

Glossary of Terms

AAPFCO -
Association of
American Plant Food
Control Officials

Acidity and Basicity
of Fertilizers

Activity Index (A.I.)

Activity of Water-
Insoluble Nitrogen in
Mixed Fertilizers
(Nitrogen Activity)

Ammonia

The membership of the Association shall consist of:

- 1) The officers charged by law with execution of the state, provincial, dominion, and federal laws in the Continent of North America, Hawaii, and Puerto Rico regulating and enforcing of laws relating to the control of sale and distribution of mixed fertilizers and fertilizer materials.
- 2) The heads or chiefs of experiment stations, departments of agriculture, bureaus, divisions, sections, and laboratories and employees thereof charged by law with the examination of mixed fertilizers and fertilizer materials.
- 3) Research workers employed by state, provincial, dominion, or federal agencies who are engaged in any investigation concerning mixed fertilizers, fertilizer materials, their effect and/or their component parts.

Since 1948, the AAPFCO has taken the place of the Committee on Definitions of Terms and Interpretations of Results of Fertilizers of the AOAC. Decisions of the AAPFCO are final and are not referred to the AOAC for approval. AAPFCO publishes an annual bulletin giving the official regulations and interpretations, many of which are reprinted here.

The acidic residue of any fertilizer in the soil, measured in terms of calcium carbonate required to neutralize it, is called physiological-, equivalent-, residual-, or potential acidity. Likewise, the basic residue of any fertilizer, in terms of its calcium carbonate equivalent is called the equivalent-, physiological-, residual-, or potential basicity of that fertilizer.

In 1933, Pierre introduced a chemical method of determining the equivalent acidity and basicity of fertilizers. He showed that only one-third of the phosphoric oxide (P_2O_5) and one-half of the nitrogen (N), applied as fertilizer, contribute to the residual acidity of the soil. The remainder of the applied phosphorus and nitrogen is used by plants, absorbed by soil, lost in the drainage water, or otherwise removed from the soil solution. The acid- and base-forming nutrients and their equivalent acidities or basicities, in terms of calcium carbonate ($CaCO_3$) per unit (20 pounds) of nutrient, are as follows: *Principal Acid-Forming Nutrients*, sulfur (S) 63, chlorine (Cl) 28, phosphoric oxide (P_2O_5) 14, nitrogen (N) 36; *Principal Base-Forming Nutrients*, calcium (Ca) 50, magnesium (Mg) 82, potassium oxide (K_2O) 22, and sodium (Na) 43. The acidic and basic nutrients in the common potash salts, excepting potassium nitrate, neutralize each other to form physiologically neutral compounds. Super-phosphates have no permanent effect on the soil reaction for the same reason.

Values for the physiological acidity (A), or basicity (B), in terms of pounds of calcium carbonate equivalent to 100 pounds of the commonly used fertilizer materials having average composition, are as follows: Urea-form 68A.

An AOAC method for determining the value of water-insoluble nitrogen fertilizer.

The active insoluble nitrogen determinations given in this dictionary are by the alkaline permanganate method.

The AAPFCO has adopted the following policy statement:

"The alkaline and neutral permanganate methods distinguish between the better and the poorer sources of water-insoluble nitrogen, and do not show the percentage availability of the materials. The available nitrogen of any produce can be measured only after carefully conducted vegetation experiments.

■ (a) The methods shall be used on mixed fertilizers containing water-insoluble nitrogen amounting to three-tenths (0.3%) of 1 percent or more of weight of the material. If a total nitrogen exceeds the minimum guarantee and is accompanied by a low activity of the insoluble nitrogen, the over-run shall be taken into consideration in determining the classification of the water-insoluble nitrogen.

■ (b) The water-insoluble nitrogen in mixed fertilizers showing an activity below 50% by the alkaline method and also below 80% by the neutral method shall be classed as inferior. This necessitates the use of both methods, also the provision as to over-run in (a), before classifying as inferior."

The AAPFCO official definition: The term ammonia shall mean agricultural anhydrous ammonia (NH_3) fertilizer.

NU-GRO TECHNOLOGIES, INC.

Ammoniation

The process of introducing ammonia (liquid anhydrous ammonia liquor or aqua ammonia; solutions of fertilizer compounds such as ammonium nitrate or urea in a mixture of ammonia and water) into superphosphate, forming ammoniated super-phosphate, or into a mixture of superphosphate and other fertilizer ingredients to make fertilizer mixtures.

Various reaction products result, depending on the proportion of ammonia used, temperatures resulting, time of standing, and the other materials included in the mixture. The ammonia reacts with the free acid and the monocalcium phosphate ($\text{CaH}_4\text{P}_2\text{O}_8$) present in the superphosphate, forming other compounds. The water enters the reaction and is mostly fixed as combined water, resulting in dry, well-conditioned products. (See Ammoniated Superphosphate).

Normal superphosphate has the capacity to absorb 9.6 pounds, and concentrated superphosphate 6.4 pounds, of ammonia per unit of P_2O_5 present. However, ammoniation to maximum capacity causes excessive loss of ammonia and reversion of phosphorus to forms that are unavailable to crops. Therefore, the commercial operator works in the range of 5 to 6 pounds of ammonia per unit of P_2O_5 in normal superphosphate and 3 to 4 pounds per unit in concentrated superphosphate.

The practical ammonia absorption capacity is governed by such physical factors as density, size, and structure of the particle, and free moisture content of the superphosphates; temperature of ammoniation; reaction period; and the concentration of P_2O_5 in the superphosphates or in the fertilizer mixture being ammoniated.

Factors governing process efficiency are:

■ **Ammoniation Rate:** Other factors being equal, an increase in the ammoniation rate from 3 pounds to 7 pounds per unit of P_2O_5 in normal superphosphate decreases the absorption efficiency from 100% to 84%. Absorption efficiency refers to the amount of ammonia absorbed in terms of percent of that added. Increasing the ammoniation rate from 2 pounds to 5 pounds per unit of P_2O_5 in concentrated superphosphate decreases the absorption efficiency from 99% to 83%.

■ **Moisture Content:** The absorption efficiency is 93% for normal superphosphate containing 6% free moisture and ammoniated at the rate of 6 pounds of ammonia per unit of P_2O_5 also for concentrated superphosphate containing the same percentage of moisture and ammoniated at the 4-pound rate. Absorption efficiencies of these same superphosphates, ammoniated at the same rates, is increased from 70% to 96% by varying the moisture content from 1% to 7%.

■ **Particle Size and Density:** When normal superphosphate, made up of equal weights of various size fractions containing 6% moisture, is ammoniated with 6 pounds of ammonia per unit of P_2O_5 , analyses of the various size fractions of the products show that the fraction finer than 80 mesh preferentially absorbs 6.5 pounds of ammonia per unit of P_2O_5 , and the fraction coarser than 10 mesh absorbs only 4.3 pounds per unit.

Similar tests were carried out with two types of concentrated superphosphate, one with bulk density of 49 pounds/cubic foot, containing soft porous particles having a crushing strength of 78 psi, and the other with a bulk density of 57 pounds/cubic foot, containing hard grainy particles having a crushing strength of 122 psi. The minus 80-mesh fraction in both materials, containing 5.7% moisture and ammoniated with 4 pounds of ammonia per unit of P_2O_5 , absorbs 100% of the ammonia added, whereas the fraction coarser than 10 mesh absorbs only 49% in the case of the hard, dense material as compared with 85% in the case of the soft porous material.

■ **Reaction Period:** Extending the reaction period from one to four minutes makes very little difference in the absorption efficiency of normal superphosphate treated with 4 pounds of ammonia per unit of P_2O_5 but increases the absorption efficiency from 72 to 88% for the same superphosphate treated with 7 pounds of ammonia per unit of P_2O_5 .

■ **Temperature:** Raising the reaction temperature in the ammoniation of normal superphosphate give no significant difference in the absorption of ammonia. However, in the ammoniation of concentrated superphosphate with 5 pounds of ammonia per unit of P_2O_5 , an increase in temperature from 149° F to 216° F, increases the absorption from 79% to 90%.

■ **Phosphate Solubility:** Contents of citrate-insoluble and water-soluble P_2O_5 in ammoniated normal superphosphate after 30 days of storage are virtually straight-line functions of the degree of ammoniation. Products made with 6 pounds of ammonia per unit of P_2O_5 contain about 33% of total P_2O_5 as water-soluble and 6% as citrate-insoluble. In the case of concentrated superphosphate, the absorption of ammonia up to 2 pounds per unit of P_2O_5 is accompanied by rapid changes in the contents of water-soluble and citrate-insoluble forms of P_2O_5 but further absorption up to 4.3% has no further effect on the water-soluble and increases only slightly the citrate-insoluble P_2O_5 . At the higher ammoniation rate about 59% of the total P_2O_5 is water-soluble and about 10% is citrate-insoluble. These data should serve as a guide in the formulation of superphosphate fertilizers with high proportions of neutralizing ammonia.

Analysis

AOAC - Association of Official Analytical Chemists

The percentage composition as found by chemical measurement, expressed in those terms that laws require or permit.

Established in 1884, the Association of Official Analytical Chemists is an association devoted to the development, testing, validation, and publication of methods of analysis of fertilizers, pesticides, foods, feeds, drugs, water and other substances related to food, agriculture, and public health.

AOAC accomplishes this by coordinating the development, testing, and validation of methods each of which undergoes collaborative study before being approved as an official AOAC method. Other AOAC activities include meetings, courses, symposia, training workshops, and publishing of the *Journal of the AOAC*, manuals, proceedings, and other books.

AOAC members are analytical chemists, biologists, microbiologists, biochemists, toxicologists, and other scientists in regulatory agencies, regulatory industries, and academia.

Available

This term, as applied to each of the three primary fertilizer constituents, nitrogen, phosphorus, and potassium, has somewhat different meanings. In each case all that is soluble in water is available. In addition, however, some of each that is not soluble in water is available to plants.

It is preferable to use the terms "active" and "inactive" as applied to insoluble nitrogen, unless the results of actual field or growing tests can be used. Animal and vegetable materials may decompose in damp, warm soils, and part or all of the nitrogen thus becomes available to growing plants. Some of the nitrogen may, however, remain unavailable. In order to anticipate the relative value of the nitrogen contained in organic (animal or vegetable) materials, empirical laboratory methods have been developed which give results in reasonable agreement with field tests.

Available phosphate in ammonium phosphates, superphosphates, or mixed fertilizers, is the water-soluble plus the ammonium citrate-soluble phosphoric acid. In practice a weighed portion of sample is washed with water and the residue is treated with neutral ammonium citrate solution. The difference between the amount remaining in the residue and the total is the available.

For basic slag, fused phosphates, and rock phosphates the available P_2O_5 is determined as the part soluble in a 2% citric acid solution.

Available potash is considered to be that which is soluble in water, aqueous ammonium oxalate, or aqueous ammonium citrate according to an applicable AOAC method.

Official methods of analysis for determining the availability of fertilizer nutrients have been adopted by the AOAC (which see). Available plant food is intended to mean that which is in a form capable of being assimilated by the growing plants or of being converted into such a form in the soil during the growing season.

Biodegradable

Biuret
($NH_2CONHCONH_2 \cdot H_2O$);
(Carbamylurea)

Any material that can readily be decomposed in the soil by the action of microorganisms.

A compound, toxic to some crops, formed by thermal decomposition of urea, to be avoided in the manufacture of fertilizer urea.

Brand/Brand Name

The AAPFCO official definition: "A *brand* is a term, design or trademark used in connection with one or several grades of fertilizers."

Bulk Blending

The practice of mixing dry, individual, granular materials or granulated bases. The product is a mixture of granular materials rather than a granulated mixture. The practice adheres to a marketing system intended to decrease the costs of transportation, chemical processing, and bagging. It usually brings the raw materials directly from the primary producer to the bulk blending plant located in the market area. The blender often applies the fertilizer to the land according to the specifications of the customer. This service to the farmer has been very popular. About 67% of all domestic solid fertilizers is applied in bulk form.

Uniformity in particle size of the ingredients of the bulk blend is essential in avoiding problems of segregation of the ingredients during handling and application. Rotary and ribbon mixers appear to be the most satisfactory in the mixing operation. Coating the granules of the blend with finely divided micronutrients ensures uniform distribution of these essential micronutrients. Some storage facilities at the blending location ensure against the possibility of a short supply of fertilizer materials at the peak of the fertilizer season.

Bulk Density

The weight of fertilizer per unit volume is ordinarily reported in pounds per cubic foot. To convert apparent specific gravity values in grams per cubic centimeter to bulk density values in pounds per cubic foot, multiply by 62.43.

The bulk density of a given fertilizer is altered considerably by such factors as moisture content, degree of packing under the weight of large piles, the degree of aeration, and the size and shape of particles in the material. To avoid costly errors in such operations as construction of bins and selection of bag sizes, these factors are necessarily considered. For example, phosphate rock, ground to 80% through 200 mesh and 100% through 100 mesh, is reported to weight about 90 pounds/cubic foot when packed and 45 pounds/cubic foot when highly aerated. A bulk density of 60 to 70 pounds/cubic foot is ordinarily recommended. At this density the rock flows freely and is resistant to flooding.

Caking

A process by which a fertilizer loses its desirable free-flowing property. The principal reason for caking is change of moisture content.

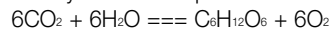
Carbon (C)

Diamond is the most expensive and least valuable form of the element carbon. Other natural forms of the element occur as graphite and in coal. Large quantities occur in the constituents of petroleum and natural gas and in enormous masses of carbonate formations known as limestones and dolomites. Carbon, in its most important form, is present in a great variety of substances making up the structure and offal of plants and animals. This latter group of carbon compounds is essential to life on earth.

Carbon Cycle

The carbon cycle is chiefly the uptake of atmospheric carbon dioxide by plants in the presence of sunlight and water to form carbon compounds of the plant structure, consumption of plants by man and animal, and the return of carbon dioxide to the atmosphere by decay of plant and animal matter.

The cycle in its simplest form is a "reversible reaction" represented by the equation:



Carbon dioxide reacts with water during the process of photosynthesis to produce carbohydrates and oxygen or the reverse, in which organic compounds such as carbohydrates react with water and carbon dioxide. The materials involved and shown in this equation will always be present in the same proportion by weight.

For example, in photosynthesis, 264 pounds of atmospheric carbon dioxide react with 108 pounds of water to form 180 pounds of carbohydrate in the growing plant and 192 pounds of oxygen released to the atmosphere, or, in decay, 180 pounds of carbohydrate react with 192 pounds of atmospheric oxygen to produce 108 pounds of water and 264 pounds of carbon dioxide released to the atmosphere. No material has been gained or lost in the cycle.

This fundamental law of nature exists regardless of claims by environmental alarmists that nature is being forced out of balance by man. The answer to such claims is that, if carbon dioxide placed in the atmosphere by man is ever so great as to even double the present content, it will combine under the process of photosynthesis with double the weight of water shown in the above equation to produce twice as much carbohydrate and release twice as much oxygen to the atmosphere, and under the process of decay, the same double-weights of materials will be present in the reverse reaction.

Hundreds of thousands of chemical compounds and biological organisms are involved in these reactions that bring equilibrium in a continuous state of creation, transformation, and decomposition on land, in the sea, and in the air. Many of the reactions can be demonstrated in a closed system on a laboratory workbench. The biosphere of the earth is essentially a closed system. Some of the reactions require light, others do not. Different reactions occur at vastly different rates and the same reaction varies in rate according to its environment. For example, an increase in carbon dioxide content of the atmosphere always leads to greater photosynthesis. Where economically feasible, fertilization with carbon dioxide frequently produces increased crop yields of 100 to 150%.

Decomposition of organic matter in the soil by different microorganisms liberates carbon dioxide, some of which may be caught immediately by the leaves of the plants directly above, thus resulting in a rapid turnover of carbon in its cycle. However, some of the liberated carbon dioxide may be caught in air currents and carried thousands of miles to distant oceans where it is dissolved at the surface and may be deposited as metal carbonates on the ocean floor. At the same time the sea is yielding about the same amount of carbon dioxide to the atmosphere, thus maintaining the equilibrium of the carbon cycle even though the cycle may extend over a period of thousands of years.

The amount of carbon added to the atmosphere by the recovery and burning of fossil fuels up to the present time is very minute as compared with the total mass of life-giving

Cation Exchange (Base Exchange)

carbon that is recycled in the biosphere. It would be strange indeed if man's activity in this area of utilizing stored energy did not add a few parts per million of carbon dioxide to the atmosphere, but it would be even more strange if nature could not handle the increase, especially when plant physiologists have shown conclusively that photosynthesis of plants could use from 4 to 20 times more carbon dioxide than the 0.03% now available in the atmosphere.

The exchange of cations held at the surface of soil particles for other cations in the soil solution. For example, when a puddled soil, rich in sodium, is treated with calcium sulfate (gypsum), some of the calcium ions replace the sodium ions at the surface of soil particles and tend to relieve the tight, sticky, or puddle condition. Cation exchange is a basic principle involved in soil fertility.

The small numbers by the symbols for the cations indicate the number of charges carried by that cation. Where no number appears, one positive charge is present. The numbers of different kinds of ions involved in the exchange reaction depend on the number of charges carried by each ion. One calcium ion with two positive charges (Ca^{+2}) replaces two hydrogen ions, each having one positive charge (H^{+1}). Three doubly charged calcium ions are required to replace two triple charged aluminum ions. When aluminum is displaced by calcium, it enters the basic soil solution and is precipitated as insoluble aluminum oxide or hydroxide where it remains as an inert solid as long as the soil is neutral. Thus, the injurious effect of soluble aluminum on plants in acid soils is greatly reduced by liming.

Cation Exchange Capacity (CEC)

A measure of the total amount of exchangeable cations that can be held by a given mass of soil, expressed in milliequivalents (meq. per 100 grams of soil at neutrality (pH 7) or at some other stated pH value, formerly called base exchange capacity). The exchange capacity of soils usually ranges between 2 and 50 meq. per 100 grams of soil. One meq. per 100 grams is equivalent to 400 pounds of calcium per acre--the amount of calcium in a half-ton of pure limestone.

In a well-limed agricultural soil, about 80 to 90% of the exchange capacity is ordinarily occupied with calcium plus magnesium: there are about 5 to 10 times as many calcium ions as magnesium ions. Potassium may be expected to occupy 2 to 5% of the capacity, and hydrogen (acid) the remainder.

Cation Exchange Sites

Fractions of the surface of soil particles that exhibit the power to hold the positively charged cations. They occur at the surface of clay and organic colloids. They are more abundant in fine-textured soils having high contents of clay and organic matter than in sandy soils that are low in clay and organic matter. Calcium is held more firmly at the surface of soil colloids than potassium.

Chlorophyll

The green photosynthetic coloring matter found in plants, particularly in the leaves, where it is continually being manufactured.

Coated Slow-Release Fertilizer

The AAPFCO official definition: "*Coated Slow-Release Fertilizer* - A product containing sources of water-soluble nutrients, release of which in the soil is controlled by a coating applied to the fertilizer."

An example is: Osmocote (various grades) consists of granules or prills of soluble nutrients enclosed in a water-permeable, resinous film. The coating accounts for 6.5-15% of the weight of the material. The thickness of the films as well as its chemical composition determines the leach rate.

Because of the prolonged leach rate imparted by the coating, the product is reported to be well-suited to commercial and institutional turf, floriculture, etc., especially those that take longer than 80 days to mature.

Controlled Release Fertilizers

Fertilizers in which one or more of the nutrients have limited solubility in the soil solution, so that they become available to the growing plant over a controlled period. The ideal in such a fertilizer would be the release of nutrients at a rate exactly equal to the needs of the plant. The limited solubility may be an inherent characteristic of the fertilizer such as in the urea-formaldehyde reaction products and magnesium ammonium phosphate (which see); or it may be imparted to a soluble fertilizer by coating the particle with such materials as molten sulfur, waxes, and plastics.

Some examples are: Ureaform, IB (isobutylidene diurea), CDU (Crotonylidene diurea), Osmocote, and SCU (sulfur coated urea). Current use of these products is confined largely to specialty goods.

Triuret ($\text{NH}_2\text{CONHCONHCONH}_2$) is a controlled release nitrogen product prepared from urea hydrochloride at a cost presently too high for its agricultural use.

A demonstration-scale (10.5 tons per hour) plant for production of SCU was put in operation by TVA in late 1978. After producing about 33,000 tons of SCU and other sulfur coated products, the plant was shut down and sold to private industry. Presently, these are from commercial producers of SCU using TVA sulfur-coating technology.

The AAPFCO official definition: "Slow or Controlled Release Fertilizers. A fertilizer containing a plant nutrient in a form which delays its availability for plant uptake and use after application, or which extends its availability to the plant significantly longer than a reference 'rapidly available nutrient fertilizer' such as ammonium nitrate or urea, ammonium phosphate, or potassium chloride. Such delay of initial availability or extended time of continued availability may occur by a variety of mechanisms. These include controlled water solubility of the material (by semipermeable coatings, occlusion, or by inherent water insolubility of polymers, natural nitrogenous organics, protein materials, or other chemical forms) by slow hydrolysis of water-soluble low molecular weight compounds, or by other unknown means."

Conversion Factors

Multipliers by which percentage expressed in one kind of chemical term can be converted to another. For example, if one wishes to know how much ammonia corresponds to 20% nitrogen he will find in the accompanying table the factor 1.2160. Multiplying $20 \times 1.2160 = 24.320$. Therefore, if the substance contained 20% N, it corresponds to 24.320% ammonia.

Dicyanodiamide (DCD)

An organic amide of the composition $\text{C}_2\text{H}_4\text{N}_4$ used as a nitrification inhibitor in ammonical fertilizers and urea. DCD crystallizes as colorless thin rhombic plates; the fine-grained crystalline powder is nonhygroscopic and is thermally stable up to 170°C in air. The compound is non-toxic ($\text{LD}_{50} = 12000 \text{ mg/kg}$) to mammals. At high field application rates, DCD has occasionally exhibited phytotoxicity. However, at rates sufficient for use as a nitrification inhibitor (20 kg/ha), no phytotoxicity was exhibited. DCD can be readily incorporated into solid, fluid, and suspension fertilizers. Its decomposition rate during incorporation and storage of fertilizers is minimal.

The AAPFCO official definition: "Dicyanodiamide (cyanoguanidine) is a water-soluble organic compound of formula ($\text{C}_2\text{H}_4\text{N}_4$) which contains at least 65% nitrogen. It is a source of slowly available nitrogen." (Dicyanodiamide is classified as a nitrification inhibitor) tentative 1999.

See also *Nitrification Inhibitor*.

Dolomite

A material used for liming soil in areas where magnesium as well as calcium is needed.

Fertilizer

(Acid Forming, Non-Acid Forming)

The AAPFCO definition follows: "The term *fertilizer* means any substance containing one or more recognized plant nutrient(s) which is used for its plant nutrient content and which is designed for use or claimed to have value in promoting plant growth, except unmanipulated animal and vegetable manures, marl, lime, limestone, wood ashes, and other products exempted by regulation."

See also *Acidity and Basicity of Fertilizers*.

Fertilizer Grade

The grade of a fertilizer indicates the nutrient content expressed in terms of percentages of N, P_2O_5 and K_2O in that order.

The AAPFCO definition and interpretation follow:

■ "Fertilizer Grade - The minimum guarantee of available plant food expressed in terms of total nitrogen (not ammonia), available phosphate and soluble potash and potassium. The numerals for nitrogen (N), available phosphate (P_2O_5), soluble potash (K_2O), or available phosphorus (P), and soluble potassium (K) appearing as the grade must coincide with the guaranteed analysis statement. Only one set of numerals may be used in the grade designation."

■ "Grade - the grade of a fertilizer shall be used by the registrant/licensee in the labeling and by the control official in his reports and publications. No numerals shall be used in the grade of a fertilizer except those referring to Total Nitrogen (N), Available Phosphate (P_2O_5) and Soluble Potash (K_2O)."

Fertilizer Material

The AAPFCO definition follows: A *fertilizer material* is a fertilizer which either:

- A. Contains important quantities of no more than one of the primary plant nutrients: nitrogen (N), phosphate (P), and potassium (K), or
- B. Has 85% or more of its plant nutrient content present in the form of a single chemical compound, or

■ C. Is derived from a plant or animal residue or by-product or natural material deposit which has been processed in such a way that its content of plant nutrients has not been materially changed except by purification and concentration.

Filler

A substance added to fertilizer materials to provide bulk, prevent caking, or serve some purpose other than providing essential plant nutrients.

Fixation

Fixation of applied nutrients by the soil is the process whereby they are rendered relatively unavailable for plant uptake. Of greatest concern has been the fixation of added soluble phosphates, especially on acid, mineral soils and humid regions. On these soils, the phosphorus reacts largely with iron and aluminum to form various compounds of low solubility in the soil solution. These compounds are deposited as precipitates or absorbed on the surfaces of clay particles and on iron and aluminum oxides. A large number of different compounds can be formed with the phosphorus recombining over time to form compounds that are increasingly less soluble. The more acid the soil and the higher its clay content, the greater is its capacity to fix phosphorus. On such soils, liming and applying the phosphate in bands to lessen its contact with the soil have been the conventional remedies to lessen fixation. On alkaline, calcareous soils of the western U.S., the soluble phosphates also revert to less soluble compounds, but these consist largely of calcium compounds, and, to a lesser extent, compounds containing magnesium. The calcium compounds include the relatively insoluble di- and tricalcium phosphates, and the much more insoluble apatite-like compounds. At one time, phosphorus fixed in the soil was considered as almost irretrievably lost to plants. It is now known that continued application of phosphate fertilizers does result in a residual accumulation of available phosphorus from the past applications. In many cases, the point has been reached where the amount of phosphate applied in annual applications can be reduced and sometimes omitted without undue risk, providing that the available phosphate content of the soil is carefully monitored.

Potassium from fertilizers also can be fixed in soils but not to the extent of phosphorus. The mechanism for potassium fixation, however, is much different than for phosphorus. The fixed potassium ions are trapped between the silica sheets of certain clay minerals that occur in soils, including especially vermiculite and illite. The potassium ion is of such size as to fit into the cavities that exist between the silica sheets, and once in place, it is very firmly held by electrostatic forces. These trapped ions, however, may be slowly-released over time. Soils differ in their capacity to fix potassium, depending on the kinds and amounts of clay minerals they contain. Some soils have been identified as high-fixing as a result of their requiring larger than normal applications of potash to meet crop needs.

Ammonium ions from ammonia-based fertilizers also can be fixed by the same clay minerals that fix potassium, and in the same manner. However, ammonium fixation appears of less practical importance inasmuch as the ammonium ions usually nitrify rapidly to nitrates following application.

The term "fixation" also is applied to any process whereby the nitrogen in the air is transferred to stable chemical form such as occur in nature and in industrial processes for ammonia synthesis.

Formula

Quantities of various ingredients combined to make a fertilizer.

Grade

Often used synonymously with analysis, but grade usually is applied only to the three primary plant nutrients: nitrogen, phosphorus, potash (N, P, K).

Granular Fertilizer

Fertilizer in the form of particles sized between an upper and lower limit or between two screen sizes, usually within the range of 1-4 mm and often more closely sized. The desired size may be obtained by agglomerating smaller particles, crushing and screening larger particles, controlling size in crystallization processes, or prilling.

See also Granulation.

Granulated Fertilizers

See Granulation.

Granulation (Granulated/Pelleted Fertilizers)

Granulation is a method of processing that has been widely adopted as a means of improving the storage and handling properties of fertilizers.

Growing Season

The period of time from the last plant-killing frost in the spring to the first plant-killing frost in the fall.

Guaranteed Analysis

The AAPFCO Uniform Fertilizer Bill states: "The term *Guaranteed Analysis* shall mean the minimum percentage of plant nutrients claimed in the following order and form:

- A. Total Nitrogen (N), Available Phosphate (P_2O_5), Soluble Potash (K_2O)
- B. For unacidulated mineral phosphatic material and basic slag, bone, tankage, and other organic phosphatic materials, the total phosphate and/or degree of fineness may also be guaranteed.
- C. Guarantees for plant nutrients other than nitrogen, phosphorus, and potassium may be permitted or required by regulation. The guarantees for such other nutrients shall be expressed in the form of the element. The source (oxides, salts, chelates, etc.) of such other nutrients may be required to be stated on the application for registration and may be included on the label. Other beneficial substances or compounds, determinable by laboratory methods, also may be guaranteed by permission and with the advise of the Director of the Agricultural Experiment Station. When any plant nutrients or other substances or compounds are guaranteed, they shall be subject to inspection and analysis in accord with the methods and regulations prescribed."

Isobutylidene Diurea

The AAPFCO official definition: "*Isobutylidene Diurea* is a condensation product of isobutyraldehyde and urea having a minimum total nitrogen content of 30%. It is a source of slowly available nitrogen by virtue of particle size, solubility decreasing with increase in particle size. Material conforming to the description of a granular fertilizer will have 90% of its nitrogen content in the water-insoluble form prior to grinding as tested by method of AOAC 945.01 (15th Edition)."

Substances occurring as minerals in nature or obtainable from them by chemical means.

Nitrogen in combination with other elements, not animal or vegetable form.

Removal of soluble material from a system by passage of a liquid through it.

In agriculture, leaching refers to the downward movement of free water (percolation) out of the plant root zone. It occurs when the amount of rainfall or irrigation water entering the soil becomes greater than its water-holding capacity. On western irrigated lands, leaching is intentionally brought about to remove accumulations of soluble salts from soils.

Leaching of nitrates originating from fertilizers can be appreciable in the eastern humid region or in the heavily irrigated sections of the Great Plains or western states. In the humid region, most of the leaching occurs during the spring when evaporation and plant uptake of water are low and the soil has reached its water-holding capacity over winter. Nitrates left over from the previous cropping season or fall applied are then vulnerable to leaching. Leaching seldom occurs during the height of the growing season since most of the water going into the soil is removed by evaporation and the growing plant. Neither phosphate nor potash leaches except in very sandy soils.

A fluid in which the plant nutrients are in a true solution.

(or primary nutrients): nitrogen, phosphorus and potash (N, P, K).

A chalky substance used as a liming material. It is formed by precipitation of lime from fresh water by natural processes.

Frequently referred to as trace or minor elements. They are required in small amounts, but in amounts more than a trace, and certainly they are not minor in importance. Used in excess, they can be harmful to plants; this is especially true of boron and molybdenum.

The AAPFCO official definition: "*Secondary and Micronutrients* - Those other than the primary nutrients that are essential for the normal growth of plants and that may need to be added to the growth medium. Micronutrients shall include boron, chlorine, cobalt, copper, iron, manganese, molybdenum, sodium and zinc. (Official 1965)."

Some examples are: Complex solutions of the micronutrient elements, Cu, Fe, Mn, or Zn. Oxy-Plex and Oxy-Multiplex are multinutrient mixtures of the micronutrient mixtures.

See also *Plant Nutrients and Secondary Nutrients*.

Inorganic

Inorganic nitrogen

Leaching

Liquid Fertilizer

Macronutrients

Marl

Micronutrients

Microorganisms

Mineralization

Mixed Fertilizers

Forms of life too small to be seen with the unaided eye, or barely discernible.

The conversion of an element from an organic form to an inorganic state as a result of microbial decomposition.

The AAPFCO official definition: "A *mixed fertilizer* is a fertilizer containing any combination or mixture of fertilizer material.

Two or more fertilizer materials mixed, or granulated together into individual pellets. The term includes dry mixed powders, granulates (bulk blends), granulated mixtures, and clear liquid mixed fertilizers, suspensions, and slurries.

They were erroneously called complete fertilizers, but are now referred to as multinutrient mixtures. Some mixed fertilizers contain only one primary nutrient, such as those made from superphosphate and manganese sulfate."

The AAPFCO official definition: "A deficiency in an official sample of mixed fertilizer resulting from non-uniformity is not distinguishable from a deficiency due to actual plant nutrient shortage and is properly subject to official action."

Natural Organics

By-products from processing of animal or vegetable substances that contain sufficient plant nutrients to be of value as fertilizers (see Organic). This class of fertilizers include dried blood, castor pomace, cottonseed meal, tankage, bone meal, tobacco stems, and many similar substances. The nitrogen in them is combined with carbon, hydrogen, and oxygen and sometimes other elements to form very complex compounds, which must decompose in the soil before the nitrogen is available. Bone meal is primarily a phosphatic and tobacco stems a potassic fertilizer. Natural organics up until about 1900 supplied 90% or more of all nitrogen in the U.S. fertilizers, and over 11% as late as 1942. They were replaced with inorganic nitrogen materials as these became more plentiful. The higher nitrogen natural organics also found a more profitable use in livestock feeds.

The AAPFCO official definition: "*Natural organic fertilizer* - This term shall refer to materials derived from either plant or animal products containing one or more elements (other than carbon, hydrogen, and oxygen) which are essential for plant growth. These materials may be subjected to biological degradation processes under normal conditions of aging, rainfall, sun-curing, air drying, composting, rotting, enzymatic, or anaerobic/aerobic bacterial action, or any combination of these. These materials shall not be mixed with synthetic materials or changed in any physical or chemical manner from their initial state except by physical manipulations such as drying, cooking, chopping, grinding, shredding or pelleting."

See also *Nitrogen*.

Nitrates

Nitrification

The salts of nitric acid may be formed by the action of nitric acid on metal or alkalies.

Nitrification is the term applied to the oxidation of ammonium to nitrite and nitrate. Nitrification is a two step biological process whereby the ammonium ion (NH_4) is first converted to nitrite (NO_2) by Nitrosomonas or nitrite-forming bacteria, and then the nitrite is converted into nitrate (NO_3) by Nitrobacter or nitrate-forming bacteria. The process is the same regardless of where the ammonium ion originates, whether from soil organic matter, ammonium-containing fertilizers, or anhydrous ammonia. Nitrification is not rapid in warm, moist but not wet, and approximately neutral soils; and the process halts entirely when the temperature drops to about 37°F. In an effort to reduce nitrification of fall-applied ammonia-base fertilizers and thus reduce possibilities of nitrate leaching losses, the North Central States recommend delaying applications until the soil temperature reaches 45° or 50°F. Also, nitrification inhibitors are now being used to reduce nitrification. These usually inhibit the growth or the activity of the nitrification bacteria. (See also Nitrogen Cycle).

A substance that inhibits the biological oxidation of ammoniacal nitrogen to nitrate nitrogen.

Nitrification Inhibitor

Nitrogen (N)

A colorless, odorless, inert gas, constituting about four-fifths of the air. For the manufacture of synthetic ammonia, nitric acid, ammonium nitrate, urea, and cyanamid, nitrogen is obtained from the air by several methods; (a) Liquid air (Linde process): when liquid air is allowed to warm, the nitrogen distills off first and is separated from the oxygen. (b) Burning coke in air removes the oxygen; when steam is also present, the resulting gases include nitrogen and hydrogen. (c) When natural gas is mixed with air and passed over a catalyst under proper conditions, the methane (CH_4) is cracked, the carbon (C) burning to form CO_2 , leaving hydrogen mixed with nitrogen, CO_2 , and other gases.

Nitrogen Cycle of the Ecosystem

When mixtures of nitrogen and hydrogen in proper proportions are compressed in the presence of a suitable catalyst, ammonia (NH_3) is formed. There are four general classes of fertilizer materials containing fixed nitrogen: (1) Nitrates, (2) Ammonium Salts, (3) Natural Organics, and (4) Synthetic Organic Chemicals.

Nitrogen is a constituent of every living cell. It is a part of chlorophyll, of protein and of many other substances in animals and plants. As a fertilizer it is needed in large amounts by all growing crops. It promotes growth of leaf and stem and increases plant vigor. It adds crispness to leaf crops, and improves their quality. It increases the protein content of food and feed crops and helps increase yields of many crops. It insures a dark, green color in leaves containing chlorophyll.

The atomic number of nitrogen is 7, and there are two known stable isotopes, i.e. two species of the atom having the same atomic number but different atomic weights. The most common species, N-14, has an atomic weight of 14.00750 and the other N-15, has an atomic weight of 15.00489. The atmosphere (80% N) contains 0.366 atom percent of N-15. The modern mass spectrograph is used to determine the relative masses of the two species with an accuracy of 1 part in 10,000. The two species can be readily concentrated with respect to one another by diffusion methods and relative abundance can be accurately measured. N-15 is frequently concentrated in the matrix of N-14 and is then used as tracer for nitrogen in various processes to identify the contribution of a "control" source of nitrogen. In addition to these two nonradioactive isotopes, there are 4 radioactive isotopes of nitrogen, but the half-life is so short that they are seldom used in agronomic tracer techniques.

Too much nitrogen may injure quality of tobacco and fruits, may delay maturity, cause lodging of grain, and increase susceptibility to disease.

Nitrogen deficiency may be recognized by pale, thin, yellow green leaves, slow growth, and low yields.

The routes taken by nitrogen from the atmosphere through soils, plants, animals, and man, back to the atmosphere again, and the conditions under which it must travel to avoid being "sold down the river."

There are three routes it may take from the atmosphere to the soil: (1) Nitrogen oxides or nitric acid produced in electric storms plus ammonia and ammonium compounds in the air are carried to the soil by rainfall; (2) Rhizobia bacteria in the root nodules of legume plants fix nitrogen from the atmosphere, and some forms of algae are also capable of fixing atmospheric nitrogen; and (3) Application of nitrogen fertilizers. The best route is via fertilizers because transportation via rainfall and rhizobia combined is grossly inadequate for supplying food, feed, and fiber to sustain the population of Earth.

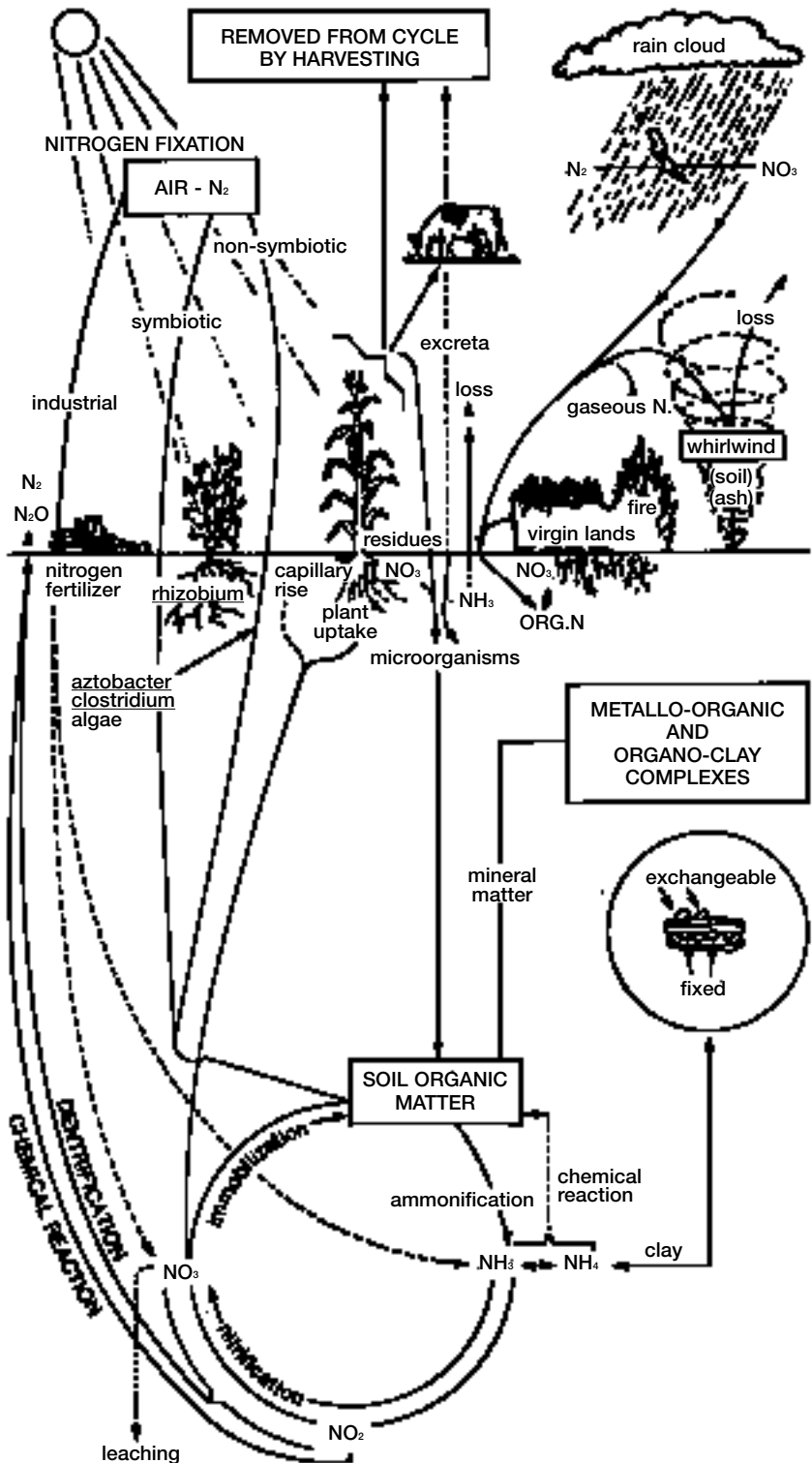
The rhizobia route furnishes direct transportation for nitrogen from the atmosphere to the legume plant, and is well chosen when legumes serve a purpose in good soil management. Nitrogen reaching the soil by either of the other two routes first enters the soil solution in the form of ions, such as the cation, (NH_4) or the anion (NO_3) in which form it may be assimilated by plants through their root systems.

Energy from sunlight is used by plants to convert nitrogen into nitrogenous substances, such as protein, the constituents of foods used by animals and man, much of which is returned to the soils as organic matter, and some back to the atmosphere as ammonia, after animals and man have used up the energy within it. Unused portions of plants, such as roots, also form a part of the organic residue returned to the soil.

Organic matter in the soil usually contains 5 to 6% nitrogen, largely in the form of protein, that is unavailable to crops until it has undergone decay by the action of bacteria, actinomycetes, and fungi, and finally set free in the form of ammonia by the action of microbes. The latter process is referred to as *ammonification* or *mineralization*.

Fertile soils having adequate supplies of decaying organic matter, a carbon: nitrogen ratio of 30 or greater, and a high microbial population are capable of storing enormous quantities of nutrients for future continuous use by plants. This is possible because of microbial organisms that consume nitrogen in forms such as ammonia. It explains why ammonia is seldom washed from the soil into the drainage water. In soils having a low content of organic matter, a carbon:nitrogen ratio of less than 15, and a quantity of ammonia ions in excess of that which can be absorbed by either the plant or certain microbes, the excess ammonium nitrogen is oxidized by *nitrification*, first to nitrite by bacteria such as nitrosomas, and then to nitrate by other bacteria such as nitrobacter. In clogged soils lacking air circulation, nitrate may be reduced to nitrogen gas by microbes that tear down the nitrate ions simply to satisfy their demand for oxygen, and the nitrogen eventually finds its way back to the atmosphere from whence it came.

On permeable soils having low organic matter content, excessive application of fertilizer nitrogen may send some nitrate into the drainage water, especially under conditions of high rainfall. Climatic condition and type of soil determine the level at which organic matter in the soil can be maintained in different regions of the United States. Nevertheless, at whatever level the organic content of the soils can be carried, it will act accordingly as a reservoir for nitrogen until the crop is able to assimilate this nutrient element. Thus, with good soil management, unnecessary losses of a valuable plant nutrient are not likely to occur.



Occlusion

To enmesh within a particle or substance this restricting free movement.
Example: urea enmeshed within the NITROFORM particles (granules or powder).

Organic Fertilizers

A material containing carbon and one or more element other than hydrogen and oxygen essential for plant growth.

The AAPFCO official definition: "An *organic fertilizer* is a material containing carbon and one or more elements other than hydrogen and oxygen essential for plant growth."

pH (Log Reciprocal of Hydrogen Ion Concentration)

The pH value of any solution, soil or compound is simply a number denoting its degree of acidity or alkalinity. A neutral solution has a pH value of 7.0; values above 7.0 denote alkalinity and below 7.0 denote acidity, on a logarithmic scale. Thus pH 5 is 10 times as acidic as pH 6 and so on. The pH of the soil offers valuable clues to plant-growth troubles and points the way to additional tests that are generally necessary for accurate diagnosis.

Phosphate

The AAPFCO official definition: "The term *phosphate* designates phosphorus pentoxide P₂O₅".

Plant Nutrients

Elements required for normal growth and development of plants. Plants are composed of the following elements in roughly the proportions indicated in Tables 1 and 2.

These percentages vary for different species and for the same species grown under different conditions. For average conditions the order of magnitude is as show:

Element	Amount in Whole Plants %
Oxygen	45
Carbon	44
Hydrogen	6
Nitrogen	2
Phosphorus	0.5
Potassium	1.0
Calcium	0.6
Sulfur	0.4
Magnesium	0.3
Boron	0.005
Chlorine	0.015
Copper	0.001
Iron	0.020
Manganese	0.050
Molybdenum	0.0001
Zinc	0.0100
Total	99.9011

Carbon, oxygen, and hydrogen form the plant structure. They are readily obtained from air and water.

Normally, the plant obtains its remaining nutrients from the soil solution. The *primary nutrients*, nitrogen, phosphorus, and potassium, and the *secondary nutrients*, calcium, magnesium, and sulfur, are referred to as *macronutrients*—macro-, meaning "large"—because they are required by growing plants in relatively large amounts. The *micronutrients*, boron, chlorine, cobalt, copper, iron, manganese, molybdenum, and zinc, are so-called because—micro-, meaning "small"—they are required by the growing plant in relatively small amounts.

Sodium is not known to be essential to plant growth but it is present in all plant materials and is used advantageously by some plants, especially when a low supply of potassium is likely to limit plant growth. Sodium is indispensable to animals. *Fluorine, iodine, silicon, aluminum*, and other elements are present in soil-grown plants but are not known to be essential to plant growth. Cobalt appears to be essential to some plants, and cobalt, fluorine and iodine are indispensable in animal nutrition.

Polymer Coated Urea (PCU)

Potash (K₂O; Potassium Oxide)

Process Tankage (Nitrogenous Tankage)

Ratio

Recuperative Potential

Residual Fertilizer

Rhizome

Salt Index

The AAPFCO recommends the following regulation: "Other plant nutrients when mentioned in any form or manner shall be registered and shall be guaranteed. Guarantees shall be made on the elemental basis. Sources of the elements guaranteed and proof of availability shall be provided by the manufacturer upon request. Except guarantees for those water-soluble nutrients labeled for hydroponic or continuous liquid feed, the minimum percentages which will be accepted for registration are as follows:

"Guarantees or claims for the above listed plant nutrients are the only ones which will be accepted. Proposed labels and directions for the use of the fertilizer shall be furnished with the application for registration upon request. Any of the above listed elements which are guaranteed shall appear in the order listed immediately following guarantees for the primary nutrients of nitrogen, phosphorus, and potassium.

The AAPFCO official definition: "*Polymer Coated Urea* is a coated slow-release nitrogen consisting of urea particles coated with a polymer (plastic) resin. It typically contains about forty percent (40%) nitrogen. It is a source of slowly available nitrogen."

Potassium oxide is a strongly corrosive alkali, which when dissolved in water forms caustic potash (see below). It is never used as such in fertilizers. The trade term, "potash" is used interchangeably with the word "potassium" and expresses the percentage of potassium oxide (K₂O) in potash salts and mixtures.

The AAPFCO official definition: "The term *potash* designates potassium oxide (K₂O)."

Manufactured from materials containing unavailable nitrogen by treatment with steam under pressures of from 30 to 100 pounds per square inch for 20 to 90 minutes. Addition of 0.5% sulfuric acid facilitates the hydrolysis at a lower temperature. The materials used to make such tankage are leather scrap, feathers, hair, wool waste, discarded printing press rollers, silk and woolen rags, old fur garments and felt hats, and similar wastes. The keratin of these materials is hydrolyzed to purines and amino acids. If carried too far, ammonia is formed.

Process tankage is a dark-brown, fluffy material than not only provides nitrogen, but acts as a conditioner in nongranular mixed fertilizers.

More than a dozen U.S. manufacturers have produced process tankage during the past 70 years, but very few are doing so now. Also, it has been imported from Europe. Some brands consistently run higher or lower in N and P₂O₅ than others, due to kind of raw materials used. They may contain from 4 to 12% N and small amounts of most other nutrient elements.

Some examples are: Agrinite, Available Process Tankage, Georgia Process Tankage, Hynite, Nitrolene, Omega, Org-Amo, Organo, Rhemsdorf, and Smirow.

The AAPFCO official definition: "*Process tankage* is a product made under steam pressure from crude inert nitrogenous materials, with or without the use of acids or bases, for the purpose of increasing the activity of the nitrogen. These products shall be called "Process Tankage" with or without further qualification. The water-insoluble nitrogen in these products shall test at least 50% active by alkaline, or 80% by the neutral permanganate method."

The numerical ratio among the concentrations of the primary nutrients in a fertilizer. For example, 5-10-15 grade would have a 1:2:3 ratio.

The ability of turfgrasses to recover from injury through vegetative growth from lateral creeping stems (rhizomes and stolons).

The amount of fertilizer that remains in the soil after one or more growing seasons.

Horizontal stems that grow below the surface of the soil and initiate roots and shoots.

An excessively high concentration of soluble salts in the soil solution may develop an osmotic pressure of the solution exceeding that of the plant sap and cause dehydration, permanent injury, or even death of the plant. Salt index is a measure of the relative tendency of a fertilizer to increase the osmotic pressure of the soil solution as compared to the increase caused by an equal weight of sodium nitrate as a reference material. The lower the salt index, the lesser the risk of causing crop injury in periods of extreme drought or with localized placement of fertilizers.

The following table gives data for calculating the salt index of fertilizer mixtures. The salt index per ton of mixture is obtained by multiplying the salt index per unit of plant nutrient in each ingredient by the total number of units which the respective material supplies in the mixture and adding the resulting values.

When sulfuric and/or phosphates are used in formulating ammoniated mixtures, the value per 100 pounds of acid is multiplied by the cwt. of acid used and the resulting value added to that of the other materials used in the mixture. The salt index of the ammonia reacting with the acid is included in the salt index of the acid, and must not be counted again as contributing to the salt index of the mixture.

Per Equal Weights of Materials Material and Analysis Nitrate = 100	Per Unit (20 lbs.) Basis: Sodium Nutrients⁽¹⁾	of Plant
NITROGEN		
Ammonia, 82.2% N	47.1	0.572
Ammonium nitrate, 35% N	104.7	2.990
Ammonium sulfate, 21.2% N	69.0	3.253
Nitrogen solution, 406 (22-65-0), 40.6% N	78.3	1.930
Ammonium nitrate-limestone, 20.5% N	61.1	2.982
Calcium nitrate, Ca(NO ₃) ₂ , 4H ₂ O, 11.9% N	52.5	4.409
Calcium nitrate, com. grade, 15.5% N	65.0	4.194
Calcium cyanamide, 21% N	31.0	1.476
Sodium nitrate, 16.5% N	100.0	6.060
Urea, 46.6% N	75.4	1.618
Ureaform, 38% N	10.0	—
Methylene urea, 40% N	24.6	—
Nitrate of Soda Potash, 15% N, 14% K ₂ O	92.0 ⁽²⁾	3.173
Natural organic, 5% N	3.5	0.702
Natural organic, 13% N	3.5	0.270
PHOSPHATE		
Normal superphosphate, 20% P ₂ O ₅	7.8	0.390
Concentrated superphosphate, 45% P ₂ O ₅	10.1	0.224
Concentrated superphosphate, 48% P ₂ O ₅	10.1	0.210
Monoammonium phosphate, 12/2% N, 61.7% P ₂ O ₅	29.9	0.405
Diammonium phosphate, 21.2% N, 53.8% P ₂ O ₅	34.2	0.456
POTASH		
Potassium chloride, 60% K ₂ O	116.3	1.936
Potassium chloride, 63.2% K ₂ O	114.3	1.812
Potassium nitrate, 13.8% N, 46.6% K ₂ O	73.6	1.219
Potassium sulfate, 54% K ₂ O	46.1	0.853
Monopotassium phosphate, 52.2% P ₂ O ₅ , 34.6% K ₂ O	8.4	0.097
Manure salts, 20% K ₂ O	112.7	5.636
Manure salts, 30% K ₂ O	91.9	3.067
Sulfate of potash-magnesia, 21.9% K ₂ O	43.2	1.971
MISCELLANEOUS		
Dolomite, 20% MgO	0.8	0.042
Magnesium oxide, MgO	1.7	0.002
Gypsum, 32.6% SO ₄	8.1	0.247
Calcium Carbonate, 56% CaCO ₂	4.7	0.083
Calcined kieserite, 33.5% MgO	38.7	1.156
Epsom salts, 16.4% MgO	44.0	2.687

(1) Based on plant nutrients shown in column 1.

(2) Calculated.

Secondary Nutrients

The AAPFCO official definition: "Secondary and micro plant nutrients - Those other than the primary nutrients that are essential for normal growth of plants and that may need to be added to the growth medium. Secondary plant nutrients shall include calcium, magnesium, and sulfur."

Calcium, magnesium, and sulfur are called secondary nutrient elements because they are essential to plant growth in lesser quantity than the primary nutrients and in greater quantity than the micronutrient elements.

Salts containing the secondary nutrient elements, such as calcium nitrate, magnesium nitrate and ammonium sulfate, are used in solid form, and in solution form as liquid fertilizers or foliar sprays.

Sewage Sludge

Solids removed from sewage by screening sedimentation, chemical precipitation or bacterial digestion. Five types of sludge are produced, as follows: (1) raw, (2) digested, (3) activated, (4) digested activated, and (5) chemically precipitated. Refer to current Manual of Practice Federation of Sewage Works Associations.

Dried digested sludge has been produced in some 4000 plants. Most of it was used as fertilizer. Large quantities are sold in bulk to fertilizer mixers or farmers. Only a few cities heat-dry it and sell it in bags. When bagged the moisture content must be below 5% or the microorganisms will rapidly destroy the bags.

Many cities dispose of air-dried digested sludge containing roughly 3 to 6% primary nutrients and 10 to 30% moisture. This bulk material is relatively high in micronutrient content.

Activated sewage sludge is prepared by inoculating the sewage with special microorganisms and aerating for several days. The sludge is filtered off and requires immediate disposal or further treatment. Twenty or more cities use the activated process but only a few heat-dry it and sell it as a commercial fertilizer, because heat-drying is not practical on a small scale.

The AAPFCO official definition: "*Activated sewage products* are those made from sewage freed from grit and coarse solids, and aerated after being inoculated with microorganisms. The resulting flocculated organic mater is withdrawn from the tanks, filtered, with or without the aid of coagulants, dried, ground and screened."

An example is: "Organiform SS is a granular copolymer of sewage sludge protein and methyleneureas (Grade 20-0-0) produced in a patented process involving the conversion of pathological inhibitors into microbiological stimulants. The product contains 7% soluble organic nitrogen and 13% water-insoluble nitrogen. It is reported to stimulate the activity of soil microorganisms without the addition of pathogens.

When a fertilizer material or fertilizer mixture contains recognized and determinable forms of water-soluble nitrogen with slowly available properties, then the guarantees for those components, if claimed, should be shown as footnotes rather than as a component in the nitrogen breakdown. (*example below*)

SLOW FERTILIZER 20-0-0

GUARANTEED ANALYSIS

Total Nitrogen (N).....20%
8.0% Urea Nitrogen
2.0% Other Water-Soluble Nitrogen
2.9% Slowly Available Water-Soluble Nitrogen*
7.1% Water-Insoluble Nitrogen

*Slowly Available Nitrogen from _____

OR

SLOW FERTILIZER 20-0-0

GUARANTEED ANALYSIS

Total Nitrogen (N).....20%
8.0% Urea Nitrogen
4.9% Other Water-Soluble Nitrogen*
7.1% Water-Insoluble Nitrogen
*% Slowly Available Nitrogen from _____

NOTE: When other recognized forms of water-soluble nitrogens are listed in the N breakdown, then the term "other" must precede the "water-soluble nitrogen" footnoted breakdown.

Slowly Available Water-Soluble Nitrogen

Slowly-Released Plant Nutrients

- (a) No fertilizer label shall bear a statement that connotes or implies that certain plant nutrients contained in a fertilizer are released slowly over a period of time, unless the nutrient or nutrients are identified and guaranteed at a level of at best 15% of the total guarantee for that nutrient(s).
- (b) Types of products with slow-release properties recognized are (1) water-insoluble Nitrogen such as natural organics, ureaform materials, urea-formaldehyde products, Isobutylidenediurea, oxamide, etc. (2) coated slow-release, such as sulfur coated urea and other encapsulated soluble fertilizers. (3) occluded slow-release, where fertilizers or fertilizer materials are mixed with waxes, resins, or other inert materials and formed into particles, (4) products containing water-soluble nitrogen such as ureaform materials, urea-formaldehyde product, methylenediurea (MDU), dimethylenetriurea (DMTU), dicyanodiamide (DCD), etc. The terms "water-insoluble", "coated slow-release", "slow-release", "controlled release", "slowly available water-soluble", and "occluded slow-release" are accepted as descriptive of these products, provided the manufacturer can show a testing program substantiating the claim (testing under guidance of Experiment Station personnel or recognized reputable researcher. A laboratory procedure, acceptable for evaluating the release characteristics of the product(s) must also be provided by the manufacturer.
- (c) to supplement (b) when the nitrogen is organic, it should be established that if a label states the amount of organic nitrogen present in a phrase, such as "nitrogen in organic form equivalent to X% N", then the water-insoluble nitrogen guarantee must not be less than 60% of the nitrogen so designated. For example: If the total nitrogen guarantee for a fertilizer is 10% and the label states, "Nitrogen in organic form equivalent to 2.5% N then the W.I.N. guarantee must not be less than 1.5%. ($2.5\% \times 0.6 = 1.5\%$).
- (d) When a slowly-released nutrient is less than 15% of the guarantee for either total nitrogen (N), available phosphate (P_2O_5), or soluble potash (K_2O), as appropriate, label shall bear no reference to such designations.
- (e) Until more appropriate methods are developed, AOAC method 970.04 (15th Edition), or as it shall be designated in subsequent editions, is to be used to confirm the coated slow-release and occluded slow-release nutrients and others whose slow-release characteristics depend on particle size. AOAC method 945.01 (15th Edition) shall be used to determine the water-insoluble nitrogen of organic materials.

Soil Reaction

The degree of acidity or alkalinity of a soil expressed as a pH value.

Soil Texture

The relative proportions of various soil size groups—sand, silt and clay.

Solubility

To be available to plants a nutrient must be at least slightly soluble in the soil solution. The amount of substance that will dissolve at a given temperature in 100 parts of water is known as its solubility.

Solubility of most chemicals is slightly higher at higher temperatures; that of others, especially ammonium and potassium nitrates, increases rapidly with temperature. The presence of other substances in the solution may either increase or decrease the solubility.

Solubility of a Fertilizer

The mass of fertilizer that will dissolve in a specific volume of water or other solution at a given temperature.

Starter Fertilizer

Fertilizer applied at planting either in direct seed contact or to the side and below the seed. Exact position is not implied.

Liquid or solid fertilizer, placed near or in contact with the seed, the roots, of new transplants, is commonly considered as starter fertilizer. In early practice, the low-analysis fertilizer then on the market was usually placed with the seed. Later, with increased concentrations and higher rates of application, the fertilizer was banded 2 inches below and 2 inches to the side of the seed in order to avoid poor germination and seedling injury. Such fertilizers were commonly called starter fertilizers. However, banding did not stimulate early plant growth as well as the former practice of placing the fertilizer with the seed. A present practice which has gained acceptance, especially in the corn belt, is that of placing a small portion (usually less than 100 pounds per acre) of so-called "pop-up fertilizer" with or very near the seed. The remainder of the application may be broadcast, plowed down, or banded. Research data and practical experience show that advantages of "pop-up" use over conventional practice may include (1) reduction in planting time; (2) faster, more uniform emergence and early growth rate; and under certain conditions, less lodging, rapid maturity, and increased yield. For maximum benefit and safety of use, "pop-up" fertilizer should have a high concentration of all three primary plant phosphates, or other compounds that might liberate ammonia in the soil. It should have a low salt index, a high proportion of nitrogen in the nitrate form, and low proportions of sodium and chlorine.

NU-GRO TECHNOLOGIES, INC.

Sulfur Coated Urea (SCU)

SCU is a controlled-release nitrogen fertilizer, developed by TVA, which is being manufactured by Nu-Gro Technologies, Inc.

SCU was developed to provide a minimum cost slow-release product that could be used on turf and horticulture to increase efficiency of nitrogen use, require fewer applications, and reduce nitrogen losses by leaching and denitrification. Sulfur was selected as the principal coating material because of its low cost and its value as a plant nutrient.

In a manufacturing process, preheated urea granules (or prills) are sprayed with molten sulfur as they fall from special flight arrangements in a rotary drum. The sulfur coated granules are then sprayed in another drum with a waxlike sealant to seal any flaws in the sulfur coating. The material is cooled and conditioned with diatomaceous earth to prevent caking. The thickness of the sulfur shell can be varied to control the dissolution rate of SCU in the soil. A standard dissolution test, used by TVA, involves its immersion in water for 7 days and its slow-release nitrogen is expressed as percent not dissolved at that time.

The final SCU products made by TVA contained 36 and 38% nitrogen as compared to 46% for the original urea. The sulfur content ranged between 13 and 16%. Numerous field experiments conducted in major rice-growing regions of the world have shown that single applications of SCU usually have a marked yield advantage over single or multiple applications of uncoated urea, especially where delayed or intermittent flooding is practiced. Good responses have been obtained on sugarcane, pineapple, grass forages, turf, certain ornamentals and fruits and on vegetables grown on sandy soils subject to leaching. SCU seldom shows an advantage when applied on corn, sorghum, small grains, soybeans, cotton, or potatoes. Most of these crops require nitrogen in peak periods at a rate faster than SCU will provide.

The AAPFCO official definition: "Sulfur coated urea - A coated slow-release fertilizer consisting of urea particles coated with sulfur. The product is usually further coated with a sealant (2-3% of total weight) and a conditioner (2-3% of total weights). It typically contains about 30% to 40% nitrogen and 10% to 30% sulfur."

A fluid containing dissolved and undissolved plant nutrients.

Materials that are manufactured chemically by synthesis from their elements or other chemicals, as contrasted to those found ready-made in nature.

An accumulation or mat of undecomposed clippings, withered leaves and other organic materials.

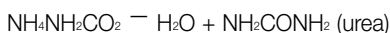
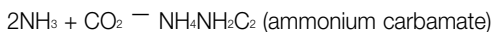
The AAPFCO definition: "Fertilizer legislation - The uniform bill and regulations are the result of considerable study and deliberation. Control officials and industry should keep each other advised of pending legislation and provide necessary information to promote uniformity."

The term "unit" represents 1% or 20 pounds of a nutrient in a ton (2000 pounds) of fertilizer. Thus, a 5-20-10 fertilizer contains 5 units of N, 20 units of P₂O₅, and 10 units of K₂O per ton.

The AAPFCO official definition: "Unit - Twenty pounds of plant food or 1% of a ton"

Urea (CO(NH₂)₂)

A white crystalline, or granular, solid synthesized from ammonia and carbon dioxide under high temperature and pressure by a number of processes.



Many plant installations of urea use processes that provide a granular product. The main processes used are spray-drum granulation (Spherodizing) and pan granulation. The main advantages are that a wide range of granule sizes can readily be produced - up to forestry size (4 to 5 mm) or larger. The granules also have much higher crushing strength than prills. Removal of fumes and particulates, to meet environmental standards, is less difficult than with prilling, because a much smaller volume of air is handled.

Capacities of the larger plants are 1500 tons per day. The undesirable content of biuret formed in the evaporation and prilling steps of the earlier processes has been virtually eliminated in the present-day product. Urea for some crops, such as in foliage sprays for citrus should not contain more than 0.25% biuret. High analysis (45 to 46% N).

Urea has wide use in solid and liquid complex fertilizers and for direct application. It is used in foliage sprays, with or without the addition of pesticides and micronutrients. About 10 pounds of urea per 100 gallons of spray solution is readily absorbed through the leaves of many plants and efficiently utilized as a plant food.

Suspension Fertilizer

Synthetic Materials

Thatch

Uniform Fertilizer Legislation

Unit

Urea Ammonium Sulfate

Urea-Feed Grade

Urea-Form

Urea-Form Fertilizer Materials

Urea Formaldehyde Products

Urea-Formaldehyde Reaction Products (Urea-Form)

Urea-Formaldehyde Solution

The AAPFCO official definition: "Urea is the commercial synthetic acid amide of carbonic acid and it shall contain not less than 45% nitrogen."

Granulated homogenous mixtures of urea and ammonium sulfate containing 30 to 40% N and 4 to 13% S. The products have greater granule strength than urea alone.

Smaller Prill size (42% N) for better blending into animal feeds as a protein source.

see *Urea-Formaldehyde Reaction Products*

see *Urea-Formaldehyde Reaction Products*

see *Urea-Formaldehyde Reaction Products*

A class of synthetic insoluble nitrogenous materials, methylene ureas and urea formaldehyde, made by reaction of urea and formaldehyde in a form slowly available to plants.

The AAPFCO official definition:

■ "Urea-form fertilizer materials (*sparingly soluble*) are reaction products of urea and formaldehyde containing at least 35% nitrogen largely in insoluble but slowly available form. The water-insoluble content shall be at least 60% of the total nitrogen. The water-insoluble nitrogen in these products shall have an activity of not less than 40% when determined by the appropriate AOAC method."

■ "Urea-formaldehyde products (*sparingly soluble*) are reaction products of urea and formaldehyde which contain less than 35% nitrogen, largely in soluble but slowly available form. They shall have the percentage of total nitrogen as part of the product name; for example: 20% N Urea-Formaldehyde. The water-insoluble nitrogen shall be at least 60% of the total nitrogen. The activity index of the water-insoluble nitrogen shall be either (1) not less than 40% by the AOAC method for urea-formaldehyde products or (2) not less than 50% by the AOAC alkali permanganate method or 80% by the neutral permanganate method."

■ "Urea-formaldehyde products (*water-soluble*) are reaction products of urea and formaldehyde which contain at least 30% nitrogen, largely in water-soluble form. Some slowly available nitrogen products are present. Stable aqueous solutions may be prepared from these materials. The reaction products shall contain a maximum of 55% free urea, with the remainder of the urea being chemically combined as methylolureas, methylolurea ethers, and/or methylenediurea (MDU) and dimethylenetriurea (DMTU)."

■ "Methylene Urea (MU) is a product obtained by the reaction of urea with formaldehyde and contains ligomers of urea bonded together by methylene (-CH₂-) linkages. It is chiefly composed of cold-water-soluble fractions from methylenediurea (MDU) and dimethylenetriurea (DMTU), hot-water-soluble fractions from trimethylenediurea (TMTU) and Tetramethylenepentaurea (TMPU) and hot-water-insoluble fractions from longer-chained oligomers. It is generally free of methylolureas or methylolurea ethers. It contains at least 38% nitrogen and **is a source of slowly available nitrogen.**"

■ "Methylenediurea (MDU) is a water-soluble condensation product resulting from the reaction of one molecule of formaldehyde with two molecules of urea, with the elimination of one molecule water. It has a minimum total nitrogen content of 4% and **is a source of slowly available nitrogen.**"

■ "Dimethylenetriurea (DMTU) is a water-soluble condensation product resulting from the reaction of two molecules of formaldehyde with three molecules of urea, with the elimination of two molecules of water, and having a minimum total nitrogen content of 41%. **It is a source of slowly available nitrogen.**"

Specially stabilized solutions containing urea and formaldehyde. When mixed with fertilizer materials to make ordinary mixtures ureaform is produced in the mixture, up to about 20% of the total N of the solution.

When additional urea is added to any of these solutions and the solution is acidified it polymerizes to form a methylene urea. Under proper conditions it produces urea-form, a slowly available fertilizer, but under others it forms a plastic that is unavailable as a plant nutrient.