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UNIVERSITY OF ALASKA FAIRBANKS

Field Crop Fertilizer Recommendations for Alaska

FERTILIZER NUTRIENT SOURCES AND LIME

CONTENTS

FERTILIZER

Numerous manufactured and natural fertilizers are available in Alaska. Manufactured fertilizers typically contain a high percentage of a nutrient element or elements per unit. Natural fertilizers include animal manures, fish by-products (e.g., fish meals) and crop residues. The nutrient levels in manures and other residues are usually lower than those found in many manufactured fertilizers. In addition, many of the nutrient elements found in manures and residues are bound to the organic matter and are not immediately available to plants. Nutrient levels in manures vary substantially, depending upon the degree of decomposition 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 is used by the plant primarily in the nitrate and ammonium forms. These forms come either from manufactured or naturally occurring sources. Nitrate is chemically the same from either source. Ammonium from a manufactured source is chemically identical to ammonium from a naturally occurring source. The difference lies in availability of manufactured versus organically bound nutrients in manures and residues. The nitrogen in manure, fish by-products and plant residues must be converted to nitrate and ammonium by soil microorganisms. The conversion takes time and depends to a large extent on the kind of crop residues or manures, soil temperature and moisture. The converting process for fish by-products is usually relatively fast.

Phosphorus and potassium are also supplied by manufactured and naturally occurring sources. Naturally occurring phosphorus 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 nitrogen or phosphorus. Manufactured potassium sources such as potassium chloride and potassium sulfate are readily plant available.

Sulfur behaves much like nitrogen in the soil, with nearly all sulfur occurring in the organic fraction. If applied in elemental form, sulfur must be converted in the soil to sulfate, the form of sulfur that can be used by plants. For this reason, sulfur fertilizers should be scrutinized for their relative plant availability. Another manufactured sulfur fertilizer is ammonium sulfate. Sulfur in ammonium sulfate is readily available to plants; therefore, where immediate sulfur response is required, a sulfate source should be selected. In a soil sulfur building program or where long term sulfur availability is required (perennial crops), a combination of elemental sulfur and sulfate is desirable. Care should be used when applying elemental sulfur as this material lowers soil pH during the converting process.

Calcium, and magnesium if required, is normally applied in liming materials discussed in the next section. Gypsum (calcium sulfate) and calcium nitrate are sources of calcium that do not significantly raise the pH of the surrounding soil.

The micronutrients required by plants include zinc, manganese, copper, iron, boron, nickel and molybdenum. The term micronutrient accurately describes these nutrient elements because they are required in very small amounts for plant growth, although they are just as important as macronutrients. For this reason, micronutrients are often applied with seeds or in foliar sprays. Table 2 lists various inorganic micronutrient sources and their solubility in water.

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

Although boron is essential for proper plant growth, it is phytotoxic in even relatively small amounts. It is therefore important to ensure that a constant but minute supply is available to the plant.

LIME

Lime applications are required on many of Alaska's acidic soils to raise the pH. Raising the pH is necessary to 1) increase soil microbial activity, 2) increase phosphorus availability, 3) reduce micronutrient toxicity, 4) reduce aluminum toxicity and 5) overcome poor plant performance.

Lime contains calcium, or a combination of calcium and magnesium, and neutralizes acidity. Agricultural lime, or ag lime, is primarily calcium carbonate. It is the most commonly used liming material and contains plant-available calcium and acidity-neutralizing carbonate (see UAF Cooperative Extension Service publication FGV-00242A, *Soil Fertility Basics).*

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 materials are grouped: carbonates, oxides, hydroxides and by-product materials.

Carbonates

Carbonates are widely available and are the most commonly used liming materials. Mined high-grade calcitic limestone, when ground, is almost pure calcium carbonate. This is an excellent liming material because of its relatively low cost and availability and its effectiveness in neutralizing soil acidity. Dolomitic limestone (a naturally occurring combination of magnesium carbonate and calcium carbonate), although more costly, is also widely used in areas with low soil magnesium levels because it provides both calcium and magnesium along with its acidity-neutralizing capabilities.

Marls come from naturally occurring deposits of calcium and magnesium 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

Oxides, liming materials commonly known as burned lime, quicklime and unslaked lime, are made by baking or roasting crushed calcitic or dolomitic lime in an oven or furnace, which drives off carbon dioxide and leaves a pure oxide. These oxides 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. Because of the large amount of energy required to remove carbon dioxide, oxide materials are more expensive to manufacture than carbonate materials.

Hydroxides

Hydroxides are hydrated oxides, or simply, oxides mixed with water. Hydroxide limes, also known as slaked lime, hydrated lime or builder's lime, 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. 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 used to be an important lime source in Alaska. Probably the major problems 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.

Ag lime, dolomitic lime, hydrated lime and prilled lime are all available in Alaska. Prilled lime is very finely ground ag lime that is pelletized (held together with a water-soluble binding agent). The pellets can be spread with a regular fertilizer spreader. Once on the ground, water dissolves the binding agent and the lime is released to the soil. The prilled product is more expensive than other products, but it is easier for the homeowner to spread.

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. The CCE scale (Table 3) compares all liming materials to pure calcium carbonate, which is assigned a value of 100. Note that on a per-pound basis, marl, slags, sludges and wood ashes have considerably less acid-neutralizing power than the oxides, hydroxides or carbonates because of their high level of impurities.

Physical Composition

Because agricultural limestone is produced by crushing limestone rock, particle sizes vary. Particle size is important because it is related to the speed of the acid-neutralizing activity. Finely ground materials (smaller particle size) react more rapidly in soil than coarsely ground materials (large particle size). Most ground limestone will pass through a U.S. Standard No. 8 sieve (8 wires per inch, each opening 0.0937 by 0.0937 inches) and as much as 40 percent passes through 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. See UAF Cooperative Extension Service publication FGV-00643, *Field Crop Fertilizer Recommendations for Alaska Vegetables*, for a list of soil pH ranges for vegetable crops. 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 overliming, which, in addition to being expensive, 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

In order to affect pH, the liming material must react in the soil. Therefore, early applications of finely ground, high CCE materials are encouraged when rapid pH change is desired. 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 applications of dry lime than does a spinner-type spreader. If the material is finely ground (will pass through a 250 micron/60 mesh sieve) and has at least an 85 percent 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 but may instead require several years to change the soil pH to the desired level.

ESSENTIAL PLANT NUTRIENTS

There are 17 elements that are essential for growth of all plant species.

Primarily from the atmosphere	Primarily from the soil	
	Macronutrients	**Micronutrients**
Carbon(C)	Nitrogen (N)	Iron (Fe)
Hydrogen (H)	Phosphorus (P)	Manganese (Mn)
Oxygen (O)	Potassium (K)	Zinc (Zn)
		Copper (Cu)
		Boron (B)
	Secondary Macronutrients	Molybdenum (Mo)
	Calcium (Ca)	Chlorine (Cl)
	Magnesium (Mg)	Nickel (Ni)
	Sulfur (S)	

All essential nutrients are equally important for healthy plant growth, but there are large differences in the amount of each nutrient that the plant needs. Nitrogen, phosphorus and potassium are considered the macronutrients because plants need these in larger amounts than other nutrients and our soils are naturally more likely to be deficient in them. Calcium, magnesium and sulfur are called secondary macronutrients because they are required in lesser amounts than nitrogen, phosphorus and potassium. The micronutrients (Fe, Mn, Zn, Cu, B, Mo, Cl and Ni) are elements that are required in minute amounts, although a shortage of them can still limit crop production.

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.

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