Chapter 3

SCIENTIFIC PRINCIPLES SUPPORTING RIGHT SOURCE

The core scientific principles that define right source for a specific set of conditions are the following.

- **Consider rate, time, and place of application.**
- **Supply nutrients in plant-available forms.** The nutrient applied is plant-available, or is in a form that converts timely into a plant-available form in the soil.
- **Suit soil physical and chemical properties.** Examples include avoiding nitrate application to flooded soils, surface applications of urea on high pH soils, etc.
- **Recognize synergisms among nutrient elements and sources.** Examples include the P-zinc interaction, N increasing P availability, fertilizer complementing manure, etc.
- **Recognize blend compatibility.** Certain combinations of sources attract moisture when mixed, limiting uniformity of application of the blended material; granule size should be similar to avoid product segregation, etc.
- **Recognize benefits and sensitivities to associated elements.** Most nutrients have an accompanying ion that may be beneficial, neutral or detrimental to the crop. For example, the chloride (Cl^-) accompanying K in muriate of potash is beneficial to corn, but can be detrimental to the quality of tobacco and some fruits. Some sources of P fertilizer may contain plant-available Ca and S, and small amounts of Mg and micronutrients.
- **Control effects of non-nutritive elements.** For example, natural deposits of some phosphate rock contain non-nutritive trace elements. The level of addition of these elements should be kept within acceptable thresholds.

These core principles are integrated into the concepts presented in the rest of this chapter.

All plants require at least 17 essential elements to complete their life cycle. These include the 14 mineral nutrients shown in **Table 3.1** and the three non-mineral elements carbon (C), hydrogen (H), and oxygen (O). The macronutrients are required in relatively large amounts by plants, while the micronutrients are used in much smaller quantities. Nutrient availability in many native soils is too low in at least one or more of the essential nutrients to allow crops to express their genetic potential for growth. In unfertilized ecosystems, native plants adapt to nutrient deficits by limiting their growth rate, a strategy not generally acceptable to farmers concerned with food production and economic returns.

Each plant nutrient has specific functions within the plant; some are relatively simple while others take part in extremely complicated biochemical reactions. Once within the plant, the original source of the mineral nutrient is no longer important.

Table 3.1 Important characteristics of plant mineral nutrients.

Category	Nutrient	Symbol	Primary form of uptake	Main form in soil reserves	Relative # atoms in plants
Macronutrient	Nitrogen	N	nitrate, NO_3^-, ammonium, NH_4^+	organic matter	1 million
Macronutrient	Phosphorus	P	phosphate, HPO_4^{2-}, $H_2PO_4^-$	organic matter, minerals	60,000
Macronutrient	Potassium	K	potassium ion, K^+	minerals	250,000
Macronutrient	Calcium	Ca	calcium ion, Ca^{2+}	minerals	125,000
Macronutrient	Magnesium	Mg	magnesium ion, Mg^{2+}	minerals	80,000
Macronutrient	Sulfur	S	sulfate, SO_4^{2-}	organic matter, minerals	30,000
Micronutrient	Chlorine	Cl	chloride, Cl^-	minerals	3,000
Micronutrient	Iron	Fe	ferrous iron, Fe^{2+}	minerals	2,000
Micronutrient	Boron	B	boric acid, H_3BO_3	organic matter	2,000
Micronutrient	Manganese	Mn	manganese ion, Mn^{2+}	minerals	1,000
Micronutrient	Zinc	Zn	zinc ion, Zn^{2+}	minerals	300
Micronutrient	Copper	Cu	cupric ion, Cu^{2+}	organic matter, minerals	100
Micronutrient	Molybdenum	Mo	molybdate, MoO_4^{2-}	organic matter, minerals	1
Micronutrient	Nickel	Ni	nickel ion, Ni^{2+}	minerals	1

Additional elements—including sodium (Na), cobalt (Co), and silicon (Si)—have been shown to be essential or beneficial in some, but not all, plant species.

3.1 Where Nutrients Come From

Since the concentrations of some plant nutrients are often less than optimal in soil, farmers commonly supplement the native supply with on-farm and off-farm resources. On-farm resources may include legume cover crops, animal manure, and crop residues. Off-farm resources may include various processed and unprocessed nutrients and soil amendments.

Of the nutrients, all except N are derived from naturally occurring earth minerals. A sophisticated global industry has been developed to extract these nutrients and concentrate them into forms that are convenient to handle and transport, and that provide a readily available nutrient to plant roots. Some earth minerals can be used directly as sources of plant nutrients or soil amendments, but many others require processing to increase solubility or concentrate the nutrients for efficient transport. Insoluble minerals release plant nutrients very slowly into the soil solution.

Leguminous plants (such as alfalfa, clovers, vetches, and beans) are capable of hosting bacteria (*Rhizobia, Bradyrhizobia, Sinorhizobia, etc.*) in root nodules. These nodules are the site where atmospheric N_2 gas is converted into plant-available forms of N. Legumes that are removed from the field for hay or animal feed may not leave large amounts of residual N in soil. Legumes that are grown and left in place (called green manure) contribute fixed N to nourish the crops that follow and build soil organic matter. The residual N following a cover crop will vary tremendously depending on the plant species and the local conditions.

Animal manures and composts are excellent sources of plant nutrients when used appropriately. Manures contain all elements essential to plants, though their relative ratios often differ from the relative amounts needed. Because some of the N, P, and S forms are organic, they may require a period of breakdown (mineralization) before they are converted into forms that can be assimilated by roots. Composts undergo controlled decomposition during their incubation period, resulting in an organic product that is relatively stable and slower to decompose than animal manures. The nutrients in manures and composts came from feed and hay harvested fields that likely received fertilizer; nutrients added to crops cycle from fields both nearby and far away. Of course animals produce no nutrients during their digestion, but merely excrete what is not absorbed from their feed.

Almost all nutrients enter plants through the root system. The primary form of uptake is shown in **Table 3.1**. Foliar fertilization can be useful in some situations, such as overcoming a developing deficiency or supplementing the nutrient supply during periods of peak demand. However plants are adapted to acquiring most of their nutrients from the soil solution through their roots.

3.2 Selecting the Right Source

The idea of selecting the most appropriate nutrient source seems simple in concept, but many factors need to be considered when making this choice. In addition to the six core scientific principles mentioned earlier, factors such as fertilizer delivery issues, environmental concerns, product price, and economic constraints can all be important. Decisions may be influenced by the availability of various materials within reasonable distance. The accessibility of fertilizer application equipment may also narrow the options. It is tempting to rely on tradition and experience when making these decisions, but a periodic review of these factors helps farmers gain the maximum benefit from these valuable resources and the significant economic investment they represent and allows consideration of new fertilizer materials.

Selecting the right fertilizer source begins with determining which nutrients are actually required to meet production goals. Nutrients that are limiting can be determined through the use of soil and plant analysis, tissue tests, nutrient omission plots, leaf color sensors, or visual deficiency symptoms (see Chapter 8). All of these need to be done in advance of the fertilizer application decision. Merely guessing at the needed nutrients can lead to numerous problems associated with under- or over-fertilization and can lead to ignoring specific nutrients until shortages become severe. Guessing at specific nutrient requirements can also result in poor economic return if over-applied nutrients are already present in adequate concentrations.

It is common to focus on a single nutrient that is in short supply to the exclusion of other nutrients. For example, a lack of adequate N is easy to detect by observing stunted growth and chlorotic leaves. However, the maximum benefit from applied N fertilizer will not be obtained if other deficiencies (such as P or K) are not also corrected. Although we often focus on individual nutrients, all the nutrients function together to support healthy plant growth.

Each plant nutrient is available in different chemical forms and they undergo unique reactions after entering the soil. Regardless of their original source and their soil reactivity, they must be in a soluble and plant-available form before they can be taken up by plants.

Fertilizers are normally sold with a grade, or guaranteed minimum analysis. The grade is represented as a series of numbers representing percent nutrient content by weight. The first number represents total N; the second, available P as P_2O_5 equivalent, and the third, soluble K as K_2O equivalent. For example, 100 kg of a 10-15-20 fertilizer contains 10 kg of N, 15 kg of P_2O_5, and 20 kg of K_2O. For fertilizers containing other nutrients, additional numbers can be added with the chemical symbol of the nutrient; for example, a 21-0-0-24S fertilizer contains 21% N and 24% S.

Questions ?

1. One of the seven core scientific principles that define **right source** for a specific set of conditions is to
   a. apply only plant-available forms of nutrients.
   b. suit soil physical and chemical properties.
   c. ignore blend compatibility.
   d. avoid applying associated elements.

2. An element is considered essential to plant growth if
   a. the soil contains only small quantities of it.
   b. plants require it in its elemental form.
   c. all plants require it to complete their life cycle.
   d. it is capable of being taken up by plants.

3. Selecting the right source of fertilizer should be based on
   a. tradition and experience.
   b. price alone.
   c. focusing only on a single nutrient in short supply.
   d. determining which nutrients are limiting.

4. The chemical forms of P and K in fertilizers are
   a. expressed as P_2O_5 and K_2O equivalents.
   b. P_2O_5 and K_2O.
   c. P and K.
   d. converted to elemental form by multiplying by 2.29.

Questions follow standard exam format but are designed to review main points and stimulate group discussion. For answers, see page A-7.

Note that the chemical forms of P and K in fertilizers are not P_2O_5 or K_2O. Rather, the oxide form is the traditional unit used for these fertilizer expressions. Phosphorus and potassium contents of fertilizers are expressed as P_2O_5 and K_2O equivalents, respectively. To convert from the oxide form to the elemental form, use the following conversion factors:

$$P_2O_5 \times 0.437 = P$$
$$P \times 2.29 = P_2O_5$$
$$K_2O \times 0.830 = K$$
$$K \times 1.20 = K_2O$$

Figure 3.1 Three types of compound fertilizers (containing a combination of N, P, and K in each granule)

3.3 Forms of Fertilizer

The form of fertilizer to be used is frequently one of the first decisions to make.

Bulk blends consist of a mix of various granular fertilizers in a batch that will meet the specific needs of a customer. Blends are adjusted with differing ratios of nutrients for individual crop and soil conditions. They are popular because they are made from least-cost components and mixed with relatively simple and inexpensive equipment. The individual fertilizer components must be chemically and physically compatible for mixing and storing.

Attention needs to be given to possible segregation of the individual components that may occur during transportation and handling. Fertilizer blending operators are aware of this concern and try to match uniform particle sizes of different nutrients to minimize segregation of the blended materials during transportation.

Compound fertilizers are a mixture of multiple nutrients within a single solid fertilizer particle (**Figure 3.1**). This approach differs from a blend of individual fertilizers mixed together to achieve an average nutrient composition. Each particle of compound fertilizer delivers a mixture of nutrients as it dissolves in the soil and eliminates the potential for any segregation of particles during transport

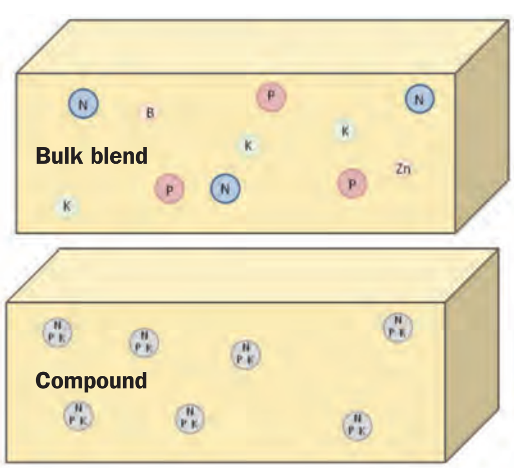


Figure 3.2 Nutrient distributions in soil comparing bulk blend and compound fertilizers. The more uniform distribution with compound fertilizers can be important for nutrients applied at low rates, the bulk blend offers more opportunity to match the recommended rate for each nutrient.

Questions ?

5. Compound fertilizers can be useful for
   a. single-nutrient applications.
   b. supplying differing ratios of nutrients to meet specific needs.
   c. eliminating potential segregation of particles.
   d. macronutrients without micronutrients.

6. Fluid fertilizers are popular because they
   a. are blended with granular fertilizers.
   b. can easily be added to irrigation water.
   c. are made from least-cost components.
   d. combine multiple nutrients within a single particle.

or application (**Figure 3.2**). A uniform distribution of micronutrients throughout the root zone is also possible when they are included in compound fertilizers. There are certain ratios of nutrients that are commonly available for various agronomic application and they offer simplicity in making fertilizer decisions.

Fluid Fertilizers are popular because they allow for mixing many nutrients into a single homogeneous, clear liquid that can be applied uniformly in the field. These clear fluids can be custom blended and applied as a starter fertilizer, a subsurface concentrated band, or dribbled as a topdress application. They are very popular for addition to irrigation water. Fluids are easy to handle and are excellent carriers for a variety of micronutrients, herbicides, and pesticides. Blending several materials together can reduce the number of trips required in the field, thereby reducing soil compaction and fuel consumption.

Fluid fertilizer

Not all fluid fertilizers are compatible with each other when mixed. **Figure 3.3** provides guidelines for mixing compatibility when combining fluid materials. It is always recommended to mix a small amount of fertilizer or chemical in a jar to test the mixing suitability before blending large quantities.

Applying fluid fertilizer with irrigation water (fertigation) is commonly done to save labor, increase the flexibility of timing nutrient application, and improve nutrient efficiency. This is done in both pressurized irrigation systems (such as drip, microsprinklers, or pivots) and in furrow irrigation. It

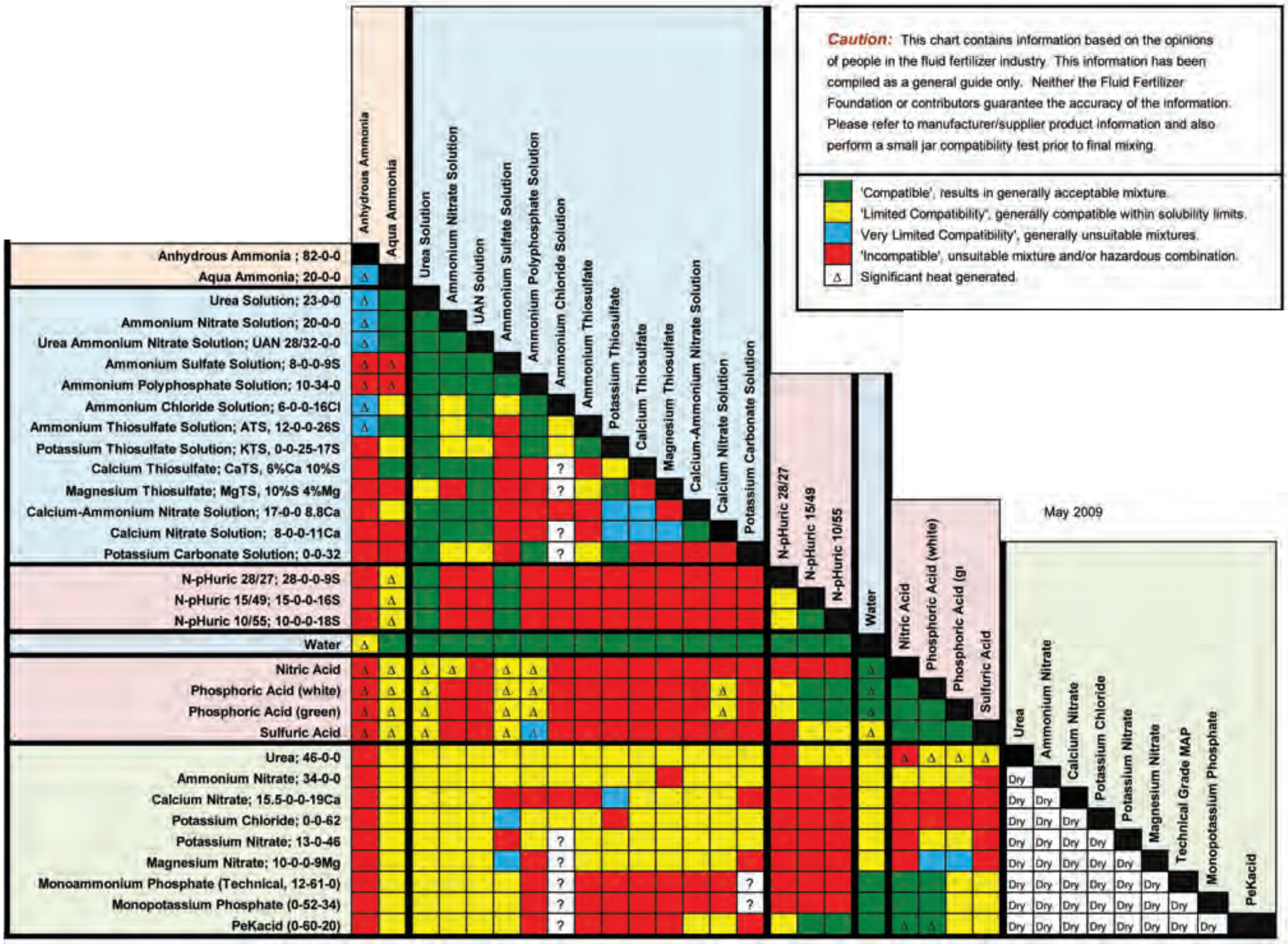


Figure 3.3 Compatibility of mixtures of fluid fertilizer (adapted from Fluid Fertilizer Foundation, 2009).

is important that nutrients used for fertigation do not cause clogging of the irrigation equipment or chemically precipitate before reaching the target area.

There are many excellent fertilizers that are compatible with any type of irrigation system. Particular attention needs to be given when adding P fertilizers to any irrigation water that contains abundant Ca or Mg in order to avoid chemical precipitation and plugging in the pipes and emitters. Also remember that nutrient distribution through fertigation can be no better than the uniformity of the water delivery system in the field.

Foliarly applied fertilizer

Fluid fertilizers are also used for foliar nutrition, spraying a dilute nutrient solution onto leaves. This technique can be particularly effective in overcoming or preventing nutrient shortages or for meeting periods of peak nutrient demand when root uptake may be insufficient to meet plant needs. However, foliar nutrition is generally considered as a supplement to nutrient uptake through the root system. Many high solubility materials are used as foliar fertilizers to meet every potential nutrient deficiency. The solution sprayed onto the leaf surface is generally relatively dilute in order to avoid salt (osmotic) damage to the foliage. When the fertilizer concentration is too high in the foliar spray, the leaf tissue can become desiccated and damaged (commonly referred to as leaf burn). Product labels should be closely followed to achieve maximum nutritional benefit.

Suspension fertilizers are made by suspending very small particles within a solution. A suspending clay or gelling agent is used to keep the fertilizer particles from settling out of the liquid. Suspensions allow use of fertilizer materials lower in solubility than those that can be used with clear liquid fertilizers, and higher nutrient concentrations can be achieved. Larger quantities of micronutrients can be incorporated into suspensions, as well as herbicides and insecticides that are not suitable for clear fertilizers. Some type of agitation is commonly used in the tank to keep the suspension well mixed. Larger nozzles are used for application than with clear fluid fertilizers.

Enhanced-efficiency fertilizers are not a single group of materials, but consist of products or technologies that generally improve fertilizer use efficiency beyond standard practices and materials.

Slow-release and controlled-release fertilizers can be useful for improving nutrient use efficiency. There are several mechanisms for controlling nutrient release from a fertilizer particle. The most common is when a protective coating of polymer or S is added to a fertilizer in order to control the dissolution and release of nutrients (**Figure 3.4**). Typical release rates range from a few weeks to many months. Other slow-release fertilizers may have low solubility or a resistance to microbial decomposition to control nutrient release. Each of these products may be well suited to a specific set of conditions, but that does not mean that they are well suited to all conditions. Specific products must be matched with the proper soil, crop, and environmental conditions in order to get maximum benefit. Nitrogen is the nutrient generally targeted for controlled release, but there are circumstances when sustained release of other nutrients is also desirable.

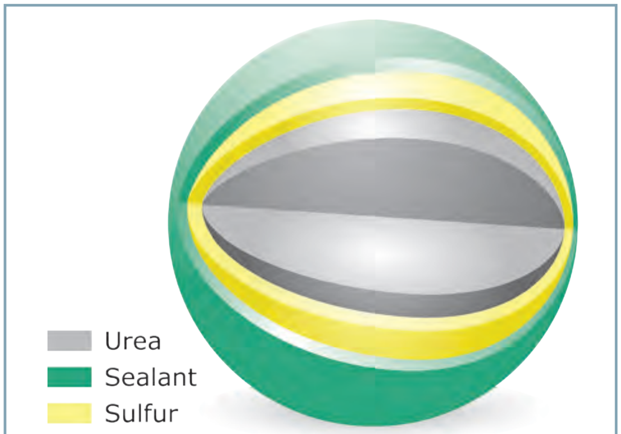


Figure 3.4 Coated enhanced fertilizer example.

Biological and chemical inhibitors are sometimes added to fertilizer to temporarily enhance or disrupt very specific soil reactions. Nitrification inhibitors are additives which slow the conversion of ammonium to nitrate in soil, which may reduce the possibility of nitrate leaching or denitrification. Urease inhibitors, another class of additives, can be used with urea fertilizer to temporarily delay its transformation to ammonium by inactivating urease, a common soil enzyme. This delay can reduce ammonia volatilization losses to the atmosphere, especially when urea is applied to the soil surface.

Polymeric materials are liquid polymers developed to temporarily bind with soil cations with the objective of reducing chemical reactions that can decrease P solubility.

3.4 Forms of Organic Amendment: Manures, Composts

Organic materials can be excellent sources of both macro and micronutrients for crop nutrition. Since these materials are extremely variable depending on their source, handling, and processing, only general principles are given here.

Much of the N in manure and composts is present in organic compounds which must be converted by soil microbes (mineralized) to ammonium or nitrate before uptake by roots. Mineralization rates are determined by microbial activity, which varies with environmental factors (such as temperature and moisture), the properties of the organic material (such as the C:N ratio and lignin content) and the placement (incorporation) of the organic material. Failure to synchronize N release with crop uptake can lead to N shortages and plant nutrient deficiencies, or lead to excessive N release beyond the growing season. (**Figure 3.5**). The ratio of N to P in many manures is not in proper balance with plant requirements. When manures are added to meet the N requirement of crops, P may be overapplied by 3 to 5 times the crop demand. Long-term manure application can result in P accumulation unless attention is given to this imbalance.

Animal manures vary tremendously in their chemical and physical composition due to specific feeding and manure management practices. Nitrogen in manures is present in both inorganic and organic compounds. Nitrogen in fresh manure can be unstable because ammonia can be readily lost through volatilization. Application of fresh manure or slurry on the soil surface can result in large losses of N by volatilization in some situations. Application timing and placement are important considerations for minimizing such losses. Estimating the correct application rate for manure should begin with an accurate chemical analysis of the nutrient content and prediction of N mineralization rates following application. The majority of P in manures and composts is in the inorganic phosphate form and all of the K is present as inorganic K^+, immediately available for plant uptake.

Composts generally contain low concentrations of nutrients. Properly composted materials typically decompose slowly and behave as a slow-release source of N over many months or years. Composts can vary tremendously in quality, maturity, and nutrient content based on the materials included, the conditions of the process, and their handling.

3.5 Nutrient Interactions

Interactions occur when the chemical form or the concentration of a specific nutrient influences the behavior of another nutrient. These interactions are not always well understood or documented, but they are known to occur in the fertilizer, in the soil, in the root zone, and within the plant. Favorable interactions (synergisms) are observed with some nutrients. Undesirable interactions (antagonisms) can

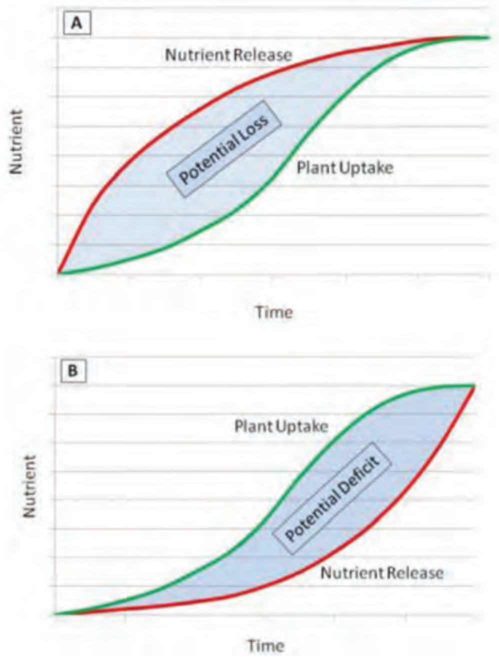


Figure 3.5 Synchronizing nutrient release with plant demand is a challenge with organic materials. Rapid release from organic sources with a low C:N ratio may supply nutrients more rapidly than the plant's demand (A). An organic material with a high C:N ratio may not release nutrients sufficiently rapid to meet the need of growing plants (B).

be avoided by monitoring nutrient status with plant and soil analysis to prevent extreme conditions.

A few examples of nutrient interactions include: (i) the presence of NH_4^+ can improve P availability to plants, thereby improving plant growth, (ii) excessive fertilization with K can lead to depressed uptake of Mg by some forages, resulting in nutritional problems for grazing cattle (grass tetany) or higher incidence of milk fever and retained placentas when fed to dry dairy cows, (iii) high concentrations of P in the soil can interfere with Zn assimilation in some plants, (iv) increases in soil pH following addition of limestone may improve the availability of P and Mo, but reduce the solubility of Cu, Fe, Mn, and Zn.

There is no one single right source of nutrient for all conditions. The need of specific nutrients should be established in advance of application whenever possible. Factors such as fertilizer product availability, nutrient reactions in soil, spreading equipment, and economic return, all need to be considered. These complex decisions should be continually re-evaluated in order to make the right fertilizer selection. **4R**

REFERENCES

Havlin, J.L. et al. 2005. Soil Fertility and Fertilizers: An Introduction to Nutrient Management. 7th edition. Pearson Prentice Hall. NJ, USA.

UNIDO-IFDC. 1998. Fertilizer Manual. Kluwer Academic Publishers, Dordrecht, the Netherlands.

Questions ?

7. Controlled-release fertilizers can improve nutrient use efficiency
   a. under specific field conditions.
   b. equally for all nutrients.
   c. by inactivating the urease enzyme.
   d. under all field conditions.

8. Urease inhibitors reduce losses of ammonia most when applied with
   a. urea broadcast on the soil surface.
   b. urea incorporated into the soil.
   c. ammonium sulfate broadcast on the soil surface.
   d. urea ammonium nitrate incorporated into the soil.

9. For a short time after application, monoammonium phosphate (MAP) differs from diammonium phosphate (DAP) in that
   a. DAP provides phosphorus in a more plant-available form.
   b. the nitrogen in DAP will be used more readily by the plant.
   c. only MAP will convert to polyphosphate.
   d. the soil pH around a MAP granule will be lower.

10. Most potassium fertilizer sources
    a. contain potassium in different chemical forms.
    b. differ primarily in the accompanying anions.
    c. should be selected based only on price.
    d. are more effective than manure as a potassium source.

Questions 9 and 10 refer to material in the modules for section 3.3 on the following pages.

M

Module 3.1-1 The right source of potash improves yield and quality of banana in India. Potassium is an important nutrient in banana production, for both yield and quality. Sulfate of potash (K_2SO_4 or SoP) has a lower salt index and supplies the plant nutrient S, as compared to muriate of potash (KCl or MoP) which supplies the plant nutrient chloride (Cl^-), in addition to K. A study on banana in the south Indian state of Tamil Nadu showed benefits to applying SoP as compared to MoP, as indicated in **Figure 1** below. **Adapted from:** Kumar, A.R. and N. Kumar. 2008. EurAsia J BioSci 2(12):102-109.

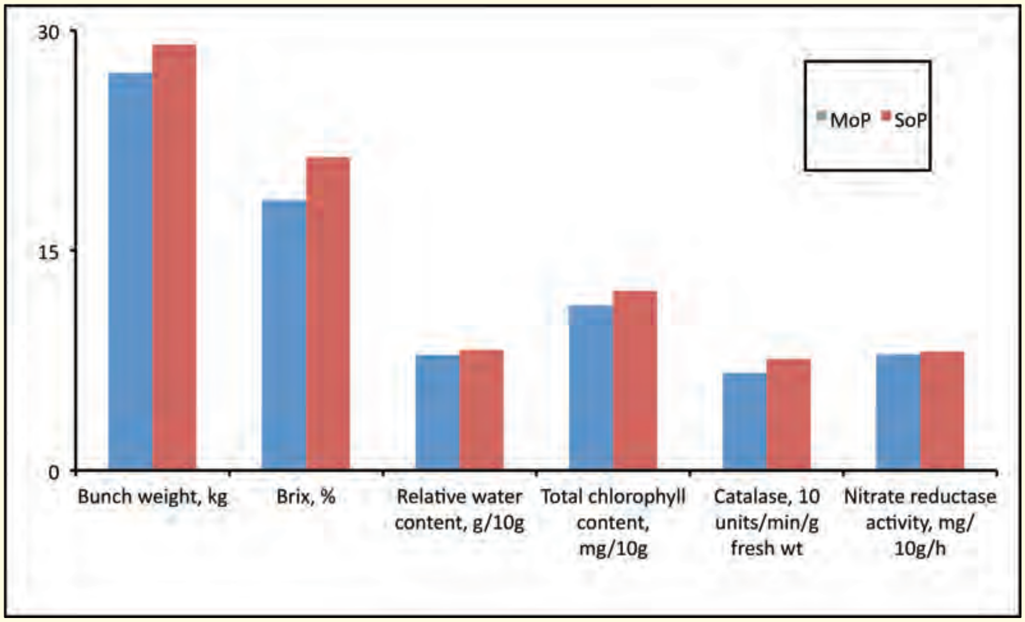
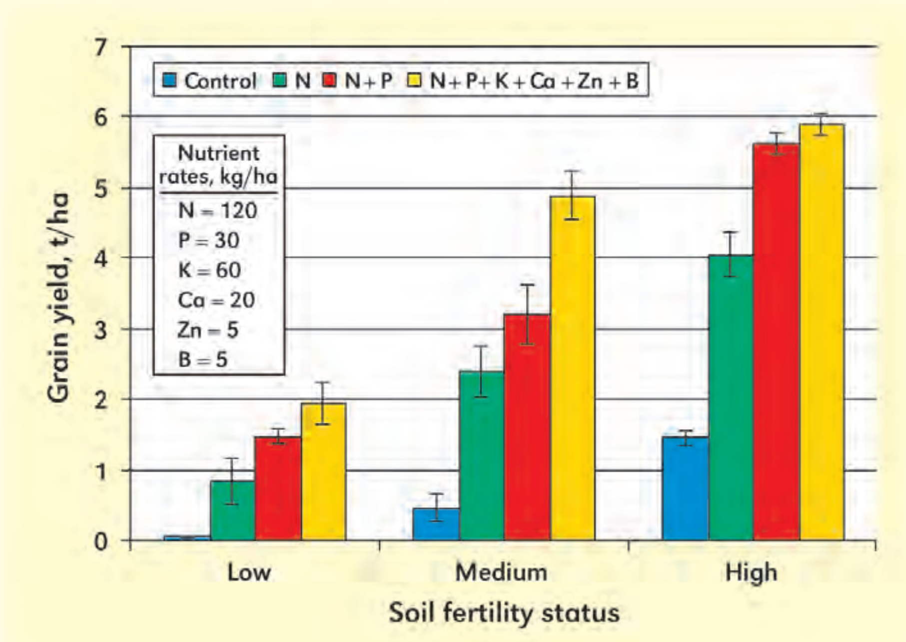


Figure 1. Banana bunch weight, Brix (total soluble sugars), relative water content, and photosynthetic parameters (chlorophyll content, catalase, and nitrate reductase activity) as affected by MoP and SoP as potassium sources.

Submitted by H.S. Khurana, IPNI, India, December 2011.

M

Module 3.2-1 Balancing organic and mineral nutrients for maize in Africa. Studies in sub-Saharan (SSA) show that fertilizer use is consistently more profitable and efficient on fertile fields. When soils are degraded, restoration of soil fertility through balanced fertilization and organic matter additions is necessary to achieve high crop productivity. Other options for managing soil fertility, such as manure, crop rotations, and improved fallows are most effective when strategically combined with fertilizer. In trials conducted on fields varying in soil fertility across many locations in SSA, application of N alone gave the largest maize yield increase under high and medium soil fertility conditions. Addition of P also led to a significant increase in yields on the high fertility fields, but in medium fertility fields, addition of base cations (K and Ca) and micronutrients (Zn and B) was required to significantly increase crop yields above the N treatment. On the low fertility fields, yields were increased to less that 1 t/ha by applying N and to less than 2 t/ha by applying N, P, K, Ca, Zn and B. Under such conditions, addition of organic resources to increase soil organic matter is required to increase retention of soil nutrients and water, better synchronize nutrient supply with crop demand, and improve soil health through increased soil biodiversity.
Source: Zingore, S. 2011, Better Crops with Plant Food 95(1): 4-6.



Submitted by S. Zingore, IPNI, Kenya, December 2011.

Urea

Module 3.3-1 Urea is the most widely used solid nitrogen fertilizer in the world. Urea is also commonly found in nature since it is expelled in the urine of animals. The high N content of urea makes it efficient to transport to farms and apply to fields.

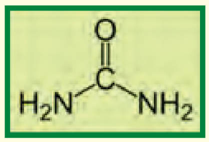
Production. The production of urea fertilizer involves controlled reaction of ammonia gas (NH_3) and carbon dioxide (CO_2) with elevated temperature and pressure. The molten urea is formed into spheres with specialized granulation equipment or hardened into a solid prill while falling from a tower.

During the production of urea, two urea molecules may inadvertently combine to form a compound termed biuret, which can be damaging when sprayed onto plant foliage. Most commercial urea fertilizer contains only low amounts of biuret due to carefully controlled conditions during manufacturing. However, special low-biuret urea is available for unique applications.

Urea manufacturing plants are located throughout the world, but most commonly located near NH_3 production facilities since NH_3 is the major input for urea. Urea is transported throughout the world by ocean vessel, barge, rail, and truck.

Chemical Properties

Chemical formula:	$CO(NH_2)_2$
N content:	46% N
H_2O Solubility (20°C):	1,080 g/L



Agricultural Use. Urea is used in many ways to provide N nutrition for plant growth. It is most commonly mixed with soil or applied to the soil surface. Due to the high solubility, it may be dissolved in water and applied to soil as a fluid, added with irrigation water, or sprayed onto plant foliage. Urea in foliar sprays can be quickly absorbed by plant leaves.

After urea contacts soil or plants, a naturally occurring enzyme (urease) begins to quickly convert the urea back to NH_3 in a process called hydrolysis. During this process, the N in urea is susceptible to undesirable gaseous losses as NH_3. Various management techniques can be used to minimize the loss of this valuable nutrient.

Urea hydrolysis is a rapid process, typically occurring within several days after application. Plants can utilize small amounts of urea directly as a source of N, but they more commonly use the ammonium (NH_4^+) and nitrate (NO_3^-) that are produced after urea is transformed by urease and soil microorganisms.

Management Practices. Urea is an excellent nutrient source to meet the N demand of plants. Because it readily dissolves in water, surface-applied urea moves with rainfall or irrigation into the soil. Within the soil, urea moves freely with soil water until it is hydrolyzed to form NH_4^+. Care should be used to minimize all N losses to air, surface water, and groundwater. Losses of ammonia by volatilization can be managed by careful attention to timing and placement. Avoid urea applications when the fertilizer will remain on the soil surface for prolonged periods of time. Undesired N losses may also result in loss of crop yield and quality.

Urea is a high N-containing fertilizer that has good storage properties and causes minimal corrosion of application equipment. When properly managed, urea is an excellent source of N for plants.

Non-agricultural Use. Urea is commonly used in a variety of industries. It is used in power plants and diesel exhaust systems to reduce emission of nitrous oxide (NO_x) gases. Urea can be used as a protein supplement in the diet of ruminant animals, such as cattle. Many common industrial chemicals are made using urea as an important component.

Source: http://www.ipni.net/specifics

M

Urea-Ammonium Nitrate

Module 3.3-2 Liquid fertilizer solutions or fluid fertilizers are popular in many areas because they are safe to handle, convenient to mix with other nutrients and chemicals, and are easily applied. A solution of urea [$CO(NH_2)_2$] and ammonium nitrate [NH_4NO_3] containing between 28 and 32% N is the most popular N fluid fertilizer.

Production. Liquid urea-ammonium nitrate (UAN) fertilizer is relatively simple to produce. A heated solution containing dissolved urea is mixed with a heated solution of ammonium nitrate to make a clear liquid fertilizer. Half of the total N comes from the urea solution and half from the ammonium nitrate solution. UAN is made in batches in some facilities or in a continual process in others. No emissions or waste products occur during mixing.

Since UAN is a concentrated N solution, its solubility increases as the temperature rises. To prevent the N components from precipitating as crystals, UAN solutions are made more dilute in regions with cold winter temperatures. Therefore, the N concentration in commercial UAN fertilizers will vary from 28% N to 32% N depending on geography. A corrosion inhibitor is usually added to the final solution to protect the steel in storage tanks.

Chemical Properties

	28% N	30% N	32% N
Composition (% by weight)			
Ammonium Nitrate:	40	42	44
Urea:	30	33	35
Water:	30	25	20
Salt-out temperature (ºC):	-18	-10	-2
Solution pH:	- - - -	approximately 7	- - - -

Agricultural Use. Solutions of UAN are widely used as a source of N for plant nutrition. The NO_3^- portion (25% of the total N) is immediately available for plant uptake. The NH_4^+ fraction (25% of the total N) can also be assimilated directly by most plants, but is rapidly oxidized by soil bacteria to form NO_3^-. The remaining urea portion (50% of the total N) is hydrolyzed by soil enzymes to form NH_4^+, which is subsequently transformed to NO_3^- in most soil conditions.

Solutions of UAN are extremely versatile as a source of plant nutrition. Due to its chemical properties, UAN is compatible with many other nutrients and agricultural chemicals, and is frequently mixed with solutions containing P, K, and other plant nutrients. Fluid fertilizers can be blended to precisely meet the specific needs of a soil or crop.

UAN solutions are commonly injected into the soil beneath the surface, sprayed onto the soil surface, dribbled as a band onto the surface, added to irrigation water, or sprayed onto plant leaves as a source of foliar nutrition. However, UAN may damage foliage if sprayed directly on some plants, so dilution with water may be needed.

Management Practices. UAN makes an excellent source of N nutrition for plants. However, since half of the total N is present as urea, extra management of timing and placement may be required to avoid volatile losses. When UAN remains on the surface of the soil for extended periods (a few days), soil enzymes will convert the urea to NH_4^+, a portion of which can be lost as ammonia gas. Therefore, UAN should not remain on the soil surface for more than a few days in order to avoid significant loss. Inhibitors that slow these N transformations are sometimes added. When UAN is first applied to soil, the urea and the NO_3^- molecules will move freely with water in the soil. The NH_4^+ will be retained in the soil where it first contacts cation exchange sites on clay or organic matter. Within 2 to 10 days, most of the urea will be converted to NH_4^+ and no longer be mobile. The originally added NH_4^+ plus the NH_4^+ coming from urea will eventually be converted to NO_3^- by soil microorganisms.

Source: http://www.ipni.net/specifics