A UNIBEST PST-1 Resin Capsule

absorbs chemical elements (as ions) from the soil solution (the water in a moist soil) like a plant root

U.S Patent 5,355,736
Canadian Patent 2,087,153

Shifting the View

According to a ***traditional theory***, plants simply extract nutrients from a soil which we try to emulate with lab extraction methods. However, a laboratory extraction does not account for ion release and transport within a soil. In the ***nutrient bioavailability theory***, soil and plant roots are seen as a dynamic system. Ion exchange resins respond to nutrient availability because they resemble the plant root process of ion adsorption (Skogley 1994). This means resin adsorption directly accounts for the effects that soil chemical and physical properties have on the availability of chemical elements.

Plant Nutrient Uptake

Plants (and other soil organisms) take most of their nutrients from the soil as ions to obtain chemical elements used for metabolism. Ions move from the soil solution "outside" of plant cells to the "inside" by "passive" and "active" processes. As a root hair (figure 1) removes ions from the soil solution, concentrations near the hair become lower, causing ions to diffuse toward the root from the higher concentrations in the bulk soil. This process continually supplies the root with nutrients.

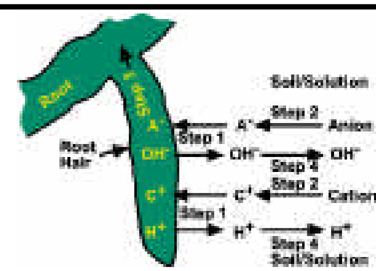


Figure 1
Diagram of a root hair and the steps associated with nutrient uptake.

Resin Capsules

Each PST-1 resin capsule (figure 2) contains thousands of resin beads charged with H+ and OH- ions held within a porous fabric membrane. The mixed-bed resins act as a strong sink for ions from soil solution. In a soil the capsule adsorbs chemical elements through an ion exchange process that occurs very close to the capsule surface. The amount of each ion adsorbed by a resin capsule (Schaff and Skogley 1982, Dobermann et al. 1994) during a specific time depends on the:

- Initial soil solution concentration of each ion
- Diffusion rate of each ion through the soil, and
- Capsule surface area in contact with the soil.

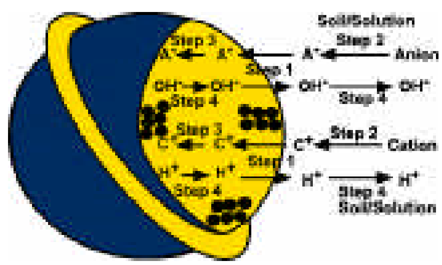


Figure 2
Illustration of a PST-1 resin capsule with individual resin beads containing either positive or negative charges showing steps associated with ion adsorption.

Adsorption Step 1

Initial adsorption takes place across the capsule membrane when it contacts a moist soil. The resins adsorb both positive (+) and negative (-) ions from the soil solution in exchange for H+ or OH- ions.

Because exchange reactions occur independently for each soil solution ion, the resin will simultaneously adsorb all types of available ions. This includes plant nutrients as well as elements like Mercury, Lead, Cadmium, Arsenic and Selenium. ***Only*** the bioavailable ***ionic*** forms of an element are taken up.

The quantity of each ion adsorbed by the resin during the first phase of accumulation depends on the amount of each ion in the soil solution when the capsule is placed in the soil. In Figure 3 this appears as the amount of adsorption during day one. For plants, this occurs when seedlings emerge or as roots grow into the new soil. This initial ion exchange reaction sets the stage for the following steps.

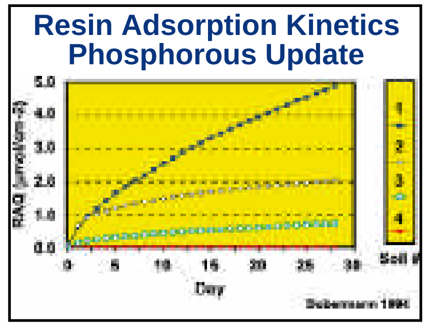


Figure 3 - Bioavailability for four soils

Step 2

The soil solution concentration of each ion at the resin-soil or root-soil interface decreases relative to ion concentrations in the bulk soil (figure 4) creating a "diffusion gradient." Diffusion gradients cause soil solution ions to move toward the resin capsule from ever-increasing distances in the soil. When ions reach the resin surface they are also exchanged for H+ or OH- ions. In this way, the resin capsule continues to function as a "sink," similar to a plant root taking up nutrient ions.

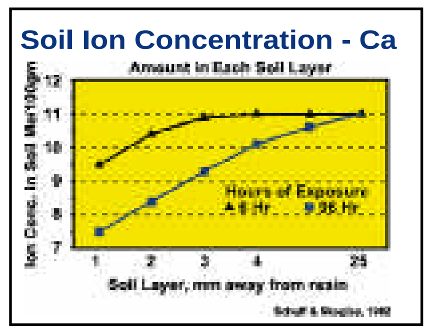
Soil properties regulate the rate of ion diffusion through a soil. These effects are different for each soil and each ion. This is the slowest part of the process, or the "rate-limiting" step and affects the amount of each ion accumulated by the resin during a given time. In the graph (figure 3) this step is shown as a continuous increase over the long term (Dobermann, et al. 1994). For the capsule to provide accurate results, it must be in place long enough for the effects of diffusion to be expressed. This usually requires two or four days, depending on diffusion conditions.

Step 3

An accumulation of ion occurs inside the capsule in the resin at the capsule-soil interface creating a diffusion gradient within the resin capsule. These ions then diffuse toward the center of the capsule where the specific ion concentration starts out at zero. The rate of ion diffusion through the resin capsule is much faster than ion diffusion through the soil, so this step is not rate-limiting. Step 3 in plants is the mass transport of ions by sap flowing from the root to other plant tissues.

Step 4

A continuous process results as electrical neutrality must be maintained in all parts of the system, as required by Mother Nature. The resin counterions, H+ and OH-, diffuse outward as other ions diffuse inward. Because most soils have more cations than anions that can diffuse to a sink, more H+ then OH- ends up in the soil surrounding a resin capsule. This causes a decrease in soil pH near the capsule, and this can increase the solubility of some elements representing a plant root function.



Conclusions

At the end of an accumulation period, the amount of each ion in a resin capsule is a measure of its "bioavailability" for the soil conditions during that period, therefore:

- Resin capsules can be used to directly measure the bioavailability of plant nutrients and soil ions.
- Soil chemical dynamics can be observed the way a plant does—in all types of soil.
- Site management strategies can be developed that deal with actual ion bioavailability or toxicity.
- Management decisions can be made on data representing actual soil processes.

References

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