Potassium Placement for Efficiency

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Agronomic efficiency for potassium (K) is the increase in yield per unit of applied K. Larger, periodic K applications can have efficiencies similar to smaller, annual ones, providing farmers with flexibility in timing and placement. Band applications are typically more efficient than broadcast applications when lower rates are applied. In reduced tillage systems, bands of K deeper in the soil may provide nutritional advantages under dry growing conditions.

Farmers have two basic placement options: broadcasting and banding. Broadcasting involves applying potassium (K) fairly uniformly over the soil surface. Broadcast K can be either left at the surface when no tillage is used or incorporated a few centimeters into the soil. Banding is the placement of fertilizer in small zones. These zones can be at the surface or below.

Which placement method is most efficient depends on the cropping system, the management practices used, the genetics employed, and the environmental conditions encountered. We will focus on maize in the temperate region of the U.S. Corn Belt, which is usually grown in rotation with soybean. Management is large scale and mechanized with typical row widths of 76 cm. Hybrid maize is usually planted in April and May and harvested in October. High rates of K uptake usually occur in June. Seeding rates average 74,000 to 86,000 seeds/ha. Potassium is typically broadcast in the fall after soybean harvest, prior to the spring when maize is planted. Land ownership varies, and owned and rented land are often present within one farming operation.

Potassium Efficiency

When we use the word "efficiency", we often think of "getting more for less". There are many different ways to define efficiency; however, we examine how much additional yield is gained from a K application – termed "agronomic efficiency" (AE). It is calculated by dividing the yield response to K by the amount of K applied and is reported in units of kg grain/kg K_2O.

Most often, efficiency is calculated for one season, but this doesn't work for scenarios when single, larger rates are applied that last for several years. Larger, periodic applications can be just as efficient as smaller, annual ones. As an example, a study from Iowa (Mallarino et al., 1991) compared large broadcast applications that resulted in a total of 675 kg K_2O/ha at the start of the study to annually broadcast applications of 54 to 81 kg K_2O/ha (**Table 1**). Maize and soybean were grown in rotation. After 10 years, both approaches had applied a cumulative amount of 675 kg K_2O/ha. The AEs were nearly identical: 10.6 kg grain/kg K_2O for the annual applications and 10.0 kg grain/kg K_2O for the initially large applications.

A large application is often chosen when land is owned, K prices are lower, and sufficient capital exists for the larger initial purchase. Smaller, annual applications are often utilized when ground is rented and capital is limited; however their cost is more subject to price fluctuations.

Basic Principles of Banded Applications

Band applications of K are often made to get the highest yield increase possible from a low K rate. They have a couple of key advantages over broadcast applications: 1) they can be sub-surface applied near the crop row where they are within reach of developing root systems, and 2) the K is concentrated in a zone, creating a higher quantity of plant-available K. Concentrated zones are more critical early in the season when maize roots take up K most rapidly.

In a classic study that compared banded and broadcast applications (Parks and Walker, 1969), banded applications had a higher AE than those that were broadcast (**Figure 1**). A low K rate had a higher AE than a high K rate (compare **Figures 1a** and **1b**). This was the result of a rapid increase in maize yield with the first few increments of applied K. At the highest rate applied (**Figure 1b**), AE was lower but overall yields were higher. This is an important point when talking about efficiency. The goal is to optimize, rather than to maximize, efficiency. Overall production, as well as several other ecosystem services, must be considered.

There is another important principle in **Figure 1**. At higher soil test levels, differences between band and broadcast placements diminish, especially at higher K rates. In fact, at high rates of applied K, broadcast

Table 1. A comparison, at the end of ten years, of the agronomic efficiency (AE) of 675 kg K_2O/ha applied by the initiation of the experiment to the AE of annual applications of 54 to 81 kg K_2O/ha applied each year (Mallarino et al., 1991).

Fertilizer rate	Total K applied after 10 years	Cumulative maize response	Cumulative soybean response	Total response	AE
	(kg K_2O/ha)	--------------- (kg grain/ha) -----------			(kg grain/kg K_2O)
554 to 81 kg K_2O/ha/y	675	5207	1922	7129	10.6
675 kg K_2O/ha	675	5584	1183	6767	10.0

Note: responses for maize and soybean are each summed over 5 years. Maize grain yield was adjusted to 15.5% moisture but soybean grain yield was not adjusted for moisture content.

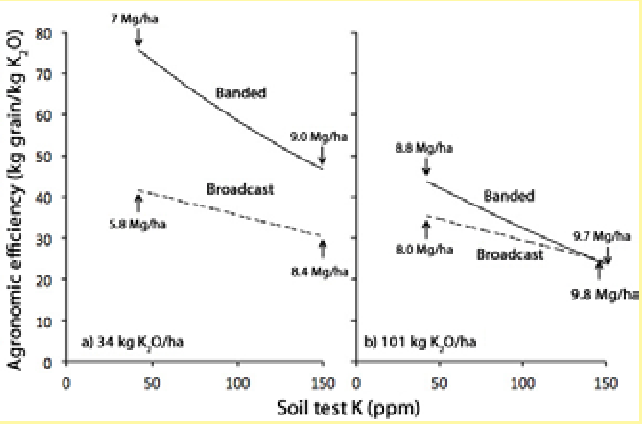

Figure 1. Agronomic efficiency of maize grain yield response to banded and broadcast applications of a) 34 kg K_2O/ha and b) 101 kg K_2O/ha at various soil test levels. Responses are from a multivariate regression model. Modeled grain yields at low and high soil test K levels are provided for each placement method (Parks and Walker, 1969).

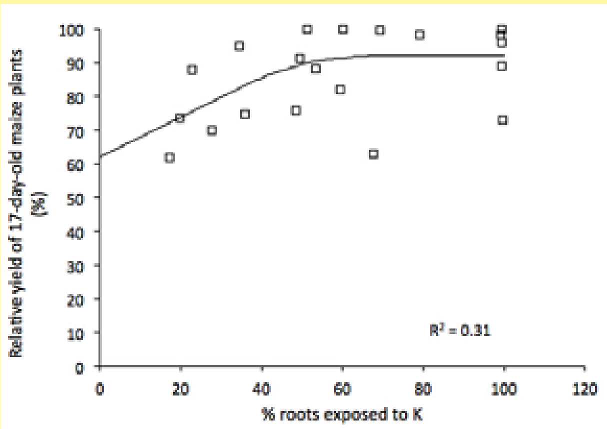

Figure 2. Aboveground biomass yield of 17 day-old maize plants expressed as a percentage of maximum biomass yield for various percentages of the root volume exposed to K (Claassen and Barber, 1977).

applications are expected to outperform banded ones. Why? It has to do with how much soil volume is fertilized.

A disadvantage of a band application is that it is not well distributed throughout the soil. Earlier work with young (17 day-old) maize plants (Claassen and Barber, 1977) demonstrated that about 50% of the roots needed to be exposed to K to maximize growth (**Figure 2**). This work suggests that if K is placed only in bands, the bands should be applied in different positions over time to expand the volume of soil that is fertilized. What many producers have done is to combine larger, periodic broadcast applications of K with banded ones. The broadcast applications fertilize a larger soil volume while the banded applications provide concentrated zones that young root systems can access.

When banding K, it's best to co-apply either phosphorus (P), nitrogen (N), or both. Why? The answer has to do with root proliferation. When maize roots grow into a concentrated band of either N or P, hormonal feedback mechanisms within the plant signal root branching. Roots in the bands form secondary, tertiary, and higher laterals, resulting in a mass of roots in the band. More roots aren't necessarily produced; rather, a greater proportion of the root system is in the band. Potassium doesn't evoke this response. So without N or P, plant roots will grow right through a K band. Of the two nutrients to co-apply, P doesn't move far in soils and has residence times longer than a single season, just like K; however, N bands are typically short-lived. So P and K banded together create an enriched zone that roots can explore for more than one season.

Banding to Anticipate Dry Weather in Reduced Tillage Systems

A phenomenon of reduced or no tillage is K stratification in soil. Soil at the surface contains more K than soil deeper down. Surface levels can be two to three times as concentrated in K (Karathanasis and Wells, 1990).

The change from more to less soil disturbance affects more than just the distribution of K. It also affects where in the soil maize gets its K. Back in the 1980s, a group of researchers at Purdue University compared conventional (moldboard plow) tillage to no-till (Mackay et al., 1987). They combined field measurements with a mechanistic model and came up with some interesting findings. Their results, **Figure 3**, show that maize grown under no-till gets more of its K from the uppermost soil layer than maize under conventional tillage. The researchers concluded that,

"Conservation tillage systems may be less tolerant of unfavorable growing conditions during periods of rapid nutrient uptake (late June and early July in the [U.S.] Cornbelt) because of the increased dependence on K… near the soil surface. Some deep placement of fertilizer…K may therefore be desirable after several years of no-till cropping, to provide…K to roots growing deeper in the soil and to lessen the dependence on nutrients in the soil surface layer."

Years earlier, one of the researchers from this group had discovered that maize responded more to K when the growing season was drier (Barber, 1959). **Figure 4** shows that maize yield was increased 30% under such conditions but was much lower when the season was wetter.

All of this evidence pointed to the possibility of

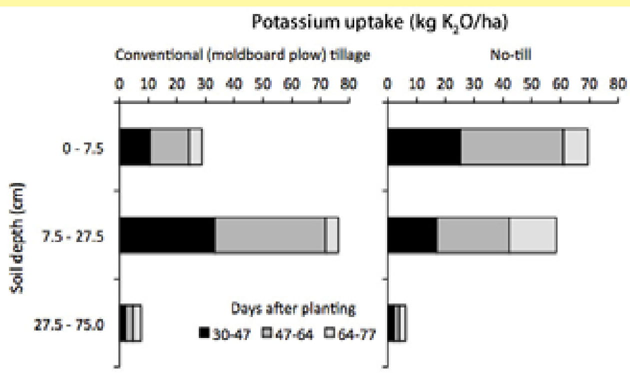

Figure 3. Potassium uptake from three soil depths (0 to 7.5, 7.5 to 27.5, and 27.5 to 75 cm) for two tillage systems (conventional and no-till), measured at three intervals during the growing season (30 to 47, 47 to 64, and 64 to 77 days after planting) (Mackay et al., 1987).

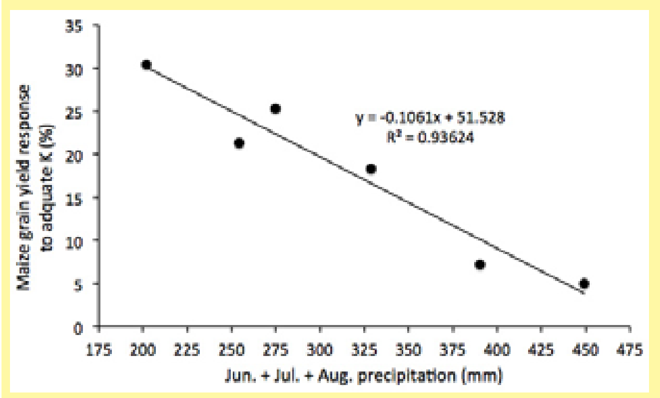

Figure 4. Response of maize grain yield to adequate levels of soil K at various levels of total precipitation for the months of June, July, and August, expressed as a percentage of maximum yield (Barber, 1959).

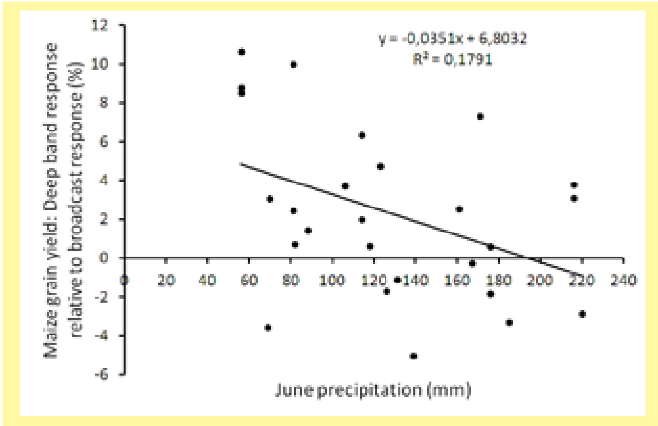

Figure 5. Maize grain yield response to deep banded K for various amounts of rainfall in June, expressed as a percentage of maize yield attained with broadcast K applications. Positive percentages indicate higher yields with banding (Bordoli and Mallarino. 1998).

placing K deeper in the soil to increase the fertilized soil volume and make it strategically available in reduced tillage systems, especially under dry growing conditions. This is exactly what researchers investigated almost a decade later.

In the state of Iowa in the U.S., scientists placed K in bands at a depth of 15 to 20 cm below the soil surface (Bordoli and Mallarino, 1998). The bands themselves were about 2.5 cm wide. These bands were applied and maize planted over the top of them, so that they were directly below the crop row. Trials were conducted both at research farms as well as on farmers' fields. Maize responded at some sites but not others. When responsive and non-responsive sites were all grouped together, deep bands of K increased maize yield by about 0.2 Mg/ha in trials on research farms and by about 0.6 Mg/ha in farmers' fields. These responses occurred even when soil samples taken to a depth of 15 cm indicated adequate or high K fertility.

The researchers noticed that there appeared to be a relationship between maize response and weather conditions, just as the researchers from Purdue had theorized:

"It is likely that the responses to deep-banded K were related with weather conditions, particularly soil moisture….The correlations do suggest, however, that response to deep-banded K was greater when there was little rainfall in June."

Their data, which were not graphed in the original publication, are provided in Figure 5. While not strong, there is a trend toward greater yield responses with lower precipitation during June, the month when nutrient accumulation is rapid.

Summary

Gaining the most yield from an application of K requires knowledge of the cropping system, management practices, genetics, and environmental conditions. For maize grown in the U.S. Corn Belt, farmers have flexibility in gaining the most efficiency from K fertilization. Periodic, larger applications appear to be just as efficient as smaller, annual ones. At lower soil test levels when only low rates of K are applied, banding has greater efficiency; however at higher rates, broadcast and banded applications may be equally effective. In reduced tillage systems, a deep band of K below the crop row may be a good strategy to minimize malnutrition problems if the growing season becomes dry during periods of rapid nutrient uptake.

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