

Soil pH Effects on Nutrient Availability in the Everglades Agricultural Area¹

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Introduction

The Everglades Agricultural Area (EAA) originated in seasonally-flooded conditions growing predominately sawgrass (*Cladium jamaicense*) and other wetland vegetation, which led to accumulation of organic matter above the bedrock limestone (calcium carbonate). These peat soils developed throughout a period of several thousand years due to the presence of flooded conditions in which organic matter accumulation rates exceeded decomposition rates. Due to the drainage of these soils for water control and crop production in the early 1900's, the flooded conditions that led to organic matter accumulation were removed. Instead, soils were drained for most of the year, which led to much higher organic matter decomposition rates, soil compaction resulting from agricultural practices, promotion of muck fires, and increased potential for soil loss due to wind erosion. These factors have led to decreases in soil depth above the bedrock limestone, a phenomena commonly referred to as soil subsidence.

This document pertains to the organic soils in southern Florida and addresses management aspects to improve crop production while minimizing potential adverse environmental effects. The intent of this publication is to identify strategies that could be used to address the problem of the increasing pH in muck soils. The target audience for this publication includes growers within the EAA, state and federal personnel dealing with organic soils in southern Florida, researchers, and Certified Crop Advisers or other consultants making fertilizer and amendment recommendations.

Soil pH

When these soils were initially drained, pH values were much lower. Most organic soils historically have pH values ranging from 4.5 to 5.5. In contrast to that pH range, the current typical range for the shallow muck soils of the EAA range from 6.5 to 7.5, although pH is spatially variable. This document directly addresses this large change in soil pH and the controlling factors.

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Due to tillage operations for bed preparation, weed control, incorporation of fertilizers, and planting, particles of calcium carbonate are transported from the subsurface into the root zone of the surface soil. Since calcium carbonate is the source of agricultural lime, tillage of shallow muck soils is effectively liming the soil. Normally, growers would only intentionally add agricultural lime to a field to avoid aluminum toxicity and improve nutrient availability. Since muck soils have little aluminum, toxicity is not an issue. Nutrient availability can be adequate under moderately acid conditions in muck soils, while similar acidity levels would cause nutrient availability problems in mineral soils. Therefore, introduction of lime into the profile is not a desirable outcome for consistently high quality commercial crop production on organic soils in the EAA.

This tillage-induced transport is more problematic for many of the shallow soils less than 2 feet in depth. Additionally, carbonates dissolved in water can move up in the soil profile due to capillary action, and are often deposited at or near the soil surface after water is evaporated. Evidence of this effect can be observed by the white crust, a combination of calcium carbonate and calcium sulfate, formed on the soil surface during dry weather conditions. These factors have significantly increased soil pH with continued farming. In light of the probable continuance of subsidence in the future, soil pH can be expected to continue to increase, which will result in decreases in the availability of plant nutrients to crops.

Soil pH Effects on Nutrient Availability

It is critical for growers to have a clear understanding about factors affecting micronutrient availability and pH. Organic soils within the EAA formed as oligotrophic wetlands, meaning that most nutrient concentrations were commonly deficient for growth of plants other than the native vegetation. Micronutrients are mineral elements needed by plants in small quantities. Small variations from the optimum levels required for plant growth can be damaging and stunt growth and reduce yields. This deficiency is readily observed for phosphorus and

micronutrients, such as manganese, copper, and zinc. Early research has shown that application of these nutrients as fertilizers significantly increased crop growth and yield. However, rates of fertilizer application that historically produced a crop response have increased with time, corresponding with decreasing soil depth and increasing soil pH.

Nutrients in soil are strongly affected by soil pH due to reactions with soil particles and other nutrients, so in fact the availability of many nutrients has been determined as a function of soil pH. At the original pH of muck soils, total concentrations of phosphorus and micronutrients were too low to support crops, thus the need for supplemental fertilization. Most micronutrients and P are readily available to crops at low pH values, but P and micronutrient availability are optimal at pH values below the current pH of most muck soils. The problem is not so much that total nutrient concentrations are low but rather their availability to plants is too low. Although micronutrients differ somewhat in the response to pH, all show decreased availability with increasing pH at values commonly observed in most muck soils. Thus, the muck soils are increasingly developing conditions where most applied fertilizer nutrients are being made less and less available to crops.

Mechanisms of P and Micronutrient Fixation in Soil

Limestone is comprised of calcium carbonate, although some magnesium carbonate can be present. Upon reaction with water, the calcium carbonate is broken down into calcium ions and carbonates. The calcium ions can be readily adsorbed to soil particles and organic matter. However, the carbonates in turn react with hydrogen ions in solution (which act to keep the pH low), thus causing an increase in soil pH. The higher the amounts of carbonates in soil the higher the pH will be until a maximum pH of approximately 8.3 to 8.5 is reached. To control pH, it is advantageous to minimize incorporation of limestone into surface organic soils.

Fixation refers to the reactions of soil particles and elements, such as Ca, Al, and Fe, with P, which renders the P unavailable to plants. Some of these reactions are reversible so the P can be released,

however, a change in soil or environmental conditions is often necessary to release fixed P. Phosphorus availability to plants is strongly influenced by soil pH, and its availability is maximized when pH is between 5.5 and 7.5. Acid soil conditions (pH < 5.5), although not generally prevalent on muck soils of the EAA, cause dissolution of aluminum and iron minerals which precipitates with P effectively "tying" it up. Basic soil conditions (pH > 7.5) cause excessive calcium to be present in soil solution, which can precipitate with P, ultimately decreasing its availability.

Micronutrients are retained by the cation-exchange sites of soil particles, which can make some tightly bound micronutrients unavailable to crops. Micronutrients also undergo a number of other chemical and physical transformations affecting plant availability. Micronutrients are attracted and held tightly to calcium carbonate minerals, and soils with high pH have limited micronutrient availability since their reaction with these minerals increases with increasing pH. As a result, plants growing in soils containing high levels of calcium carbonate often have micronutrient deficiencies. In contrast, micronutrient availability can increase with the addition of organic matter due to the increase in exchangeable and soluble micronutrients, with the micronutrients bound to dissolved organic matter being slowly released and made available to crops. However, not all micronutrients behave the same in organic and mineral soils. Copper can form tight bonds with organic matter (more so than other micronutrients), which may reduce its availability in the organic soils in the EAA.

How to Address the pH Problem

There are several practical ways to address the problem of increasing soil pH. One way is to add an acid-forming amendment to reduce the soil pH, resulting in increased nutrient availability. Another means involves adopting specific fertilizer management strategies, such as timing, placement, split applications of fertilizers, and use of slow-release fertilizers. To address the vertical movement of calcium carbonate, cultural practices, such as a reduction in the number and intensity of tillage operations, can be effective as well as having

an ancillary benefit of reducing energy costs. Reductions in the rate of soil subsidence by flooding of fields during fallow will also help to decrease pH. During crop production, it is likely that stabilizing the water table will slow the movement of solubilized calcium carbonate upward with capillary water movement.

Soil pH Adjustment

A common method to reduce soil pH in the EAA is the application of elemental sulfur. When mixed into soil, sulfur-oxidizing microorganisms utilize the sulfur and convert it to sulfate, and in the process generate acid-forming hydrogen ions, which decrease the soil pH. However, depending on the buffering capacity of the soil, large quantities of sulfur are often needed to effect a change in soil pH. The buffering capacity is a measure of soil's ability to reduce changes in pH, and is largely affected by the mineral content, such as calcium carbonate. Research at the EREC has shown that up to 4000 lbs of sulfur per acre were needed to reduce the soil pH by one unit, although the effect did not last beyond 1 year (Beverly and Anderson, 1986; Burdine and Guzman, 1969). Thus, the buffering capacity of muck soils in the EAA is fairly high, which requires considerable amounts of sulfur for neutralization.

The cost-effectiveness of using sulfur to reduce soil pH may not be realistic due to the large amounts that would be necessary each year. This is especially true considering the large amounts of calcium carbonate present in EAA soils that can potentially counter the effects of sulfur addition. Thus, the buffering capacity of muck soils probably limits the effectiveness of using elemental sulfur to reduce pH.

Banding of sulfur near the plant row may be an effective means of adding considerably less sulfur while affecting nutrient availability in sufficient soil volume to satisfy the crop nutrient requirements for phosphorus and micronutrients. This technique has been used successfully with sugarcane in the EAA.

Alternative Strategies: Fertilizer Management Practices

Fertilizer management strategies can be used to avoid or minimize nutritional problems associated with increasing soil pH. One mechanism is just to increase total fertilizer application rates to overcome nutrient limitation. However, due to rising fertilizer costs and potential for damage to sensitive wetlands, this option is not practical.

Banding of fertilizers has been recognized as a significant practice that can decrease fertilizer application rates while maintaining crop yields, and is even more important in light of the changing soil conditions. In many cases, fertilizers are banded in a broad swath about 1-2 feet across the prepared beds, with the expectation that roots will be able to utilize these fertilizers more efficiently than broadcasted fertilizers. More precise application methods such as utilization of narrow bands of fertilizer will minimize direct contact of fertilizers with soil, maintaining high plant-available nutrient concentrations for the longest period of time. These spans of fertilizer should be in close proximity to the crop row to allow plant root access to the fertilizer within the band.

Another potential strategy is the split application of fertilizers, which would also reduce nutrient fixation to soil and increase its availability to crops. The timing of applications would be more time-consuming and require additional trips through the field, increasing fuel and equipment costs, but may ultimately reduce the total amount of fertilizer necessary to produce crops. With the increasing costs of fertilizers, the expanded use of split applications may prove viable in the future.

Most fertilizers are soil-applied at planting, which has proven reliable in the past. However, another option to combat nutrient deficiencies brought about by increasing soil pH may be the expanded use of foliar application. Many micronutrients are currently applied via foliar application, especially for vegetable crops. Since soil-applied micronutrients are increasingly rendered unavailable to crops due to rising soil pH, their application directly to plants may be a viable option in the future to meet the crop's needs.

The use of slow-release fertilizers (SRF) has not received much attention in the EAA in the past due to their higher cost than traditional fertilizers. However, SRFs offer potential benefits including the slow-release of nutrients, which will minimize their fixation to soil and increase their availability to plants. The disadvantage of the higher costs of SRFs can be offset somewhat by the lower application rates that may be required. The result of wide-spread use of SRFs may also include a potential reduction in the total amount of fertilizers applied to EAA soils, which may in fact help to reduce export of phosphorus and other nutrients into Everglades wetlands while still permitting commercial yields and quality to be produced.

Conclusions

The pH of muck soils in the EAA has increased slowly with time since drainage first occurred. The problem has been made worse as the organic soils become shallower, resulting from incorporation of bedrock limestone into surface soils by tillage. The pH has increased to the point that nutrients are becoming increasingly unavailable to crops when using traditional fertilizer application methods and rates. Options to combat this problem include adjusting the soil pH using sulfur amendments and by developing new fertilization strategies. Soil pH adjustment by sulfur addition has proven temporarily effective, but the large amount and cost required may limit its utilization. The expanded use of banding, split application, foliar application, and slow-release fertilizers appear to be viable options to combat the increasing pH. Cultural practices, such as reduced tillage and field flooding, may also be employed to reduce the rate of subsidence and the increase in pH. Coupled with the knowledge of how subsidence and cultural practices influence soil pH, use of new fertilizer management strategies appear to hold the most promise in addressing the increasing soil pH in the EAA. An added benefit to all of these strategies dealing with nutrient availability induced by increasing soil pH is the decreased potential for nutrient movement off the EAA farms.

Other Information

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