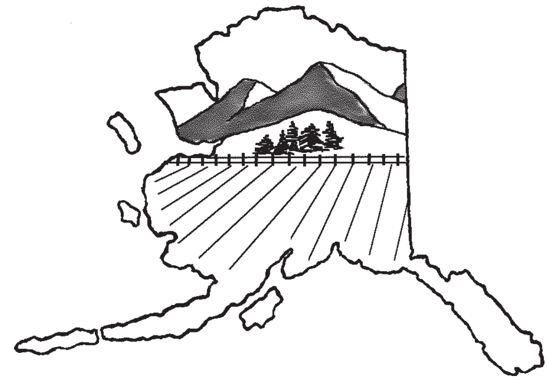
# Crop Production
## and
# Soil Management Series



**FGV-00348**

### Field Crop Fertilizer Recommendations For Alaska

# FERTILIZER NUTRIENT SOURCES AND LIME

by
R.G. Gavlak *

**CONTENTS**



## FERTILIZER

Numerous manufactured and natural fertilizers are available in Alaska. Manufactured materials are typically high analysis fertilizers; fertilizers that contain a high percentage of a nutrient element or elements per unit. Natural materials include animal manures and crop residues. The nutrient levels in manures and other residues are usually lower than those found in many manufactured materials. In addition, many of the nutrient elements found in manures and residues are organically bound and are not immediately available to plants. Nutrient levels in manures can vary substantially depending upon the degree of composting and whether the manure has been stored under cover or has been left exposed. Table 1 lists many commonly available fertilizers and their respective analyses.

Nitrogen (N) is used by the plant primarily in the nitrate ($NO_3^-$) and ammonium ($NH_4^+$) forms. These N forms come either from manufactured or naturally occurring sources. Nitrate is chemically the same from either source. Ammonium from either manufactured or naturally occurring sources is also chemically identical. The difference lies in nutrient availability of manufactured versus organically bound nutrients in manures and residues. The N in manure and residues must be converted to $NO_3^-$ and $NH_4^+$ by soil microorganisms. The conversion takes time and depends to a large extent on the kind of crop residue or manure, soil temperature, and moisture.

Phosphorus (P) and potassium (K) are also supplied by manufactured and naturally occurring sources. The plant uses P primarily in the mono-

*Raymond G. Gavlak is Extension Agronomist, Palmer Research Center, University of Alaska Fairbanks.

basic ($H_2PO_4^-$) and dibasic ($HP_2O_4^=$) forms. Naturally occurring P sources such as rock phosphate are not as readily plant available as manufactured sources. Potassium is taken up by the plant as $K^+$ ion. Potassium from naturally occurring sources is often more plant available than N or P. Manufactured K sources such as potassium chloride (KCl) and potassium sulfate ($K_2SO_4$) are readily plant available.

Sulfur (S) behaves much like N in the soil with nearly all S occurring in the organic fraction. If applied in the form of elemental S, both naturally occurring and manufactured sources must be converted in the soil to sulfate ($SO_4^=$), the form of S utilized by plants. For this reason, S fertilizers should be scrutinized for their relative plant availability. Where immediate S response is required, a sulfate source should be selected. In a soil S building program or where long term S availability is required (perennial crops), a combination of elemental S and sulfate is desirable. Care should be used when applying elemental S as this material lowers soil pH.

Calcium (Ca) and magnesium (Mg), if required, are normally applied in liming materials discussed in the next section.

The micronutrients required by plants include zinc (Zn), manganese (Mn), copper (Cu), iron (Fe), boron (B), nickel (Ni) and molybdenum (Mo). The term micronutrient accurately describes these nutrient elements because they are required in very small amounts for plant growth, though just as important as macronutrients. For this reason, micronutrients are often applied in foliar sprays. Table 2 lists various inorganic micronutrient sources and their solubility in water.

Metallic micronutrients (Mn, Cu, Fe, & Zn) are also commercially available in chelated forms. Chelates are designed to hold the micronutrient atom in solution for increased plant availability. These forms are important agriculturally because micronutrients are often plant unavailable due to soil physical and chemical limitations or are relatively water insoluble and therefore difficult to apply in foliar sprays. Four important chelates are ethylenediaminetetraacetic acid (EDTA), diethylenetriaminepentaacetic acid (DTPA), cyclohexanediaminetetraacetic acid (CDTA), and ethylenediaminedi (o-hydroxyphenylacetic acid) (EDDHA). Although these chelates act similarly and their effectiveness is fairly uniform, their individual activity varies with soil chemical conditions.

Boron is phytotoxic in relatively small amounts. It is therefore important to provide a constant supply to the plant. A method of managing the release rate of B was developed which fused B into glass. The glass was shattered to a particular size and soil applied. The process produced frits which are typically low in B (2-6% B) and are slow release. This form B is rarely used today.

## LIME

Liming materials are incorporated into the soil to increase pH. Lime applications are required on many soils in Alaska to (1) reduce aluminum toxicity, (2) increase P availability, (3) reduce micronutrient toxicity, (4) increase soil microbial activity, and (5) overcome poor plant performance.

Lime contains calcium (Ca) or magnesium (Mg) and neutralizes acidity. Calcium carbonate ($CaCO_3$) is the most commonly used liming material that contains plant available Ca and acidity neutralizing $CO_3^{2-}$ (see CES Publication FGV-00242A, *Soil Fertility Basics–pH).*

Gypsum (calcium sulfate, $CaSO_4$) and calcium nitrate ($Ca(NO_3)_2$) are not liming materials. Although both materials add calcium to the soil, the sulfate and nitrate have little capacity to neutralize acidity.

Numerous materials come under the heading of lime including limestone, burned lime, slaked lime, marl, oyster shells, slag, wood ashes, mine tailings, and many more. There are four categories into which these material are grouped. They are oxides, hydroxides, carbonates and by-product materials.

### Carbonates

Carbonates are widely available and the most commonly used liming materials. Mined high-grade limestone or calcitic limestone, when ground, is almost pure calcium carbonate ($CaCO_3$). This is an excellent liming material due to relatively low cost and availability. Dolomitic limestone (a combination of $MgCO_3$ and $CaCO_3$) is also widely used though usually more costly. Dolomite is important in areas with low soil Mg levels since this material provides both Ca and Mg.

Marls come from naturally occurring deposits of Ca and Mg carbonates, clay, and shell remnants and can be used to increase soil pH. Oyster shells are pure calcium carbonate which, when finely ground, increase soil pH.

### Oxides

Quicklime, unslaked lime and burned lime are examples of oxide liming materials. Crushed calcitic or dolomitic limestone is oven- or furnace-burned which drives off $CO_2$ forming pure oxide (CaO or MgO). These materials are the most efficient liming materials on a pound-for-pound basis and react rapidly with the soil to increase pH.

Oxides are powdery, caustic, and reactive with moisture so they are usually sold in bags. Due to the large amount of energy required to remove $CO_2$, oxide materials are more expensive than carbonate materials.

### Hydroxides

Hydroxides are hydrated oxides or simply oxides mixed with water. Common hydroxide limes include slaked lime, hydrated lime or builder's lime. Hydroxides react similarly to oxides in the soil and are also powdery and unpleasant to handle.

### By-Product Materials

Mining, refining, processing, and manufacturing industries produce numerous by-products useful for increasing soil pH. Slags from blast and electric furnaces along with fly and bottom ash from coal burning plants are used in agricultural liming. Sugar beet processing plants use large amounts of lime in the sugar extraction process. This process generates lime sludge that is used as a liming material. Wood ashes from wood stoves and fireplaces can also be used to increase soil pH. Carbide lime from acetylene production is nearly pure $Ca(OH)_2$ and an important lime source in Alaska. Probably the major problem with by-product lime sources involve variability in quality (purity) and fineness. Also, these materials may contain other elements or minerals which may be either toxic to plants or accumulate in the soil.

## LIME QUALITY

Chemical composition (purity) and particle size are the two attributes which define the potential effectiveness of liming materials.

### Chemical Composition

Calcium Carbonate Equivalence (CCE) is used to measure the relative effectiveness of liming materials and is a function of purity. The scale is designed to compare all liming materials to pure calcium carbonate, which is assigned a value of 100. CCE values for various liming materials are shown in Table 3. Note that marl, slags, sludges and wood ashes have considerably less acid-neutralizing power than the oxides, hydroxides or carbonates. This is due to the high level of impurities found in by-product lime sources.

### Physical Composition

Since agricultural limestone is produced by crushing limestone rock, particle sizes vary. Particle size is important because it is related to acid-neutralizing activity. Finely ground materials (smaller particle size) react more rapidly in soil than coarse ground materials (large particle size). Most ground limestone will pass a U.S. Standard No. 8 sieve (8 wires per inch, each opening 0.0937 by 0.0937 inches) and as much as 40% passes a 100 mesh sieve.

## LIME REQUIREMENT

The lime requirement is the amount of lime needed to increase soil pH to a desired level. The amount is determined by testing the soil. Lime recommendations are established by comparing individual soil test values to values from calibration experiments. Crops differ in their sensitivity to soil acidity so soil testing for lime should be crop specific. A combination of water pH and SMP buffer index is used for making lime recommendations in Alaska.

**Application Rate**

Lime application rates are typically much higher than fertilizer application rates. Soils should be limed to a pH of 6.0 to 6.5 for the best crop production. Observing proper lime application rates will limit the chance of over-liming, which can drastically reduce soil productivity. Table 4 is provided for use with SMP buffer soil test information. Simply find the SMP buffer value for each soil sample in the first column, then follow horizontally across to either of the lime requirement columns, tons/acre or pounds/100 square feet. Use these recommended amounts of lime to increase soil pH to approximately 6.5.

**Application Timing**

Lime must 'react' in the soil following application. Increasing lime particle surface exposure to the soil will increase the speed at which the neutralizing reaction occurs. Therefore, early applications of high CCE materials are encouraged when possible. Fall application is recommended to allow lime incorporation if soils are not frozen. Also, an even lime distribution across the field incorporating to six inches, will hasten neutralizing activity. Finely ground liming materials are difficult to handle and apply evenly. A drop-box type spreader (similar to a grain drill) provides more accurate dry lime applications than spinner-type spreaders. If the material is finely ground (pass through a 250 micron/60 mesh sieve) and has at least an 85% CCE, then liquid application as a slurry is possible, leading to more uniform application. Some liming materials, either high in impurities or coarsely ground, will not reduce soil pH appreciably in the year of application.

Table 1. Primary and secondary fertilizer nutrient source composition.

| Fertilizer Material | Chemical Formula | Nutrient Composition | | | | | |
|---|---|---|---|---|---|---|---|
| | | Primary | | | Secondary | | |
| | | N | $P_2O_5$* | $K_2O$ | S | Ca | Mg |
| | | % | | | | | |
| Ammonium nitrate | $NH_4NO_3$ | 34 | - | - | - | - | - |
| Ammonium nitrate sulfate | $NH_4NO_3(NH_4)_2SO_4$ | 30 | - | - | 6.5 | - | - |
| Ammonium phosphate sulfate | $NH_4H_2PO_4(NH_4)_2SO_4$ | 16 | 20 | - | 15 | - | - |
| Ammonium sulfate | $(NH_4)_2SO_4$ | 21 | - | - | 24 | - | - |
| Calcium nitrate | $Ca(NO_3)_2$ | 16 | - | - | - | 21 | - |
| Calcium sulfate *gypsum* | $CaSO_4$ | - | - | - | 17 | 22 | - |
| Diammonium phosphate (DAP) | $(NH_4)_2HPO_4$ | 18 | 46 | - | - | - | - |
| Elemental sulfur | | - | - | - | 99 | - | - |
| Fish meal, dried* | | 10 | 6 | | | | |
| Magnesium sulfate *Epsom salt* | $MgSO_4$ | - | - | - | 13 | - | 10 |
| Manure (fresh)* | | | | | | | |
| Chicken | | 1.1 | 0.9 | 0.5 | | | |
| Cow | | 0.5 | 0.2 | 0.5 | | | |
| Horse | | 0.6 | 0.3 | 0.5 | | | |
| Sheep | | 0.9 | 0.5 | 0.8 | | | |
| Swine | | 0.6 | 0.5 | 0.4 | | | |
| Monoammonium phosphate (MAP) | $NH_4H_2PO_4$ | 11 | 48 | - | - | - | - |
| Potassium chloride | KCl | - | - | 60 | - | - | - |
| Potassium nitrate | $KNO_3$ | 13 | - | 44 | - | - | - |
| Potassium magnesium sulfate | $K_2SO_4 \cdot 2MgSO_4$ | - | - | 22 | 23 | - | 11 |
| Potassium sulfate | $K_2SO_4$ | - | - | 50 | 18 | - | - |
| Salmon bone meal* | | 2-9 | 12 | | | | |
| Seaweed (kelp)* | | - | 0.6 | 1.3 | | | |
| Single superphosphate | $Ca(H_2PO_4)_2$ | - | 20 | - | 12 | 20 | |
| Sulfur-coated urea | $CO(NH_2)_2 \cdot S$ | 32 | - | - | 30 | - | - |
| Triple superphosphate (TSP) | $Ca(H_2PO_4)_2$ | - | 45 | - | 1 | 12 | |
| Urea | $CO(NH_2)_2$ | 45 | - | - | - | - | - |
| Wood ashes | | - | 1.8 | 5 | - | ** | ** |

* Values presented are averages as many factors affect actual composition. These materials also contribute secondary nutrients.

** If unleached, acid neutralizing potential equivalent to ½ agricultural grade lime.

Table 2. Micronutrient sources and water solubility.

| Fertilizer Material | Chemical Formula | Element % | Water Solubility g/100g $H_2O$ | Temperature °F |
|---|---|---|---|---|
| *Boron* | | | | |
| Granular borax | $Na_2B_4O_7{\cdot}10H_2O$ | 11.3 | 2.5 | 33 |
| Sodium tetraborate, anhydrous | $Na_2B_4O_7$ | 21.5 | 1.3 | 32 |
| Solubor | $Na_2B_8O_{13}{\cdot}4H_2O$ | 20.5 | 22 | 86 |
| Ammonium pentaborate | $NH_4B_5O_8{\cdot}4H_2O$ | 19.9 | 7 | 64 |
| *Copper* | | | | |
| Copper sulfate | $CuSO_4{\cdot}5H_2O$ | 25.0 | 24 | 32 |
| Cuprous oxide | $Cu_2O$ | 88.8 | * | |
| Cupric oxide | $CuO$ | 79.8 | * | |
| Cuprous chloride | $Cu_2Cl_2$ | 64.2 | 1.5 | 77 |
| Cupric chloride | $CuCl_2$ | 47.2 | 71 | 32 |
| *Iron* | | | | |
| Ferrous sulfate | $FeSO_4{\cdot}7H_2O$ | 20.1 | 33 | 32 |
| Ferric sulfate | $Fe_2(SO_4)_3{\cdot}9H_2O$ | 19.9 | 440 | 68 |
| Iron oxalate | $Fe_2(C_2O_4)_3$ | 30.0 | very soluble | |
| Ferrous ammonium sulfate | $Fe(NH_4)_2(SO_4)_2{\cdot}6H_2O$ | 14.2 | 18 | 32 |
| Ferric chloride | $FeCl_3$ | 34.4 | 74 | 32 |
| *Manganese* | | | | |
| Manganous sulfate | $MnSO_4{\cdot}4H_2O$ | 24.6 | 105 | 32 |
| Manganous carbonate | $MnCO_3$ | 47.8 | 0.0065 | 77 |
| Manganese oxide | $Mn_3O_4$ | 72.0 | * | |
| Manganous chloride | $MnCl_2$ | 43.7 | 63 | 32 |
| Manganous oxide | $MnO$ | 77.4 | | |
| *Molybdenum* | | | | |
| Sodium molybdate | $Na_2MoO_4{\cdot}H_2O$ | 39.7 | 56 | 32 |
| Ammonium molybdate | $(NH_4)Mo_7O_{24}{\cdot}4H_2O$ | 54.3 | 44 | 77 |
| Molybdic oxide | $MoO_3$ | 66.0 | 0.11 | 64 |
| *Zinc* | | | | |
| Zinc sulfate | $ZnSO_4{\cdot}H_2O$ | 36.4 | 89 | 212 |
| Zinc oxide | $ZnO$ | 80.3 | * | |
| Zinc carbonate | $ZnCO_3$ | 52.1 | 0.001 | 60 |
| Zinc chloride | $ZnCl_2$ | 48.0 | 432 | 77 |
| Zinc oxysulfate | $ZnO{\cdot}ZnSO_4$ | 453.8 | - | - |
| Zinc ammonium sulfate | $ZnSO_4{\cdot}(NH_4)_2SO_4{\cdot}6H_2O$ | 16.3 | 9.6 | 32 |
| Zinc nitrate | $Zn(NO_3)_2{\cdot}6H_2O$ | 22.0 | 324 | 68 |

* denotes insolubility

*Source*: Western Fertilizer Handbook, 7th Edition.

Table 3. Calcium Carbonate Equivalence (CCE) values of various liming materials.

| Liming Material | Chemical Composition | CCE |
|---|---|---|
| Calcitic limestone | $CaCO_3$ | 98 - 100 |
| Dolomitic limestone | $CaMg(CO_3)_2$ | 100 - 109 |
| Hydroxides | $Ca(OH)_2$ or $Mg(OH)_2$ | 120 - 136 |
| Oxides | CaO or MgO | 150 - 179 |
| Marl | $CaCO_3$•X* | 60 - 90 |
| Slags | $CaSiO_3$•X* | 50 - 90 |
| Sludges | $CaCO_3$•X* | 30 - 80 |
| Wood ashes | X* | 30 - 50 |

* X indicates unknown impurities.

*Source:* Mahler, R.L. and R.E. McDole. 1986. Liming materials. University of Idaho Current Information Series No. 787.

Table 4. Recommended lime application rates to increase the surface 6 inch soil pH to approximately 6.5.

| SMP Buffer pH | Amount of Lime to Apply T/a | pounds lime/ 100 sq ft |
|---|---|---|
| 6.4 | 1.9 | 9 |
| 6.3 | 2.3 | 11 |
| 6.2 | 2.7 | 12 |
| 6.1 | 3.1 | 14 |
| 6.0 | 3.5 | 16 |
| 5.9 | 3.9 | 18 |
| 5.8 | 4.2 | 19 |
| 5.7 | 4.6 | 21 |
| 5.6 | 5.0 | 23 |
| 5.5 | 5.5 | 25 |
| 5.4 | 5.9 | 27 |
| 5.3 | 6.2 | 28 |
| 5.2 | 6.6 | 30 |
| 5.1 | 7.0 | 32 |
| 5.0 | 7.4 | 34 |
| 4.9 | 7.8 | 36 |

*Source:* Loynachan, T.E., 1979. Lime requirement indices of Alaskan soils. University of Alaska Fairbanks, Agricultural and Forestry Experiment Station Bulletin No. 52.

UNIVERSITY OF ALASKA
FAIRBANKS
College of Rural Alaska
Cooperative Extension Service

Visit the Cooperative Extension Service Web site at
www.uaf.edu/coop-ext

111/3-92/RG/1000 Reprinted May 2003