From Forest Nursery Notes, Summer 2008

41. Understanding plant nutrition: fertilizers and media pH. Argo, B. and Fisher, P. Greenhouse Grower 26(8):54, 56, 58, 60. 2008.

Understanding Plant Nutrition: Fertilizers And Media pH

Argo and Fisher take a microscope to the details that can help growers make informed decisions on nutrients.

by ***BILL ARGO*** and ***PAUL FISHER***

CHOOSING fertilizers can be one of the most important decisions you can make for managing the media pH of container grown crops. It is therefore important to understand how fertilizers raise or lower media pH, which results largely from the form of fertilizer nitrogen (ammoniacal, nitrate or urea). This article will help you understand why fertilizers are classified as acidic or basic and how the reactions produced by the fertilizer affect media pH.

You Can't Measure Fertilizer Acidity With A pH Meter!

Here is a trick question: Which is the most acidic fertilizer in Table 1? The table shows the nitrogen (N):phosphorus (P_2O_5):potassium (K_2O) ratio, the fertilizer label description in terms of potential acidity or basicity, along with the percent of nitrogen in the ammoniacal form (the rest of the nitrogen in these formulas is made up of nitrate). We prepared a solution of 200 parts per million of nitrogen (ppm N) in deionized water, and measured the pH of that solution. Acid solutions have low pH below 7, and basic solutions have high pH above 7.

Table 1. pH effects of three fertilizer solutions.

N-P-K ratio	Potential acidity or basicity (lb/ton)	Percentage of nitrogen in the ammonium form	pH of a 200 ppm N solution
20-10-20	429 acidic	40%	4.75
17-4-17	0 neutral	25%	4.37
15-0-15	420 basic	13%	4.08

Even though 15-0-15 has the lowest pH of the three solutions at 200 ppm N, it is actually classified as potentially "basic." 20-10-20 is classified as a potentially "acidic" fertilizer, and 17-4-17 is classified as potentially "neutral." How is this possible?

The effect that a fertilizer has on media pH is dependent on the reactions that take place after the fertilizer has been applied to the crop. This reaction is determined by the nutrients (especially nitrogen) contained in the fertilizer, rather than the pH of the fertilizer solution that you can measure with a pH meter.

Predicting Fertilizer Reactions

The potential acidity or basicity value (examples are shown in Table 1) is usually printed on the fertilizer label. This value is calculated from the "Pierre equation," which was developed in the 1920s using field soils and fertilizers ranging from cow manure to the "new" synthetic fertilizers like ammonium nitrate. Values from the "Pierre equation" describe whether a fertilizer will generally raise media pH (acidic reaction) or lower media pH (basic reaction). Research to update this formula for container grown crops is currently underway at the University of Florida.

Units are given in terms of acidity or basicity in equivalent pounds of calcium carbonate ($CaCO_3$, which is the main constituent of lime) per ton of fertilizer. For example, if 20-10-20 has a potential acidity of 429 pounds per ton, then the reaction produced by one ton of the fertilizer will neutralize 429 pounds of calcium carbonate. If 15-0-15 has a potential basicity of 420 pounds per ton, then the reaction produced by one ton of the fertilizer will be equivalent to 420 pounds of calcium carbonate.

The potential acidity or basicity should be interpreted as a general tendency of the fertilizer to raise or lower medium pH over time, because it is based on many assumptions that do not always apply to container-grown crops. When comparing specific fertilizers, use a broad range for determining which fertilizers will produce different reactions in the medium. A safe bet is that if the difference in the calcium carbonate equivalency of two fertilizers is

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Table 2. Relative strengths of different solutions

	Relative units of acid or base
Nutrient solution at pH 5.0	1 acid
Nutrient solution at pH 9.0	1 base
100 ppm of ammonium-N	1420 acid

more than 200 pounds per ton, then the reaction produced by the fertilizers will be different. If the difference is less than 200 pounds per ton, then consider the reaction produced by the fertilizers to be similar.

The Effect Of Nitrogen On Media pH

There are three types of nitrogen used in water-soluble fertilizers: ammoniacal nitrogen (NH_4-N), nitrate-nitrogen (NO_3-N) and urea (Figure 1).

Ammoniacal nitrogen is acidic (a mental reminder is that both words begin with the letter "A"). When ammoniacal nitrogen is taken up by roots, the plant can secrete an acidic H^+ into the soil solution. The more H^+ contained in the root media, the lower the media pH.

Urea is easily converted into ammonium in the substrate and therefore can be thought of as another source of acidic nitrogen.

In contrast, uptake of nitrate nitrogen increases substrate-pH because basic OH^- or HCO_3^- are secreted by plant roots into the root media. Since OH^- and HCO_3^- are bases, nitrate uptake therefore can cause the media-pH to increase.

Another important process is called nitrification. Several types of bacteria in container substrates convert ammonium to nitrate. Nitrification releases acidic H^+ into the soil solution, causing the media pH to decrease.

Ammoniacal nitrogen is about three times stronger an acid than nitrate nitrogen is a base. For example, a fertilizer such as 17-4-17 has about 25 percent ammoniacal nitrogen and 75 percent nitrate nitrogen (1 NH_4-N:3 NO_3-N ratio), and the reaction produced by the 17-4-17 fertilizer tends to be neutral. With 40 percent of the nitrogen in the ammoniacal form and 60 percent in the nitrate form, 20-10-20 has an acidic overall effect (2 NH_4-N:3 NO_3-N ratio). In comparison, 15-0-15 contains only 13 percent of its nitrogen in the ammoniacal form and 87 percent in the nitrate form (0.5 NH_4-N:3 NO_3-N ratio). And the reaction produced by 15-0-15 tends to be basic.

The nitrogen in a fertilizer solution (measured in ppm N) has much more acid or base strength than the pH of that solution measured using a pH meter, as shown in Table 2.

For example, a solution with a pH of 5.0 would supply about 0.01 milliequivalents/liter of acidic hydrogen ions to the substrate. If all the 100 ppm ammonium-N were converted into nitrate-N through nitrification, the maximum amount of acidity produced would be 14.2 milliequivalents/liter of acidic hydrogen, or about 1,420 times more acidity than would be supplied by a solution with a pH of 5.0. Put another way, applying 100 ppm of ammoniacal nitrogen has the potential to supply the same amount of acidity as a solution with a pH of 1.8. The acidity produced by a solution with a pH of 5.0 would be equivalent to the nitrification of 0.14

ppm ammoniacal nitrogen (almost undetectable). Also, doubling the concentration of ammonium from 100 to 200 ppm N doubles the acidity.

While the effect that different nitrogen forms have on the substrate pH is much more complicated than this simple example, it does give you an idea why the nitrogen form of the fertilizer has a much greater effect on the substrate pH than does the solution pH.

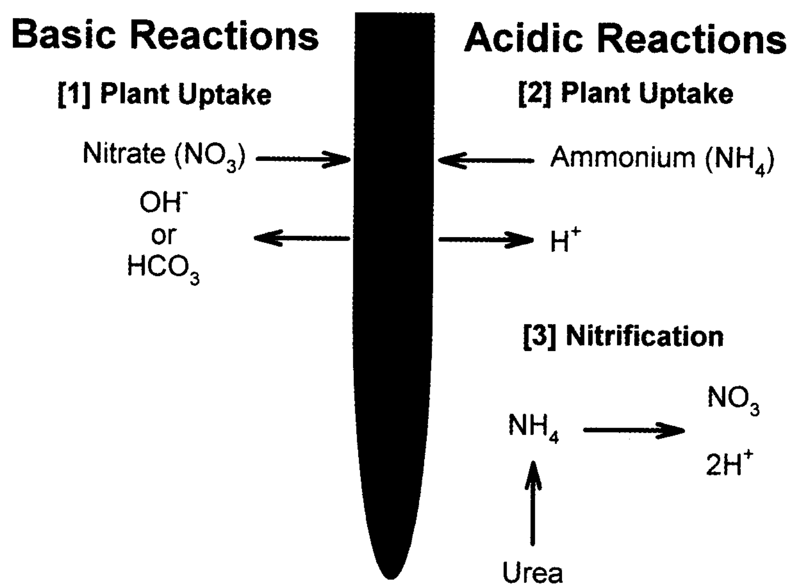

Figure 1. The effect of different forms of nitrogen on medium-pH. Nitrate nitrogen (NO_3-N) only affects medium-pH through plant uptake [1]. Ammoniacal nitrogen (NH_4-N) affects medium-pH through both plant uptake [2] and nitrification [3]). Urea must first be converted into ammoniacal nitrogen before it can be taken up by the plant [2] or go through nitrification [3].

Other Factors Affect Acidity And Basicity

- Nitrate nitrogen (NO_3-N) can cause the substrate-pH to increase, but only if it is taken up by the plant. If plants are small, or stressed and not growing, nitrate has little influence on substrate pH.
- Nitrification of ammoniacal nitrogen (NH_4-N) is inhibited by low substrate-pH (starting at around 5.5), low substrate temperature (less than 60°F or 15°C) and lack of oxygen through water-logging. Under these conditions, ammoniacal nitrogen is less acidic.
- Uptake of other positively charged nutrients such as potassium (K^+), calcium (Ca_2^+) and magnesium (Mg_2^+) can also cause the secretion of acidic hydrogen ions (H^+), similar to the uptake of ammoniacal nitrogen.
- Uptake of negatively charged nutrients such as phosphate (H_2PO_4-) or sulfate (SO_4^{2-}) can cause the secretion of basic OH^- or HCO_3^- ions, similar to nitrate nitrogen uptake.
- The effect nutrient uptake has on media pH will depend on the balance between the uptake of positively

In Person At OFA: More On Irrigation And Nutrition

Do you want to hear more about nutrition as it relates to irrigation? Check out the sessions at OFA Short Course. The authors of the Understanding Plant Nutrition series, Bill Argo and Paul Fisher, will be featured in sessions on water management. Here are the details:

New Research On Annuals, Part 3: Nutrition And Irrigation
Paul Fisher
Sunday, July 13, 4 pm

Learn the best ways to manage fertilizer and water for your annual crop, especially with young plants. Paul will address questions such as, "Should you add fertilizer to the mist? How do you know if plants are getting too much water?"

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Managing Crop Inputs & Environment: The Importance Of Water Quality
Bill Argo
Monday, July 14, 2:30 pm

Water quality and availability has become one of the most critical challenges facing many growers. The goal of this session is to have growers understand important aspects of water quality. Topics will include irrigation water alkalinity, EC, individual nutrient concentrations and how their presence or absence in the water affects pH and nutritional management.

Water Management: Vendor Attendee Interaction
Water Management: Trade Show Interactive
Paul Fisher, Ratus Fisher, Peter Konjoian, Rick Yates
Tuesday, July 15, 8 am and 9:15 am

These two sessions spotlight water treatment technologies and the best way to deliver water to crops. In the first session, vendors from water treatment and equipment manufacturers share overviews of their technologies. The second session moves to the trade show floor, with attendees touring booths featuring irrigation technology.

charged nutrients and negatively charged nutrients. If more positively charged nutrients are taken up, the net affect will be acidic. If more negatively charged nutrients are taken up, the net affect will be basic.

On a molecular basis, nitrogen is taken up more than other nutrients. Therefore, nitrogen form has a bigger effect on media pH than other nutrients.

The acidity or basicity value on the fertilizer bag is only a relative measurement of how the fertilizer formulation will affect media pH. Why is 20-10-20 more acidic than 15-0-15? Because 20-10-20 has more ammonium than 15-0-15. If media pH tends to drift up over time in your greenhouse crops, consider using a fertilizer higher in ammonium percentage, such as 20-10-20. 15-0-15 is more suitable if media pH tends to drift downward over time.

In next month's article, we will discuss how fertilizer formulation will affect nutrient supply. **GG**

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