Nutrient Sources and Applications Module

Certified Crop Advisor

State Performance Objectives

General New Mexico Plant Nutrient Sources and Applications Competency Areas:

1. Basic concepts of nutrient sources
2. Chemical, soil, climatic, management and geological/geographic factors influencing fertilizer use
3. Why soil testing and fertilizer calibration is needed
4. Environmental concerns to consider when using fertilizers
5. Fertilizer application methods

Learning Objectives

The objectives for the New Mexico Nutrient Management Module are:
- Know how the nutrients, soil and geological factors play into fertilizer use decisions
- Know why you should carefully weigh decisions to use fertilizers
- Know the environmental constraints when using certain nutrient sources
- Know the different ways nutrients can be applied to crop land
- Know the application technologies available for fertilizer use

Competency Area One. Basic concepts of nutrient sources and applications

This competency area will review basic plant nutrient sources and applications.

Pre-Study Questions for Review

1. What three characteristics of fertilizers determine if they will move into groundwater?
   a. persistence, quantity and weight
   b. permeability, persistence and charge
   c. solubility, soil absorption and persistence
   d. solubility, stability and quantity
2. What are three routes that nitrogen fertilizer can be lost from the soil by waterl?
   a. evaporation, leaching and litigation
   b. runoff, erosion and residual loss
   c. leaching, runoff and erosion
   d. volatilization, litigation and runoff
3. The chemical composition of manure that can be applied to crop land is determined by?
   a. animal species, age/condition of the animals, nature/amount of litter and handling/storage
   b. food intake of the animal, size of the animal, handling/storage, age
   c. height of the animal, location of the animal, stored age, consistency
   d. consistency of the manure, color, weight, handling/storage
4. Land application of municipal biosolids regulate ceiling levels of potential _____.
   a. prominent perks
   b. pollutants
   c. pesky pests
   d. wildlife hazards
5. Chemigation can be used without mishap if you prevent _____.
   a. kinks in the injection line from the fertilizer source
   b. dripping nozzle tips in overhead irrigation systems
   c. running out of fertilizer during irrigation

d. back-siphoning

Check your answers before proceeding into the unit to find out how much you already know about basic concepts of nutrient sources and applications. Each correct answer is worth 20 points, based on a total of 100 points for the five questions. Answers: 1. c.; 2. c.; 3. a.; 4. b.; 5. d.

Basic concepts of nutrient sources

Applied correctly and at the proper rate, fertilizer materials may be applied timely and at a rate needed for a specific soil and crop. Some of the nutrient materials are more convenient to apply than others and some may be less likely to produce environmental contamination when used on certain sites. Careful calibration of nutrient needs based on available minerals already in the soil, knowledge of the needs of the crop being grown as well as attention to environmental concerns will optimize crop use of the nutrients and be economically sustainable for the farmer whether using commercial fertilizers as a supplement or manures or even green manures. The nutrient forms in which minerals are available for use by crop plants as well as the most common fertilizers used for the primary and trace minerals additions have already been discussed in a previous section. Review this information along with the general fertilizer recommendations for specific crops for an idea of the nutrients needed during a cropping cycle. Know the available nutrients within the field, the crop being grown, the mobility of each nutrient from the soil or from the addition of a commercial fertilizer, manure or a green manure crop and the potential for tie up of some of the nutrients and you can begin to estimate fertilizer needs. Soil testing as well as plant tissue testing can refine your estimate and optimize the economics in fertilizer additions.

Accelerated eutrophication is one of the water quality problems caused by excessive nitrogen and phosphorus loading within a site. Groundwater may be affected by overloads of nutrients by causing poor water taste and foul odors from eutrophication. Surface waters may show nuisance algal blooms, heavy aquatic weed growth and even fish kills from eutrophication. Nitrogen contamination of drinking water supplies can increase the rate of “blue baby” incidence unless the nitrogen amount is controlled and contained. Soil testing is a key element in proper fertilizer management as it can reduce the losses of nitrogen and phosphorus from crop land.

Some of the best management practices for controlling the losses of commercial fertilizers to surface and ground waters include:

1. soil testing—can help determine proper fertilization rates
2. proper fertilization rates—can reduce the potential nitrogen losses by 35-94 percent as compared to excessive rates
3. spring fertilizer application just before spring and summer crops—can limit losses
4. split applications of nitrogen—can reduce losses by up to 30 percent, especially in areas of intensive irrigation
5. level terraces on sloped land—can reduce nitrogen losses by as much as 85 percent but where ground water contamination potential exists, contour farming may be more beneficial
6. drainage control—can reduce nitrate losses by 50-98 percent on irrigated tracts
7. slow-release nitrogen fertilizers—may reduce nitrogen losses by as much as 95 percent
8. crop rotations, no-till and conservation tillage where useful—may reduce surface nitrogen losses by 40-85 percent
9. incorporation of broadcast fertilizer—can limit losses
10. level terraces on sloped ground—can reduce phosphorus losses by as much as 67 percent
11. rotational grazing, crop rotations, cover crops and conservation tillage—can reduce phosphorus losses by 40-70 percent
12. sedimentation basins and flow control especially on irrigated land—can decrease phosphorus losses

Specifically in nitrogen management, the method of fertilizer application and the farm management practices, including irrigation practices, can influence losses. In New Mexico, intensive, high-dollar crops that are subirrigated with fertilizer placement above the subirrigation lateral or carefully calibrated fertilizer metered into the drip system is superior to flood, furrow and sprinkler irrigation from the standpoint of minimizing nitrogen movement below the plant root zone. Simultaneous knifed applications of nitrogen and phosphorus can produce consistently higher winter wheat yields than either broadcast or band applications. Sulfur coated urea, when used, will reduce the nitrogen leaching due to inhibition of the release of NO_3 nitrogen from the applied fertilizer. Alfalfa is an economically effective control of sediment and total nutrient loads but over time, the soluble nitrogen concentration should be monitored in areas where shallow ground water could be affected. Increased plant cover resulting from fertilization of grassland, can eventually decrease nutrient losses by decreasing runoff volume and soil erosion. Nitrogen losses from southwest prairies can be minimized by controlling sedimentation and following soil test results for proper fertilizer application rates. Phosphorus runoff from irrigated tracts can be limited by minimizing the quantity of surface drainage water and by using sediment retention basins or low slope drains. Nitrogen and phosphorus application rates should not at any time exceed the assimilative capacity of the crop. Where possible, timing of the nitrogen application should be matched with maximum plant nutrient demand. Applications that best place these nutrients within reach of a crop will decrease potential losses to surface and ground waters.

Chemical, soil, climatic, management and geological/geographic factors influencing fertilizer use

When choosing the best fertilizer to use for a job, remember to consider how the nutrients can affect the potential for optimum nutrient use by the crop and how the surrounding land, water and environment will be affected. Some of the factors to look at when considering fertilizer use are the chemical characteristics, the soil constraints, climate effects, management practices and the geological limitations. Fertilizers can vary in their potential to move into surface and ground water as well as leach, volatilize or become unavailable.

Three major chemical characteristics to keep in mind on fertilizers are their solubility, soil adsorption and persistence. The greater the water solubility of the fertilizer, the more potential for leaching down into the soil profile away from crop roots and possibly into ground water. If the fertilizer used becomes attached to soil particles the minerals may not be leached downward quickly but they may also become so strongly adsorbed that the fertilizer is quickly unavailable to crop plants. Persistence of the fertilizer formulation will also make a difference. Some fertilizers are available early after incorporation but later are tied up to soil. Some fertilizer formulations may be slow-release, thus prolonging availability to crop plants and lessening the possibility that the fertilizer may be leached out of the root profile. Depending on the environmental limitations within a site, you may have to choose certain fertilizers over others.

The soil characteristics may also be important to limit fertilizer loss from a site. The three key characteristics that may affect fertilizers in soil are soil texture, soil permeability and soil organic matter. The soil texture, the proportions of sand, silt and clay, will affect adsorption of nutrients, especially to clay and organic matter. Coarse or sandy soils will allow many fertilizers to leach with water down deeper into the soil profile and possibly away from crop roots. Finer textured soils allow slower movement into the profile and also contain more silt and organic matter that can tie up nutrients more. Soil permeability indicates how fast water can move downward in soils and may on mobile nutrients leach them below the rooting zone. Soil organic matter determines not only if nutrients can be tied up in soils but also how much water the soil can hold before downward leaching may occur.

Climatic factors may affect persistence and movement of fertilizers. Time applications during favorable weather conditions to limit losses during or shortly after applications.

Crop rotation, tillage and irrigation all influence applied fertilizers. Use sensible management practices to prevent contamination from nutrients applied to a site.

Geological limitations may also exist on site. Ground or surface water distance from the fertilizer application site will determine if pollution potential exists. Permeability of geological layers is also important. Sinkholes within a site could allow fertilizer to drain to further depths than anticipated, even with only a moderate rain or irrigation.

Why soil testing and fertilizer calibration is needed

Soil testing and calibration of fertilizer applications are necessary in order to prevent excess nutrients from being applied. Excess nutrients can cause environmental contamination of ground and surface waters, toxicity to crop plants, excessive cost and loss of sustainability of the field and in some cases excess nutrients may limit the availability of other minerals by activity competing for plant absorption sites or by masking the availability of some trace minerals.

Soil testing is a means of using chemical analysis to assess the nutrient levels in the soil. From this analysis, decisions on fertilizer can be more scientifically based for profitable crop production. From an environmental point of view, a soil test can safeguard against improper fertilizer applications.

Fertilizer recommendations, even with soil testing, may be based on three approaches for cropping needs. These approaches are: deficiency correction; maintenance; and, nutrient removal or a balanced application. Under the deficiency correction philosophy, fertilizer is added only to the point of an economic yield recommendation. In other words, a correlation is made to determine different crop yields at varying nutrient levels from which the optimum yield is determined using the soil test level (calibration) to the point where enough fertilizer will be added to correct any deficiency. This is a practical approach to fertilizer recommendations for farmers who may be dealing with short-term leases that do not provide time for recovery of fertilizer investments made when applying rates required to build the soil or to farmers trying to save money during periods of fertilizer shortages or extremely high costs. With the deficiency correction method, the farmer will be looking for maximum economic yield, the point where he can make the most profit from the fertilizer applied. Under the maintenance philosophy, the farmer is maintaining the soil fertility at the level of maximum economic yield or slightly above this level. This is the common recommendation plan suggested by commercial soil testing laboratories. This maintenance plan with some “build” in the recommendation is practical for a land owner who expects to utilize the land for many years and can continue this maintenance plan over time. The nutrient removal or balance philosophy bases fertilizer recommendations on the best ratio of basic cations with the best total base saturation for a soil for optimum growth of a crop. This balance concept keys in on the ratio of calcium, magnesium and potassium in a soil to optimize the CEC of the soil. This plan makes the assumption that higher soil fertility levels will grant long-range high soil fertility that will pay off in ever-increasing yields. The advantage is that this plan returns nutrients taken off when crops are harvested and thus should retain the soil’s initial productivity. The disadvantage of this approach is that it can sometimes over-recommend nutrients as it does not completely account for the soil’s own ability to supply many of the essential nutrients to plants.

Soil test values are used to indicate deficiencies or excesses of nutrients in soil and are also used to base recommendations for fertilizers. However, not all laboratories use the same reporting methods. You need to be able to interpret the items on a soil test report. On nitrogen, some laboratories report in parts per million (ppm), some in pounds per acre of actual nitrogen, and some in pounds per acre of NO_3.

Interpreting Soil Test Results on Nitrogen
(converting between ppm and pounds per acre on a 6-inch soil depth)

PPM (NO_3-N)	Pounds per Acre (NO_3-N)
5	10
10	20
20	40
40	80

The average soil contains from 2,000 to 3,000 pounds per acre of total phosphorus (P_2O_5) in the plow layer. The amount in the soil solution, however, is usually only in the range of 0.01 to 0.5 ppm (one pound per acre). The phosphate molecule easily reacts with calcium in alkaline soils and will also react with iron and aluminum in acid soils, thus limiting the solubility of phosphorus in soils. A large portion is also tied up in the organic fraction of the soil. To determine the fraction of phosphorus that is available to plants, most laboratories in the western part of the United States that are working with neutral, alkaline or calcareous soils will use the Olsen extracting solution method. In acid soils with fine textures, the Bray P-1 extraction method works best. In acid, sandy soils such as found on the coastal plains of the Eastern United States, the Mehlich double acid extraction is used. The Morgan extraction method is used on soils that are acid and have medium to coarse textures. From these test levels, a recommendation can be made based on yield goal for the crop.

Available potassium is reported in pounds potassium per acre, parts per million (ppm), or milliequivalents per 100 grams (meq/100 grams). The amount of potassium available is made by taking a soil sample and displacing the potassium ions from the soil's CEC sites with an ammonium acetate solution so that the ammonium ions will exchange sites with the potassium and those allow the potassium content to be read by an atomic absorption spectrophotometer. With potassium, recommendations are usually simply made based on maintenance or buildup. Even under a rotation, fields should be built up to the level for the crop requiring the highest level of potassium so that adequate, available amounts are accessible to the crops.

Other nutrients required by crops can also be tested for in the laboratory from field soil samples. It is important to accurately determine the amount of nutrients needed in a field for specific crops. The use of plant tissue analyses from one crop may also be helpful in determining needs for later crops. Correct determination of nutrient needs is important in order to produce the maximum economic yield that allows 1.) a realistic yield goal to be produced; 2.) a minimization of the expense of the fertilizer and the application made; 3.) optimization of the application method and timing to be allowed; 4.) an increase in the value of the land owned or to minimize the expense of the rental land; and, 5.) to optimize the value of the crop produced. In order to optimize these factors, soil testing must take into account the soil type, slope, degree of erosion, plant nutrient removal from previous crops, other soil tests and nutrient applications, soil drainage, location of surface and ground waters, and the amount of precipitation or irrigation expected on the land. This allows the fertility program to environmentally match the needs of the site. This will also allow more information toward determining when and how a nutrient application should be made as well as the correct calibration of the equipment to apply the fertilizer. Correct calibration from soil testing results takes into account the following factors: crop type, plant populations, realistic yield potentials, variety characteristics, soil type characteristics, nutrient effects on the soil and environment, crop use of nutrients, nutrient uptake requirements, growing season length, crop rotation effects, location of ground and surface waters, soil erosion, tillage affects. Correct interpretation of soil test results will allow adequate nutrient amounts to be used without endangering a site to environmental contamination or other concerns. It also determines the calibration needed to successfully implement a safe and sustainable fertility program.

Environmental concerns to consider when using fertilizers

Some of the general environmental concerns you should consider before applying fertilizers have been discussed. However, each fertilizer has different chemical characteristics that are important to know about when using the fertilizer.

Nitrogen fertilizers

Anhydrous ammonia is one of the most commonly used fertilizers. Normally, it is the least expensive nitrogen source even though it has higher related costs associated with manufacturing and handling this material at the retail dealer level. The guaranteed analysis is 82-0-0, or 82 percent nitrogen. Relatively a pure product, NH_3 is a gas at room temperature. When applied to the soil surface, the ammonia will evaporate and be lost to the air. Thus, it is injected below the surface where the ammonia is temporarily trapped in the soil water.

$NH_3 + H_2O \leftarrow\text{-}\rightarrow NH_3H_2O \leftarrow\text{-}\rightarrow NH_4^+ + OH^-$

Next, the ammonium is immobilized in soil in an available but stable form by adsorbing onto clay and organic matter surfaces through the CEC reaction.

NH_4^+ (aquous) + K^+ clay $\leftarrow\text{-}\rightarrow$ K^+ + NH_4^+ clay

Although some retention of the nitrogen in this form is set, water movement through a sandy soil will move NH_4^+. Ammonia should not be applied with the seed. A safe distance from the seed is three inches n heavy soils and four inches in sand. Ammonia will also move more in very dry soils than in moist soils. It moves upward in wet soils, especially when soil does not cover over the application path. Thus, ammonia should not be placed directly under crop seed, since it may track upwards along the knife track. Shallow placed ammonia can sometimes become positionally unavailable. Dry surface soils can prevent nitrogen uptake by plant roots. Anyhdrous ammonia may also be side-dressed in crops. Again, the fertilizer must be knifed into the soil as free ammonia escaping from a badly sealed application can burn crop leaves. Ammonia does not have any adverse effects on soil structural properties, but microbial populations may be higher in the knifed in areas after a time due to their use of the available nitrogen and their increase in population near this resource.

Urea is a white, granular fertilizer has usually has an analysis around 46-0-0. It can be broadcast or banded or sometimes used as a top-dress application. Urea is hygroscopic, it attracts water and thus storage of this fertilizer must be in an area where humidity is kept as low as possible and out of snow or rain. Urea cannot be mixed with all dry fertilizer products as it has some compatibility problems (such as with ammonium nitrate and triple super phosphate) that can cause the material to become wet and unspreadable. Compatibility checks are always important, especially if the urea is impregnated with a liquid agrichemical as these too can turn the stable urea into an unspeadable mess. Once applied to the soil, urea converts to ammonia before being adsorbed onto clay and organic matter. Under moist conditions, warm temperatures and as an application onto crop residues, urea more quickly will breakdown. Ammonia released from breakdown is susceptible to volatilization losses, especially if water is evaporating from the soil. Urea is best managed by covering with soil soon after application by incorporating broadcast applications or by knifing in the product or by subsurface banding at seeding. Because ammonia volatilization can occur with urea, urease inhibitors have been developed. These compounds (such as phenyl phosphorodiamidate, PPD, and N-(n-butyl) thiophoshoric triamide, NBPT) can lengthen the time needed between application and a rainfall (that incorporates in the urea) but can add

cost to the fertility program. The nitrogen and sulfur containing fertilizer, ammonium thiosulfate--ATS, also shows some uresease inhibiting properties, especially when mixed with 28 percent and banded on the soil surface.
Ammonium nitrate is a dry, white granular. It should not be mixed with any organic matter or finely divided metal powder as it is explosive. Fertilizer grade ammonium nitrate is not so hazardous but there are different grades. This fertilizer, 34-0-0, can leach from the root zone with rainfall or excessive irrigation. It does have a greater salt index than urea, but it does not release free ammonia as much as urea. It does not lose ammonia to the air when spread on the soil, so it is preferred over urea by no-till and pasture systems.

Ammonia sulfate is a light brown to white dry granular around 21-0-0-24, with 24 percent sulfur. Dry storage is important but caking is not common. Applied broadcast or banded, the ammonium can volatilize although less than with urea except on calcareous soils under warm, moist soil conditions.

UAN (urea/ammonium nitrate solutions) are non-pressure solutions at 28-0-0. It will not salt out (crystallize) even a low temperatures but is a clear solution that may be dyed yellow or green by the manufacturer. Broadcast or side-dressed, this nitrogen source can volatilize some unless incorporated within two to three days but may be used on pastures as it will have less losses than urea on surface applications.

Aqua ammonia and low pressure nitrogen solutions are a higher nitrogen analysis than true solutions such as 28%. Pricing is between anhydrous and true solutions. These are soil applied products that are injected like ahnhydrous ammonia because surface applications would lead to volatilization losses.

Other nitrogen fertilizers include natural products, manure and waste products such as municipal biosolids, process wastewater (bioproducts from manufacturing processes such as high fructose sugar processing), and use of hydrothermal water from greenhouses or other sites that may contain some nitrogen. With these products as with the commercially developed nitrogen fertilizers, correct calibration of the quantity used is important to prevent environmental contamination or toxicities from the analyses.

Animal manure

Manure is applied as a combination of feces, urine, feed wastage and sometimes bedding (litter). Chemcial composition varies widely depending on the animal species (especially ruminant versus nonruminant), age and condition of the animals, nature and amount of the litter, and handling and storage of the manure before it is applied. The moisture content of fresh manure can vary from 60 to 85 percent, making it even more difficult to spread with consistency. Modern commercial fertilizers carry 20 to 30 percent times the nutrient content of manure and have more phosphorus content. The bulky character of manure along with more difficult handling and spreading per unit of fertilizer places it at a disadvantage to commercial fertilizers, especially when the nutrient content can vary. The nutrient imbalances must be carefully monitored and possibly corrected through supplemental soil treatments.

General Composition of Manure from Farm Animals
(averaged from numerous references)

Animal	Feces/Urine Ratio	Water (%)	Nitrogen	Phosphorus	Potassium
				(pounds/ton)	
Dairy cattle	80:20	85	10.0	2.7	7.5
Feeder cattle	80:20	85	11.9	4.7	7.1
Poultry	100:0	62	29.9	14.3	7.0

Swine	60:40	85	12.9	7.1	10.9
Sheep	67:33	66	23.0	7.0	21.7
Horse	80:20	66	14.9	4.5	13.2

There may also be a range of other nutrients found in manure. Here are some possible secondary and micronutrients available expressed as pounds per ton:

Calcium	2.4 to 74.0
Magnesium	1.6 to 5.8
Sulfur	1.0 to 6.2
Iron	0.08 to 0.93
Zinc	0.03 to 0.18
Boron	0.02 to 0.12
Manganese	0.01 to 0.18
Copper	0.01 to 0.03
Molybdenum	0.001 to 0.011

In general to balance the N:P:K ratio, additional phosphorus must be added to that contained in manures. A close watch on the other nutrients is also necessary. Storage, treatment and management of manure also requires added handling procedures and timing as the nutrient content, especially the nitrogen, can change in storage over time. For this reason, some utilize manure after the fermentation process (decomposition) but much nitrogen can be lost in this process. Long-term, manure can add to the humus in soils as can green manures.

With any form of animal manure, there is a general check list to consider before use. When using manure do: time applications to crop uses; incorporate; consider all erosion potentials; document the amount and content of the material applied; and, do avoid excessive applications.

Green manures

Turning green crops to condition the soil has been used for additional crop nutrients and added soil tilth. This practice of turning under undecomposed green plant tissue is referred to as green manuring. The four main benefits for this practice in cropping rotations is to add organic matter, add nitrogen (if the green manure is a legume), nutrient conservation, and place ground cover on the soil surface during erosion-prone periods of the year. An ideal green manure crop is easily established and grows rapidly.

Most Common Green Manure Crops Used

Legumes		***Nonlegumes***	
Warm Regions	Wide Range	Wide Range	
Crimson clover	Alfalfa	Rye	Ryegrass
Bur clover	Red clover	Oats	Sudangrass
Lespedeza	Sweet clover	Barley	Mustard
Crotalaria	Soybean	Millet	Rape
Vetch	Canadian field pea	Buckwheat	Weeds
Austrian winter pea	Cowpea		

The two major problems with green manure crops are that nonlegumes used may have sufficiently high C:N ratios as to depress nitrogen uptake in the rotational crop and in arid conditions the green manure crop may deplete soil moisture to the point that the following crop will suffer from drought. In low rainfall areas, the moisture regime definitely dictates the use of green manure crops. In general, areas with less than 18 to 20 inches of annual rainfall have limited benefits from a green manure crop unless the land is irrigated for the succeeding crop and the green manure crop can help in breaking pest cycles in the field.

Municipal biosolids

Use and disposal of sewage sludge is allowed with strict record keeping and use constraints under guidelines through the Environmental Protection Agency (EPA) known as Title 40, part 503. Under this rules, sewage sludge may be sold or given away if the concentration of any pollutant does not exceed ceiling concentration levels.

Pollutant Ceiling Concentration Levels

Pollutant	Concentrations Allowed	Cumulative Loading Rate		
	(mg/kg on a dry weight basis)	(kg/ha over time)	(mg/ha/month)	(kg/ha/year)
Arsenic	75	41	41	2.0
Cadmium	85	39	39	1.9
Copper	4300	1500	1500	75
Lead	840	300	300	15
Mercury	57	17	17	0.85
Molybdenum	75			
Nickel	420	420	420	21
Selenium	100	100	100	5.0
Zinc	7500	2800	2800	140

The annual application rate for domestic septage applied to agricultural land, forest or a reclamation site will not exceed the annual application rate which is calculated this way:

$$AAR = \frac{N}{0.0026}$$

where, AAR = annual application rate in gallons per acre per 365 day period
N = amount of nitrogen in pounds per acre per 365 day period needed by the crop or vegetation grown on the land.

Although nitrogen is the main nutrient utilized through municipal biosolids, an accurate accounting for other trace minerals, especially heavy metals is essential in order to maintain the productivity of the land, prevent environmental contamination and stay within the guidelines required by EPA. Biosolids may be applied on the surface or tilled into the soil. The heavy metal limitations can not be exceeded, with records maintained on monthly/annually/cumulative rate specifications. Also, certain pathogen or vector requirements and site restrictions are imposed. Vector attraction reduction standards are also demanded for land applied biosolids. Thus, two key limitations in the use of biosolids for a nutrient source are maintenance of records and many of the heavy metals within the biosolids above the nitrogen nutrient wanted. Also, because these biosolids are usually treated before land application can be done, complete analyses may reveal other constraints besides the heavy metals such as salts or other contaminants that must be limited over time. Contents of biosolids may vary drastically depending on source and influent gathering points.

Process wastewater

Some manufacturing processes may have wastewater than can be land applied. Like biosolids, strict record keeping is essential so that no pollutants or contaminates are added to the land or so that nutrients and other additives are kept in a balance that will maintain soil productivity and tilth. Complete analyses of water contents are necessary and restrictions on water loading are required. This is important on such wastewater additives as that from processes such as high fructose sugar processing from corn. Water containing high levels of calcium, sodium or other salts can create havoc on soil structure and tilth over time unless properly balanced within specific soils and allowed a slow leaching process that is not detrimental to ground or surface waters.

Other organic sources

Other organic sources may be applied to crop land. Kill floors in beef processing plants often land apply blood byproducts in the industry. Again, strict record keeping must be maintained in order to balance the byproduct load onto land. Like biosolids, these organic sources must have certain possible pollutants and vector limitations.

With any form of nitrogen fertilizer, there is a general check list to consider before use. When using nitrogen do: avoid excessive applications; time applications; know your soil types; restrict excess mineral release; rotate crops; inhibit fertilizer release or transformation; incorporate surface applications; and control surface application at times when runoff potential is high.

Phosphate fertilizers

Commercial fertilizers with phosphate are derived from phosphate rock deposits mined in the southeastern United States or from deposits near the Idaho/Wyoming border. These fertilizers are produced by a reaction with phosphoric acid, with or without ammonia during the process. Ammoniated phosphates may have certain advantages over calcium phosphates due to soil reaction differences. Differences in color and grade exist among phosphate fertilizers. Ammonium phosphates such as MAP (monoammonium phosphate, 11-52-0 or 10-50-0) or DAP (diammonium phosphate, 18-46-0) supply nitrogen along with phosphate. These formulations tend to acidify the soil zone adjacent to the phosphate band, which can increase the phosphate availability in high pH soils. They also tend to be more soluble than calcium phosphates. Both products are dry, granular, dark brown-gray-green fertilizers. If used next to the seed, MAP is preferred over DAP (at levels higher than 100 lb/A) as the nitrogen in DAP is more prone to forming free ammonia in high pH soils. Incorporation of either helps the positional availability of both the nitrogen and phosphorus as well as limits runoff.

10-34-0 (APP)

The most common liquid phosphate fertilizer in use, APP is a clear, green fertilizer from superphosphoric acid and ammonia. Used as a starter fertilizer in bands two inches below and two inches to the side of seed, it can also be used as a “pop-up” fertilizer with rates of eight gallons or less safe for small grains. This fertilizer has a higher cost per unit of plant food than most dry fertilizer grades.

6-18-6 and other complete liquid grades

These green products are for farmers wanting N, P, K and chloride so the use is limited. Other micronutrients are easily blended with these fertilizers but the limitation remains the higher salt index so these formulations are usually used as pop-up fertilizers with complete fertilizers applied in a 2 x 2 band.

Phosphate containing fertilizer, triple superphosphate

This dry, gray, granualar fertilizer can be broadcast, banded or knifed in soil. The analysis is 0-44-0 to 0-46-0 but is seldom used when nitrogen fertilizer is also needed. The water solubility is a little lower than that of MAP or DAP and the reactivity with soil minerals is higher and it has the lowest germination damage potential to seed of any phosphate fertilizer. As phosphates are not volatile, they may be applied to the soil surface; however, they are susceptible to water and wind erosion and they need to be in the root zone for best efficiency.

Phosphate fertilizers are added on a maintenance or build-up schedule. The maintenance program is cheaper, but if soil test levels of phosphate are low and environmental conditions favor higher yields, yields will be limited without ample quantities of this essential nutrient. Some crop rotations may also result in dramatic, favorable crop responses to newly available phosphorus.

With any form of phosphorus fertilizer, there is a general checklist to consider before use. When using phosphate fertilizers do: control erosion; manage soil pH to maximize the efficiency of the fertilizers; incorporate, if possible; and band rather than broadcast when possible.

Potassium fertilizers

It is impractical to build high potassium levels in sandy soils because they cannot retain large amounts for long periods of time. In heavy soils, it may take 10 pounds of K_2O to raise the soil levels of potassium by one pound.

Muriate of potash

This fertilizer, 0-0-60 to 0-0-62, is also known as potassium chloride and vast deposits are mined in Canada and in the western United States. It is a white to red dry granule whose size and color indicate the mine source and degree of purification. Refined, white potash, often called soluble grade potash, is used to make liquid grade clear solutions or suspensions. This fertilizer can injure seedlings if banded with the seed.

Potassium sulfate

This is a special chloride-free potassium source for sensitive crops such as potato or for areas where chlorides are already high. It is more costly and the analysis is usually 0-0-52-17, with 52 percent K_2O and 17 percent S.

K-Mag, Sul-Po-Mag, Potassium magnesium sulfate

Dry granule that provides magnesium where dolomitic limestone is needed and where potassium and sulfur may also be required.

Sulfur fertilizers

Elemental sulfur is usually a 90 percent degradable granule. It can also be a fine powder when used in suspension fertilizers. Sulfur must be oxidized by sulfur bacteria before plants can use it, thus it cannot correct a deficiency quickly. It may take months to become available and it is not easily mobile. Ammonium sulfate is a form that can be added to a fertilizer blend to help with early season sulfur deficiencies as discussed earlier. Ammonium thiosulfate, 12-0-0-26, is a liquid fertilizer that can be mixed with 28% or added to irrigation water later in the season. Higher in price than ammonium sulfate, it is relatively non-corrosive to aluminum and has a strong sulfur odor. It is a short-term urease inhibitor, so some farmers mix a small percentage with 28% when irrigating to increase nitrogen fertilizer efficiency. It can not be a seed placed starter and is generally not used as a foliar additive. Ammonium polysulfide (APS) is a red fertilizer with 20 percent nitrogen and 40 to 45 percent sulfur. It reacts immediately with soil to form colloidal elemental sufur.

Calcium fertilizers

A rare deficienty, calcium needs in tomato or apple is usually due to plant physiological disturbances or due to high, competitive levels of ammonium nitrogen, salinity or even bicarbonate soil levels. Balancing the nitrogen nutrition as well as choosing varieties carefully can eliminate some calcium deficiencies. Sodic soils (high in sodium) with low gypsum levels may sometimes be reclaimed by adding gypsum ($CaCl_2$).

Magnesium fertilizers

Generally magnesium deficiencies are in low pH soils where dolomitic limestone can be used. In high pHs, potassium magnesium sulfate or a similar product may be used. Recently, a liquid magnesium chloride fertilizer has been developed but many do not need the chloride included in the formulation.

Zinc fertilizers

Several forms of zinc are available including zinc sulfate, zinc oxide, zinc complexes, ammoniated zine and zinc chelates. On crops, broadcast applications of the granule zinc sulfate will correct most problems for years. It is also more soluble than zinc oxide and quicker acting on plants. Chelate use is limited in that they do not mix well with liquid starters and cost more. Zinc complexes are not true chelates and are hard to predict their fate on high pH soils. Zinc sulfate, ammoniated zinc and zinc chelates are sometimes used as foliar treatments to correct deficiencies on specialized crops such as pecans.

Manganese and copper fertilizers

This deficiency can be induced by soil iron applications. Copper sprays are also used to combat some plant diseases. The sulfate form of the metal or a chelate formulation are usually used but these are rare deficiencies.

Boron fertilizers

Usually applied in a mix using a soluble powder of 20 percent boron or as a dry borate granule of 14 percent, it is easy to reach toxicity levels. Crops with higher boron requirements include sunflower, cauliflower, sugarbeet and alfalfa.

Molybdenum fertilizers

Very rare, molybdenum availability increases with soil pH. If needed, a molybdenum seed treatment is used to verify the deficiency before considering additions.

Chloride fertilizers

Small grains use chloride and if needed it is usually applied through starter fertilizer such as muriate of potash. Many soil minerals and potassium bearing soil minerals do not contain chloride. Usually not needed, chloride levels tend to build in dry years and leaches readily as nitrate when water moves through soil. It should not be in close proximity to seed or germination and seedling problems result.

In general, fertilizers can cause environmental impacts if not used judiciously and if not correctly calibrated for application. Besides affecting crop seeds and seedlings with certain formulations, point or nonpoint source pollution from fertilizers can create concerns for ground and water resources, toxicity to plants and site contamination with unusual contaminates found in biosolids, wastewater or manures. Knowing the complete analyses of all products used, the crop needs and soil or site limitations along with correctly choosing and using any fertilizer additives will benefit the crop productivity and economics of a field. New technologies using intensive soil sampling such as grid or globally positioned systems (GPS) sites will allow more specific fertilizer applications to be made where the nutrients are actually needed. Terrogators set up with GPS maps may release specified mixtures (currently for up to three granular nutrients) on land, eliminating much waste of nutrients across fields and optimizing the economics of fertilizer quantities used. With time even more specific applications may be possible.

Fertilizer application methods

Nitrogen

Anhydrous ammonia is applied using an applicator that has a metering device, a manifold, and “knives” that direct the ammonia into the soil. More modern applicators use an electronic controller following a cold-flow chamber or a variable orifice meter with older applicators using a ground-driven meter (usually higher maintenance). The electronic controller has greater precision and can more evenly apply ammonia at different temperatures as well as can adjust flow rates on-the-go. Ammonia is injected as a mixture of both liquid and vapor. Applications must be beneath the soil surface to prevent losses to the air.

Urea is banded and can be applied with any granular fertilizer applicator such as with the pneumatic-boom style dry fertilizer applicator as can ammonium nitrate or ammonium sulfate.

UAN, aqua ammonia and low pressure nitrogen solutions are side-dressed or in the case of UAN may be broadcast from liquid fertilizer rigs. Likewise some of the liquid effluents of wastewater may also be applied with liquid rigs either as a broadcast that is incorporated before planting or as a side-dress most commonly.

Manure or biosolids are usually broadcast and incorporated in before planting. Depending on the consistency of the material, they may be applied through liquid rigs or with solid materials may be disseminated with manure wagons that fling the dried material within a swath.

All nitrogen application rigs can be calibrated and should be checked periodically to insure that the right amount of nitrogen is being applied to a land area without concern of over-application.

Phosphorus

Phosphorus, depending on form, may be applied by a dry or liquid rig or may be applied at planting as a pop-up fertilizer.

Potassium

This nutrient is applied from dry rig applicators that can be calibrated to optimize the granular output.

Sulfur, calcium, magnesium, zinc, manganese, copper, boron, molybdenum and chloride

These are available as granulars, powders, or liquids depending on the manufactured product and are often part of other fertilizer applications of the primary nutrients. Careful calibration, especially on any of the metals, is essential to insure a soil with a balance of trace nutrients and no toxicity to plants.

Most applications of fertilizers are banded, broadcast (and often incorporated), top-dressed (such as liquid nitrogen), or may be applied through fertigation (such as 28% used as a nitrogen source through irrigation water). With fertigation, fertilizer used within a chemigation system, Use of an inexpensive anti-backflow device will prevent fertilizers from being sucked into the water source from which you are irrigating once the system is turned off. These backflow prevention devices, called back-siphoning prevention devices, will save you fertilizer and water contamination problems. Considerations of the environmental problems that could result if fertility needs are not properly determined and applied at accurate rates should be evaluated before any application is made. Economics and safety concerns dictate that proper application of fertilizers are made.

Post-Study Questions for Review

1. One of the most commonly used forms of nitrogen fertilizer is?
    a. ammonium thiosulfate
    b. aqua ammonia
    c. biosolids
    d. anhydrous ammonia
2. One of the best management practices for limiting nutrient loss to ground or surface waters is to?
    a. add only a small overload quantity to the lab recommended amount to a field
    b. use a soil test
    c. use the same recommendation every year
    d. change your fertilizer application only if you change the crop in the field
3. One of the animal manures that is highest in nitrogen content is?
    a. horse
    b. dairy cattle
    c. poultry
    d. dog
4. Two main problems with green manure crops are?
    a. they take too long to establish and they are hard to plow under
    b. nonlegume crops may have high C:N ratios and in arid conditions they utilized precious water later needed by the rotational crop
    c. legume crops may add too much nitrogen and may conserve too much moisture in the soil profile
    d. they harbor diseases and they help conserve moisture for later crops
5. What fertility philosophy simply replaces the nitrogen utilize by a crop that will be needed for the next crop?
    a. a build-up program
    b. a maintenance program
    c. a need be program
    d. a guess and bless program
6. Nutrient loading rates specified in the part 503 standards for use of municipal biosolides are called _____ by EPA.
    a. nutrient needs
    b. pollutant potentials
    c. ceiling concentrations
    d. sludge sliding scales
7. In the phosphate fertilizers, which form—MAP or DAP—is more prone to volatilization in high pH soils?
    a. MAP when it is applied on water-logged soils
    b. DAP
    c. MAP
    d. DAP only if it is used at rates above 100 pounds per acre
8. The most volatile fertilizer listed below is?
    a. triple superphosphate
    b. muriate of potash

   c. ammonium sulfate
   d. urea
9. Zinc complexes are?
   a. true chelates and easy to calibrate
   b. not easy to determine their fate on high pH soils
   c. are injected right into the root system of crop plants
   d. not true chelates but easy to use on high pH soils
10. One of the micronutrients that you want to not have toxicity from and is one of the ones that is most difficult to recommend is?
   a. boron
   b. calcium
   c. nitrogen
   d. potassium

Check your answers before proceeding into the unit to find out how much you already know about basic concepts of nutrient sources and applications. Each correct answer is worth 10 points, based on a total of 100 points for the ten questions. Answers: 1. d.; 2. b..; 3. c.; 4. b.; 5. b.; 6. c.; 7. b.; 8. d.; 9. b.; 10. a.