adequate. There is very little probability of a yield response to added zinc.
If zinc test > 2.0 ppm: Soil zinc level is excessive. Use a starter fertilizer without zinc if possible.

Crop Code 167:
Topdress 40 - 60 pounds nitrogen per acre in spring after tillering (growth stage 30). Use lowest topdress rate for lodging susceptible varieties.

Crop Code 177:
If S test < 15 ppm: Apply 15 pounds actual sulfur/acre, in the fertilizer blend.

If B test < 0.5 ppm: Apply 1-2 pounds actual boron/acre, broadcast in the fertilizer blend. Do not band fertilizer which contains boron.

For All Agronomic Seeding:
For any lime recommendation over 3 tons per acre: Apply 1/2 before plowing, disk in the remainder before seeding.

When plowing down sod with > 25% legume: Plowing down a legume green manure or a heavy legume hay stand can provide 40 - 75 pounds nitrogen per acre the first year. Reduce recommended nitrogen application accordingly.

For all crops:

* Lime is recommended to raise soil pH to 6.0, unless otherwise requested.

* CEC and nutrient balance calculations assume a target pH of 6.0 (current pH if higher) unless otherwise requested.

* Optimum P test level as noted for each code.

* Optimum K test level = 2.8 - 4.0 % K saturation, unless otherwise noted.

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Crop Code 201, Lawns and Playgrounds

Nitrogen requirement = 2 pounds per 1000 sq. ft.

Calc. P_2O_5 requirement = (50 - no. PX's) / 43.6 = pounds per 1000 sq. ft.

   Maximum = 1.2 pounds per 1000 sq. ft.

   Minimum = 0.7 pounds per 1000 sq. ft.

   Recommend 0 when P test exceeds 10 pounds per acre.

   Optimum P test level = 7 – 10 pounds P per acre.

Calc. K_2O requirement = (4 - % K sat.) * CEC * 0.21 = pounds per 1000 sq. ft.

   Maximum = 2.3 pounds per 1000 sq. ft.

   Minimum = 0.7 pounds per 1000 sq. ft.

   Recommend 0 when K saturation exceeds 4% <u>and</u> K exceeds 250 pounds per acre test level.

FERTILIZER OPTIONS:

1. If K_2O requirement > 1.6 and P_2O_5 requirement > 0, apply 17 pounds 12-4-8 fertilizer per 1000 sq. ft.

2. If K_2O requirement > 1.6 and P_2O_5 requirement = 0, apply 10 pounds 20-0-20 or 30 pounds 6-0-6 fertilizer per 1000 sq. ft.

3. If K_2O requirement = 0.8 - 1.6 and P_2O_5 requirement = 0, apply 8 pounds 24-0-11 or 6-7 pounds 30-0-15 fertilizer per 1000 sq. ft..

4. If K_2O requirement < 0.8 and P_2O_5 requirement = 0, apply 20 pounds of 10-0-4 or 5 pounds of 38-0-0 fertilizer per 1000 sq. ft.

5. For all other cases, apply 10 pounds of 20-4-8 or 22-6-8 fertilizer per 1000 sq. ft.

MANAGEMENT STATEMENTS:

1. For chemical fertilizers: Apply ½ of fertilizerin early spring and ½ in late August. To prevent burn, apply when grass is dry and water in immediately.

2. Limit lime topdress to 100 lbs per 1000 sq. ft. in any one year.

3. If clippings are left on: Reduce recommended yearly fertilizer rates by ½. Apply this ½ rate all in late summer or ¼ rate in spring and ¼ rate in late August.

4. For organic fertilizers (enhanced manure or compost): Adjust the application rate to provide 1 pound actual nitrogen per 1000 sq. ft. for the year. Full year rate may be applied all in the spring or all in late summer.

5. If CEC < 5 or if percent organic matter < 3 %, leave clippings on when mowing. Rake 1 inch of screened compost through the grass each year, if possible, to improve the soil's nutrient and water holding capacity over time.

Crop Code 202, Baseball Fields, Golf Fairways

Nitrogen requirement = 2 pounds per 1000 sq. ft.

Calc. P_2O_5 requirement = (50 - no. PX's) / 43.6 = pounds per 1000 sq. ft.

   Maximum = 1.2 pounds per 1000 sq. ft.

   Minimum = 0.7 pounds per 1000 sq. ft.

   Recommend 0 when P test exceeds 10 pounds per acre.

   Optimum P test level = 7 – 10 pounds P per acre

Calc. K_2O requirement = (4 - % K sat.) * CEC * 0.21 = pounds per 1000 sq. ft.

   Maximum = 2.5 pounds per 1000 sq. ft.

   Minimum = 1.2 pounds per 1000 sq. ft.

   Recommend 0 when K saturation exceeds 4% <u>and</u> K exceeds 250 pounds per acre test level.

FERTILIZER OPTIONS:

P_2O_5 requirement	K_2O requirement	apply on 1000 sq. ft.
> 0.8	> 1.6	20 pounds 20-10-20
< = 0.8	< = 1.6	10 pounds 20-4-8
0	0	5 pounds 46-0-0 or 38-0-0
> 0.8	< = 1.6	10 pounds 20-10-10
< = 0.8	> 1.6	10 pounds 20-4-16
0	> = 1.2	10 pounds 20-0-12
> 0.8	0	10 pounds 20-10-5

MANAGEMENT STATEMENTS:

1. Apply 1/3 of fertilizer in April, 1/3 in June, and 1/3 in late August. To prevent turf burn, apply when grass is dry and water in immediately.

2. Fertilizer grades recommended can be substituted by other grades of similar N -P_2O_5-K_2O ratio. Adjust application rate to match nitrogen requirement.

3. Use slow release or organic forms of nitrogen to prevent burn and to obtain more uniform growth.

4. Limit lime topdress to 100 pounds per 1000 sq. ft. in any one year.

5. If CEC < 5 or if percent organic matter < 3 %, leave clippings on when mowing. Apply a pelleted compost product each year to improve the soil's nutrient and water holding capacity over time.

Crop Code 203, Football, Soccer, Field Hockey, and other heavy-traffic athletic fields.

Nitrogen requirement = 3 pounds per 1000 sq. ft.

Calc. P_2O_5 requirement = (50 - no. PX's) / 43.6 = pounds per 1000 sq. ft.

   Maximum = 1 pound per 1000 sq. ft.

   Minimum = 0.6 pounds per 1000 sq. ft.

   Recommend 0 when P test exceeds 20 pounds per acre.

   Optimum P test level = 10 - 20 pounds P per acre

Calc. K_2O requirement = (4 - % K sat.) * CEC * 0.21 = pounds per 1000 sq. ft.

   Maximum = 2 pounds per 1000 sq. ft.

   Minimum = 1 pound per 1000 sq. ft.

   Recommend 0 when K saturation exceeds 4% <u>and</u> K exceeds 250 pounds per acre test level.

FERTILIZER OPTIONS:

P_2O_5 requirement	K_2O requirement	apply on 1000 sq. ft.
> 0.8	> 1.6	25 pounds 12-4-8
< = 0.8	< = 1.6	15 pounds 20-4-8
0	0	6-7 pounds 46-0-0 or 8 pounds 38-0-0
> 0.8	< = 1.6	14 pounds 22-6-6
< = 0.8	> 1.6	15 pounds 20-4-12
0	> = 1.2	15 pounds 20-0-12
> 0.8	0	15 pounds 20-10-5

MANAGEMENT STATEMENTS:

1. Apply 50% of fertilizer in early spring, 25 % in June, and 25 % in early August with adequate rainfall or irrigation.

2. Fertilizer grades recommended can be substituted by other grades of similar N -P_2O_5-K_2O ratio. Adjust application rate to match nitrogen requirement.

3. Apply fertilizer when turf is dry and water in immediately to prevent burn.

4. Limit lime topdress to 100 pounds per 1000 sq. ft. in any one year.

5. If CEC < 5 or if percent organic matter < 3 %, leave clippings on when mowing. Apply a pelleted compost product each year to improve the soil's nutrient and water holding capacity over time.

Crop Code 205, 206, Golf Greens and Tees

Nitrogen requirement = 3 pounds per 1000 sq. ft.

Calc. P_2O_5 requirement = (50 - no. PX's) * 1.2 / 43.65 = pounds per 1000 sq. ft.

   Maximum = 1.3 pounds per 1000 sq.ft.

   Minimum = 0.7 pounds per 1000 sq. ft.

   Recommend 0 when P test exceeds 20 pounds per acre.

   Optimum P test level = 10   - 20 pounds P per acre

Calc. K_2O requirement = (4 - % K sat.) * CEC * 0.21 = pounds per 1000 sq.ft.

   Maximum = 4 pounds per 1000 sq. ft.

   Minimum = 1.2 pounds per 1000 sq. ft.

   Recommend 0 when K saturation exceeds 4% and K exceeds 250 pounds per acre test level.

FERTILIZER OPTIONS:

P_2O_5 requirement	K_2O requirement	apply on 1000 sq. ft.**
> 0.8	> 2.0	7-8 pounds 20-10-15
< = 0.8	< = 2.0	7-8 pounds 20-4-8
0	0	4 pounds 38-0-0
> 0.8	< = 2.0	7-8 pounds 20-10-10
> 0.8	0	7-8 pounds 20-10-5
< = 0.8	> 2.0	12-13 pounds 12-4-8
0	> = 1.2	7 pounds 22-0-16

   ** Rates are for each application, assuming 2 fertilizer applications per year. **

MANAGEMENT STATEMENTS:

1. Apply recommended rates of fertilizer in early spring. Repeat same application rate in late August.

2. Apply topdress when grass is thoroughly dry or can be watered immediately to prevent burn.

3. If fertilizer grades recommended are not available, select a substitute with similar N - P_2O_5-K_2O ratio. Adjust application rate to match nitrogen requirement.

4. Limit lime topdress to 50 pounds per 1000 sq. ft. in any one year.

5. If CEC < 5 or if percent organic matter < 3 %, apply a pelleted organic product each year to improve the soil's nutrient and water holding capacity over time.

TURF SEEDING or SODDING

* Lime recommended to raise soil pH to 6.0 unless otherwise requested.

* CEC and nutrient balance calculated assuming a target pH of 6.0 (current pH if higher) unless otherwise requested.

* Optimum P test level = 10 - 20 pounds P per acre.

* Optimum K test level = 2.1 - 3.0 % K saturation.

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Crop Code 211, all Turf Seedings

Nitrogen requirement = 2 pounds per 1000 sq. ft.

Calc. P_2O_5 requirement = 4 * (50 - no. PX's) / 43.6 = pounds per 1000 sq. ft.

   Maximum = 5 pounds per 1000 sq. ft.

   Minimum = 0.1 pounds per 1000 sq. ft.

   Recommend 0 when P tests exceeds 20 pounds per acre

Calc. K_2O requirement = (3 - % K sat.) * CEC * 0.21 = pounds per 1000 sq.ft.

   Maximum = 4 pounds per 1000 sq. ft.

   Minimum = 2 pounds per 1000 sq. ft.

   Recommend 0 when K saturation exceeds 3%

FERTILIZER OPTIONS:

Fertilizer recommendations are based primarily on P_2O_5 requirement.

1. If P_2O_5 requirement > 2.0 pounds, apply 20 pounds of 10-20-20 or 40 pounds of 5-10-10 fertilizer per 1000 sq. ft.

2. If P_2O_5 requirement = 0.8 - 2.0 pounds, apply 20 pounds of 10-10-10 fertilizer per 1000 sq. ft.

3. If the P_2O_5 requirement = 0.5 - 0.7 pounds, apply 20 pounds of 10-5-10 fertilizer per 1000 sq. ft.

4. If P_2O_5 requirement = 0.1 - 0.4 pounds, apply 10 pounds of 20-4-8 fertilizer per 1000 sq. ft.

5. If P_2O_5 requirement = 0 and K_2O requirement = 0 , apply 4 pounds urea (46-0-0) or 5 pounds 38-0-0 per 1000 sq. ft.

6. If P_2O_5 requirement = 0 and K_2O requirement > 0 , apply 8 pounds of 24-0-11 or 10 pounds of 20-0-20 fertilizer per 1000 sq. ft.

MANAGEMENT STATEMENTS:

1. Spread lime and fertilizer uniformly and till in 4-6 inches deep.

2. If soil amendments are not tilled in (as with hydroseeding), use only ½ recommended rates of fertilizer and lime.

3. Other fertilizers of similar $N-P_2O_5-K_2O$ ratio may be substituted for the one recommended. Adjust application rate to match nitrogen requirement.

4. If CEC < 5 or if percent organic matter < 5, till in an inch or t wo of compost or peat with any recommended lime and fertilizer <u>before seeding</u>, to improve the soil's nutrient and water holding capacity.

COMMERCIAL VEGETABLES

Crop Codes 301 to 330

For all crops:

* Lime recommended to raise soil pH to 6.5 , unless otherwise requested or noted below.

* CEC and nutrient balance calculated assuming a target pH of 6.5 (current pH if higher) unless otherwise requested or noted below.

* All nutrient requirements rounded to nearest 10 pounds per acre.

* Optimum P range = 20 - 40 pounds P per acre.

* Optimum K range = 3.5 - 5.0 % K saturation, unless otherwise specified.

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Crop Codes 310 - All vines (cucumber, gourd, melons, pumpkin, squash); 311 - All niteshades (tomato, eggplant, pepper); 329 - Asparagus (new bed); 330 - Asparagus* (established bed).

* For crop code 330: CEC and nutrient balance are calculated at the current soil pH. No lime is recommended for established beds.

Nitrogen requirement = 75 pounds per acre

Calc. P_2O_5 requirement = 70 + (50 - no. PX's) * 6 = pounds per acre

   Maximum = 140 pounds per acre

   Minimum = 40 pounds per acre

   Recommend 0 when P test exceeds 40 pounds per acre.

Calc. K_2O requirement = 200 + (4 - % K sat.) * CEC * 9.36 = pounds per acre

   Maximum = 300 pounds per acre

   Minimum = 100 pounds per acre

Recommend 0 when K test exceeds 5 % saturation *and* 250 pounds per acre

MANAGEMENT STATEMENTS:

Crop Code 310:
At planting or transplanting apply 20 pounds N plus all P_2O_5 and K_2O in bands 2 inches below and beside seed or plants. Sidedress 55 pounds N per acre when vines begin to spread. When rain is heavy on sandy soil, apply one extra nitrogen sidedress.

Crop Code 311:
Broadcast 30 pounds N plus 1/2 - 3/4 P_2O_5 and K_2O before plowing or apply in bands 4 inches deep and 3 to 4 inches from row at planting. Sidedress 45 pounds N per acre when the first fruit are set. In years of heavy rainfall on sandy soils, apply an extra nitrogen sidedress. Alternative for early determinate tomato varieties: apply 60-100 pounds nitrogen per acre two weeks after first fruit set. If tomatoes are grown under a hoop house, sidedress 25 pounds less N than recommended above.

Crop Codes 310, 311:
When transplanting, apply 1/2 pint (one cup) of starter solution around roots. Make solution by dissolving 3 pounds plant starter (10-52-17 or similar) in 50 gallons of water. Use 1 pound in 50 gallons for melons and cucumber plants.

Crop Code 329:
Thoroughly till in N, K_2O and 1/2 P_2O_5 and lime before opening furrows. Apply other half P_2O_5 and lime in furrow bottom before setting crowns.

Crop Code 330:
Broadcast and work fertilizer in before cutting season. Apply 30 pounds N per acre at end of cutting season. No lime is recommended on established beds, due to very slow reaction rate.

Crop Codes 302 - Bean (dry and snap); 317 - Pea.

* Lime recommended to raise soil pH to 6.0 for beans, 6.5 for peas unless otherwise requested.

* CEC and nutrient balance calculated assuming a target pH of 6.0 for beans and pH 6.5 for peas (current pH if higher) unless otherwise requested.

Nitrogen requirement = 40 pounds per acre

Calc. P_2O_5 requirement = 40 + (45 - no. PX's) * 6 = pounds per acre

Maximum = 80 pounds per acre

Minimum = 40 pounds per acre

Recommend 0 when P test exceeds 40 pounds per acre

Calc. K_2O requirement = 60 + (3 - % K sat.) * CEC * 9.36 = pounds per acre

Maximum = 90 pounds per acre

Minimum = 30 pounds per acre

Recommend 0 when K test exceeds 5 % saturation

Optimum range = 2.8 - 4.0 % saturation

MANAGEMENT STATEMENTS:

Band 10 pounds N plus all P_2O_5 and K_2O at planting, two inches below and beside the seed. Apply 30 pounds N per acre when plants have 2-3 true leaves, especially in years of heavy rainfall on sandy soils.

Early *determinate* varieties have shown a positive yield response in some years to heavier sidedress N applications at the 3-leaf stage. This response would most likely occur in fields with no manure application and no legume green manure plowdowns.

Crop Codes 304 - Beet; 308 - Carrot, parsnip; 313 - Lettuce; 315 - Onion; 322 - Spinach; 328 - Roadside stand mix.

Nitrogen requirement = 100 pounds per acre

Calc. P_2O_5 requirement = 30 + (50 - no. PX's) * 6 = pounds per acre

Maximum = 60 pounds per acre

Minimum = 30 pounds per acre

Recommend 0 when P test exceeds 40 pounds per acre

Calc. K_2O requirement = 150 + (4 - % K sat.) * CEC * 9.36 = pounds per acre

Maximum = 220 pounds per acre

Minimum = 70 pounds per acre

Recommend 0 when K test exceeds 5 % saturation *and* 250 pounds per acre

MANAGEMENT STATEMENTS:

Broadcast 1/2 the recommended P_2O_5 and K_2O fertilizer before plowing. Drill 25 pounds N and the remaining P_2O_5 and K_2O in bands 2 inches below and to the side of seed at planting.

Crop Codes 304, 308:
Sidedress an additional 35 pounds N per acre at 4 weeks and again at 6 weeks after seeding.

Crop Code 304:
Use 1-2 pounds of boron (10-20 pounds of borax) per acre in the fertilizer blend.

Crop Code 313:
Sidedress an additional 35 pounds N per acre at 3 weeks and again at 5 weeks after thinning or setting in field.

Crop Code 328:
Sidedress an additional 30 - 40 pounds N per acre 3 weeks after planting and again: on fruiting vegetables after first fruit set, on vine crops when plants start to vine, on leaf and root crops when 1/3 to 1/2 grown. Apply one sidedress of 75 pounds N on corn when plants are 8 - 12 inches tall.

Crop Codes 320 - Radish; 321 - Rutabaga, turnip.

Nitrogen requirement = 35 pounds per acre

Calc. P_2O_5 requirement = 30 + (45 - no. PX's) * 6 = pounds per acre

Maximum = 60 pounds per acre

Minimum = 30 pounds per acre

Recommend 0 when P test exceeds 40 pounds per acre

Calc. K_2O requirement = 150 + (4 - % K sat.) * CEC * 9.36 = pounds per acre

Maximum = 220 pounds per acre

Minimum = 70 pounds per acre

Recommend 0 when K test exceeds 5 % saturation *and* 250 pounds per acre

MANAGEMENT STATEMENTS:

Broadcast 1/2 the recommended P_2O_5 and K_2O fertilizer before plowing. Drill N and the remaining P_2O_5 and K_2O in bands 2 inches below and to the side of seed. Use 1-2 pounds of boron (10-20 pounds of borax) per acre in the fertilizer blend.

Crop Code 321:
Sidedress an additional 30-60 pounds N per acre 4-6 weeks after seeding when rainfall has been heavy or if soil is low in organic matter.

Crop Codes 305 Broccoli, cauliflower; 306 Brussel sprout, cabbage. [transplants only]

Nitrogen requirement = 100 pounds per acre

Calc. P_2O_5 requirement = 30 + (45 - no. PX's) * 6 = pounds per acre

   Maximum = 60 pounds per acre

   Minimum = 30 pounds per acre

   Recommend 0 when P test exceeds 40 pounds per acre

Calc. K_2O requirement = 150 + (4.5 - % K sat.) * CEC * 9.36 = pounds per acre

   Maximum = 220 pounds per acre

   Minimum = 70 pounds per acre

   Recommend 0 when K test exceeds 5 % saturation *and* 250 pounds per acre

MANAGEMENT STATEMENTS:

1. Broadcast 1/2 - 3/4 of P_2O_5 and K_2O before plowing. Drill 25 pounds N plus remaining P_2O_5 and K_2O in bands 4 inches deep and 3 - 4 inches from the row at time of planting. Use 1 - 2 pounds of boron (10-20 pounds of borax) per acre in the fertilizer blend.

2. When transplanting to the field, use 1/2 pint (one cup) of starter solution around roots. Make solution by dissolving 3 pounds of plant starter (10-52-17 or similar) in 50 gallons of water.

3. Sidedress with an additional 35 pounds N per acre 2 - 3 weeks and again at 4 - 6 weeks after setting in field.

Crop Codes 335 - Broccoli and 336 - Cauliflower. [direct seeded and banded system only].

* Lime recommended to raise soil pH to 6.0, unless otherwise requested.

* CEC and nutrient balance calculated assuming a target pH of 6.0 (current pH if higher) unless otherwise requested.

Nitrogen requirement = 100 pounds per acre

Calc. P_2O_5 requirement = 30 + (50 - no. PX's) * 6 = pounds per acre

   Maximum = 100 pounds per acre

   Minimum = 30 pounds per acre

   Recommend 0 when P test exceeds 40 pounds per acre

Calc. K_2O requirement = 150 + (4.5 - % K sat.) * CEC * 9.36 = pounds per acre

   Maximum = 220 pounds per acre

   Minimum = 70 pounds per acre

   Recommend 0 when K tests exceeds 5 % saturation *and* 250 pounds per acre

MANAGEMENT STATEMENTS:

1. If soil pH is below 4.5 or if lime requirement to reach pH 6.0 exceeds 6000 pounds per acre: **Do not seed cole crops in this field this year.** Till in lime thoroughly and allow two years for complete reaction before seeding to cole crops.

2. For most efficient use of fertilizer and best crop response, band all fertilizer 2 inches below and beside row at planting or when making raised beds. Use 2 pounds of boron per acre in the fertilizer blend for broccoli, 3-5 pounds of boron per acre for cauliflower.

3. Crop code 335 nitrogen management: Apply 40 pounds N per acre in the fertilizer band. Sidedress an additional 30 pounds N per acre at 2 weeks prior to heading (about 6 weeks after

seeding). Repeat 30 pounds N sidedress when 1/2 inch heads appear (about 8 weeks after seeding). Use ammonium nitrate as the nitrogen source for sidedress.

4. Crop code 336 nitrogen management: Apply 40 pounds N per acre in the fertilizer band. Sidedress an additional 20 pounds N per acre at each application - 6, 9, and 11 weeks after seeding. Use ammonium nitrate.

Crop Code 324 (sweet corn).

* Lime recommended to raise soil pH to 6.0 unless otherwise requested.

* CEC and nutrient balance calculated assuming a target pH of 6.0 (current pH if higher) unless otherwise requested.

Nitrogen requirement = 100 pounds per acre

Calc. P_2O_5 requirement = 40 + (45 - no. PX's) * 6 = pounds per acre

    Maximum = 80 pounds per acre

    Minimum = 40 pounds per acre

    Recommend 0 when P test exceeds 40 pounds per acre

Calc. K_2O requirement = 100 + (4 - % K sat.) * CEC * 9.36 = pounds per acre

    Maximum = 150 pounds per acre

    Minimum = 50 pounds per acre

    Recommend 0 when K test exceeds 5 % saturation *and* 250 pounds per acre

MANAGEMENT STATEMENTS:

1. Apply 25 pounds N plus all P_2O_5 and K_2O in bands 2 inches below and beside seed when planting.

2. Sidedress N as indicated by mid-season nitrate soil test or apply an additional 75 pounds N per acre when plants are 8 - 12 inches tall. Sidedress only 50 pounds N if plants were started under plastic.

3. Zinc recommendations:

If zinc test < 1.0 ppm: Apply 2 pounds actual zinc per acre in starter fertilizer (banded) for 2 to 3 years, then retest before applying more. An alternative is to broadcast and till in 8 - 10 pounds actual zinc per acre once every 3 to 5 years.

If zinc test = 1.0 - 2.0 ppm: Soil zinc level is adequate. There is very little probability of a yield response to added zinc.

If zinc test > 2.0 ppm: Soil zinc level is excessive. Use a starter fertilizer <u>without</u> zinc if possible.

For All Commercial Vegetables:

ADDITIONAL MANAGEMENT STATEMENTS

For any lime recommendation over 4 tons per acre: Limit lime application to 8000 pounds per acre in any one year. Total lime requirement to reach a target pH can be met over 3 years.

When plowing down sod with > 25% legume: Plowing down a legume green manure or a heavy legume hay stand can provide 40 - 75 pounds nitrogen per acre the first year. Reduce recommended nitrogen application accordingly.

If soil P and organic matter are not excessive: Animal manures are a good source of organic matter and essential nutrients. 650 bushels of cow, hog, or horse manure or 325 bushels of poultry, sheep, or goat manure per acre can generally be substituted for 1/4 - 1/3 the recommended N, P_2O_5, and K_2O.

CONVENTIONAL HOME GARDEN

Crop Code 391

Includes Vegetables and Small Fruit

(less than 1 acre)

* Lime recommended to raise soil pH to 6.5, unless otherwise requested.

* CEC and nutrient balance calculated assuming a target pH of 6.5 (current pH if higher), unless otherwise requested.

* All lime and fertilizer recommendations are made on a 1000 sq. ft. basis.

* Optimum P range = 20 - 40 pounds P per acre.

* Optimum K range = 3.5 - 5.0 % K saturation.

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Nitrogen requirement = 2.5 pounds per 1000 sq. ft.

Calc. P_2O_5 requirement = (50 - no. PX's) * 5 / 43.56 = pounds per 1000 sq. ft.

   Maximum = 5.75 pounds per 1000 sq. ft.

   Minimum = 1.15 pounds per 1000 sq. ft.

   (Minimum P_2O_5 recommendation optional when P test falls between 40 - 80 pounds per acre)

   Recommend 0 when P test exceeds 80 pounds per acre

Calc. K_2O requirement = (4.5 - % K sat.) * CEC * 0.21 = pounds per 1000 sq. ft.

Maximum = 6.9 pounds per 1000 sq. ft.

Minimum = 1.15 pounds per 1000 sq. ft.

Recommend 0 when K saturation exceeds 4.5%

FERTILIZER OPTIONS:

1. If P_2O_5 requirement >= 4 and K_2O requirement >= 4, apply 40 to 50 pounds of 5-10-10 fertilizer per 1000 sq. ft.of area.

2. If P_2O_5 requirement = 3-4 and K_2O requirement >= 3, apply 23 pounds of 10-15-15 fertilizer per 1000 sq. ft. of area.

3. If P_2O_5 requirement < 3 and K_2O requirement < 3, apply 23 pounds of 10-10-10 fertilizer per 1000 sq. ft. of area.

4. If P_2O_5 requirement < 3 and K_2O requirement >= 3, apply 17.5 pounds of 15-8-12 fertilizer per 1000 sq. ft. of area.

5. If P_2O_5 requirement >= 3 and K_2O requirement < 4, apply 40-50 pounds of 5-10-5 fertilizer per 1000 sq. ft. of area.

** For all fertilizer options 1 - 5: Other fertilizer grades with similar N-P_2O_5-K_2O ratio can be substituted if the application rate is adjusted to match nitrogen requirement.

6. If P_2O_5 requirement <= 1.15 and K_2O requirement <= 2, major nutrient needed is nitrogen, unless soil organic matter is optimum or excessive (see Management Statement 6 below). Apply 10 pounds of 10-10-10 or 14-14-14 fertilizer per 1000 sq. ft. of area. Apply in early spring as a starter. When plants are 3-4 weeks old, sidedress with 2 pounds of ammonium nitrate or 2 pounds of urea per 1000 sq. ft. of area.

7. For all but option 6 above, you may more accurately meet your N-P_2O_5-K_2O requirements by substituting a fertilizer mixed from single-nutrient sources as follows:

5.5 pounds of urea (46-0-0)

plus

(P_2O_5 req. * 2.2) = pounds triple-superphosphate (0-46-0)

plus

(K_2O req. * 1.7) = pounds muriate of potash (0-0-60)

Mix these components together very thoroughly and broadcast on 1000 sq. ft. of garden area or band beside and below 1000 ft. of row as a substitute for the commercial blend recommended.

MANAGEMENT STATEMENTS:

1. When lime is needed, broadcast uniformly over soil at the specified rate and till in to a depth of 6-7 inches in spring or fall.

2. Limit lime application rate to 175 pounds per 1000 sq. ft. in any one year. Lime requirement can be met over a period of several years.

3. For best efficiency, fertilizer should be banded 2 - 3 inches below and 2 - 3 inches beside the rows. Banding is more important when soil P or K test low. When banding, assume 1000 sq. ft. of area equals 1000 ft. of row (1 ft. rooting width). Fertilizer may be broadcast and tilled in to adjust overall fertility, but this may encourage weed growth. Fertilizer should always be applied in the spring.

4. If soil pH exceeds 7.0, apply 15 pounds yellow (elemental)sulfur per 1000 sq. ft. of area to reduce pH to 6.5. Use 30 pounds per 1000 sq. ft. if pH exceeds 7.5. Broadcast sulfur uniformly if needed and till in thoroughly. Aluminum sulfate may be used at 6 times the above sulfur rates for the same effect in less time.

5. In general, 15 bushels of cow, hog, or horse manure; or 7 - 8 bushels of poultry, sheep, goat, or rabbit manure per 1000 sq. ft. may be used as a substitute for 1/4 to 1/3 of the recommended fertilizer additions. Manure use should be curtailed or stopped for a year or more if either soil P or organic matter test levels are excessive.

6. Optional nitrogen credit for organic matter level: If organic matter test = 5 - 8 %, the natural breakdown of soil organic matter should supply half or more of the total seasonal nitrogen requirement of most vegetables. If organic matter tested > 8 %, the soil should be able to supply the full seasonal nitrogen requirement of most vegetables. These organic matter/nitrogen equivalences assume the regular use of animal manures or compost. These assumptions may not be valid following the heavy use of peat moss, sawdust, or wood chips.

To make an adjustment, use the same rate of a lower nitrogen fertilizer than the one recommended (example: 5-10-10 rather than 10-10-10) or adjust the rate of the nitrogen fertilizer when sidedressing (Fertilizer Option 6) or when mixing your own fertilizer blend (Fertilizer Option 7).

7. If no lime is needed or if potassium is excessive and you are using wood ash, discontinue the use of ash until both lime and potassium are needed again. This will help avoid problems with excessive pH and nutrient imbalances.

8. If both K_2O and lime are needed: wood ash acts as both a liming material and a source of potash (K_2O). Reduce lime application rate 1.5 pounds for each 1 pound of wood ash used. A fertilizer lower in K_2O than the one recommended may be substituted if wood ash is used (example: 5-10-5 rather than 5-10-10).

9. For garden potatoes: reserve an area for potatoes and rotate alternate years with sweet corn. Maintain pH in the reserve area at 5.5, lime remaining garden to pH 6.5. If pH is already above 5.5, grow scab-resistant potato varieties such as Norland, Belrus, Waseon, Superior, or any Russet variety.

10. For information on lead contamination of garden soils, see "Lead Scan" on p. 16 in the front part of the Handbook.

GENERAL ORGANIC

Crop Code 392

Includes Home Gardens, Commercial Vegetables,

Small Fruits and Flowers.

* Lime recommended to raise soil pH to 6.5, unless otherwise requested.

* CEC and nutrient balance calculations assume a target pH of 6.5 (current pH if higher) unless otherwise requested.

* All lime and nutrient source recommendations made on a 1000 sq. ft. basis.

* Optimum P range = 20 - 40 pounds P per acre.

* Optimum K range = 3.5 - 5.0 % K saturation.

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RECOMMENDED NITROGEN SOURCES:
(to supply 2.5 pounds N per 1000 sq. ft.)

50 pounds cottonseed meal per 1000 sq. ft.
<u>OR</u>
20 pounds bloodmeal per 1000 sq. ft.
<u>OR</u>
25 pounds fishmeal per 1000 sq. ft.
(only if P test is not excessive)

Reduce these amounts if soil organic matter is optimum or excessive
(see Management Statement 6).

PHOSPHORUS REQUIREMENT TABLE:

Pounds per acre P (soil test)	P source recommendation
≤ 2	75 pounds of rock phosphate* or 40 pounds bonemeal per 1000 sq. ft.
2-4	65 pounds of rock phosphate* or 35 pounds bonemeal per 1000 sq. ft.
4-8	50 pounds of rock phosphate* or 30 pounds bonemeal per 1000 sq. ft.
8-22	25 pounds of rock phosphate* or 10 pounds bonemeal per 1000 sq. ft.
22-40	4 pounds bonemeal per 1000 sq. ft. as a starter in early spring.
40-80 (optional)	4 pounds bonemeal per 1000 sq. ft. as a starter in early spring.
> 80	No P recommended this year.

*If pH >= 6.5, use bonemeal only. Rock phosphate releases very slowly at high soil pH.

POTASSIUM REQUIREMENT TABLE:

% K saturation (soil test)	K source recommendation
≤ 2	1.If no lime or Mg are needed, use 750 pounds greensand per 1000 sq. ft.* 2. If Mg is needed but no lime, use 20 pounds langbeinite (Sul-Po-Mag) per 1000 sq. ft. 3.If both lime and Mg are needed, use 20 pounds langbeinite (Sul-Po-Mag) or 90 pounds dry unleached wood ash per 1000 sq. ft.
2-4.5%	1. If no lime or Mg are needed, use 500 pounds greensand per 1000 sq. ft.* 2. If Mg is needed but no lime, use 15 pounds langbeinite (Sul-Po-Mag) per 1000 sq. ft. 3. If lime and Mg are both needed, use 15 pounds langbeinite (Sul-Po-Mag) or 70 pounds dry unleached wood ash per 1000 sq. ft.
> 4.5%	No K needed this year.

*Greensand and granite dust release available K at a very slow rate. Application rate listed are those necessary to correct a soil K deficiency in the first year. For a long-term adjustment, use 1/4 - 1/2 the recommended rates.

MAGNESIUM SOURCES:

1. If lime is needed, use a magnesium lime.

2. If no lime is needed, but K is needed, use Sul-Po-Mag as a source of both Mg and K.

3. If no lime or K are needed, very few alternative organic sources of Mg are available. Low soil Mg level cannot be corrected economically until either lime or K are needed again.

MANAGEMENT STATEMENTS:

1. When lime is needed, broadcast it uniformly over the soil at the specified rate and till in to a depth of 6-7 inches in spring or fall.

2. Limit lime application rate to 175 pounds per 1000 sq. ft. in any one year. Lime requirement can be met over a period of several years.

3. Most organic N-P-K nutrient sources should be applied in the spring. They may be broadcast overall and tilled in 6 - 7 inches or thoroughly worked into the soil of raised beds or rows.

4. If soil pH exceeds 7.0, apply 15 pounds yellow (elemental)sulfur per 1000 sq. ft. of area to reduce pH to 6.5. Use 30 pounds per 1000 sq. ft. if pH exceeds 7.5. Broadcast sulfur uniformly if needed and till in thoroughly in spring or fall.

5. In general, 15 bushels of cow, hog, or horse manure; or 7 - 8 bushels of poultry, sheep, goat, or rabbit manure per 1000 sq. ft. may be used as a substitute for 1/4 to 1/3 of the recommended N-P-K nutrient additions. Manure use should be curtailed or stopped for a year or more if either soil P or organic matter test levels are excessive.

6. Optional nitrogen credit for organic matter level: If organic matter test = 5 - 8 %, the natural breakdown of soil organic matter should supply half or more of the total seasonal nitrogen requirement of most vegetables. If organic matter tested > 8 %, the soil should be able to supply the full seasonal nitrogen requirement of most vegetables. Adjust the recommended application rate of nitrogen sources downward accordingly. These organic matter/nitrogen equivalences assume the regular use of animal manures or compost. These assumptions may not be valid following the heavy use of peat moss, sawdust, or wood chips.

7. If no lime is needed or if potassium is excessive and you are using wood ash, discontinue the use of ash until both lime and potassium are needed again. This will help avoid problems with excessive pH and nutrient imbalances.

8. If both K and lime are needed: wood ash acts as both a liming material and a source of potassium (K). Reduce lime application rate 1.5 pounds for each 1 pound of wood ash used.

9. For potatoes: reserve an area for potatoes and rotate alternate years with sweet corn. Maintain pH in the reserve area at 5.5, lime remaining garden to pH 6.5. If pH is already above 5.5, grow scab-resistant potato varieties such as Norland, Belrus, Waseon, Superior, or any Russet variety.

10. For information on lead contamination of garden soils, see "Lead Scan" on p. 16 in the front part of the Handbook.

HOME TREE FRUIT

Crop Code 393

* Lime recommended to reach a soil pH of 6.0, unless otherwise requested.

* CEC and nutrient balance calculated assuming a target pH of 6.0 (current pH if higher) unless otherwise requested.

* All lime and fertilizer recommendations are made on a 1000 sq. ft. basis.

* Optimum P range = 9 - 13 pounds P per acre.

* Optimum K range = 2.1 - 3.0 % K saturation.

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Nitrogen requirement = 1.4 pounds per 1000 sq. ft.

P_2O_5 requirement not calculated for home tree fruit.

Calc. K_2O requirement = (3 - % K sat.) * CEC * .215 = pounds per 1000 sq. ft.

   Maximum = 6.0 pounds per 1000 sq. ft.

   Minimum = 1.8 pounds per 1000 sq. ft.

   Recommend 0 when K saturation exceeds 3%

FERTILIZER OPTIONS:

1. If K_2O requirement = 0, apply either 4 pounds 33-0-0 or 3 pounds 46-0-0 fertilizer per 1000 sq. ft.

2. If K_2O requirement <= 3.0, apply 15 pounds 15-8-12 or 12 pounds 15-15-15 fertilizer per 1000 sq. ft.

3. If K_2O requirement > 3.0 and <= 5.0, apply either 40 pounds 5-10-10 or 20 pounds 10-20-20 fertilizer per 1000 sq. ft.

4. If K_2O requirement > 5.0, apply either 50 pounds 5-10-10 or 25 pounds 10-20-20 fertilizer per 1000 sq. ft.

MANAGEMENT STATEMENTS:

1. Broadcast fertlizer in 4-8 ft. circles around established trees.

2. Apply fertilizer between April 15 and June 1. Later application may cause winter damage.

3. Limit lime topdress on established trees to 100 pounds per 1000 sq. ft. in any one year.

4. When planting new trees, apply lime at the recommended rate and till in thoroughly. Add peat or compost at 1/3 to 1/4 by volume to the soil in the planting hole. Also add the recommended fertilizer at the per plant rate. Mix all materials together thoroughly before planting. Water in well.

COMMERCIAL FRUIT

Crop Codes 401 to 412

For all crops:

* Lime recommended to raise soil pH to 6.0, unless otherwise requested or noted below.

* CEC and nutrient balance calculations assume a target pH of 6.0 (current pH if higher), unless otherwise requested or noted below.

* Nutrient requirements rounded to nearest 10 pounds per acre, unless otherwise specified.

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Crop Code 401 - Apples (new plantings only).

Nitrogen requirement: see management statements below.

Calc. P_2O_5 requirement = 1.2 * (50 - no. PX's) = pounds per acre

    Minimum = 25 pounds per acre

    Recommend 0 when P test exceeds 13 pounds per acre

    Optimum range = 9 - 13 pounds P per acre

Calc. K_2O requirement = (3 - % K sat.) * CEC * 9.36 = pounds per acre

    Maximum = 260 pounds per acre

    Minimum = 80 pounds per acre

Recommend 0 when K saturation exceeds 3%

Optimum range = 3.5 - 5.0 % K saturation

* If Ca saturation is less than 60 % and no lime is needed (soil pH >= 5.8):

Calc. calcium requirement = (80 - % Ca sat.) * CEC * 17.40 = pounds per acre **gypsum**

MANAGEMENT STATEMENTS:

1. Be sure any lime or phosphate fertilizers are thoroughly tilled in before planting.

2. After planting, apply 1 ounce of actual nitrogen per tree after growth begins - between April 15 and June 1. Nitrogen applied after June 1 could lead to excessive winter damage.

3. Applying fertilizer in a 6 to 8 ft. band down the tree rows will reduce grass growth between rows.

4. For established orchards, use a foliar analysis in combination with a soil analysis to determine nutrient requirements.

Crop Codes 404 - Raspberry (established bed), 405 - Raspberry (new bed), 406 - Strawberry (established bed), 407 - Strawberry (new bed).

Nitrogen requirement = 35 pounds per acre

Calc. P_2O_5 requirement = 15 + (50 - no. PX's) * 4 = pounds per acre

Maximum = 150 pounds per acre for established beds (crop codes 404 & 406)

Maximum = 200 pounds per acre for new beds (crop codes 405 & 407)

Minimum = 25 pounds per acre

Recommend 0 when P tests excessive

Optimum range = 10 - 40 pounds P per acre

Calc. K_2O requirement = $40 + (4 - \% \text{ K sat.}) * CEC * 9.36$ = pounds per acre

Maximum = 160 pounds per acre for established beds (crop codes 404 & 406)

Maximum = 220 pounds per acre for new beds (crop codes 405 & 407)

Minimum = 40 pounds per acre

Recommend 0 when K saturation exceeds 4%

Optimum range = 2.8 - 4.0 % K saturation

MANAGEMENT STATEMENTS:

Crop Code 405:
Thoroughly till in all lime and fertilizer before planting.

Crop Code 404:
Sidedress brambles as soon as growth begins in the spring. Later applications may increase winter injury. Mulch may be applied to retain soil moisture and inhibit weed growth, though it may delay primocane emergence in the spring.

Crop Code 407:
Till in recommended nutrients before planting. Broadcast 30 pounds additional nitrogen per acre around plants one month after planting. Repeat nitrogen application between August 15-30 to stimulate flower bud formation.

Crop Code 406:
Apply fertilizer immediately after harvest or at renovation time.
A light application of nitrogen (8 - 10 pounds actual N per acre) in early spring may increase fruit size. Heavier application will cause fruit softening and encourage disease and mite problems.

For all Crop Codes 404 - 407:
To obtain lime and fertilizer rates on a 1000 sq. ft. basis, multiply per acre recommendations by .023.

Crop Code 408 - Stone Fruit.

Nitrogen requirement = 40 pounds per acre

Calc. P_2O_5 requirement = 1.4 * (50 - no. PX's) = pounds per acre

   Maximum = 70 pounds per acre

   Minimum = 40 pounds per acre

   Recommend 0 when P test exceeds 13 pounds per acre

   Optimum range = 9 - 13 pounds P per acre

Calc. K_2O requirement = (3 - % K sat.) * CEC * 9.36 = pounds per acre

   Maximum = 140 pounds per acre

   Minimum = 40 pounds per acre

   Recommend 0 when the K saturation exceeds 3 %

   Optimum range = 2.1 - 3.0 % K saturation

MANAGEMENT STATEMENTS:

Broadcast fertilizer under trees in a band 6 to 8 ft. wide between April 15 and June 1. To avoid winter injury, do not apply nitrogen after June 1.

Limit lime application to 4000 lbs per acre per year when topdressing established trees.

Crop Codes 409 - Highbush blueberry (new bed), 410 - Highbush blueberry (established bed).

* CEC and nutrient balance are calculated at the current soil pH.

* Nutrient and sulfur recommendations are made on a 1000 sq. ft. basis to the nearest 0.1 pound, unless otherwise specified.

* Optimum P range = 9 - 13 pounds P per acre.

* Optimum K range = 2.1 - 3.0 % K saturation.

Nitrogen requirement: see management statements below.

Calc. P_2O_5 requirement = (35 - no. PX's) * 0.11 = pounds per 1000 sq. ft.

   Maximum = 1.8 pounds per 1000 sq. ft.

   Minimum = 0.9 pounds per 1000 sq. ft.

   Recommend 0 when P test exceeds 14 pounds per acre

Calc. K_2O requirement = (3 - % K sat.) * CEC * .215 = pounds per 1000 sq. ft.

   Maximum = 1.8 pounds per 1000 sq. ft.

   Minimum = 0.9 pounds per 1000 sq. ft.

   Recommend 0 when K saturation exceeds 3%

Calc. calcium requirement = (25 - % Ca sat.) * CEC * .41 = pounds **gypsum** per 1000 sq. ft.

Recommend 0 when Ca saturation exceeds 25%

Calc. magnesium requirement = (15 - % Mg sat.) * CEC * .55 = pounds **epsom salts** (10 % Mg) per 1000 sq. ft.

Recommend 0 when Mg saturation exceeds 15%

Sulfur requirement: Highbush blueberries prefer a soil pH between 4.8 and 5.2. Apply elemental (yellow) sulfur at the following rates. If sulfur is not available, use <u>aluminum</u> sulfate (not to be confused with ammonium sulfate) at 6 times the rate recommended for sulfur.

<u>Sulfur requirement table:</u>
Soil pH of 5.2-5.4 = 10 pounds per 1000 sq. ft.
Soil pH of 5.5-5.7 = 20 pounds per 1000 sq. ft.
Soil pH of 5.8-6.0 = 30 pounds per 1000 sq. ft.
Soil pH of 6.1-6.5 = 40 pounds per 1000 sq. ft.
Soil pH of 6.6-7.0 = 60 pounds per 1000 sq. ft.*

* recommend selection of another location with lower pH.

Notes on sulfur application: The above rates of sulfur are expected to adjust soil pH to the optimum range in an "average" soil. Heavy, fine-textured soils may require up to 1.5 times the recommended rate for the desired effect on soil pH. Sandy, coarse-textured soils may need as little as 1/2 the recommended rate for the desired effect. To maximize the reaction rate, be sure the sulfur is well tilled in.

Lime requirement: In some rare cases, the soil pH may actually be too low for optimum Highbush blueberry production. In those cases, a small application of lime should be considered. For each 0.2 pH units below pH 4.5, apply 30 pounds of lime per 1000 sq. ft.

Lime requirement table
Soil pH of 4.3 - 4.4 = 30 pounds per 1000 sq. ft.
Soil pH of 4.1 - 4.2 = 60 pounds per 1000 sq. ft.
Soil pH of 3.9 - 4.0 = 90 pounds per 1000 sq. ft.

MANAGEMENT STATEMENTS:

Crop Code 409 (new bed):

1. Build up the soil during the summer or fall before planting by broadcasting and incorporating the calculated amounts of sulfur, P_2O_5, K_2O, gypsum, and epsom salts.

2. Approximately three weeks after planting, apply 1 oz. ammonium sulfate per plant in a 15 in. circle. Mulch plants with 4-6 inches of shredded bark, wood chips, or similar material.

3. Use sulfate sources for nitrogen and potash if soil pH is above 4.9.

4. Incorporation of organic matter, such as manure, will improve the early growth of blueberry plants.

Crop Code 410 (established plantings):

1. Broadcast 1/2 the calculated fertilizer needs around the plants at bud break in the spring. Broadcast the second half one month later - at tip dieback. Caution: To avoid excess winter damage, do not apply any fertilizer after July 15.

2. Nitrogen source depends on soil pH. Use ammonium sulfate if the soil pH is above 4.9. More conventional sources, such as urea or a blended fertilizer like 10-10-10, may be used if the soil pH is 4.8 or lower. Application rate is based on plant age as follows:

years from planting	oz. per plant* 10-10-10	oz. per plant* ammonium sulfate
1	2 oz.	1 oz.
2	4 oz.	1.5 oz.
3	6 oz.	2 oz.
4	8 oz.	3 oz.
5	10 oz.	4 oz.
6	12 oz.	4 oz.

*Note: Nitrogen application rate should be doubled for heavily mulched plants.

Crop Codes 411 - Cranberry (new bog), 412 - Cranberry (established bog).

* CEC and nutrient balance are calculated at the current soil pH.

* Current recommendations are derived from Massachusetts and Wisconsin guidelines and are based only on pounds per acre levels.

* Optimum P range = 10 - 20 pounds P per acre.

* Optimum K range = 20 - 80 pounds K per acre.

* Optimum Mg range = 20 - 50 pounds Mg per acre.

* Optimum Ca range = 40 - 150 pounds Ca per acre.

Sulfur requirement: Cranberries prefer a soil pH below 5.0. Apply elemental (yellow) sulfur at the following rates:

Sulfur requirement table:
Soil pH of 5.0-5.2 = 250 pounds per acre
Soil pH of 5.3-5.5 = 500 pounds per acre
Soil pH of 5.6-5.7 = 750 pounds per acre
Soil pH of 5.8-6.0 = 1000 pounds per acre
Soil pH of 6.1-6.2 = 1250 pounds per acre
Soil pH of 6.3-6.5 = 1500 pounds per acre
Soil pH of 6.6-6.7 = 1750 pounds per acre
Soil pH > 6.7 = 2000 pounds per acre

Notes on sulfur application:

The above sulfur rates are for a 6 inch layer of **sand**, not peat or topsoil. Decrease application rates proportionately for a shallower sand layer. Increase application rates by 50 % for topsoil and double the rates for peat or other highly organic soil materials.

Apply sulfur only to well-drained, unsaturated soils with **no** standing water. Saturated soils can produce sulfides, which are toxic to plants.

Use granulated or prilled sulfur and wear a particle mask to avoid breathing dust. Powdered sulfur dust is a health hazard.

Calcium requirement - For new or established bogs with < 40 pounds Ca per acre:

Apply 90 - 130 pounds **gypsum** per acre.

Magnesium requirement - For new or established bogs with < 20 pounds Mg/acre:

   If soil K < 50 pounds per acre, apply 100 - 200 pounds **Sul-Po-Mag** (11 % Mg)/acre
   to boost both K and Mg.

   If soil K >= 50 pounds per acre, apply 100 - 300 pounds **epsom salts** (10 % Mg)/acre.

Crop Code 411 (new bog) Specific Recommendations:

Before planting new vines, it is important that any adjustments to the pH and phosphorus level of the sand layer be made while tillage is still possible. Pre-plant recommendations are as follows:

If soil P < 10 pounds per acre: Apply 100 pounds triple-superphosphate (0-46-0) per acre. Broadcast the full rate of TSP on top of the sand or broadcast 50 pounds per acre before sanding and the remainder on top of the sand before vine disk-in.

MANAGEMENT STATEMENTS:

1. Apply any recommended sulfur, gypsum, or epsom salts and till in at least one month before planting.

2. After planting, apply 5-10 pounds actual nitrogen per acre every 2-3 weeks until mid-August. Alternate applications between urea or ammonium sulfate and a complete N-P-K fertilizer.

Crop Code 412 (established bog) Specific Recommendations:

If soil P <= 10 pounds per acre and K <= 20 pounds per acre:

   Apply 200 pounds 5-10-10 or 100 pounds 10-20-20 per acre in May.

If soil P <= 10 pounds per acre and K > 20 pounds per acre:

   Apply 200 pounds 5-10-5 or 100 pounds 10-20-10 per acre in May.

If soil P > 10 pounds per acre and K <= 20 pounds per acre:

   Apply 100 pounds 10-10-10 or 70 pounds 14-14-14 per acre in May.

If soil P > 10 pounds per acre and K > 20 pounds per acre:

   Apply 30 pounds 33-0-0 or 20 pounds 46-0-0 per acre in May.

MANAGEMENT STATEMENTS:

1. Apply an additional 10 pounds nitrogen per acre at bloom and again at fruit set. If vines are short or yellow, additional nitrogen may be applied for a total of up to 40 pounds nitrogen per acre for the entire year.

2. Notes on sulfur application to established bogs:
Split the sulfur application into several 100-200 pound per acre applications, spaced 4-6 weeks apart. Use a field testing kit to check your pH before each application. There is little economic benefit to applying more than 500 pounds sulfur per acre in any one year on established bogs.

COMMERCIAL POTATOES

Crop Codes 501 to 531

For all varieties- processing, seed and table stock:

* Three separate lime recommendations are made to raise soil pH to 5.2, 5.5, and 6.0 targets.

* CEC and nutrient balance calculations assume a target pH of **6.0** (current pH if higher) unless otherwise requested.

* Nutrient requirements rounded to nearest 10 pounds per acre.

* Optimum P range = 20 - 50 pounds P per acre.

* Optimum K range = 4.8 - 7.0 % K saturation (Buildup and Maintenance system).

* K Sufficiency level = 450 pounds K per acre.

Early and Low Nitrogen-demand Varieties (Superior, Kennebec, Atlantic)

Crop Codes 501, 506, 511. For a 300-325 CWT tuber yield.

Processing and Seed Use

Crop Code 501: after heavy red clover or alfalfa green manure.

Nitrogen requirement = 60 to 80 pounds per acre

Calc. P_2O_5 requirement = 40 + (50 - no. PX's) * 5 = pounds per acre

   Maximum = 240 pounds per acre

   Minimum = 60 pounds per acre

   Recommend 0 when P test exceeds 50 pounds per acre

Buildup and Maintenance Potash Recommendation:

Calc. K_2O requirement = 160 + (7 - % K sat.) * CEC * 9.36 = pounds per acre

   Maximum = 280 pounds per acre

   Minimum = 50 pounds per acre

Sufficiency Level Potash Recommendation

Calc K_2O requirement = 450 – lb/A soil test K = pounds per acre

   Maximum = 280 pounds per acre

   Minimum = 50 pounds per acre

Recommend 0 when K test exceeds 600 pounds per acre.

Crop Code 506: after underseeded grains, non-legume green manures, broccoli, or old sod.

Nitrogen requirement = 110 to 130 pounds per acre

Calc. P_2O_5 and K_2O requirement = same as 501

Crop Code 511: after grains (not underseeded with clover) or replanted potatoes.

Nitrogen requirement = 120 to 140 pounds per acre

Calc. P_2O_5 and K_2O requirement = same as 501

MANAGEMENT STATEMENTS:

Crop Codes 501, 506:
A credit of 60 lb/A phosphate (P_2O_5) can be taken after a green manure or clover cover crop is plowed down.

All Crop Codes (501, 506, 511):
For seed potatoes: Reduce nitrogen application rate by 10 % from that recommended above.

For processing potatoes: Reduce nitrogen application rate by 10 pounds per acre per week, when planting after May 24.

Early and Low Nitrogen-demand Varieties (Superior, Kennebec, Atlantic)

Crop Codes 516, 526, 529. For a 325-350 CWT tuber yield.

Table Stock

Crop Code 516: after heavy red clover or alfalfa green manure.

Nitrogen requirement = 60 to 80 pounds per acre

Calc. P_2O_5 requirement = 50 + (50 - no. PX's) * 5 = pounds per acre

Maximum = 240 pounds per acre

Minimum = 60 pounds per acre

Recommend 0 when P test exceeds 50 pounds per acre

Buildup and Maintenance Potash Recommendation:

Calc. K_2O requirement = 180 + (7 - % K sat.) * CEC * 9.36 = pounds per acre

Maximum = 300 pounds per acre

Minimum = 60 pounds per acre

Sufficiency Level Potash Recommendation

Calc K_2O requirement = 450 – lb/A soil test K = pounds per acre

   Maximum = 300 pounds per acre

   Minimum = 60 pounds per acre

   Recommend 0 when K test exceeds 600 pounds per acre.

Crop Code 526: after underseeded grains, non-legume green manures, broccoli, or old sod.

Nitrogen requirement = 110 to130 pounds per acre

Calc. P_2O_5 and K_2O requirement = same as 516

Crop Code 529: after grains (not underseeded with clover) or replanted potatoes.

Nitrogen requirement = 120 to140 pounds per acre

Calc. P_2O_5 and K_2O requirement = same as 516

MANAGEMENT STATEMENTS:

Crop Code 516, 526:
A credit of 60 lb/A phosphate (P_2O_5) can be taken after a green manure or clover cover crop is plowed down.

Mid-Season Varieties and Shepody

Crop Codes 504, 509, 514, For a 300 - 325 CWT tuber yield.

Processing and Seed Use

Crop Code 504: after heavy red clover or alfalfa green manure.

Nitrogen requirement = 80 to 100 pounds per acre

Calc. P_2O_5 requirement = 40 + (50 - no. PX's) * 5 = pounds per acre

   Maximum = 240 pounds per acre

   Minimum = 60 pounds per acre

   Recommend 0 when P test exceeds 50 pounds per acre

Buildup and Maintenance Potash Recommendation:

Calc. K_2O requirement = 160 + (7 - % K sat.) * CEC * 9.36 = pounds per acre

   Maximum = 280 pounds per acre

   Minimum = 50 pounds per acre

<u>Sufficiency Level Potash Recommendation</u>

Calc K_2O requirement = 450 – lb/A soil test K = pounds per acre

   Maximum = 280 pounds per acre

   Minimum = 50 pounds per acre

   Recommend 0 when K test exceeds 600 pounds per acre.

Crop Code 509: after underseeded grains, non-legume green manures, broccoli, or old sod.

Nitrogen requirement = 130 to 150 pounds per acre

Calc. P_2O_5 and K_2O requirement = same as 504

 Crop Code 514: after grains (not underseeded with clover) or replanted potatoes.

Nitrogen requirement = 140 to 160 pounds per acre

Calc. P_2O_5 and K_2O requirement = same as 504

MANAGEMENT STATEMENTS:

Crop Code 504, 509:
A credit of 60 lb/A phosphate (P_2O_5) can be taken after a green manure or clover cover crop is plowed down.

All Crop Codes (504, 509, 514):
For seed potatoes: Reduce nitrogen application rate by 10 % from that recommended above.

For processing potatoes: Reduce nitrogen application rate by 10 pounds per acre per week, when planting after May 24.

Mid-Season Varieties and Shepody

Crop Codes 519, 520, 521, For a 325 - 350 CWT tuber yield.

Table Stock

Crop Code 519: after heavy red clover or alfalfa green manure.

Nitrogen requirement = 80 to 100 pounds per acre

Calc. P_2O_5 requirement = 50 + (50 - no. PX's) * 5 = pounds per acre

   Maximum = 240 pounds per acre

   Minimum = 60 pounds per acre

   Recommend 0 when P test exceeds 50 pounds per acre

<u>Buildup and Maintenance Potash Recommendation:</u>

Calc. K_2O requirement = 180 + (7 - % K sat.) * CEC * 9.36 = pounds per acre

  Maximum = 300 pounds per acre

  Minimum = 60 pounds per acre

 Sufficiency Level Potash Recommendation

Calc K_2O requirement = 450 – lb/A soil test K = pounds per acre

  Maximum = 300 pounds per acre

  Minimum = 60 pounds per acre

  Recommend 0 when K test exceeds 600 pounds per acre.

Crop Code 520: after underseeded grains, non-legume green manures, broccoli, or old sod.

Nitrogen requirement = 130 to150 pounds per acre

Calc. P_2O_5 and K_2O requirement = same as 519

 Crop Code 521: after grains (not underseeded with clover) or replanted potatoes.

Nitrogen requirement = 140 to160 pounds per acre

Calc. P_2O_5 and K_2O requirement = same as 519

MANAGEMENT STATEMENTS:

Crop Code 519, 520:
A credit of 60 lb/A phosphate (P_2O_5) can be taken after a green manure or clover cover crop is plowed down.

Russet Burbank

Crop Codes 502, 507, 512. For a 300-325 CWT tuber yield.

Processing and Seed Use

Crop Code 502: after heavy red clover or alfalfa green manure.

Nitrogen requirement = 110 to 130 pounds per acre

Calc. P_2O_5 requirement = 50 + (50 - no. PX's) * 5 = pounds per acre

  Maximum = 260 pounds per acre

  Minimum = 60 pounds per acre

  Recommend 0 when P test exceeds 50 pounds per acre

Buildup and Maintenance Potash Recommendation:

Calc. K_2O requirement = 180 + (7 - % K sat.) * CEC * 9.36 = pounds per acre

    Maximum = 300 pounds per acre

    Minimum = 60 pounds per acre

 Sufficiency Level Potash Recommendation

Calc K_2O requirement = 450 – lb/A soil test K = pounds per acre

    Maximum = 300 pounds per acre

    Minimum = 60 pounds per acre

    Recommend 0 when K test exceeds 600 pounds per acre.

Crop Code 507: after underseeded grains, non-legume green manures, broccoli, or old sod.

Nitrogen requirement = 160 to 180 pounds per acre

Calc. P_2O_5 and K_2O requirement = same as 502

Crop Code 512: after grains (not underseeded with clover) or replanted potatoes.

Nitrogen requirement = 170 to 190 pounds per acre

Calc. P_2O_5 and K_2O requirement = same as 502

MANAGEMENT STATEMENTS:

Crop Code 502, 507:
A credit of 60 lb/A phosphate (P_2O_5) can be taken after a green manure or clover cover crop is plowed down.

All Crop Codes (502, 507, 512):
For seed potatoes: Reduce nitrogen application rate by 10 % from that recommended above.

For processing potatoes: Reduce nitrogen application rate by 10 pounds per acre per week, when planting after May 24.

Russet Burbank

Crop Codes 517, 527, 530. For a 350-400 CWT tuber yield.

Table Stock

Crop Code 517: after heavy red clover or alfalfa green manure.

Nitrogen requirement = 110 to 125 pounds per acre

Calc. P_2O_5 requirement = 60 + (50 - no. PX's) * 5 = pounds per acre

Maximum = 260 pounds per acre

Minimum = 80 pounds per acre

Recommend 0 when P test exceeds 50 pounds per acre

Buildup and Maintenance Potash Recommendation:

Calc. K_2O requirement = 200 + (7 - % K sat.) * CEC * 9.36 = pounds per acre

Maximum = 340 pounds per acre

Minimum = 80 pounds per acre

Sufficiency Level Potash Recommendation

Calc K_2O requirement = 450 – lb/A soil test K = pounds per acre

Maximum = 340 pounds per acre

Minimum = 80 pounds per acre

Recommend 0 when K test exceeds 600 pounds per acre.

Crop Code 527: after underseeded grains, non-legume green manures, broccoli, or old sod.

Nitrogen requirement = 160 to 175 pounds per acre

Calc. P_2O_5 and K_2O requirement = same as 517

Crop Code 530: after grains (not underseeded with clover) or replanted potatoes.

Nitrogen requirement = 170 to 185 pounds per acre

Calc. P_2O_5 and K_2O requirement = same as 517

MANAGEMENT STATEMENTS:

Crop Code 517, 527:
A credit of 60 lb/A phosphate (P_2O_5) can be taken after a green manure or clover cover crop is plowed down.

Late maturing varieties

Crop Codes 503, 508, 513. For a 300-325 CWT tuber yield.

Processing and Seed Use

Crop Code 503: after heavy red clover or alfalfa green manure.

Nitrogen requirement = 100 to 120 pounds per acre

Calc. P_2O_5 requirement = 50 + (50 - no. PX's) * 5 = pounds per acre

Maximum = 260 pounds per acre

Minimum = 60 pounds per acre

Recommend 0 when P test exceeds 50 pounds per acre

Buildup and Maintenance Potash Recommendation:

Calc. K_2O requirement = 180 + (7 - % K sat.) * CEC * 9.36 = pounds per acre

Maximum = 320 pounds per acre

Minimum = 60 pounds per acre

 Sufficiency Level Potash Recommendation

Calc K_2O requirement = 450 – lb/A soil test K = pounds per acre

Maximum = 320 pounds per acre

Minimum = 60 pounds per acre

Recommend 0 when K test exceeds 600 pounds per acre.

Crop Code 508: after underseeded grains, non-legume green manures, broccoli, or old sod.

Nitrogen requirement = 150 to 170 pounds per acre

Calc. P_2O_5 and K_2O requirement = same as 503

 Crop Code 513: after grains (not underseeded with clover) or replanted potatoes.

Nitrogen requirement = 160 to 180 pounds per acre

Calc. P_2O_5 and K_2O requirement = same as 503

MANAGEMENT STATEMENTS:

Crop Code 503, 508:
A credit of 60 lb/A phosphate (P_2O_5) can be taken after a green manure or clover cover crop is plowed down.

All Crop Codes (503, 508, 513):
For seed potatoes: Reduce nitrogen application rate by 10 % from that recommended above.

For processing potatoes: Reduce nitrogen application rate by 10 pounds per acre per week, when planting after May 24.

Late maturing varieties

Crop Codes 518, 528, 531. For a 350-400 CWT tuber yield.

Table Stock

Crop Code 518: after heavy red clover or alfalfa green manure.

Nitrogen requirement = 100 to120 pounds per acre

Calc. P_2O_5 requirement = 60 + (50 - no. PX's) * 5 = pounds per acre

   Maximum = 260 pounds per acre

   Minimum = 80 pounds per acre

   Recommend 0 when P test exceeds 50 pounds per acre

Buildup and Maintenance Potash Recommendation:

Calc. K_2O requirement = 200 + (7 - % K sat.) * CEC * 9.36 = pounds per acre

   Maximum = 340 pounds per acre

   Minimum = 80 pounds per acre

 Sufficiency Level Potash Recommendation

Calc K_2O requirement = 450 – lb/A soil test K = pounds per acre

   Maximum = 340 pounds per acre

   Minimum = 80 pounds per acre

   Recommend 0 when K test exceeds 600 pounds per acre.

Crop Code 528: after underseeded grains, non-legume green manures, broccoli, or old sod.

Nitrogen requirement = 150 to 170 pounds per acre

Calc. P_2O_5 and K_2O requirement = same as 518

Crop Code 531: after grains (not underseeded with clover) or replanted potatoes.

Nitrogen requirement = 160 to 180 pounds per acre

Calc. P_2O_5 and K_2O requirement = same as 518

MANAGEMENT STATEMENTS:

Crop Code 518, 528:
A credit of 60 lb/A phosphate (P_2O_5) can be taken after a green manure or clover cover crop is plowed down.

ADDITIONAL MANAGEMENT STATEMENTS:

Increased potash application can reduce black spot bruise in susceptible varieties. But, on average, an increase of 100 lb K_2O/acre results in a 3 pt. decline in specific gravity.

If the K_2O requirement exceeds 180 pounds per acre, broadcast (preplant) any K_2O in excess of 180 pounds to minimize seed piece damage.

If soil Mg saturation < 20 %, use a fertilizer containing magnesium to help maintain optimum nutrient balance.

Boron recommendations (all codes):

If boron test < 0.6 ppm: Apply ½ pound actual boron per acre in the fertilizer blend OR by foliar sprays: spray ¼ lb actual boron/A in early season, ¼ lb/A again before mid-season.

If boron test = 0.6 – 1.2 ppm: Soil boron level is sufficient. To avoid possible toxicity (decreased top growth, tuber set, and yield), apply no additional boron.

If boron test > 1.2 ppm: Soil boron level is excessive. To avoid possible toxicity (decreased top growth, tuber set, and yield), apply no additional boron.

Zinc recommendations (all crop codes):

If zinc test < 1.0 ppm: Broadcast 4 - 5 pounds actual zinc per acre in a fertilizer blend (or spray 12 pounds zinc sulfate per acre) and till in before planting. Retest zinc level before applying more in subsequent years.

If zinc test = 1.0 - 2.0 ppm: Soil zinc level is adequate to support any reasonable crop yield. There is very little probability of a yield response from additional zinc.

If zinc test > 2.0 ppm: Soil zinc level is excessive. Further application of zinc may result in plant toxicity and yield loss.

FORESTRY

Crop Codes 601 to 604

For all crops:

* Lime is recommended to raise soil pH to 5.5 and 6.0, unless otherwise requested.

* CEC and nutrient balance calculations assume a target pH of 6.0 (current pH if higher) unless otherwise requested.

* Nutrient requirements rounded to nearest 10 pounds per acre or nearest 0.1 pound per 1000 sq. ft.

* Optimum P range = 9 - 13 pounds P per acre.

* Optimum K range = 2.1 - 3.0 % K saturation.

** Note: The procedures and interpretations used in the Standard Soil Testing System are not meant to be used on "true" forest soils. The Forestry crop codes assume tree growth to be on presently or formerly tilled field soils. Forest soils which have never been cultivated should be analyzed using the Forest Soil Protocols, which provide a more thorough characterization of both organic and mineral horizons.

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Crop Codes 601 (general forestry), 602 (Christmas trees).

Nitrogen requirement = 100 pounds per acre

Calc. P_2O_5 requirement = 2 * (50 - no. PX's) = pounds per acre

   Maximum = 100 pounds per acre

   Minimum = 40 pounds per acre

   Recommend 0 when P test exceeds 13 pounds per acre

Calc. K_2O requirement = (3 - % K sat.) * CEC * 9.36 = pounds per acre

   Maximum = 100 pounds per acre

   Minimum = 40 pounds per acre

   Recommend 0 when K saturation exceeds 3 %

Crop Code 603 (forest tree nursery).

Same recommendations as 601 and 602 above, except on a 1000 sq. ft. basis.

MANAGEMENT STATEMENTS

Crop Code 602 (Christmas trees):
To minimize weed competition, restrict fertilizer application to a 3-foot band down tree rows.

Off-color (yellow) foliage is commonly caused either by a nitrogen deficiency or by a high pH-induced manganese deficiency. Frazer fir seems especially prone to manganese deficiency. A target pH of 5.5 is recommended for Frazer fir, a 6.0 target pH for Balsam fir. If trees lack greenness, acidify if pH exceeds 6.0 and/or apply an additional 50 pounds nitrogen per acre.

Full N, P_2O_5, and K_2O recommendations are for established plantings of Christmas trees. To prepare soil before planting, apply only lime and phosphate fertilizer (P_2O_5) when recommended and till in thoroughly. Nitrogen and potash (K_2O) are best applied as a topdress after trees have developed a well established root system (1 to 2 years after planting).

Crop Codes 601 - 603 (all):
If lime is to be tilled in, apply full rate recommended. If applied as a topdress, no economic advantage is gained from apply more than 1/4 the full recommended rate in any one year.

ORNAMENTALS

Crop Codes 701 to 707

<u>For all crops</u>:

* All lime and fertilizer recommendations are made on a 100 sq. ft. basis.

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Crop Code 701 - Annuals: flower beds, cut flowers.

* Lime recommended to raise soil pH to 6.5, unless otherwise requested.

* CEC and nutrient balance calculations assume a target pH of 6.5 (current pH if higher), unless otherwise requested.

* Optimum P range = 20 - 40 pounds P per acre.

* Optimum K range = 3.5 - 5.0 % K saturation.

FERTILIZER OPTIONS:

1. If P test < 5 pounds per acre and % K saturation < 2.5 %, apply 3-4 pounds of 5-10-10 or 1.5-2 pounds of 10-20-20 fertilizer per 100 sq. ft. of area.

2. If P test >= 5 pounds per acre and % K saturation >= 2.5 %, apply 1.5 pounds of 10-10-10 or 1 pound of 15-15-15 fertilizer per 100 sq. ft. of area.

3. If P test >= 5 pounds per acre and % K saturation < 2.5 %, apply 1.25 pounds of 15-8-12 fertilizer per 100 sq. ft. of area.

4. If P test < 5 pounds per acre and % K saturation >= 2.5 %, apply 3-4 pounds of 5-10-5 or 1.5 pounds of 10-20-10 fertilizer per 100 sq. ft. of area.

5. If P test > 40 pounds per acre and % K saturation > 5 %, <u>broadcast</u> 3/4 pound of 20-4-4 fertilizer, or 1/2 pound of ammonium nitrate (33-0-0), or 1/3 pound of urea (46-0-0) per 100 sq. ft. of area in early spring.

MANAGEMENT STATEMENTS:

1. If lime is needed, broadcast uniformly at the recommended rate and work in with the fertilizer.

2. Except for no. 5 (above), till fertilizer to a depth of 2-4 inches in early spring.

3. In all cases, if the recommended fertilizer blend is unavailable, a fertilizer of similar N-P_2O_5-K_2O ratio may be substituted if the application rate is adjusted to match the nitrogen requirement.

4. For cut flowers: at planting, apply 1/2 the recommended fertilizer 2 inches below and 2 inches beside rows. Sidedress the remaining fertilizer just before rapid growth begins.

5. If soil pH exceeds 7.0: to lower soil pH to 6.5, apply 2 pounds elemental sulfur or 9 pounds aluminum sulfate per 100 sq. ft. and till in thoroughly.

6. If soil pH exceeds 7.5: to lower soil pH to 6.5, apply 3 pounds elemental sulfur or 18 pounds aluminum sulfate per 100 sq. ft. and till in thoroughly.

Crop Code 702 - Roses and other Perennials.

* Lime recommended to raise soil pH to 6.5, unless otherwise requested.

* CEC and nutrient balance calculations assume a target pH of 6.5 (current pH if higher), unless otherwise requested.

* Optimum P range = 20 - 40 pounds P per acre.

* Optimum K range = 3.5 - 5.0 % K saturation.

FERTILIZER OPTIONS:

1. If P test < 5 pounds per acre and % K saturation < 2.5 %, apply 3 pounds 5-10-10 fertilizer per 100 sq. ft. (5 ounces per plant)or 1.5 pounds 10-20-20 fertilizer per 100 sq. ft. (2-3 ounces per plant).

2. If P test < 5 pounds per acre and % K saturation >= 2.5 %, apply 3-4 pounds of 5-10-5 fertilizer per 100 sq. ft.(5-6 ounces per plant).

3. If P test >= 5 pounds per acre and % K saturation >= 2.5 %, apply 1.5 pounds 10-10-10 fertilizer per 100 sq. ft. (2-3 ounces per plant)or 1 pound 15-15-15 fertilizer per 100 sq. ft. (2 ounces per plant).

4. If P test >= 5 pounds per acre and % K saturation < 2.5 %, apply 1 pound 15-8-12 fertilizer per 100 sq. ft.(2 ounces per plant).

5. If P test exceeds 40 pounds per acre and % K saturation exceeds 5 %, apply 3/4 pound 20-4-4 fertilizer per 100 sq. ft. (1 ounce per plant). As an alternative, use 1/2 pound of ammonium nitrate (33-0-0)or 1/3 pound of urea (46-0-0) per 100 sq. ft.

MANAGEMENT STATEMENTS:

1. For best results, apply fertilizer in 2 ft. diameter circles around plants and work lightly into the soil. Use 1/3 more per plant than is listed above for large bushes.

2. Apply fertilizer at recommended rate in early spring. Repeat at 1/2 rate in mid-July.

3. If lime is needed, apply at the recommended rate and work in with fertilizer in early spring.

4. If soil pH exceeds 7.0: to lower soil pH to 6.5, apply 2 pounds elemental sulfur or 9 pounds aluminum sulfate per 100 sq. ft. and work in as much as possible.

5. If soil pH exceeds 7.5: to lower soil pH to 6.5, apply 3 pounds elemental sulfur or 18 pounds aluminum sulfate per 100 sq. ft. and work in as much as possible.

Crop Code 704 - Azalea, Rhododendron, other acid loving plants.

* CEC and nutrient balance calculated at current soil pH.

* Optimum P range = 9 - 13 pounds P per acre.

* Optimum K range = 3.5 - 5.0 % K saturation.

SULFUR REQUIREMENT: (to lower soil pH below 5.4)

   (soil pH - 5.4) * 10 = pounds <u>aluminum sulfate</u> per 100 sq. ft.

FERTILIZER OPTIONS: (P test not considered)

1. If % K saturation < 2 %, apply 3 pounds of 5-10-10 fertilizer per 100 sq. ft. of area (about 1 cup for an average 3 ft. plant). Broadcast in 4 ft. diameter circles around plants in early spring.

2. If % K saturation = 2-3.4 %, apply 2.5 pounds of 5-10-10 fertilizer per 100 sq. ft. of area (about 2/3 cup for an average 3 ft. plant). Broadcast in 4 ft. diameter circles around plants in early spring.

3. If % K saturation = 3.5-4.9 %, apply 2 pounds of 5-10-10 fertilizer per 100 sq. ft. of area (about 1/2 cup for an average 3 ft. plant). Broadcast in 4 ft. diameter circles around plants in early spring.

4. If % K saturation >= 5 %, apply 1/3 pound of ammonium sulfate (41-0-0) per 100 sq. ft. of area. Broadcast uniformly in early spring.

Crop Code 705 - Other shrubs.

* Lime recommended to raise soil pH to 6.0, unless otherwise requested.

* CEC and nutrient balance calculations assume a target pH of 6.0 (current pH if higher), unless otherwise requested.

* Optimum P range = 9 - 13 pounds P per acre.

* Optimum K range = 3.5 - 5.0 % K saturation.

FERTILIZER OPTIONS: (P test not considered)

1. If % K saturation < 2.5 %, broadcast 3 pounds 5-10-10 fertilizer per 100 sq. ft. of area (1 cup for an average 3 ft. plant)in early spring.

2. If % K saturation = 2.5-4.9 %, broadcast 1.5 pounds 10-10-10 fertilizer per 100 sq. ft. of area (1/2 cup for an average 3 ft. plant) in early spring.

3. If % K saturation >= 5 %, broadcast 1/2 pound of ammonium nitrate (33-0-0) or 1/2 pound of urea (46-0-0) per 100 sq. ft. of area in early spring.

Crop Code 706 - Shade trees (deciduous).

* Lime recommended to raise soil pH to 6.0, unless otherwise requested.

* CEC and nutrient balance calculations assume a target pH of 6.0 (current pH if higher), unless otherwise requested.

* Optimum P range = 9 - 13 pounds P per acre.

* Optimum K range = 2.1 - 3.0 % K saturation.

FERTILIZER OPTIONS:

1. If P test < 5 pounds per acre and % K saturation < 2.5 %, apply 4 pounds of 5-10-10 fertilizer per inch of trunk diameter. Use 10 auger holes 12-18 inches deep per inch of trunk diameter. Space holes uniformly within drip line area and apply 6-7 ounces per hole.

2. If P test < 5 pounds per acre and % K saturation >= 2.5 %, apply 4 pounds of 5-10-5 fertilizer per inch of trunk diameter. Use 10 auger holes 12-18 inches deep per inch of trunk diameter. Space holes uniformly within drip line area and apply 6-7 ounces per hole.

3. If P test >= 5 pounds per acre and % K saturation < 2.5 %, apply 1 pound of 15-8-12 fertilizer per inch of trunk diameter. Use 10 auger holes 12-18 inches deep per inch of trunk diameter. Space holes uniformly within drip line area and apply 1-2 ounces per hole.

4. If P test >= 5 pounds per acre and % K saturation >= 2.5 %, **broadcast** 1/2 pound of ammonium nitrate (33-0-0) or 1/3 pound of urea (46-0-0) per 100 sq. ft. of area within drip line of trees.

Crop Code 707 - Shade trees (evergreens).

* Lime recommended to raise soil pH to 5.5, unless otherwise requested.

* CEC and nutrient balance calculations assume a target pH of 5.5 (current pH if higher), unless otherwise requested.

* Optimum P range = 9 - 13 pounds P per acre.

* Optimum K range = 2.1 - 3.0 % K saturation.

FERTILIZER OPTIONS: (P test not considered)

1. If % K saturation < 2.5 %, apply 2 pounds of 5-10-10 fertilizer per inch of trunk diameter in spring. Place fertilizer in auger holes 6-12 inches deep within drip line of tree, using 10 holes per inch of trunk diameter and about 3 ounces of fertilizer per hole.

2. If % K saturation >= 2.5 %, no fertilizer is recommended.

Crop Codes 704 - 707: All shrubs and shade trees.

MANAGEMENT STATEMENT:

When planting a new tree or shrub: Apply lime (or sulfur) at the recommended rate and till in thoroughly before opening a planting hole. After the hole is dug, mix in peat moss or compost at 1/3 to 1/4 by volume with the soil from the hole. Also mix in any recommended fertilizer at the per plant rate. Mix all materials together thoroughly before backfilling around the roots. Water in very thoroughly. Be sure the plant receives adequate water the first year.

MAINE SOIL TESTING SERVICE

Standard Soil Testing Procedures

With the exception of the Cation Equilibration procedure, all these methods can also be found in the Northeast Regional publication "Recommended Soil Testing Procedures for the Northeastern United States", 2nd edition. 1995. University of Delaware Agricultural Experiment Station Bulletin # 493.

Note: For all procedures, soil should be *air* dried, crushed, and passed through a standard no.10 (2 mm) sieve. Heat drying of soils (above 35 C) can result in the fixation of a significant portion of available K and Mg in non-extractable forms, resulting in an artificially low test level for these two nutrients. All samples should be thoroughly homogenized before subsampling for each analysis. Sieved soil samples tend to segregate by particle size as storage racks are moved and samples are processed.

Quality Control/Quality Assessment:

An in-house reference soil is included in the sample stream every 25 samples and is run for all analyses. Results for each reference soil should agree within 2 standard deviations of the cumulative mean value for each test parameter. Any results outside of 3 standard deviations from the cumulative mean value will result in the rerun of the associated group of samples for that parameter. Any two occurrences in a row between 2 and 3 standard deviations from the cumulative mean value will also result in the rerun of the associated group of samples for that parameter.

The Maine Soil Testing Service/Analytical Lab is also enrolled in the North American Proficiency Testing Program (NAPT). In this program, the accuracy of all routine soil and plant testing methods are evaluated quarterly.

Soil pH (water)

1) Weigh 5 (+/- 0.02) gm soil into a paper portion cup.

2) Add 5 (+/- 0.2) ml distilled water, stir, let sit 30 min. Measure pH to nearest 0.1 units using single junction pH and reference electrodes and pH meter.

Note: Calibrate apparatus with pH 4.0 & 7.0 buffers. Calibration should be verified, at a minimum, every 60 samples.

Mehlich Buffer pH/Lime index

1) To water/soil mix, from water pH procedure, add 5 (+/- 0.2) ml Mehlich buffer solution, stir, let sit 15 min.

2) Stir at 15 min., let sit an additional 15 min.

3) Stir after 15 min., (30 min. total contact time). Immediately measure pH to nearest 0.01 units with calibrated electrode/meter apparatus used in water pH procedure.

Note: buffer pH should be measured after 30 minutes minimum contact time while under agitation. Calibration should be verified every 36 samples.

Mehlich Buffer solution (2 liter total volume)

add to about 1 liter distilled or deionized water:

5.0 ml glacial acetic acid (concentrated)

20 ml 50 % triethanolamine

36.0 gm sodium glycerophosphate

86.0 gm ammonium chloride (NH_4Cl)

24.0 gm calcium chloride ($CaCl_2.2H_2O$)

Dilute to 2 liters.

Stir until all salts are dissolved (less than 30 min).

Adjust to pH 6.46 (+/- 0.04) as made or pH 6.60 (+/- 0.04) when diluted 1:1 with distilled water. Use triethanolamine to raise pH or acetic acid to lower pH.

Make fresh only what will be needed each week, to prevent microbial growth in storage. Disinfect all containers and dispensors with dilute chlorine bleach (sodium hypochlorite) between batches of solution. Rinse very well with distilled or deionized water.

Organic Matter (loss on ignition)

1) Weigh crucible and record. Add 5 - 10 gm soil and place in 110 C drying oven for a minimum of 2 hr.

2) Remove from oven and weigh as soon as it can be handled (while still warm) and record. Place in muffle furnace. Heat to 375 C and maintain temperature for 2 hr.

3) Remove, weigh crucible as soon as it can be handled (while still warm), and record.

Note: it is important that air-dried soils be oven-dried before ignition, since air-dried soils retain 1 - 4 % moisture depending on texture. If crucibles cannot be weighed while still warm, place them in a desiccator to avoid re-adsorption of moisture from the atmosphere.

Convert loss on ignition to Walkley-Black equivalent organic matter using the following regression equation:

$$\text{Organic matter} = 1.04 \times \% \text{ LOI} - 1.0$$

Modified Morgan Nutrient Extraction

1) Fill a standard 5 cc scoop heaping full, tap the scoop handle to settle, and strike off the excess, level with the top of the scoop. Weigh and record the scoop contents and empty into a 50 ml flask in shaker rack.

2) Add 20 (+/-0.2) ml pH 4.8 ammonium acetate (Modified Morgan) solution.

3) Shake on a platform shaker at 180 oscillation/min for 15 min.

4) Filter immediately through fast filter paper (Whatman 2 or equivalent).

5) Analyze filtrate for Ca, K, Mg, P, Na, Pb, Zn by plasma emission.

Modified Morgan Extraction solution (40 liter total volume)

add to about 20 liters distilled or deionized water:

2875 ml concentrated glacial acetic acid

1825 ml concentrated ammonium hydroxide

Dilute to 40 liters total volume and mix thoroughly.

Adjust pH to 4.8 (+/- 0.05) with acetic acid or ammonium hydroxide.

Cation Equilibration

1) Weigh 2 (+/-0.02) gm soil into 50 ml flask in shaker rack.

2) Add 20 (+/- 0.2) ml equilibration solution.

3) Shake for 15 min. on a platform shaker at 180 oscillation/min for 15 min.

4) Filter through fast filter paper, (Whatman 2 or equivalent).

5) Analyze filtrate for Ca, K, Mg, P, and Ba by plasma emission.

Equilibration Solution

0.35 mM KCl

5.00 mM $CaCl_2.2H_2O$

   1. mM $MgCl_2.6H_2O$

0.30 mM $BaCl_2.2H_2O$

Effective CEC (estimated) = 0.00048 x adBa**3 - 0.012 x adBa**2 + 0.244 x adBa

where adBa = ug Ba adsorbed/100 mg soil

This is an internally developed procedure used as an auxiliary CEC estimate on high pH soils and as a general index of cation activity. For information on similar procedures, see:

"Baker Small Exchange Method", p. 100-111. <u>IN</u> Handbook on Reference Methods for Soil Testing. 1980. Council on Soil Testing & Plant Analysis.

"CEC of Acid Soils", p. 154-157. <u>IN</u> Methods of Soil Analysis, Agronomy no. 9, part 2, second edition. 1982. American Society of Agronomy.