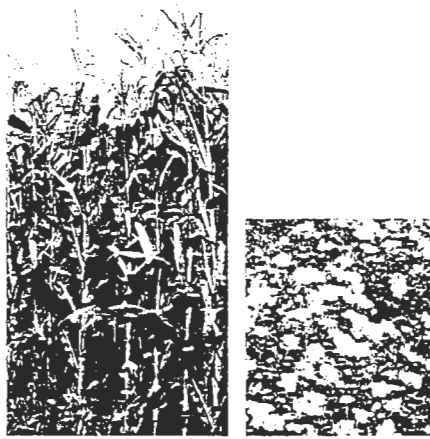


Cornell Field Crops and Soils Handbook



SECOND EDITION

New York State College of Agriculture and Life Sciences
Ithaca, New York



The Cornell pH kit can be used to determine the soil pH and whether lime is needed. It does not determine the amount of lime needed. A complete soil test should be used to determine the quantity of lime to be applied.

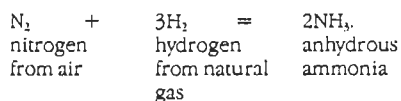
If the pH is 5.5 or below, lime should be applied at least a year before a pH-sensitive crop such as alfalfa or barley is planted. It is usually recommended that a split application of lime be applied and a less-sensitive crop such as corn or clover be planted for at least 1 year before planting alfalfa.

The last summer or fall that a field is in sod is a good time to apply small maintenance additions of lime. At that time the soil is firm, and lime can be applied with less likelihood that the spreader trucks will get stuck, rut the fields, or compact the soil.

Manufacture of Fertilizers

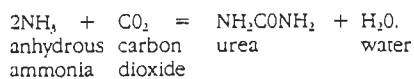
The manufacture of fertilizer uses large quantities of energy as well as raw materials. Likewise, it requires energy to transport these materials to the point of use. A combination of availability of raw materials, energy, and transportation facilities and quantity of fertilizer used determines the location of the fertilizer plants.

Nitrogen. Anhydrous ammonia (NH_3). Anhydrous ammonia is made by reducing natural gas (methane) to carbon dioxide and hydrogen. The hydrogen is reacted with nitrogen from the air to produce anhydrous ammonia.



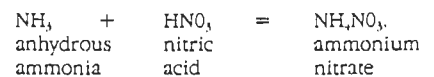
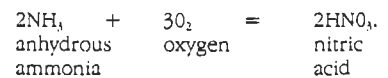
The combination of hydrogen and nitrogen will only occur at very high temperatures and pressures and thus uses energy. Approximately 40,000 cubic feet of natural gas are required to produce 1 ton of anhydrous ammonia. As much natural gas is required to make 3 to 4 tons of anhydrous ammonia as to heat an average insulated house for a year. To conserve nitrogen (use only that quantity necessary for maximum economic yields) is as important as to conserve energy. The other sources of commercial nitrogen fertilizers, except some industrial by-product ammonium sulfate, are made from anhydrous ammonia (NH_3).

Urea (NH_2CONH_2). To manufacture urea either for feed or fertilizer, anhydrous ammonia is reacted with the carbon dioxide obtained from natural gas in the presence of a catalyst to produce urea and water.



The urea is granulated and dried. This also requires energy. Thus, urea NH_2CONH_2 , costs more to produce than anhydrous ammonia.

Ammonium nitrate (NH_4NO_3). Ammonium nitrate is made by oxidizing (burning) anhydrous ammonia in the presence of a platinum screen and other catalysts to form nitrous oxide. The nitrous oxide is reacted with water to produce nitric acid. The nitric acid is neutralized by using more anhydrous ammonia, and ammonium nitrate is formed.



When either urea or ammonium nitrate is first produced, it is a hot molten liquid. The granules commonly used in dry fertilizer materials are prepared by spraying this hot liquid into a large revolving drum, coating the prills with clay to help prevent moisture absorption, and allowing them to cool. The purpose of the clay coating is to prevent the prills from sticking together and to help prevent moisture absorption by the fertilizer.

Ammonium sulfate [$(NH_4)_2SO_4$]. Ammonium sulfate is produced by reacting ammonia with sulfuric acid. It is generally produced as a by-product of the removal of ammonia or sulfur from manufacturing processes. Very little ammonium sulfate is made specifically for fertilizer consumption.

Nitrogen solutions—urea + ammonium nitrate ($NH_4NO_3 + NH_2CONH_2$). Nitrogen solutions are made by dissolving ammonium nitrate and urea in water. The ammonium nitrate and urea are transferred directly from the production plant to the water, thus saving the drying and the clay coating. The 28 to

32% nitrogen solutions usually contain about 50% of the nitrogen as urea and about 50% as ammonium nitrate. Other than 28 to 32% solutions can be and are produced. A gallon of 32% nitrogen solution weighs 11.06 pounds and contains 3.54 pounds of nitrogen.

Aqua ammonia and low-pressure solutions. Aqua ammonia (ammonia in a water solution) and other low-pressure nitrogen solutions are made by adding anhydrous ammonia to water under controlled conditions. The concentration of nitrogen within the water is determined by the amount of anhydrous ammonia added. Pressure is developed over the solution by the ammonia. Most aqua solutions are produced to contain 20 to 30% nitrogen.

Anhydrous ammonia can be added to ammonium nitrate and (or) urea solutions to produce more-concentrated products varying in concentration from about 30 to 42% nitrogen. These are commonly referred to as low-pressure solutions, their advantages being that they produce less pressure than anhydrous ammonia and still contain a fairly concentrated nitrogen solution for shipment and application.

The disadvantages of low-pressure solutions are that they must be handled as a material under pressure and must be soil injected the same as anhydrous ammonia to prevent ammonia loss. Both these disadvantages mean a higher equipment and application cost.

These products are not commonly sold in New York, but there has been some interest in them for certain locations.

Ammonium phosphates. The ammonium phosphates are commonly used to supply nitrogen and phosphorus. Generally, they contain smaller amounts of nitrogen than phosphate (P_2O_5). The more-common

ammonium phosphates are monoammonium phosphate ($NH_4H_2PO_4$), 13-52-0 or 11-48-0; diammonium phosphate [$(NH_4)_2HPO_4$], 18-46-0; and ammonium polyphosphate, 12-64-0. These compounds are essentially 100% water soluble and are concentrated sources of fertilizers. They are made by reacting phosphoric acid with ammonia. The quantity of ammonia added and the heat determine whether one makes monoammonium, diammonium, or ammonium polyphosphate. The ammonium phosphates are commonly used for direct application or in bulk-blended fertilizers.

Ammoniated superphosphates. Ammoniated superphosphates are made by introducing anhydrous ammonia into superphosphate or concentrated (triple) superphosphate. The result is a fertilizer containing both nitrogen and phosphorus similar to the ammonium phosphates. The chemical difference between the ammoniated and the ammonium phosphates is the presence of extra calcium in the material. Ammoniated superphosphates have the chemical formula of mono-calcium-ammonium phosphate [$Ca(NH_4HPO_4)_2$]. This compound is nearly 100% water soluble and plant available; but if too much nitrogen is added, some of the phosphorus is converted to non-water-soluble compounds. Further addition of ammonia converts some of the phosphorus to forms that are not plant available. Most producers today maintain about 60% water solubility and essentially 100% plant availability in their ammoniated superphosphates.

Both ammoniated superphosphates and monoammonium phosphates make excellent sources of nitrogen and phosphorus for band application. There appears to be little difference in plant response between these sources as long as at least

60% water solubility is maintained in the ammoniated superphosphates.

Phosphorus. *Superphosphates.* Ordinary superphosphate and concentrated (triple) superphosphate fertilizers are made by reacting a phosphorus-containing ore, usually apatite, with sulfuric acid. Ordinary superphosphate (0-20-0) contains monocalcium phosphate and calcium sulfate (gypsum). If during production the calcium sulfate is separated from the monocalcium phosphate fertilizer, concentrated superphosphate (0-46-0) is obtained. Recently, because of lower-grade phosphorus ores, the analysis of concentrated superphosphate has varied from 44% to 46% P_2O_5 . Both these superphosphates contain the same chemical phosphorus compound, monocalcium phosphate [$Ca(H_2PO_4)_2$], but ordinary superphosphate contains another major component, calcium sulfate or gypsum. Thus, ordinary superphosphate contains a major quantity of sulfur. Concentrated superphosphate may contain some sulfur—usually less than about 3%.

Phosphoric acid. Phosphoric acid is used as the phosphorus source for manufacture of the ammonium phosphates, ammonium polyphosphates, and liquid or slurry fertilizers. Phosphoric acid for most fertilizers is produced by reacting rock phosphate (apatite) with excess sulfuric acid (made from sulfur), then purifying and concentrating the resulting phosphoric acid. The amount and method of concentrating the acid determine the P_2O_5 content and, therefore, whether it is considered as the more concentrated form, polyphosphate. The phosphoric acid is then used in the manufacture of other fertilizer materials.

Ammonium phosphates. The P_2O_5 content of the phosphoric acid determines whether, when reacted with

anhydrous ammonia, an ammonium phosphate or ammonium polyphosphate is produced. The ammonium polyphosphates are made from phosphoric acids containing about 70% P_2O_5 .

When the phosphoric acid is reacted with ammonia, the resulting ammonium phosphate can be dried and granulated for the production of dry fertilizer or can be maintained as a liquid. Essentially the same chemical forms can exist as a liquid or as a dry material.

The common liquid ammonium phosphates are the 10-34-0 and 11-37-0 grades. These materials are usually stored at a blend plant and can be mixed with muriate of potash to form a liquid containing N-P-K. A disadvantage of these liquids is their low analyses. They must contain some nitrogen.

Potassium. Potassium fertilizers are primarily mined from deposits of potassium chloride, potassium sulfate, and potassium and magnesium sulfates. United States' production of potassium fertilizer has declined within recent years. We import essentially all our potassium fertilizers, mostly from Canada. Over 90% of the potassium fertilizers used in the Northeast come from Canada. Thus, we are dependent upon the supply and pricing structure of the Canadian potash for our potassium.

Some Important Reactions of Nitrogen

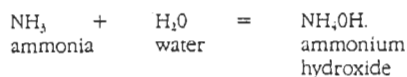
Nitrogen can be supplied to crops from several fertilizer sources. These sources can contain nitrogen in several different chemical forms. The plant may not be able to use the nitrogen in the form supplied, and some forms of nitrogen may even be toxic to plants. Under soil conditions adequate for normal growth of plants, the various forms of nitrogen are ul-

timately (usually rapidly) converted to ammonia and subsequently to nitrate. Nitrate is the form of nitrogen most often used by plants. In this section we will discuss several forms of nitrogen and the changes they undergo in the soil.

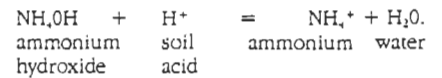
First, a general description of the changes in nitrogen that occur in soils follows.

Nitrogen transformations. *Organic nitrogen (-CNH₂).* The change from organic nitrogen (nitrogen contained in organic matter) to inorganic ammonia occurs over a wide range of soil conditions. Different types of microbes use the organic matter as a source of energy. When the content of nitrogen in the organic matter is sufficient (i.e., C to N ratio of 15 to 1), inorganic nitrogen is released as ammonia or the ammonium ion. Once the ammonia is released, it undergoes the same reaction as other ammonium fertilizer sources. This release of inorganic nitrogen is called *mineralization*. Nitrogen is generally released when any green plant, sod crop, or manure is incorporated into the soil. When sawdust, bark, or other material very low in nitrogen as compared with carbon is incorporated, nitrogen may be removed from the soil by the growing microbes and incorporated into their bodies. This process is called *immobilization*. For some materials there is no major change in the soil nitrogen status with decomposition. These crop residues include small grain straws, corn stalks, and the like.

Ammonia (NH₃, a gas). The ammonia reacts instantly with any water present in the soil to form ammonium hydroxide, a high-pH base.



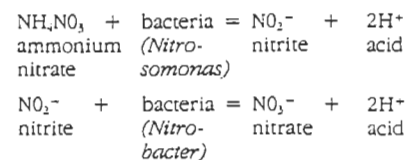
Ammonium hydroxide is the ingredient in smelling salts and, if exposed to the air, will revert to ammonia (gas) and water. Ammonium hydroxide will also react with soil acids to form the ammonium ion and water.



Thus, the initial reaction for ammonium formation from organic materials, urea, or anhydrous ammonia is a very high pH, especially if the application is concentrated in a small area such as a fertilizer band. This high pH is often harmful to germinating seeds, seedling plants, and roots.

Ammonium (NH₄⁺). The ammonium form of nitrogen (NH₄⁺) has a positive charge and will be attracted to, and held on, the negatively charged clay particles in the soil. This is why ammonium nitrogen is often classified as a nonleachable nitrogen source. The nonleachable characteristic of the ammonium ion has minimum significance in maintaining the nitrogen in warm soils because it is soon converted to the leachable nitrate ion (NO₃⁻). The nitrate ion is negatively charged and, hence, is not attracted and held by the clay particles in the soil.

Nitrate (NO₃⁻). Once the organic nitrogen becomes ammonium or when commercial fertilizers containing ammonia are added to the soil, a two-step conversion occurs.



The ammonium nitrogen is converted to nitrite by the actions of bacteria of the genus *Nitrosomonas*. *Nitrosomonas* bacteria will convert ammonium nitrogen to nitrite in a

pH range from below 5.6 to above 8.5. When the ammonium ion is converted to nitrite, acid (H^+ ion) is also produced, and thus the pH is lowered.

Bacteria of the genus *Nitrobacter* will convert nitrite to nitrate nitrogen. The conversion of ammonia or ammonium to nitrite and nitrate can and usually does occur rapidly. The conversion of 50 pounds per acre of ammonium nitrogen from ammonium sulfate or ammonium nitrate can occur in less than a week under favorable conditions. Conversion of urea and anhydrous ammonia requires up to 3 weeks because of the high pH produced. Once the nitrogen is converted to nitrate, it is readily leachable. Because these conversions occur readily in soils, there is no completely nonleachable source of nitrogen, although the nitrification process can be slowed by adding a nitrification inhibitor.

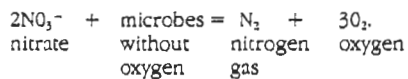
Acid is also released upon the conversion of ammonia to nitrate, further reducing the soil pH. The release of these acids is the reason most nitrogen-containing fertilizers are called acid-forming fertilizers. In general, it requires about 4 pounds of lime to counteract the acidity produced from 1 pound of ammonium nitrogen. Even on acid soils it is more economical to counteract the acidity produced by the fertilizer with lime rather than try to purchase fertilizers that are labeled as nonacid forming.

Nitrobacter bacteria convert nitrite to nitrate in a more-restricted pH range than that in which *Nitrosomonas* bacteria convert ammonium to nitrite. The pH range for *Nitrobacter* bacteria is from below 6.0 to about 8.0. Under certain conditions when there is a very high pH, nitrite will accumulate. In excessive quantities (probably about 1 lb/acre), nitrite is very harmful to plants. An excess of nitrite may occur when high concen-

trations of urea, anhydrous ammonia, and (or) diammonium phosphate are used in the fertilizer band close to the seed or seedling plants. Thus, care must be exercised in using these materials for band fertilizers.

Large concentrations of free ammonia may exist from the application of anhydrous ammonia, urea, or diammonium phosphate. Ammonia in high concentrations is also harmful to plants. It is difficult to separate the conditions of nitrite injury and ammonia injury to plants because neither produces visible symptoms. In a concentrated band these fertilizers may produce both conditions of free ammonia and excess nitrite. Reduced plant stands or lower yields may result.

Denitrification. The conversion of ammonia to nitrate occurs only when adequate oxygen is present in the soil. When the soils are wet and air movement within the soil is restricted, oxygen becomes limiting and another type of nitrogen conversion (denitrification) occurs.



The nitrate nitrogen is converted to nitrogen gas (the same nitrogen gas that makes up 78% of the air) and is lost from the soil and plant use. This process is called denitrification.

Data from New York indicate that on the average 75 to 90% of fall-applied nitrogen and about 35% of spring preplant nitrogen for corn are lost by July. Probably most of the nitrogen is lost by denitrification under most New York soil conditions. Side-dress nitrogen recommendations help to prevent loss in two ways: (1) The nitrogen is applied after the wet spring period has passed, and denitrification or leaching is minimized. (2) The nitrogen is applied just be-

fore maximum nitrogen uptake by the corn, and there is less time for loss to occur.

Characteristics of Nitrogen Fertilizers

It is often quoted that a pound of nitrogen fertilizer is equivalent to any other pound of nitrogen fertilizer regardless of the source. This is true only when the materials are applied under conditions suitable for each source. Several characteristics of the fertilizer material influence the time and method of application needed for maximum efficiency.

Anhydrous ammonia (NH_3).

Anhydrous ammonia is a liquid under pressure, contains 82% nitrogen, and weighs about 5 pounds per gallon. It becomes a gas upon application when the pressure is released. Because ammonia reacts rapidly with water to form a strong base, it is extremely caustic to the eyes, skin, and lungs, and, therefore, must be handled with care. When handled and applied properly with good equipment, it is an excellent source of nitrogen for many crops.

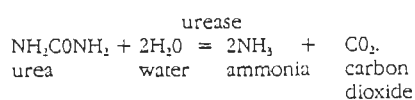
To prevent application losses, anhydrous ammonia must be placed into the soil 6 to 8 inches deep, so that the ammonia can react completely with the soil before the gas can escape. The most common application method is to knife the anhydrous ammonia into the soil as a side-dress application for corn.

Anhydrous ammonia causes a high soil pH around the point of release. Because this is harmful to young germinating seedlings, anhydrous ammonia should not be applied near the seed, but rather at midrow. When seeds are placed in or near a preplant anhydrous ammonia band, loss of stand and yield may result. It is difficult to apply preplant bands without this problem. One possible solution

is to dilute the bands as much as possible by using more, closer-spaced knives so that the rate per knife is lower or by using plow sole applications.

Anhydrous ammonia is usually one of the cheapest sources per pound of nitrogen, especially when it is purchased in large quantities; but the equipment for transportation and application is expensive. About 200 acres of corn are required for the use of anhydrous ammonia with farm-owned equipment to be economically feasible. Likewise, a retail supply of anhydrous ammonia must be nearby. Using anhydrous ammonia as an additive to corn silage would spread the investment and reduce the amount of corn required for its use as a fertilizer to be economical. The total N needed on dairy farms may make such anhydrous ammonia additions for corn unnecessary.

Urea (NH_2CONH_2). Urea is a dry, white prill containing 45 to 46% nitrogen. It is the most concentrated dry source of N available and is generally the least expensive of the more commonly used dry sources. Urea has several characteristics that influence the time and method for efficient applications. For urea to be used by plants, it must change from urea to ammonia. This change occurs by the action of the enzyme called urease on the urea. Urease is a naturally occurring enzyme that is produced as a by-product of plant decomposition and microbial growth. The urea molecule breaks down into ammonia, carbon dioxide, and water, the same components used in its production.



This breakdown of the urea to ammonia occurs rapidly under moist soil conditions. It is usually complete within a few hours after application. If the urea is placed on the soil surface, some of the ammonia is lost to the air. Under soil-drying conditions, the nitrogen loss can approach 40% of the applied nitrogen. When applied just before a rain, the urea can dissolve and enter the soil with the water before breakdown to ammonia occurs. The ammonia released from the urea can then react with the soil, and ammonia loss is prevented. If excess rain occurs, the urea can leach through the soil. An average loss for summer-applied topdressed urea is likely to be 15 to 20% of the applied nitrogen. Thus, when urea is applied, it should be mixed or covered with the soil in some manner to prevent this loss. This loss limits the usefulness of urea for topdressing pastures, meadows, and small grains as well as other crops when the material is not incorporated into the soil.

When the urea is applied in a band at planting, the ammonia released from the urea causes a high pH in the fertilizer band. This can result in seedling damage as described in the preceding section. Thus, urea should not be banded at rates greater than 20 to 30 pounds per acre at planting.

Urea can be banded as a sidedressing for corn by using disk openers and placing the urea about 2 inches below the soil surface. Likewise, it can be applied preplant incorporated without ammonia loss, but the other losses common to preplant applications of nitrogen may occur.

Ammonium nitrate (NH_4NO_3). Ammonium nitrate is a dry prill containing 33 to 34% nitrogen. It was once the primary source of fertilizer nitrogen, but urea production now exceeds ammonium nitrate production.

On most soils the losses from topdressed ammonium nitrate are less than for urea; therefore, it often is a better nitrogen source for topdressings. On high pH soils, however, some nitrogen may be lost by volatilization from ammonium nitrate, because the ammonium reacts with the carbonate from lime to form ammonium carbonate. The ammonium carbonate breaks down to ammonia, water, and carbon dioxide. The ammonia may then be lost by volatilization from the soil surface. This loss does not often exceed 10% of the applied nitrogen, even on high pH soils.

Areas for storage of ammonium nitrate should be dry and free from all petroleum products such as oils and fuels. Ammonium nitrate mixed with these products is extremely explosive. It should also be kept away from heat and explosives.

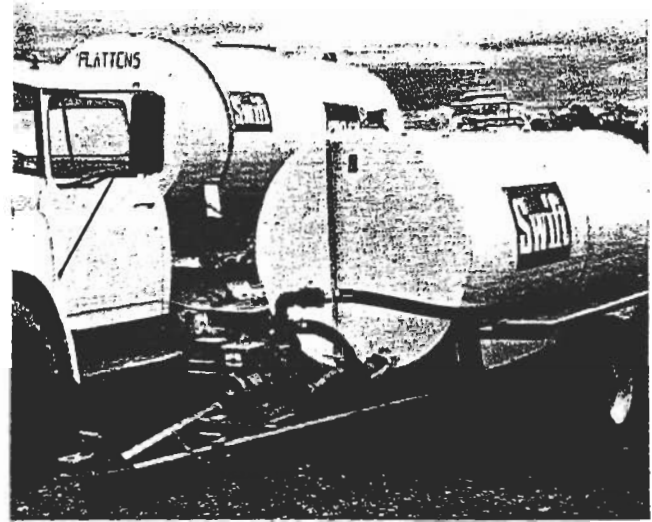
Ammonium sulfate [$(\text{NH}_4)_2\text{SO}_4$]. Ammonium sulfate is a dry, usually crystalline source containing 20% nitrogen. It is a by-product of several industries, especially steel production. Most of the ammonium sulfate is used in bulk-blended or mixed fertilizers because it is compatible with both urea and ammonium nitrate. It undergoes the same reactions and can be used in the same way as ammonium nitrate.

Nitrogen solutions (NH_4NO_3 and NH_2CONH_2 in water). Nitrogen solutions will quickly dehydrate any portion of the plant they touch. If used at high rates, the solutions may almost completely defoliate the plant; therefore, nitrogen solutions should not be used as a postemergence spray unless directed below most of the plant leaves.

Because nitrogen solutions contain about 50% of the nitrogen as urea, some nitrogen volatilization losses can be expected when nitrogen solutions are used as a topdress-



Liquid fertilizer storage facilities consist of large tanks of metal or plastic. The basic materials are usually mixed to the desired analysis just before application.



Liquid fertilizers are transported and often applied with tank trucks or trailers. The transfer of liquids by pump makes them easier and faster to handle.

ing. For sidedressing corn, the solutions should be knifed about 2 inches into the soil in a manner similar to that for anhydrous ammonia.

Nitrogen solutions are readily available, convenient, and a safe and easy nitrogen source to use. Solutions require a moderate financial investment for equipment. Likewise, more attention than that normally exercised in the past should be given to proper placement.

Solution versus Dry Fertilizers

As shown in the "Manufacture of Fertilizers" section, the same basic chemical compounds are present in the liquid fertilizers as in many of the dry fertilizers. There is no difference in the plant response obtained from liquid or dry fertilizers if they are applied to the soil in similar positions, that is, banded or broadcast. The differences between these materials, therefore, is in the methods for transporting, storing, and handling. Liquids have some advantages because they can be transferred from tanks to other equipment and applied using

liquid pumps. Pumping is usually faster and is easier than handling most dry materials. Liquid materials require a higher initial equipment investment. Dry materials would be much easier to handle if similar quantities of money were invested in dry-handling facilities.

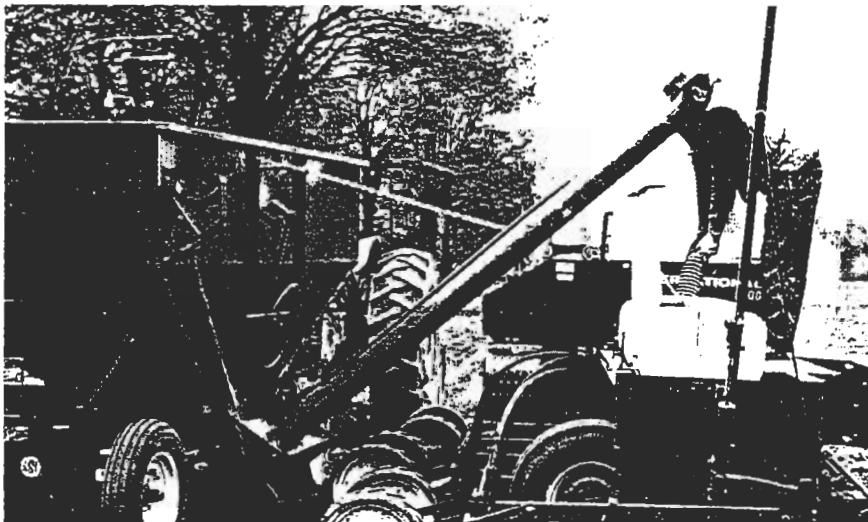
The disadvantages of liquid fertilizers are more weight must be transported and lower fertilizer analyses are often used. This may not be the case with some of the newer "slurry"-type liquids being developed. Slurries are solid particles of fertilizer suspended in a clay-water mixture that prevents the solid particles from settling to the bottom of the tank. Slurries are not commonly used in New York, but their use in other parts of the United States is increasing. The disadvantage of slurries is they can only be used as a broadcast application.

Calculations for liquid fertilizers. The analyses for liquids are expressed in exactly the same terms as for dry materials—as percentages by weight of the nutrients contained in

the total weight of the material, that is, 9-18-9 refers to 9% of nitrogen, 18% of P_2O_5 , and 9% of K_2O . This means 9, 18, and 9 pounds of N, P_2O_5 , and K_2O per 100 pounds of total liquid material. We are accustomed to thinking of liquids in gallons; to make the conversion from gallons to pounds, we must know the total weight of the product per gallon and its analyses. Most liquids have a weight of 11 to 12 pounds per gallon.

For example: How much N, P_2O_5 , and K_2O are in a gallon of 9-18-9? Assume a weight of 12 pounds per gallon. Thus, when we multiply the weight (in pounds per gallon) by the analysis of each nutrient in the fertilizer (percentage must be converted to decimal as $9\% = 0.09$), we obtain 1.08 pounds of N, 2.16 pounds of P_2O_5 , and 1.08 pounds of K_2O .

Cost comparisons for liquid fertilizers. The cost of similar fertilizer materials can and should be compared on a cost per pound of plant nutrient basis. When fertilizers are sold by the gallon, the cost per pound of plant nutrient is obtained



With the proper equipment, application of bulk dry fertilizers can be very efficient.

by dividing the selling price per gallon by the number of pounds of plant nutrients supplied per gallon. For the above example, if the selling price of a 9-18-9 fertilizer is \$3.00 per gallon, the cost per pound of plant nutrient would be \$0.69 [$\3.00 per gallon / $(1.08 + 2.16 + 1.08)$ or $(4.32$ lb plant nutrient)]. A comparable value for most commercial liquid fertilizers normally sold by weight and analysis would be about \$0.25, whereas dry materials might be about \$0.22 per pound of plant food. These prices vary with distribution, time of year, and conditions of sale; therefore, they should only be used as an illustration and not for direct comparison of materials. For a direct cost comparison, determine prices from your local dealers. The calculation does illustrate that the price per pound of plant nutrient should be a primary factor in purchasing any fertilizer material.

Fertilizer Injury

Fertilizer injury to small seedlings can occur when too much fertilizer is applied in the fertilizer band. The fertilizer salts dissolve in the soil water and are taken up by the plant too rapidly; as a result the plant dehydrates. This injury is commonly referred to as fertilizer salt injury. It can be observed, especially on windy days when the plants are small, as wilted leaves and scorched leaf tips and edges. The injury can be reduced or prevented by limiting the quantity of nitrogen plus potash used in the fertilizer band. No more than 80 pounds per acre of $N + K_2O$ should be used in the fertilizer band. The phosphorus is not included in the calculation, that is, 400 pounds per acre of 10-10-10 would be 80 pounds per acre of $N + K_2O$.

A second type of seedling injury involves the use of urea and diammonium phosphates within the fertilizer band. A discussion of the injury is included under properties of fertilizers. It is recommended that (1) no more than 20 pounds per acre

of N as urea be used in the fertilizer band; (2) no more than 30 pounds of P_2O_5 from diammonium phosphate be used in the fertilizer band; (3) no more than 20 to 30 pounds of urea nitrogen plus N from diammonium phosphate be used in the fertilizer band; and (4) no more than 30 to 40 pounds of ammonium nitrogen from all sources be used in the band with diammonium phosphate.

Determining the fertilizer ratio and grade. The fertilizer ratio is given by the smallest whole numbers that describe the ratio of N to P_2O_5 to K_2O present in the fertilizer; that is, a 1-4-4 ratio means that there are 4 pounds of P_2O_5 and K_2O to a pound of N. Recommendations are often made to apply a fertilizer of a particular ratio that will give a certain rate of one or more of the nutrients; for example, the recommendation to apply sufficient quantities of a 1-2-2 ratio fertilizer to provide 20 pounds of nitrogen would mean to apply a material such as 10-20-20 to provide 20 pounds of nitrogen. The 20 pounds of nitrogen would then be provided by adding $(20 \text{ divided by } 0.10)$ 200 pounds per acre of 10-20-20.

The fertilizer grade gives the percentages of N, P_2O_5 , and K_2O present in the fertilizer and is the basis for the sale of most fertilizers. There can be several different fertilizer grades that will fit a particular fertilizer ratio, for example a 1-1-1 ratio can be obtained with 10-10-10, 12-12-12, 15-15-15, and so forth. An individual dealer may stock only one fertilizer grade for a particular ratio.

Band Rates

The rate and ratio of fertilizer to be used in the band must be determined after the rates of individual nutrients are obtained. For example, if more than 40 pounds of nitrogen are required, the rate of nitrogen to be applied in the band rate should be