Chapter 15
Deployment of Wireless Sensor Networks for Soil Macronutrients Measurements in Farms

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ABSTRACT

Farmers need accurate information about soil nutrient content if they are to apply the correct amount of fertilizer. Farmers who do not practice regular soil tests are facing numerous difficulties such a lack of accurate statistical information for soil and crop management, increased costs for fertilizers, and environmental degradation. However, traditional laboratory testing is costly and laborious, taking up to three weeks to complete. This study presents a technology which integrated various elements into a portable in-field device that measures soil macronutrients of nitrogen (N), phosphorus (P) and potassium (K) and soil pH. Then it transmits the measured data wirelessly to remote base station for analysis, presentation and storage in real-time. Farmers can access the information from the base station server through their mobile phones. Firstly, the grower can use the test data to provide important indicators into the levels of nutrients in the soil which can be interpreted to stem over-use or under-use and efficiently manage their fertilizer application. Secondly, the system can decrease response time for the grower to implement alterations in the soil nutrient composition. And lastly, it can increase the awareness of precision agriculture, its benefits and usage amongst the average farmer. The results from this test provide important indicators into the levels of nutrients in the soil which can be interpreted to stem overuse or under-use. The grower can use the data compiled to efficiently manage their fertilizer application.

1. INTRODUCTION

All essential elements are by definition required for plant growth and completion of the plant life cycle from seed to seed. Some essential elements are needed in large quantities and others in much smaller quantities. However, from a practical standpoint, three of the six essential macronutrients are most often "managed" by the addition of fertilizers to soils, while the others are most often found in sufficient

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quantities in most soils and no soil amendments are required to supply adequate quantities. From a management perspective only, the primary nutrients are Nitrogen (N), Phosphorus (P), and Potassium (K), because they are most often limiting from a crop production standpoint. All of the other essential macronutrient elements are secondary nutrients because they are rarely limiting, and more rarely added to soils as fertilizers (Amundson, Guo, & Gong, 2003; Brady & Weil, 2002).

Nitrogen is a part of all living cells and is a necessary part of all proteins, enzymes and metabolic processes involved in the synthesis and transfer of energy. It is a part of chlorophyll, the green pigment of the plant that is responsible for photosynthesis. It helps plants with rapid growth, increasing seed and fruit production and improving the quality of leaf and forage crops. Nitrogen often comes from fertilizer application and from the air (legumes get their N from the atmosphere, water or rainfall contributes very little nitrogen) (Schaetzl & Anderson, 2005).

Like nitrogen, phosphorus (P) is an essential part of the process of photosynthesis. It is involved in the formation of all oils, sugars, starches, etc. It helps with the transformation of solar energy into chemical energy, proper plant maturation, and withstanding stress. Phosphorus effects rapid growth, encourages blooming and root growth. Phosphorus often comes from fertilizer, bone meal, and superphosphate (Schaetzl & Anderson, 2005).

Potassium is absorbed by plants in larger amounts than any other mineral element except nitrogen and in some cases, calcium. It helps in the building of protein, photosynthesis, fruit quality and reduction of diseases. Potassium is supplied to plants by soil minerals, organic materials, and fertilizer (Schaetzl & Anderson, 2005; Silva & Uchida, 2000).

Deficiencies of nutrients in plants have various visual symptoms that are usually similar regardless of the species. The most common deficiency symptom is reduced growth, which is difficult to detect and diagnose at a glance. Other visual symptoms usually involve changes in coloration following a specific pattern, such as from the leaf tip down the midrib towards the base of the leaf or from the leaf margin toward the midrib, or between the veins of the leaf. Such symptoms may appear in new leaves or old leaves, indicating the phloem-mobility of the deficient nutrient and the ability of the plant to translocate existing stocks of the deficient nutrient (Havlin, Beaton, Tisdale, & Nelson, 2005; Hillel, 2004; Lutgen & Tarbuck, 2004).

With nitrogen deficiency, plants often have stunted growth; leaves develop a yellow color, which is a condition known as chlorosis. Since nitrogen is a mobile nutrient within the plant, nitrogen moves from older growth to new growth when deficient. As a result, nitrogen deficiencies first appear in older leaves. Since deficiency symptoms are sometimes difficult to diagnose, the location of the symptom (new or old growth) helps us determine which nutrient, if any, is deficient. When nitrogen is severely deficient, chlorotic leaves may die and fall off the plant (Silva & Uchida, 2000; Soil Survery Staff, 2007).

Plants often have overall stunting, particularly during the early stages of growth during phosphorus deficiency. Phosphorus is a mobile nutrient; and so, symptoms first appear in older growth. When deficient, older leaves develop a dark green to blue green color. In certain corn and grass species, older leaves may develop a purple coloration. Phosphorus deficiencies can cause poor fruit and seed development as well as delay crop maturity (Silva & Uchida, 2000; Soil Survery Staff, 2007).

Likewise, plants often experience stunted growth with potassium deficiency. Like nitrogen and phosphorus, potassium is a mobile nutrient. Older leaves may develop chlorosis along the margin, or edge, of leaves. Certain crops may have weaken stalks, which causes lodging (toppling over) (Silva & Uchida, 2000; Soil Survery Staff, 2007).

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