

Greenhouse Nutrition

by

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Nutritional problems represent roughly 75% of the difficulties encountered in greenhouses in the upper midwest. Nutritional problems arise from over or under application of nutrients, pH modification of nutrient uptake, or competition among nutrients for uptake. This review is the first in a series of articles on nutrition management in greenhouse crop production. Each article will concentrate on a given element which is important to plant growth which we actively manipulate in production. In addition, all of the articles will tend to emphasize difficulties which may arise in the management of a given element in production using media with low cation exchange capacity and generally high pH conditions. Such conditions are prevalent in upper midwest greenhouse production. The first article will discuss the element nitrogen.

Nitrogen

Nitrogen is a macronutrient. In other words, it is a nutrient which is required in relatively large amounts for plant growth to occur. Nitrogen affects plant growth in a variety of ways. The effects of high versus low nitrogen nutrition is shown in the table on page 14. Nitrogen is a component of amino acids, proteins, vitamins, enzymes, and alkaloids.

Primarily 2 forms of nitrogen fertilizer are used in greenhouse crop nutrition: nitrate and ammonium. The forms of nitrogen vary in both their uptake and the ways in which they are utilized in the plant. For instance, most ammonium is directly incorporated into organic compounds in the roots. In contrast, nitrate forms of nitrogen must be reduced to ammonia before being incorporated into organic compounds and are mobile in the xylem. Which form is best for optimal plant growth is dependent on a number of factors. This review will discuss

both forms of nitrogen which are used in greenhouse crop production and how they interact to affect plant growth.

Nitrate- Nitrate (NO_3^-) is an anion, i.e. it is a negatively charged ion. Nitrate is actively absorbed by plants. Absorption is generally greater at low pH media compared to high pH media. Uptake can be depressed by high levels of ammonium in media surrounding roots and/or high pH. Feeding with high levels of nitrate will tend to increase the cation content of plant tissues. In other words, levels of calcium, magnesium and potassium tend to increase whereas anion content will tend to decrease. Nitrates must first be reduced before they can be utilized for plant growth.

Nitrate reduction: As mentioned before, nitrate must be reduced to ammonia before it can be utilized for plant growth. The nitrogen reduction pathway for higher plants is shown below:



The reduction of nitrate reduction to ammonia is controlled by 2 enzymes: nitrate reductase and nitrite reductase. The activity of these enzymes determines the availability of nitrogen reduced from nitrates for plant growth. The reduction of nitrate to ammonia is an energy requiring reaction which requires the presence of molybdenum.

Both roots and shoots are capable of nitrogen reduction. A number of factors affect where nitrate reduction occurs. The level of total nitrate surrounding the roots is one factor which determines the proportion of nitrate reduction which occurs in the roots versus the shoots. In general, when nitrate levels are low, a high proportion of the nitrate is reduced in the roots. In contrast, when nitrate levels are high, a greater proportion of nitrate is reduced in the shoots. In part, this may be due to the energy

requirement for nitrate reduction. Such energy would be available for nitrate reduction in shoots more readily than roots. This would certainly be the case during the day when carbohydrates are synthesized via photosynthesis.

Plant species and age also affects where nitrate reduction occurs. Woody plant species, i.e. trees and shrubs, reduce a greater proportion of nitrates in the roots compared to the shoots. Conversely, herbaceous species tend to reduce a greater proportion of nitrates in the shoots. As a plant ages, a greater proportion of nitrate is reduced in the roots.

As eluded to earlier, the environment affects nitrate reduction. Nitrate reduction is diurnal, i.e. it does not occur continuously during a day/night cycle. Nitrate reduction occurs primarily during the day and the rate of reduction is proportional to light intensity. The basis for diurnal reduction of nitrates is presumably due to the energy requirement for reduction which is provided by photosynthesis.

In addition to carbohydrate availability, the nitrate reduction is affected by the availability of nitrate reductase. Nitrate reductase is synthesized primarily during the day.

Temperature has an effect on nitrate reduction. Nitrate reduction increases as temperature increases.

Ammonium- Ammonium utilization in plant growth differs from that of nitrate in a number of ways. Ammonium uptake occurs optimally at neutral pH values. Absorption of ammonium by roots tends to decrease the plant tissue levels of a number of inorganic cations such as calcium, magnesium, and potassium while increasing the level of inorganic anions such as phosphorus, sulfur, and chlorine. Absorption of ammonium also tends to decrease the pH of the surrounding media. Ammonium cannot be stored in the plant as nitrates can. Both ammonium and its equilibrium partner, ammonia, are toxic to plant growth at low concentrations.

Detoxification of ammonium and ammonia occurs through incorporation of these compounds into amino acids, amides, and related compounds. Translocation of these compounds then occurs in the xylem.

A general reduction of growth and eventually a damaging of plant tissue can occur if ammonium levels in the media become too high. Reduction of plant growth and damage to plant tissues by high ammonium is referred to as ammonium toxicity. The exact basis for ammonium toxicity is not well understood. However, ammonia toxicity may occur due to a rapid permeation of ammonia through biomembranes. Ammonia diffuses rapidly across chloroplast membranes. Such diffusion can be destructive to these tissues. In addition, in media with a low cation exchange capacity and pH values at or above 7.5 higher ammonium levels have been shown to decrease both transpiration and photosynthesis.

As with nitrate reduction, a number of factors affect the rate of ammonium incorporation within a plant. As with nitrate reduction, ammonium incorporation requires energy. However, the energy requirement for ammonium incorporation into plant tissues is less than that for nitrate reduction. Ammonium incorporation into plant tissues requires the presence of magnesium.

As with nitrate reduction ammonium incorporation occurs primarily during the day period. This is presumably due to the energy requirement for this process.

Ammonium volatilization out of the soil can occur. Ammonium volatilization is the release of ammonia out of the soil in a gaseous form. Soil pH, calcium carbonate content, cation exchange capacity, texture, temperature, and moisture content all affect the amount of ammonium volatilization. Ammonium volatilization increases as pH increases, calcium carbonate levels increase, and temperature increase.

Which N Source to Use: The question arises as to which form of nitrogen should be applied to maximize desirable plant growth. Plant growth often is best when both sources of nitrogen are used in a fertilization program. However, there are some crops which prefer one source of nitrogen to another. For example calcifuges, or plants adapted to acidic soils, often have a preference for ammonium forms of nitrogen. Examples of calcifuges in horticulture includes azaleas, rhododendron, and blueberries. In contrast, calcicoles, or plants adapted to alkaline soils, often prefer nitrate forms of nitrogen. Examples of

calcicoles in horticulture include alpinas such as many species of gentians.

The media in which a crop is grown can determine which source is most appropriate. In soil based media or media which contain high levels of vermiculite, ammonium levels may tend to increase to undesirable levels.

The environment which plants are grown under may greatly affect which form of nitrogen is used for fertilization. For example, media temperature affects nitrogen uptake and loss. The amount of ammonium which is volatilized increases as media temperature increases. In contrast, ammonium utilization by plants is generally greater at low temperatures compared to nitrates. Greater utilization of ammonium relative to nitrates at low temperatures may cause problems. We generally see an increase in ammonium toxicity during periods of the year when we tend to grow our crops cooler. Greater ammonium uptake relative to nitrate uptake in cool temperature environments may be one factor which contributes to ammonium toxicity.

Availability of other minerals essential for plant growth may determine which form of nitrogen is best for fertilization. The uptake of a number of desirable cations can be limited by ammonium. For instance, potassium, magnesium, and calcium uptake are all reduced in the presence of ammonium forms of nitrogen. As a result applying ammonium forms of nitrogen can aggravate deficiencies of any of these cations. Nitrate forms of nitrogen inhibit anion uptake such as chloride. However, the amount of such anions needed for growth is often not limited by nitrates. Interestingly, molybdenum deficiencies are more prevalent on plants which are fed ammonium compared to plants fed nitrate forms of nitrogen.

At high pH levels ammonium uptake is preferred compared to nitrates. Crops are often grown at pH levels greater than 6.5 in the upper midwest due to the high water pH and alkalinity. Higher ammonium uptake relative to nitrate uptake at high pH levels may be another contributing factor to ammonium toxicity which we may occasionally see.

Root morphology is affected by the type of nitrogen applied. In general, High ammonium tends to decreased root elongation and increase

lateral branching. To this end ammonium forms of nitrogen may be detrimental to survival of plants in an exterior planting bed.

Based on this information in this article, the following recommendations can be made:

1) Application of ammonium to greenhouse crops should be limited if a crop is grown cool, if magnesium, calcium, potassium, or molybdenum is limited, or if media pH is high.

2) Ammonium nutrition in the greenhouse may be detrimental to survival of plants outside following transplanting.

3) Ammonium levels tend to increase more readily in media which are soil based and/or have a high cation exchange capacity. Therefore if such a media is used for crop production, soil tests will need to be done regularly to closely monitor ammonium levels.

4) High nitrogen levels early in development and late in development may be detrimental in crop production. High nitrogen levels early in development tend to decrease rooting and promote shoot growth. High nitrogen levels late in development tend to decrease the postharvest life of many of our crops.

