Understanding Plant Nutrition

Nutrient Sources: Media Cation Exchange Capacity

In a year-long series, Argo and Fisher take a microscope to the details that can help growers make informed decisions on nutrients.

by BILL ARGO, Ph. D. and PAUL FISHER, Ph. D.

EVERY university course on soil fertility discusses the importance of the "cation exchange capacity" (CEC) of the soil for buffering nutrients and pH. In this article, however, we debunk the myth that CEC is important in soilless media. Why then should you care that container media has low CEC? Because understanding that nutrient levels and pH in the medium can change very quickly (within days or hours) can help you better manage pH and fertility levels in the greenhouse or nursery.

CEC And Buffering

CEC has been used historically to describe the buffering capacity of soil (mainly based on crops grown in field soils). Buffering means the resistance to change in pH or nutrient concentration in the soil solution. Therefore, a medium that is high in CEC would help growers maintain a stable pH or nutrient concentration over time.

Media particles, such as soil or peat, have negatively charged "exchange

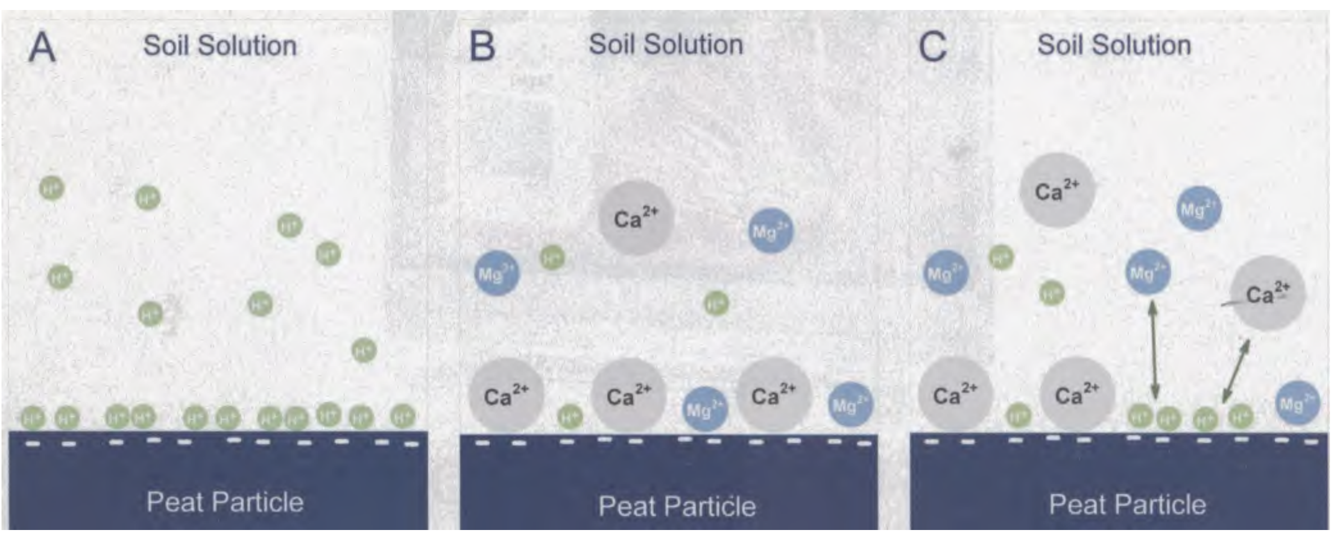

Figure 1. Examples of how cation exchange capacity buffers media pH and nutrient concentrations. (A) is an example of an acidic sphagnum peat particle. The peat particle contains several negative charges (exchanged sites) at the surface. In unlimed peat, these exchange sites are usually filled with hydrogen ions. (B) is an example of the same peat after the application of some limestone. The $CO3^{-2}$ of the limestone has neutralized most of the hydrogen ions in the soil solution as well as at the exchange sites, causing the pH to increase. Some of the calcium and magnesium (both cations) from the neutralized lime are attracted to the exchange sites. (C) is an example of the same limed peat, but after the application of an acidic fertilizer. The acidic fertilizer has produced excess hydrogen ions. If these hydrogen ions remained in solution, then the solution pH would be reduced. In this case, the excess hydrogen ions replaced a calcium and magnesium ion on the exchange site, which then entered the soil solution in their place. Because the net result was that no additional hydrogen ions entered the soil solution, the pH did not change, and therefore, the pH was buffered by the soil CEC.

sites" that allow the particles to loosely hold onto positively-charged "cations" (Figure 1). Cations include acid (hydrogen H+), fertilizer cations (e.g. ammonium NH4+, calcium Ca2+, magnesium Mg2+, potassium K+), and other waste cations (e.g. sodium Na+). Media with high CEC have the ability to absorb and release large amounts of cations from the soil solution, which evens out high and low concentrations of nutrients available for plant uptake.

Let's take an example of how CEC affects liming rates of acidic sphagnum peats. The exchange sites before liming are mainly loaded with acid (H+). The higher the CEC of the batch of peat, the more lime that must be added to raise pH up to around pH 6. That is why the amount of lime needed to reach a target pH may vary between sources, or why finer peats (higher bulk density with more exchange sites per unit volume) have greater lime requirements than coarser peats (lower bulk density with less exchange sites per unit volume).

CEC also helps explain how lime reacts with the growing medium. During the dissolution of limestone, some of the CO3-2 from the limestone neutralizes the H+ contained in the soil solution to form carbon dioxide and water. As the H+ is reduced in the soil solution, additional H+ moves from the exchange sites to the soil solution and is neutralized by the lime. Finally, calcium (Ca2+) and magnesium (Mg2+) from the neutralized lime moves from the soil solution onto the peat exchange sites. The net result is that the exchange sites become saturated with mostly calcium and magnesium, and the concentration of H+ in the soil solution is reduced (higher media pH).

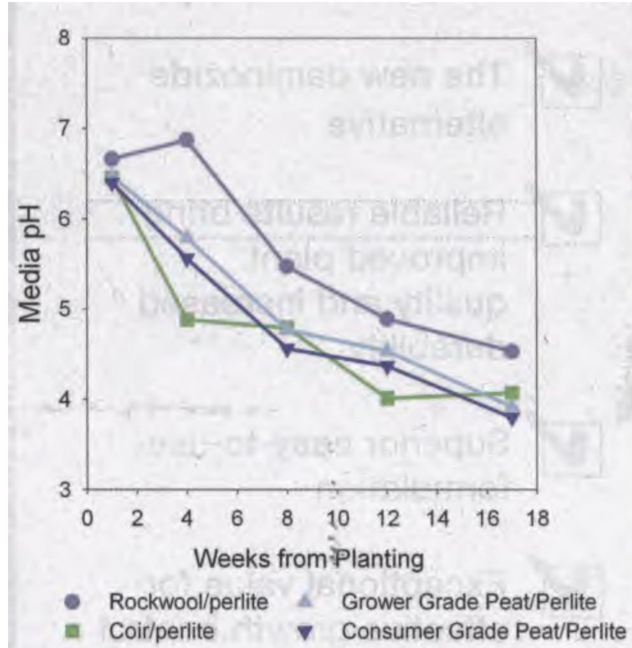

Figure 2. Effect of root media on medium pH. The grower grade peat was long fibered with little dust and the consumer grade peat was a more degraded fine peats with large amounts of dust. All media were blended with 30 percent perlite and the lime source was hydrated lime (low residual). The crop was impatiens grown with a water-soluble fertilizer containing 50 percent ammoniacal nitrogen and RO purified water. Acceptable pH ranges from 5.8 to 6.2. Research by Bill Argo and John Biernbaum.

How will CEC of the peat buffer pH during crop production? Let's assume a grower uses an acid-reaction fertilizer (e.g. 20-10-20). This fertilizer adds acid (H+) into the soil solution, which lowers the pH. However, some of that H+ in the soil solution is exchanged with the Ca2+ and Mg2+ on the peat. The acidity is removed from the soil solution, and the pH goes back up. In the process, Ca2+ and Mg2+ are also added into the soil solution.

How can CEC buffer nutrient concentrations? A growing medium can exchange nutrient cations back and forth between the exchange sites and the soil solution, in the same way as it can exchange H+ acid. Therefore, the exchange sites act as a back up "pool" of nutrients to recharge the soil solution when nutrient levels are low.

Media that have high CEC (more buffered) can resist a change in pH or nutrient concentrations for long periods of time, whereas pH or nutrient concentrations can change very rapidly in media that have low CEC (less buffered).

Bulk Density And CEC

Organic materials like peat are often shown to have

CEC values as much as 10 times greater than that of a typical field soil, based on weight. So why do media-pH and fertilizer level change so quickly in greenhouse production?

Anyone who has picked up a pot containing field soil knows that it weighs much more than a pot containing a peat-lite medium. Peat, bark, perlite, expanded vermiculite or any other material used to produce container media typically have a very low bulk density compared to soil.

In other words, you can get a lot more soil into a pot than you can a peat-lite medium. Consequently, the effective CEC of organic materials like peat measured on a volume basis (i.e. per pot) is about 40 percent to 50 percent less than that of a field soil. On balance, then, CEC of soilless container media is low and provides little buffering.

CEC And pH And Nutrition Management

Research has shown that the CEC of soilless media has little effect on resisting change in pH, or in supplying nutrients to the crop. Several experiments were completed at Michigan State University that tested the effect of CEC on long-term pH and nutrition management using impatiens as the test crop. The media tested ranged in buffering capacity from one considered very low (5 meq/liter, a 70 percent rockwool and 30 percent perlite mix) to one that would be considered highly buffered (76 meq/liter, a mix of 70 percent highly degraded consumer grade sphagnum peat and 70 percent perlite).

Hydrated lime was used as the lime source to increase the initial pH to about 6 in all media because it reacts quickly and completely and did not influence long-term pH management. The amount of hydrated lime needed ranged from 0 lbs/yd3 with the rockwool/perlite media, 0.8 lbs/yd3 with the coir perlite media, 2.5 lbs/yd3 with the grower grade sphagnum peat/perlite and 4.5 lbs/yd with the consumer grade sphagnum peat/perlite media.

When an acidic fertilizer solution was applied to the impatiens grown in the different media, pH of the rockwool medium tended to be higher than for the other media. In all media, however, the pH dropped very quickly to a low of about 4 (Figure 2) regardless of the CEC of the media.

When shoot-tissue calcium was tested after four, eight, 12 or 17 weeks of growth, there was little difference between plants grown in the media with low CEC (rockwool perlite) or relatively high CEC (consumer grade peat/perlite). The media-CEC therefore did not act as a buffer to nutrient levels available for plant uptake.

The conclusion of these and other experiments was that CEC from peat has little or no effect on either pH management or calcium and magnesium management in container grown crops.

Other Media Components

Secondary components (used at less than 40 percent of the total volume) for container media have little effect on buffering because they either have almost no CEC (perlite, polystyrene, rockwool, sand) or have such a low bulk density that its effect is minimal (vermiculite).

Calcined clay is an exception because it has a fairly high bulk density (about ½ that of the typical field soil) and CEC. But because of cost, calcined clay is typically added to container media at 5 percent or less of the total volume. Although calcined clay may affect buffering, the combination of lower bulk density and much lower incorporation rate means that its effect is limited.

CEC can be increased when a field soil is added to a container medium, which increases buffering of pH and nutrient levels because the medium has a high bulk density (weight). However, because of problems obtaining consistent and uncontaminated - field soil, and the problems for freight and retail from having a heavy soil, most growers are no longer using soil in container media.

Conclusion

In contrast to field soils, CEC of soilless media has little effect on resisting change in pH or in supplying calcium or magnesium to a crop. However, buffering does exist in soilless root media. In the next articles we explain how limestone can be used to buffer pH, calcium and magnesium. **GG**

About the authors: Bill Argo (bargo@blackmoreco.com) is technical manager at the Blackmore Company and Paul Fisher (pfisher@ufl.edu) is an associate professor and Extension specialist in the Environmental Horticulture Department at the University of Florida.

February 2008 • Greenhouse Grower