(i.e.Beijing, Tianjin, Hebei, Henan, Shangdong, and Shanxi provinces) of 7 kg/ha annually (**Table 2**).

Impact of potash application on main crops

Between 2001 and 2010, the IPNI China Programme conducted 1,044 field trials with different crops across the country (**Table 3**). These results indicated that fruit trees, cotton, tuber, and oil crops have the highest yield responses (17 to 23%) to K fertilization. Fruit trees, vegetables, and tea had the highest gains in profit (USD 875/ha to USD 3,548/ha) due to K application. Vegetables and tuber crops have the best agronomy efficiency (44 kg to 58 kg produce per kg K applied), which was significantly higher than other crops. IPNI has also summarised results from 1,041 field trials conducted over the past three decades in South China on 30 main crops. The results showed good yield responses to K fertilization in all crops. Most of the cash crops and vegetables showed better yield responses and net profits to K application than grain crops. In general, higher economic gains were found when potash was used on cash crops and vegetables first.

Soil test-based K fertiliser recommendations for selected crops

Table 4 presents optimum, soil test-based K application rates for four main crops in South China that were developed for farmer use. Many other crops in all regions also have similar recommended K fertilization rates. Further research by the IPNI China Programme and its cooperative research network will be focused on evaluating the effect of K application with varying soil water levels, nutrient spatial distribution in fields, and K movement in the farmland ecological system and its environmental effects, if any.

Conclusion

Potash fertilisation is very important and profitable in China's crop production. Our challenge is to use K efficiently to increase our crops needs.

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Precision Management of Root Zone Potassium for Corn: Considerations for the Future

T.S. Murrell and T.J. Vyn

Precision technologies allow fertilized soil volume to be managed over time to create zones of higher fertility, but just how this should be done for optimum short-term and long-term crop response is not well understood. Relevant considerations for K fertilizer placement include the persistence of increased fertility after banded applications as well as the redistribution of K within the soil that occurs simply under normal crop development. Research indicates that the location of prior crop rows may be even more important to soil K levels than the location of past fertilizer K bands.

Precision guidance systems are capable of a very high level of repeatable accuracy in geo-positioning. Currently available equipment advertises 1 in. pass-to-pass accuracy. These technologies, in conjunction with geographic information system software, allow all equipment passes to be spatially referenced, recorded, and stored.

Abbreviations and notes: K = potassium; P = phosphorus; N = nitrogen; S = sulfur; ppm = parts per million.

Such capabilities provide new opportunities to manage nutrient applications, particularly those that are banded separately from (e.g. deep banding with strip tillage), or in conjunction with, crop planting operations. Instead of settling for a random array of past band applications in the field and limited knowledge of their exact location, farmers can now decide where future fertilizer should be banded in relation to past bands. If desired, farmers can place fertilizer in the same band year after year or offset

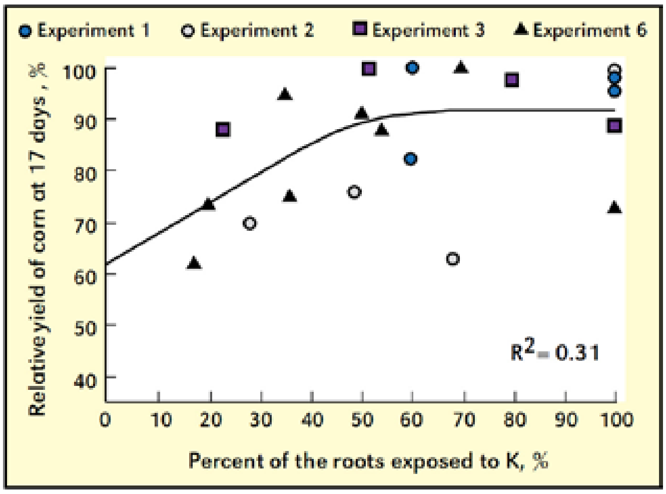

Figure 1. Relationship between relative yield of above-ground biomass of 17-day-old corn plants and the percent of roots exposed to K (Claassen and Barber, 1977).

bands from one year to the next at any desired distance from one another. Consequently, sub-surface fertilized soil volume can be managed more precisely than before. It is not clear, however, how bands should be managed over time to maximize profitability and productivity.

This article focuses on considerations for managing banded K applications over time for corn. Unlike N and P, localized placement of K does not cause roots to proliferate in enriched zones (Claassen and Barber, 1977). Consequently, if roots are to take full advantage of a concentrated supply of K in a band, either N, P, or both may need to be co-applied.

A question being addressed in current tillage and K placement research is how much of the soil volume needs to be fertilized to maximize corn yield. Some insight into the answer to this question was provided by Claassen and Barber (1977). In their growth chamber studies of young corn plants grown in pots, it was found that 17-day-old corn plants, on average, had maximum above-ground biomass accumulation when at least 50% of the soil volume was fertilized with K (**Figure 1**). Translating these results to the field, however, is not straightforward,

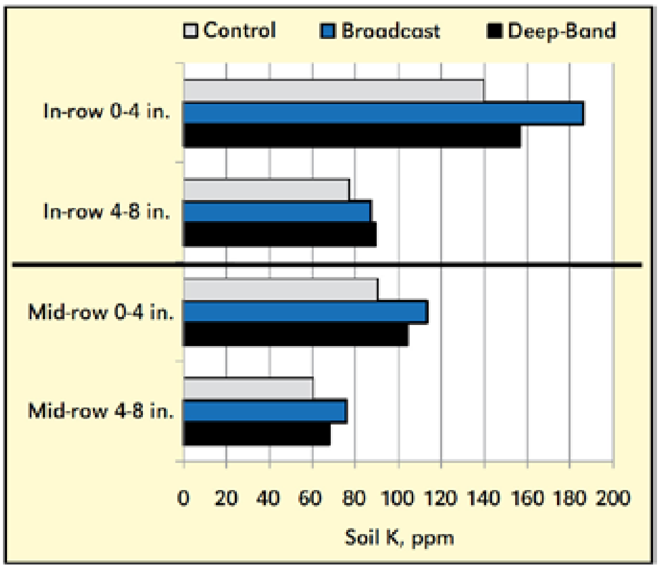

Figure 2. Soil K concentrations in spring 2008 following the third strip-till corn cycle for a corn-soybean rotation involving 30 in. strip-till corn and 15 in. no-till soybean.

given the variability in rooting depth and other factors in present-day high plant density environments as well as the need to evaluate the cumulative effects over the entire growing season.

The prevalence of conservation tillage systems has led to nutrient stratification in many fields, where both P and K are more concentrated near the surface than deeper in the soil profile (Robbins and Voss, 1991). Moncrief et al. (1985) showed that stratification occurs quickly in reduced tillage systems where broadcast fertilizer K is applied. In his study examining spring K applications in both no-till and spring chisel/field cultivator systems, higher ammonium acetate extractable K levels near the surface were measured 2 months after application. Differential soil test K stratification in the 0 to 2, 2 to 4, and 4 to 8 in. depths due to spring tillage systems (no-till, strip-till, and field cultivator) in the prior corn year were also observed just 12 months after both broadcast and deep banded application of 150 lb K_2O/A (Yin and Vyn, 2004).

Higher soil test P and K levels near the surface in reduced tillage systems appears to be among the list of possible factors altering corn root distribution in the soil profile. In a Minnesota study (Bauder et al., 1985), root distribution was compared among several different tillage systems during the summer. In the upper 3 in. of soil, no-till and ridge-till had higher root length densities and greater calculated root lengths than where soil had been moldboard plowed or chiseled. In addition, most of the roots were located directly below the row, with very few of them 7.5 to 15 in. away. Compared to no-till, chisel tillage, and moldboard plowing, ridge-till had the greatest overall root length and the greatest penetration of roots through the soil profile. In contrast, no-till had the greatest root length density below the row at the shallowest depth and the lowest root length density in all lower layers.

Stratification of nutrients, along with changes in root distribution with various tillage systems, has led researchers to investigate if there is any advantage to increasing the volume of fertilized soil in the likely rooting zone with bands at various depths. Although banded K applications made at the start of a season initially create concentrated zones in the soil, these zones may not be detectable by the end of the season when soil sampling is conducted. Low rates of K, like those found in starter fertilizer formulations, may be too low to provide long-lasting fertility increases unless they are applied repeatedly in the same areas over time. In a study examining the effects of 25 years of N-P-K applications banded 2 in. to the side and 2 in. below the corn seed at rates ranging from 11 to 23 lb K_2O/A/yr (Duiker and Beegle, 2006), only a slightly enriched zone next to the row was detected under chisel/disk tillage. Soil was sampled at 0 to 2, 2 to 4, and 4 to 6 in. depth increments along transects perpendicular to rows. In the other two tillage treatments examined, no-till and moldboard/disk, no enriched zone was detected where the starter fertilizer had been applied. This was in contrast to P, where distinct zones were found in all three tillage treatments. Instead, the most concentrated zone in the soil following grain harvest

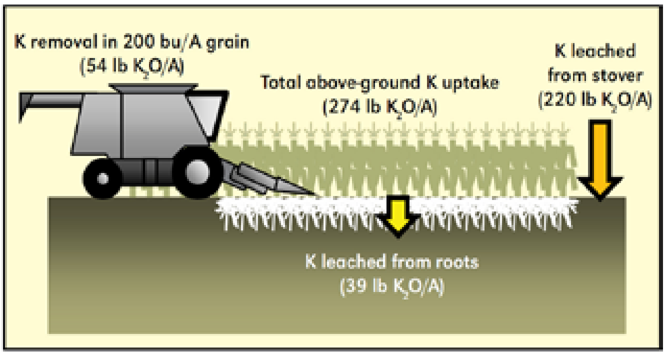

Figure 3. Estimated quantities of K_2O removed from the field with grain harvest as well as returned to the soil from the corn plant through leaching of K fro corn stover and roots. Quantities are for 200 bu/A corn grain.

was in the corn row. In studies from Iowa, enriched K zones in the corn row were detected in both chisel-disk and no-till systems after 4 years of annually deep banded K (Mallarinio and Borges, 2006). Bands were placed 5 to 7 in. deep in the spring prior to tillage and applied at a rate of 70 lb K_2O/A/yr. Corn was planted directly over the bands. Enriched zones in the row were detected consistently in both tillage systems at the 2 to 6 in. depth increment. Recently collected data from Indiana in a strip-till corn followed by no-till soybean system (**Figure 2**) shows higher K concentrations in the corn row than between rows where K had been both broadcast or deep banded. Interestingly, the same effect was observed where no K had been applied (Vyn, 2010).

Whether or not banded applications of K result in detectable zones of higher fertility may be influenced greatly by the growth of the corn crop itself. **Figure 3** shows estimates of the quantities of K taken up, removed by crop harvest, and returned to the soil through leaching by a 200 bu/A corn grain crop. The assumptions made were as follows: a) crop removal was 0.27 lb K_2O/bu; b) total above-ground plant uptake was 1.37 lb K_2O/bu; and c) leached K from the stover was the difference between total uptake and crop removal. Estimating K leached from the roots relied on estimates made by Amos and Walters for root dry matter production per plant (Amos and Walters, 2006). Grain test weight was assumed to be 56 lb/bu at 15.5% moisture. Grain yield (bu) was then converted to dry matter weight (lb). A harvest index of 0.5 was then assumed, resulting in an estimate of stover dry matter production equivalent to that of grain. This estimate included the cob weight. To subtract the cob weight, it was assumed that the cob represented 15% of the total stover dry weight. After subtracting the cob weight, the stover (minus the cob) weight was obtained. The ratio of 0.16 root:stover (minus cob) dry matter was then used to estimate total root dry weight per acre. Root K concentrations provided in Claassen and Barber (1977) were averaged and found to be 3%. This percent K was then multiplied by the total root dry weight per acre and converted to K_2O. The resulting estimates show that of the total K taken up by the above ground plant portions, most of it (approximately 80%) is returned to the soil surface through leaching from the stover. The amount of K estimated to be redistributed in the soil by the root system is 72% as much as was removed by the grain.

The quantities of K redistributed in the soil by the plant are significant compared to the quantities of K banded in the studies reported above. Consequently, it is not clear how much of the measured increases of K in the row are due to banding or simply to the redistribution of K by the corn plant itself. Some insight into this can be gained from the strip-till study from Indiana (Vyn, 2010) and an earlier no-till study from Ontario (Yin and Vyn, 2003), where higher concentrations of K were observed in the row compared to between rows, regardless of whether any K had been applied. It would seem, therefore, that redistribution of K by the plant is a major cause of higher K concentrations measured in the row and, as was the case in the Pennsylvania study (Duiker and Beegle, 2006), may make residual fertility impacts of lower, banded rates undetectable.

Precision guidance technology offers many opportunities to manage banded K applications in a number of configurations over time to create zones of higher fertility. Because the crop itself is capable of concentrating large quantities of K in the row, both at the surface and below, offsetting rows from year to year may be a viable strategy to keep K more distributed across the field over time. For instance, a second season of corn might be grown in rows placed in the middle of previous rows, with the next corn crop placed back on the original rows. The purpose of any row movement and K band movement strategy is to keep fertilized soil volumes higher over time to maximize grain yield.

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