Cornell University Cooperative Extension

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Nitrogen: All Forms Are Not Equal

Summary: By understanding the different chemical forms of nitrogen, you can manage root-zone pH and avoid toxic buildup of ammonium.

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Nitrogen form

Plants have the ability to take up several chemical forms of nitrogen. The most common are: ammonium (NH_4^+), which has a positive charge; nitrate (NO_3^-), which has a negative charge; and urea, ($(NH_2)2CO$), which has no charge. Many commercial fertilizer mixes contain a combination of all three nitrogen forms.

When these nitrogen forms are added to the growing medium natural processes can take place that convert one form to another (Figure 1). Bacteria can convert urea to ammonium or ammonium to nitrate. Hydrogen ions (H^+) which acidify the medium are released when ammonium is converted to nitrate. In growing medium urea is converted to ammonium very quickly in less than two days. Urea and ammonium are typically grouped together and referred to as ammoniacal nitrogen.

When roots take up charged molecules, such as ammonium or nitrate, they typically release an identically charged molecule to maintain a balanced pH inside the plant cells. Because nitrogen can be supplied as a positively or negatively charged form, the root substrate pH can be altered.

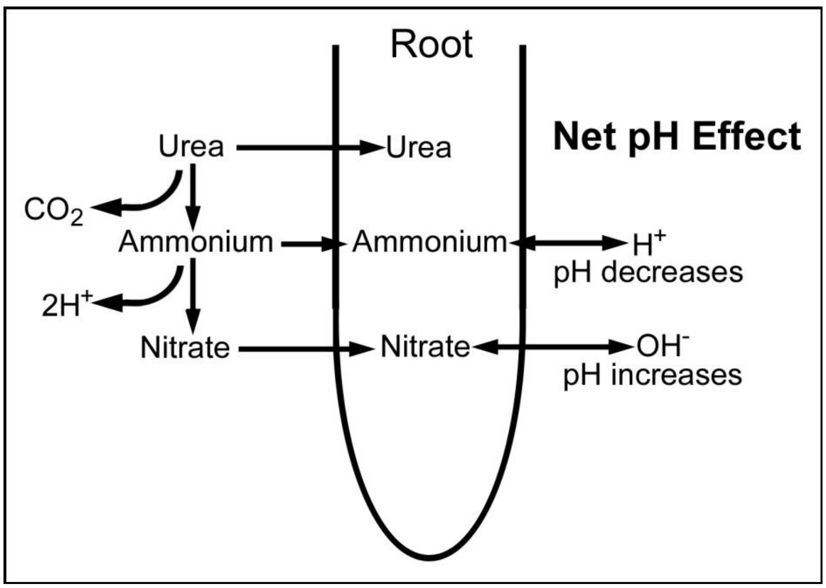

Figure 1. Conversions between nitrogen form and effect of nitrogen uptake on root-zone pH.

pH effect

Plants take up ammonium and other positively charged cations by releasing one hydrogen ion (H^+) into the medium solution for each ammonium ion absorbed. Over time, ammoniacal nitrogen uptake increases hydrogen ion concentration thereby lowering the growing medium pH.

The uptake of negatively charged anions such as nitrate is most often accomplished by releasing hydroxide ions (OH^-). In the medium solution, hydroxide and hydrogen ions combine to form water (H_2O). Over time the reaction of hydroxide and hydrogen ions decreases hydrogen ion concentration and increases the medium pH.

Under some circumstances plants absorb a nitrate anion by simultaneously absorbing hydrogen ions or releasing bicarbonate. Like hydroxide ions, bicarbonate combines with hydrogen ions and thus raises the medium pH. The net effect of using a nitrate-based fertilizer is to increase the overall medium pH.

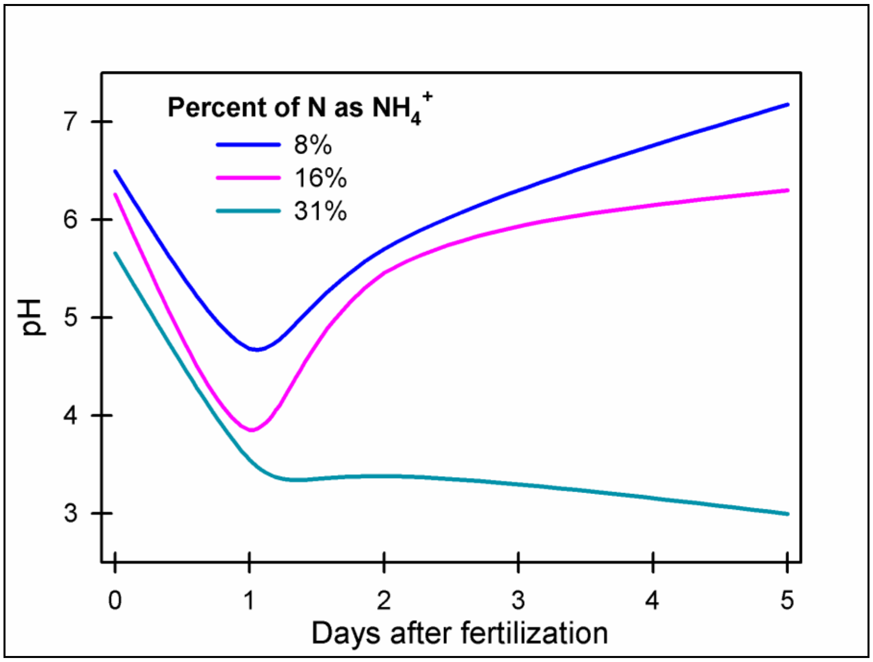

Figure 2. Change in pH of the root-zone of rose plants provided with three different percentages of ammonium.

A dramatic example of the effect of nitrogen form on growing medium pH is shown in Figure 2. Rose plants were grown hydroponically in a nutrient solution containing different percentages of ammonium. During the first day after nitrogen addition, the pH dropped by one to two units as bacteria converted ammonium to nitrate. After the initial pH drop, pH increased over time in the 8 percent and 16 percent ammonium treatments as only nitrate was left to be absorbed by the plants. In the 31 percent ammonium treatment, a combination of ammonium and nitrate was taken up by roots over the next five days which kept pH fairly steady. These effects are much more dramatic than what would occur in a commercial growing medium as it is somewhat buffered due to its chemical properties and added limestone.

Selecting a fertilizer

The ratio of nitrate to ammoniacal nitrogen in a fertilizer determines the rate of substrate pH change and can even be used to correct pH during production. The pH changing property is known as a fertilizer’s potential acidity or basicity and is listed on a fertilizer’s label (Table 1).

Table 1. Some commercially available fertilizers, their percentage of total nitrogen as nitrate or ammonium plus urea, and potential acidity or basicity [a].

Fertilizer	**NO_3**	**NH_4 [b]**	**Potential acidity [c] or basicity [d]**
Ammonium sulfate	0	100	2200 a
Urea	0	100	1680 a
21-7-7 acid	0	100	1539 a
21-7-7 acid	0	100	1518 a
Diammonium phosphate	0	100	1400 a
Ammonium nitrate	51	49	1220 a
Monoammonium phosphate	0	100	1120 a
18-9-18	47.7	53.3	708 a
20-20-20	27.5	72.5	532 a
21-5-20	62.3	37.7	407 a
20-10-20	59.5	40.5	404 a
20-10-20	60	40	401 a
21-5-20	60	40	390 a
17-5-17	70.6	29.4	106 a
20-0-20	54	46	0
15-0-20	76.7	23.3	38 b
15-5-15	80	20	69 b
15-5-15	78.7	21.3	131 b
15-0-14	82.7	17.3	165 b
15-0-15	86.7	13.3	221 b
15-0-15	80.8	18.8	319 b
Calcium nitrate	100	0	400 b
Potassium nitrate	100	0	520 b
Sodium nitrate	100	0	580 b

[a] Table adapted and revised from Paul Nelson: Greenhouse Operation and Management. p. 315. 6th ed. Prentice Hall. New Jersey.

[b] The percentage of total N in the ammonium plus urea forms; remaining N is nitrate

[c] Potential acidity is defined as the pounds of calcium carbonate limestone required to neutralize the acidity of 1 ton of fertilizer

[d] Potential basicity: applying 1 ton of this fertilizer has the pH neutralizing effect of this many pounds of calcium carbonate limestone

High pH can be corrected by switching to a more acidic fertilizer. One example is 21-5-20 fertilizer which has a potential acidity of about 400. Application of 1 ton of 21-5-20 causes acidification which would require 400 pounds of calcium carbonate limestone to counteract. Similarly, 15-0-15 has 420 pounds of potential basicity and can be used to increase a low pH.

For crops that are known to have issues with pH decline (such as zonal geraniums), using a nitrate-based fertilizer such as 15-5-15 may aid in slowing or stopping pH decline over time. The greater the potential acidity or basicity, the more pH change occurs.

Ammonium toxicity

Often nitrogen is applied at concentrations greater than plants can readily absorb. Plants can take up and store additional nitrogen to use later if nitrogen becomes limiting. Nitrate can be safely stored by plants; but when plants take up and store too much ammonium, cell damage can occur. Luckily, under normal conditions of warm temperatures and a well aerated medium, urea and ammonium are converted to nitrate by nitrifying bacteria so there is little worry about excess ammonium in the medium.

Certain conditions such as low temperatures (less than 60°F average daily temperature), water-saturated or low oxygen growing media, and low medium pH will suppress the function of nitrifying bacteria and cause ammonium to build up to toxic levels in the growing medium. Symptoms of ammonium toxicity include upward or downward curling of lower leaves depending on plant species; and yellowing between the veins of older leaves which can progress to cell death (Figure 3).

Figure 3. Symptoms of ammonium toxicity in New Guinea impatiens and tomatoes. (Photos: Cari Peters)

To avoid ammonium toxicity it is recommended to use fertilizer with 40 percent or less ammoniacal nitrogen when growing conditions are cool and wet. When cold gray weather occurs a common strategy used by growers is to alternate to a 15-0-15 “Dark Weather Forumla.” This eliminates the extra ammonium input temporarily, but then allows growers to return to their normal formula when growing conditions improve.

Impact of growing cool

With the high cost of fuel to heat greenhouses, there is an increased temptation to produce plants at cooler temperatures. If greenhouse temperatures are going to be reduced, consider adjusting the nitrogen form so that ammonium toxicity doesn’t occur. If ammonium toxicity has occurred, corrective measures include: discontinue applying the current fertilizer, leach the growing medium, add a nitrate-based fertilizer and raise temperatures.

Under conditions of severe ammonium toxicity an effective method of alleviation is a leaching treatment with gypsum. Topdress 1 tablespoon of gypsum (calcium sulfate) to each 6-inch pot and water in thoroughly with clear water. Follow with a 50 parts per million drench of calcium nitrate two hours later. The ammonium bonds with the sulfate from the gypsum and becomes highly soluble allowing it to flush easily out of the medium.

Nitrogen and finished plants

The type of nitrogen used can also influence the tone or finish of the plants. Ammonium/urea based fertilizers tend to create lush or soft growth resulting in larger leaves and darker green plants. When these plants are sold directly to consumers as patio plants or hanging baskets, lush growth and a deep green color caused by ammonium-nitrogen may be desirable. Plants must also withstand the stresses of shipping and the retail environment.

Nitrate fertilizers are used by plug growers and others that ship plants to help tone or “harden” plants. One drawback of a classic plug formula is the tendency to raise the medium pH over time leading to micronutrient deficiencies. Plug growers with high water alkalinity or high water pH are challenged with the question of adding acid to counteract the gradual pH increase. This could set up the potential for damaging plants. Look for plug fertilizer formulations with low ammoniacal nitrogen content (less than 5 percent) to provide a small amount of acidity while still delivering the low phosphorous required for strong plugs.

Please note: Trade names used herein are for convenience only. No endorsement of products is intended, nor is criticism of unnamed products implied.