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NITROGEN AS A PLANT NUTRIENT

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Introduction

Nitrogen has been known for many years as an important plant nutrient element. It is used by the plant in greater quantities than any other nutrient obtained from the soil, except water. In nature, the largest amount of this element is found in the air, which contains about 78% nitrogen. In the gaseous form, nitrogen is very inert and is of no direct use to plants. In combined chemical forms such as certain salts and organic matter, this element can be used by plants for the building of new tissues and for growth.

Until 1908, the world was dependent on natural sources of nitrogen for its fertilizer. Most of these are animal manures or Chili nitrate. At that time, Fritz Haber developed a method of fixing gaseous nitrogen in the form of ammonia. Other nitrogen forms could be made from this. This process made it possible for Germany to wage World War I (nitrogen is a constituent of all explosives) and at the same time made it possible for all nations to produce nitrogen fertilizers. Ammonia can also be produced by distillation of soft coal. This process is still used in the coke industry and generally yields ammonium sulfate.

Ammonia is changed to nitrate by the Ostwold process in which ammonia and air combine at 900°C to produce nitrogen dioxide. This material, dissolved in water, gives nitric acid, the starting point of nitrate production.

 $\frac{\text{Haber process}}{\text{M}_2 + 3\text{H}_2 + 3\text{H}_2 + 2\text{H}_3 + 21,880 \text{ Cal.}}$

Nitrogen(gas) + Hydrogen(gas) -- Ammonia(gas) + Heat

Ostwold Process

4NH ₃	+	50 ₂	→ 4NO	+	6H ₂ O	+	214,200
Ammonia	+	Oxygen	Nitric	+	Water	+	Cal.
gas		gas	Oxide				Heat

As mentioned earlier, nitrogen compounds are invariably constituents of explosives. Some fertilizer salts are also used in explosives (ammonium nitrate).

These materials have been known to explode when overheated or carelessly stored in contact with organic matter. They have never exploded in a greenhouse, farm, or home but they did cause the Texas City explosion. Store these materials in a cool, clean dry place.

Nitrogen in the Soil

Inorganic Forms

Nitrogen exists in the soil in inorganic and organic forms. The inorganic forms are ammonium and nitrate salts, such as ammonium sulfate, ammonium nitrate, potassium nitrate, and sodium nitrate. In well-aerated soils, little if any nitrogen is present as ammonia except when this form has been recently added in fertilizer. In poorly aerated soils, a considerable amount of ammonia may be found.

The conversion of ammonia to nitrate and vice versa is accomplished with the aid of soil microorganisms. The large number of organisms capable of converting various forms of nitrogen to ammonia are called ammonifiers. These organisms, due to their variety and numbers, are active under a wide range of environmental conditions. The bacteria responsible for converting ammonia to nitrate, the nitrifiers, are fewer in number and are active under more restricted conditions.

A familiar example of the activities of these organisms is the tendency for ammonia to accumulate in freshly sterilized soils, sometimes in high enough amounts to injure plants. When the soil is sterilized, the active microorganisms are killed, but the spores remain. These spores germinate and the microorganisms multiply until they are back in about the same numbers as they were before sterilization. The ammonifiers come back rapidly and there is considerable conversion of various forms of nitrogen to ammonia. The nitrifiers are slower to multiply and do not come back quickly enough to convert this ammonia to nitrate as fast as it is produced. In this way, ammonia has been known to build up to the point where it becomes toxic to plants. Poor aeration would further slow down the return of the nitrifiers and the ammonia would remain in the soil at a high level for a longer time.

When ammonium fertilizers are added to a wellaerated soil, the abundant population of nitrifiers acts rather rapidly, converting most of the ammonia to nitrate in a short time.

It will be noted that ammonia is a base or is alkaline in reaction. Nitrate is on the right-hand side of a salt formula as sodium NITRATE, and is therefore a derivative of an acid (nitric acid) and is acidic in reaction. It generally does not make any difference which form is used from a plant standpoint because it is all converted to nitrate but it does make a difference in soil pH. In ammonium sulfate, ammonium chloride and ammonium phosphate, the nitrogen is in the basic or alkaline form. When this is used by soil microorganisms, chlorides, sulfates and phosphates are left behind. These tend to make the soil acid since they will combine with water to form hydrochloric acid, sulfuric acid, and phosphoric acid. Sodium nitrate, potassium nitrate and calcium nitrate are carriers of nitrogen in the nitrate form. When the nitrate is ab-sorbed by plants, sodium, potassium and calcium are left behind. These materials will raise the pH because they combine with water to form sodium hydroxide or lye, potassium hydroxide or potash and calcium hydroxide or hydrated lime.

To depress soil pH use salts which leave acid residues like sulfate or chloride. To raise pH use fertilizers that leave alkaline residues as sodium and calcium. Some salts, such as ammonium nitrate, potassium phosphate, etc. are entirely used by plants, and have little effect on soil pH or soluble salts.

Organic Forms

The organic forms in which nitrogen is found in the soil include animal manures and dead plant and animal materials. Dead plant materials are the most important source in the field, although animal manures have been fully as important on intensively cultivated horticultural land and in prepared soils.

In general agriculture, legume crops such as alfalfa, are an important source of organic nitrogen. In this case, gaseous nitrogen, diffusing into the soil from the air is converted into useable nitrogen by the legume plant, with the help of bacteria living in its roots. This conversion is called nitrogen fixation and accounts for a great part of the nitrogen used by field crops.

The Intake of Nitrogen by Plants

Plants absorb nitrogen from the soil mostly as nitrate. Ammonium can also be absorbed, but usually is not present in very large amounts, since in well aerated soils it is fairly rapidly converted to nitrate by the nitrifying bacteria. Blueberries have been shown to use ammonium nitrogen in preference to nitrate. Azaleas should benefit from receiving their nitrogen as ammonium salts.

Nutrient absorption by plants has been shown to be mostly "active absorption." This is the way in which a plant absorbs a nutrient, such as nitrate, by expending energy obtained from respiration. This process enables the plant to accumulate nitrogen even when the supply in the soil is low. However, energy spent in doing this is gone and cannot be used for growth. For this reason it is desirable that the nitrogen supply in the soil be great enough so that the plant does not need to expend much energy to obtain nitrogen from the soil. A plant can suffer considerably reduced growth from lack of nitrogen before any visual symptoms of this lack appear.

Since this nitrogen absorption depends upon the respiration of the plant, it can be slowed down by anything which slows down respiration. Poor soil aeration and low soil temperature are two factors which may slow down respiration and nitrogen absorption by the roots, not to mention the absorption of water and other nutrients.

Some plants can absorb certain forms of nitrogen when applied to their leaves. An example of this is the use or urea sprays on apple trees. Generally it has been found that a leaf application works best in combination with adding fertilizer to the soil. The applications of this method in greenhouse production have been rather limited, to date. Preliminary results indicate the need for almost constant spraying to supply sufficient nutrients. It appears that foliar feeding is of limited value at the present time.

Functions of Nitrogen in Plants

Nitrogen is an essential part of a number of compounds in the plant. It is best known as a component of proteins. There are many proteins present in plants. One of them, chlorophyll, gives plants their green color and allows them to manufacture their food when they are in the light. Other proteins serve as materials from which the plant cells are built. Another group of proteins, the enzymes, are present in much smaller amounts but are no less important. These serve as catalysts in the numerous biochemical reactions carried out in plants which enable them to function and live.

Nitrogen is also a component of the nucleic acids, which are important materials in the plant cells. One of the nucleic acids is an important part of the cell chromosomes and is believed to play an important role in the inheritance of various features, and so makes plant breeding possible.

Nitrogen is also important as a component of certain other compounds found in plants such as growth regulators and many drugs, such as nicotine, quinine, and caffeine.

Diagnosis of Nitrogen Troubles

When the nitrogen supply is inadequate for the plant, a general slowing of growth occurs. This is not always easy to detect until the plant begins to show chlorosis or yellowing of the leaves. This yellowing, beginning low on the plant and working upward, is the characteristic deficiency symptom observed in most plants. By the time this symptom appears, the plant has already been considerably stunted. Because of this, the deficiency symptom of chlorosis is useful only as a last resort in diagnosing the shortage of nitrogen in the plant. The most useful diagnostic tool is the soil test.

When the nitrogen supply is in excess, the plant appears generally as it would with an excess of any soluble salts. The plant wilts easily and may often show a yellowing of the upper parts of the plant. When this appears, the roots have been injured severely and the plant is probably beyond satisfactory recovery. Soil testing, here again, is a reliable guide to prevent the occurrence of such a situation.

Nitrogen Fertilizers

Under conditions where plant material is being removed from the soil and where frequent watering is continually dissolving nitrogen salts and washing them from the soil, it becomes necessary to add nitrogen in some form. This becomes extremely important in greenhouse production.

Under field conditions, often the most economical way of doing this is by growing legume cover crops. Although greenhouse soils are often prepared in this way, it is necessary to maintain considerably higher fertility levels once the soil is being used in the greenhouse bench. Fertilization is the only way to accomplish this. Both organic and inorganic fertilizers have been used extensively in greenhouse production, but in recent years the organic fertilizers have been used to a much smaller extent.

Organic Fertilizers

The most commonly used organic nitrogen source in greenhouses is manure. Manure has been used more for its soil-conditioning properties than as a fertilizer, although it does contain small amounts of fertilizer elements, including usually 1/2 to 1% nitrogen. Recent work, however, has shown that, with the very liberal watering which is now recommended, the presence of manure can cause difficulty by allowing soil microorganisms to multiply and compete more seriously with the plant roots for oxygen. Because of this and due to the difficulty of obtaining manure it is being replaced more and more by peat moss for soil conditioning. The nitrogen formerly supplied by manure is replaced by adding slightly more of the inorganic fertilizers.

Other organic nitrogen fertilizers, such as dried blood, tankage, sewage sludge, fish scrap, cottonseed and linseed meal, tobacco stems, meat meal and castor meal, contain from 1 to 12% nitrogen. In these materials the nitrogen is slowly released as the materials are decomposed. The main disadvantages of these materials are (1) they are usually expensive for the amount of nitrogen they supply and (2) it is difficult to measure the nitrogen status of the soil accurately when substantial amounts of these materials are used.

There are also synthetic organic materials such as urea and the newer urea-formaldehyde compounds. These materials usually break down somewhat more rapidly than the natural organic materials. Like such materials, they are not detected in standard soil tests. This fact can be more troublesome here, as under certain conditions considerable amounts of nitrogen can be released and soluble salts injury can result.

The speed of decomposition of most of these materials depends upon the temperature. Below 50° F urea-form releases nitrogen too slowly to be of any appreciable value. At high temperatures, it breaks down much more rapidly.

Inorganic Fertilizers

The most common inorganic nitrogen fertilizers include such salts as ammonium sulfate, ammonium nitrate, sodium nitrate and potassium nitrate. These are the cheapest nitrogen fertilizers available. They are commonly used separately, as well as in mixed fertilizers such as 5-10-5, 10-10-10, 20-20-20, and numerous other mixtures. These forms of nitrogen are completely soluble in water and become available to plants as soon as they are applied to the soil. Unfortunately, they are also readily washed from the soil. This results in the need for rather frequent application of these fertilizers, especially when crops are being watered heavily in warm weather. Another advantage in the use of soluble inorganic nitrogen fertilizers is that the amount of nitrogen available to the plant can be measured in soil tests. By periodic testing of the soil and application of the indicated amounts of soluble

fertilizers, the nitrogen level in the soil can be kept within the best range for plant growth.

Many greenhouse growers have developed fertilizer programs which combine the use of soluble and slowly soluble fertilizers. The urea-form compounds may prove to be a useful addition to the list of slowly soluble materials which can be used in combination with inorganic fertilizers, if the safety and value of using them under widely varying conditions is established.

Name	% Nitrogen	Notes
Ammonium sulfate	20	makes soils acid
Sodium nitrate	15-17	
Calcium nitrate	13-16	
Ammonium nitrate	35	use pelleted form
Calcium cyanamide	21-24	
Urea	46	use pure form and with caution
Urea-form	38	slowly available
Dried blood	8-14	v
Tankage	5-10	
Sewage sludge	1-7	
Dried manures	1-2	contain peat, soil conditioner
Poultry manures	5-6	

Fertilizer practices

The usual procedure in a soluble fertilizer program is to add fertilizer to bring the nitrogen level to a high point, but below the level where injury may result, and then to fertilize again before the level falls below the lower limit of the best range. The desirable range has been found to vary with the crop being grown and so fertilizer programs have varied also. There has been some recent use of a system by which fertilizer solution is injected into the water line. In this way, a very light fertilizer application is made in each watering. This method shows much promise and seems to be a means of avoiding soluble salts injury and at the same time never allowing the nitrogen to fall low enough to be deficient in the plant.