Is Potassium Fertilizer Really Necessary?

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Potassium is required by plants. Not applying K on soils with low indigenous supplies limits yields and production and is considered a form of land degradation. On soils with high indigenous supplies, omitting K will not reduce yields or production; however, continued withdrawal of K through successive crop harvests will eventually deplete indigenous supplies to yield-limiting levels, as has been observed in several areas around the world.

Plants require 17 nutrients to develop properly. Potassium (K) is one of these and is taken up in large quantities. It is therefore termed a "macronutrient." Plants get their K from the soil via their roots. Consequently, one of the most basic questions that soil fertility and plant nutrition scientists have addressed over the past several decades is, "How much of a plant's nutrient needs can be met by what's already in the soil?"

To determine if a soil already has enough K, scientists apply incremental amounts of K then measure the degree to which plants respond. A zero rate of K, termed a "check" provides a basis for comparison. Increases in growth and yield with K additions, when compared to the check, indicate that the soil supply alone is not sufficient to meet the plant's requirements.

An experimental design that is often used to measure response is the "omission plot." Omission plots are a set of treatments that examine how the lack of one nutrient affects yields and nutrient uptake when all other nutrients are at sufficient levels. As an example, a recent meta-analysis from China summarized results from a total of 522 omission plot experiments across three major wheat-growing regions (Liu et al., 2011). The average response to K additions was 0.74 Mg ha^{-1}.

Plant response has been and continues to be the basis for determining whether or not K is needed. One general type of approach, termed "plant-based" in this article, relies primarily on these types of plant measurements. The other approach, "soil-testing based" also relies on plant response but incorporates soil analysis. We discuss each of these approaches.

Plant-Based Approaches

To determine how much of the plant's nutrient needs can be met by the soil, plant-based approaches use measurements of K uptake. Using omission plots, the "indigenous supply" of K in the soil is found by measuring the total amount of K taken up by plants that are grown where no K has been applied but where all other nutrients are in sufficient quantities (Dobermann et al., 2003). The indigenous soil K supply is compared to the amount of K taken up by plants receiving adequate K. If both quantities are the same, then plant-available K supplies in the soil are sufficient. If K uptake by fertilized plants exceeds the indigenous K supply, then the soil supply of K is inadequate.

Because it is not feasible to put omission trials on every parcel of ground that is to be evaluated, scientists assemble data from various sites and years where such trials have been conducted and create models that help them estimate indigenous soil K supplies and total uptake requirements for areas where no data exist. An example of this approach is Nutrient Expert (Pampolino, 2012).

Soil Testing-Based Approaches

Soil testing is another approach to determining how much of the plant's nutrient needs can be met by the soil. It is also built around plant response, but the emphasis has most commonly been on yield response rather than on nutrient uptake.

Soil testing was developed to provide a method for predicting, before a crop is grown, whether or not soil K supplies are adequate (Bray, 1944). Soil testing usually uses chemical solutions to remove a portion of the K from soil particle surfaces that is considered to be plant-available. Because of the way these extracting solutions work, the K that is measured is termed "exchangeable K." It is not a direct measure of the total amount of K available for plant uptake. Instead, it is simply an index that must be related to plant response to have any agronomic meaning. Creating this relationship is accomplished with a calibration study.

In a calibration study, a representative sample of the soil is taken from the experimental site and analyzed for exchangeable K. Then one of two experiments is conducted. The first option is an omission plot, like that described above, where crop yield without K (the check) is compared to crop yield fertilized with K. The second option is a K rate study, where incremental rates of K, including a check, are applied. The first approach measures yield response only. The second approach measures not only yield response but, when combined with statistical models, the quantity of K that was needed to just reach

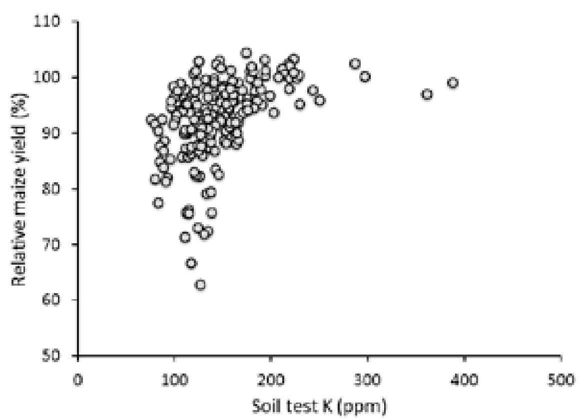

Figure 1. An example of soil test calibration data (adapated from Barbagelata and Mallarino, 2013).

Nutrient omission plots in spring wheat at the Experimental Agricultural Enterprise "Omskiy" of the Siberian Research Institute of Agriculture, Omsk District (left to right: Dr. N.A. Voronkova and Dr. V.V. Nosov). *Photo taken by V. Nosov.*

the highest yield attainable at that site. The yield of the crop grown without K is expressed as a percentage of the yield obtained with sufficient K. This percentage, called "relative yield" indicates whether or not the indigenous supply of K is adequate. A relative yield less than 100% signals deficiency. The soil test level measured at that site is then associated with the observed relative yield. This association indicates what percent of the attainable yield can be met by the supply of indigenous soil K indexed by the soil test (Dahnke and Olson, 1990).

A recent example of such a calibration comes from Iowa State University (Barbagelata and Mallarino, 2013) and is shown in **Figure 1**. Each point in the figure comes from one study conducted in one year, what scientists call a "site-year." The figure demonstrates that when many site-years of data are combined, a generalized relationship emerges: as the soil test level of K declines, crop yields decline when left unfertilized, indicated by lower relative yields. Such a relationship forms the basis of soil testing-based approaches that predict whether or not soil supplies of plant-available K are adequate at any given location.

Nutrient Budgets

A key component of both plant-based and soil testing-based approaches is the nutrient budget. It is calculated by subtracting the amount of K removed from a parcel of land from the quantity of K applied. Positive budgets indicate K enrichment while negative ones signal K depletion. Most often, "partial budgets" are calculated. These simplified budgets compare: 1) nutrients removed with harvested portions of plants, termed "crop removal" and 2) K applied with commercial fertilizers, manure, and/or biosolids. These budgets are partial because they do not consider all inputs and outputs.

Potassium budgets are of great interest to scientists around the world. They indicate whether agricultural practices are depleting, enriching, or maintaining indigenous K supplies. Where indigenous supplies of K are low, enrichment is appropriate. Depletion is appropriate where indigenous supplies are high, such as in more arid agricultural areas; however, there is a caveat to depletion. If it occurs long enough on soils with high amounts of K, the indigenous supply eventually becomes inadequate for crops.

At a workshop held in Uganda, stakeholders determined that negative nutrient budgets should be used as an indicator of land degradation (Bekunda and Manzi, 2003). The stakeholders were farmers, traders, decision and policy makers, staff of extension, researchers, and development organizations. Case studies demonstrated that, "…commercial farmers appear not to be re-investing some of the sale proceeds into replacing nutrients removed in harvests…".

Thus, K applications must not only provide enough K to meet crop needs, they also need to sustain plant-available soil K supplies over the long term.

Conclusion

Potassium is required by plants. Not applying K on soils with low indigenous supplies limits yields and production and is considered a form of land degradation. On soils with high indigenous supplies, omitting K will not reduce yields or production; however, continued withdrawal of K through successive crop harvests will eventually deplete indigenous supplies to yield-limiting levels, as has been observed in several areas around the world.

Potassium fertilizer is necessary. Both plant-based and soil testing-based approaches inform decisions about whether or not a K application is needed to provide plants with adequate nutrition and to sustain soil productivity.

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