Soil Science Spotlight

If we understand a soil,

we can improve it

Nitrogen, Phosphorus, Sulfur and Soil Microorganisms

Mobilization

You test your soil to make sure that it has enough nutrients available to your plants for them to thrive. The lab provides you test results, and may even include recommendations for adding nutrients to your soil. You make all the calculations needed to follow the recommendation only to find that your corn leaves are purple, indicating a lack of phosphorus. Why?

Recommendations provided directly from soil testing laboratories lack depth. Determining whether or not your soil will be able to provide sufficient available nutrients to your crop requires soil testing, but also requires additional in-depth analysis. Nutrient availability cannot be completely approximated by a soil test taken at one moment in time. For nutrients to be available to your crops, they need to be in the form of a positively or negatively charged molecule. For example, phosphorus is taken up by plants as a molecule called orthophosphate, which has a charge of either -1 or -2, meaning it has 1 or 2 extra electrons that will combine with a positively charged molecule. Phosphorus also can exist in the soil as phosphate, which has a charge of -3 and very readily combines with positively charged molecules, particularly calcium (Ca^{2+}) in alkaline soils and iron (Fe^{3+}), aluminum (Al^{3+}) and manganese (Mn^{2+}) in acidic soils. So, if plants need to take up charged molecules, and charged molecules want to combine with oppositely charged molecules and therefore become unavailable to plants, how are plants able to find any charged, available molecules?

When a charged molecule combines with another molecule of opposite charge, the bond can range from being very temporary to almost permanent, depending on the molecules and the conditions. Less permanent bonds allow nutrients to become bound and unbound, and in their unbound state they are available to crops. However, it is not just crops that seek these nutrients – soil microbes do as well. When a soil microorganism takes up a nutrient, it utilizes that nutrient temporarily and then excretes it as waste, or incorporates it into their body, releasing it only when the organism dies and decomposes. This process of releasing a nutrient is called mobilization.

Phosphorus

In the case of phosphorus, because it is so inclined to bond with other positive molecules, there is generally not a lot of free phosphorus available in the soil at any given time. Most of the available phosphorus is in the bodies of soil microorganisms. This means that if the soil is warm and moist all year round, the soil microbes are living and dying and there is a fair amount of available phosphorus due to the continual turnover. If the soil is warm and moist and then suddenly gets much colder and/or drier, much of the phosphorus will not be available to crops until the microbe bodies containing it are decomposed. If the soil is generally not conducive to healthy microbial activity (too cold, too hot, too dry, too wet, and/or too compacted and lacking air), much less of the soil's phosphorus will be unavailable compared to the amount shown in the soil test results. Most of the phosphorus that should have been available through mobilization will be bound to positively charged molecules. Phosphorus availability is largely controlled by soil microbial activity and turnover. Those purple streaks in your corn leaves? Probably due to the soil being too cold, too hot, too dry, too wet, or too compacted. The phosphorus is there in the soil, but not in a charged state that plants can take it up.

Nitrogen and Sulfur

Nitrogen and sulfur availability to plants is similarly controlled by microbial activity and turnover, but for opposite reasons. Where soil microbes help to keep phosphorus from being bound in the soil, soil microbes help to keep nitrogen and sulfur from leaving the soil. Unlike phosphorus which is resistant to leaving the soil, nitrogen, in the form of ammonia (NH_4^+) and nitrate (NO_3^-), and sulfur in the form of sulfate (SO_4^{2-}) leave the soil very easily through leaching and as a gas (volatilization). Soil microbes act as reservoirs to hold these nutrients in their bodies, making them available to crops as they die and decompose, just as with phosphorus. So, just as with phosphorus, the amount of available nitrogen and sulfur in the soil depends on the activity and population of the soil microbes. If the soil is not conducive to microbial activity, there will be much less available nitrogen and sulfur than would be predicted by soil test results alone. In soils that are too wet, too dry, too cold, too warm and/or too compacted, the soil microbes are not able to decompose organic matter present in the soil to free up nitrogen and sulfur for plants at the expected rate. So, even though you may have added compost and alfalfa meal to your soil to provide nitrogen to your plants, if you see signs of nitrogen deficiency, such as yellowing in older leaves, it is possible that the nitrogen is present in the soil but not available due to low activity of the soil microbes.

The easiest way to overcome low microbial activity is to improve the soil environment by having a balance of air and water as well as plenty of organic matter. However, if low microbial activity is due to the soil being too cold or too hot, you may need to consider providing nitrogen in a more readily available form. Rather than providing nitrogen in the form of alfalfa meal, soybean meal or compost, all of which need to be decomposed to release their nitrogen, urine properly and safely processed or blood meal are examples of organic fertilizers with more readily available nitrogen.