# MANAGING POTASSIUM FOR HIGH YIELD

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There are several issues that currently surround potassium (K) management. Awareness of them has increased in recent years as farmers and advisers have intensified their collection of field data. In particular, K management is facing many challenges under conservation tillage systems. These systems have led to stratification of soil test K, where K levels at or near the surface are significantly higher than those lower in the soil profile. Research efforts are currently trying to better our understanding of how K management may need to be altered to better fit these conservation tillage systems. This paper outlines some of the major issues currently faced.

An essential component of managing K is calculating a K budget. This budget compares the amount of K added to the amount removed by crop harvest. Potassium additions include both fertilizer and manure sources. In Wisconsin, alfalfa is often part of the crop rotation. This crop removes a significant amount of K. An example of K removal by a sequence of crops in a rotation representative of Wisconsin is shown in **Table 1**. This table demonstrates that alfalfa removes significantly more K per acre than does either corn or soybean. This occurs because only the grain is removed during corn and soybean harvest while most of the above-ground plant portion is removed when alfalfa is cut. When producers and advisers underestimate the amount of K removed in rotations containing alfalfa, unexpected declines in soil test K levels and associated K malnutrition problems can result.

Table 1. Example of potassium removal in a 5-year crop rotation.

| Year | Crop | Yield | Yield units | K removal |
|---|---|---|---|---|
| | | (units) | | (lb $K_2O$/A) |
| 1 | alfalfa | 2 | tons | 98 |
| 2 | alfalfa | 4 | tons | 196 |
| 3 | alfalfa | 6 | tons | 294 |
| 4 | corn | 150 | bu | 41 |
| 5 | soybean | 40 | bu | 52 |
| Total | | | | 681 |

Nutrient removal rates are those compiled by Murrell (2005).

Nutrient budgets are commonly used to estimate how much K must be applied to keep up with crop removal rates. It is commonly thought that applying K at rates equal to crop removal will maintain soils at current test levels. In a Colorado study, this hypothesis was tested by applying various rates of K every year for 3 years in which alfalfa was grown (Fixen and Ludwick, 1983). The results, shown in Table 2, demonstrated that soil test levels could be maintained by applying rates that were sometimes much less than those of crop removal.

The reasons for this behavior have been attributed to the redistribution of K within the soil profile with K uptake by alfalfa. Figure 1, taken from the same Colorado study cited above, shows that after 3 years, K had been depleted in the lower depths while K soil test levels increased near the surface. Most of this redistribution occurred during the first year. This was attributed to the higher allocation of carbon to the root system that typically occurs in the first year of alfalfa establishment. The implication of this redistribution is that soil test results representative of only shallow depths will not detect these important changes in vertical

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distribution. In fact, the increase in soil test K near the surface combined with a decrease in soil test K below the surface can lead to unpredictable changes in soil test K over time, as measure by standard, shallow samples. In a Minnesota study, broadcast applications of K produced significant stratification when measured 2-3 months after fertilization (Moncrief et al., 1985). Potassium levels in the surface 2 inches were much higher in the no-till system compared to chisel tillage. Elevated levels of K near the surface resulted in higher 0-6 inches soil test K readings in the no-till system compared to the chisel tillage system, even though the rate of applied K was the same. This study helps explain why rates of K much less than those of crop removal can maintain soil test levels as demonstrated in Table 2.

Table 2. Amount of K needed to maintain soil test levels after 3 years of alfalfa cropping (Fixen and Ludwick, 1983).

| Soil | Initial soil test K level (0-12 in. depth) | Average annual $K_2O$ removed | $K_2O$ required to maintain initial soil test level | Required/removed |
|---|---|---|---|---|
| | (ppm) | (lb $K_2O$/A) | | |
| Keith SiL | 555 | 323 | 244 | 0.75 |
| Ravola L | 126 | 358 | 80 | 0.22 |

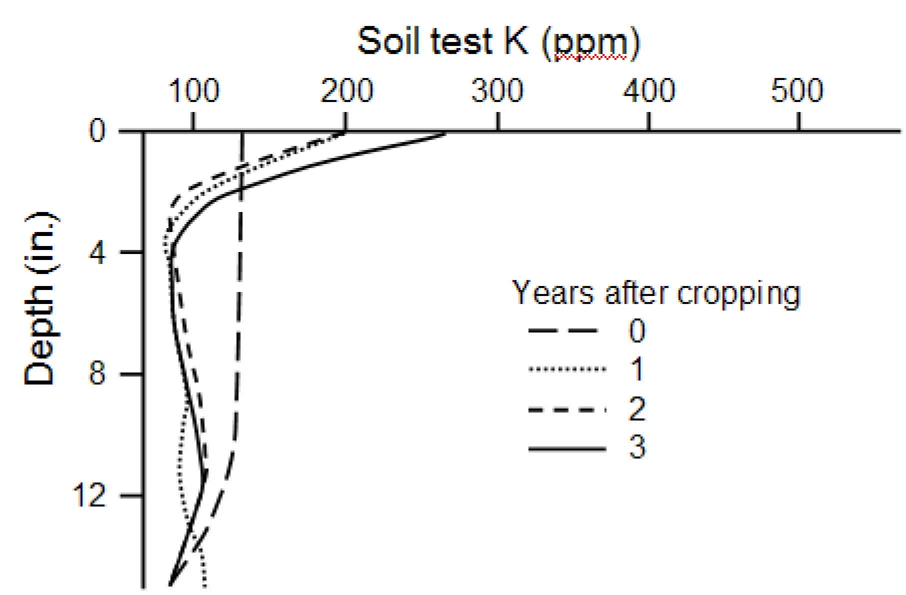


Figure 1. Change in soil test K after various durations of alfalfa cropping (Fixen and Ludwick, 1983).

The root system of alfalfa can extend very deep in the soil profile. Figure 2 shows graphically that alfalfa roots can extend downward 9 ft or more. Even so, a Wisconsin study demonstrated that that surface or near-surface applications of K result in higher recovery of applied K than bands placed deeper in the soil (Peterson et al., 1983). These findings indicate that higher root activity exists near the surface for alfalfa.

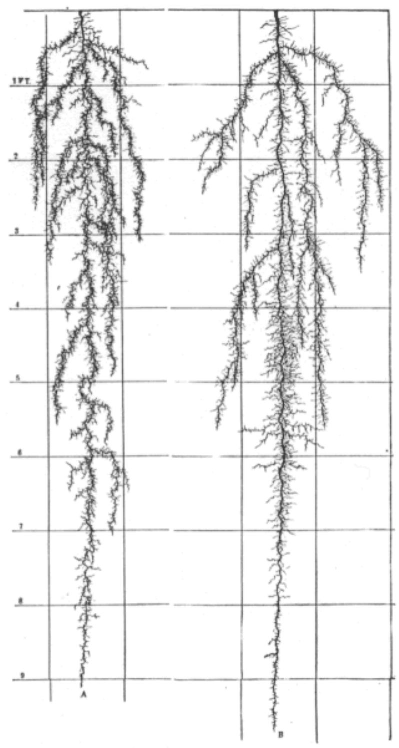


Figure 2. Root distribution of a 2 year old alfalfa stand in Nebraska under irrigated and dryland conditions (Weaver, 1926). Squares are 1 ft. x 1 ft.

When other crops are grown in rotation with alfalfa, there may be a need to place K lower in the profile, depending on the root grown habits of the crops, the soil test level, and the degree of stratification. Figure 3 shows how soybean roots are distributed in the soil profile early in the season. Most of the very early root growth is associated with elongation of the tap root which is then followed by the development of laterals in the upper part of the soil profile. At maturity, approximately 80% or more of the root system in upper 6 inches of the soil surface. As roots extend away from the plant, they grow downward to avoid competing for water and nutrients with roots from plants in adjacent rows.

Corn roots, as opposed to alfalfa and soybean roots, are fibrous (Figure 4). Early season root growth is associated with elongation of the radical and the lateral seminal roots. These roots grow at an angle relative to horizontal. Much of the development of laterals occurs on these roots. Thus, as opposed to alfalfa and soybean, little of the root system is directly below the plant early in the season.

In conservation tillage systems, the inequitable distribution of K with depth may lead to K malnutrition if zones of active uptake are not well coordinated with zones of higher soil test K. Consequently, placement of K below the soil surface may be more important in these systems.

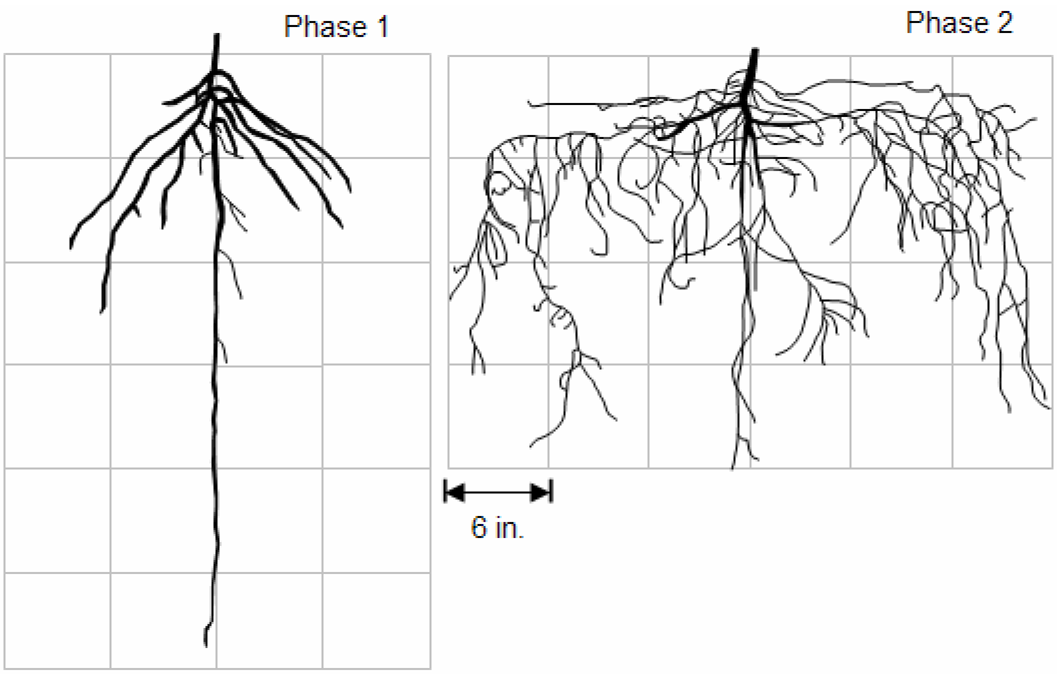

Figure 3. Phases I and II of the 3-phase root growth classification system developed by Mitchell and Russell, 1971.

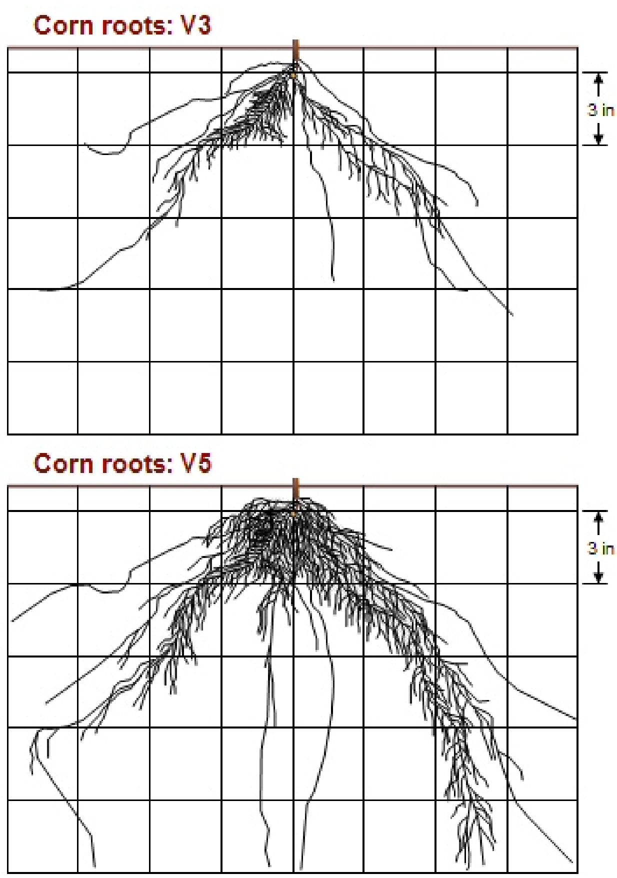


Figure 4. Generalized depiction of corn roots at growth stages V3 and V5.

Much of the current theory on best placement of P and K for corn and soybean was developed by Barber and associated scientists (Anghinoni and Barber, 1980b; Borkert and Barber, 1985b). Studies were conducted on early growth and nutrient uptake of corn and soybean. In pot studies, soil was mixed with various nutrients, including N and K. A portion of this soil was set aside and mixed with various rates of P. To study the impact of volume of soil fertilized with P, the P treated soil was placed in the same pot with non-treated soil. Phosphorus-treated and P-untreated soils were separated vertically in the pots by 16-mesh fiberglass screen, which minimized mixing of the two soils. A constant P rate per pot was applied, meaning that as the P-treated soil volume decreased, the concentration of P in that volume increased, as with field applications of banded fertilizer.

For both corn and soybean, these studies showed that maximum nutrient uptake and dry matter yield could be attained when a fraction of the soil volume was fertilized. Just how much volume needed to be fertilized with P varied with rate, shown conceptually in Figure 5. The model demonstrates that when a low P rate is applied to a low testing soil, a small fertilized soil volume (like that attained with banding), maximizes dry matter yield (dotted line in the graph). The reason for this is less soil-fertilizer contact, increasing the probability that more P will remain in more readily soluble forms. In addition, roots that find localized P supplies will proliferate. However, the localized P supply may not provide P to enough of the roots to maximize yield, compared to a higher rate of P broadcast and incorporated (solid line in the graph). Higher rates applied to a greater proportion of the soil provide P in positions that are available throughout the season.

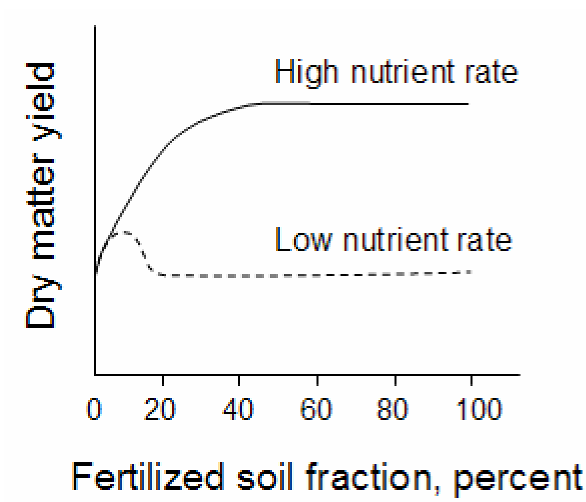


Figure 5. Conceptual model of the influence of fertilized soil volume and associated concentration affect crop dry matter yield (Anghinoni and Barber, 1980b; Borkert and Barber, 1985b).

Comparing the volumes necessary to maximize dry matter production for young corn and soybean plants reveals that soybean requires less fertilized soil volume than does corn (Figure 6). This figure combines information from separate studies using the same soil, fertilizer rates, and experimental procedures (Anghinoni and Barber, 1980a; Borkert and Barber, 1985a). This difference is due in part to the different P influx rates of corn and soybean. Corn has very high P influx rates early in the season, while soybean does not. For nutrient uptake, this means corn can take better advantage of concentrated supplies than can soybean; however, it also implies that a corn root can deplete a given supply of P that lies within short diffusion distances form it faster than can a soybean root exposed to the same conditions. This means that in shorter periods of time, more of the P supply for a corn root is coming from greater distances and may be harder to access, particularly in a concentrated zone where more competition exists by other roots. Since both corn and soybean allocate approximately equal proportions of their root system to enriched supplies of P, corn may require that more of its total root system be in close contact with P supplies. This reasoning may explain why small fertilized volumes maximize dry matter production for soybeans but do not do so for corn.

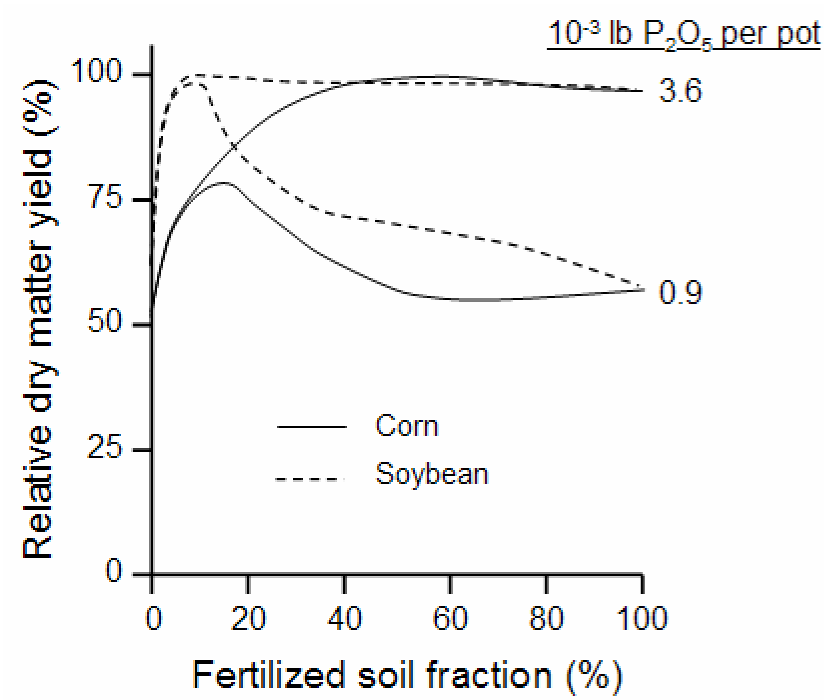


Figure 6. Differences in impact of fertilized soil volume on corn and soybean dry matter yield (Anghinoni and Barber, 1980a; Borkert and Barber, 1985a).

These concepts can be extended to K by noting some important differences. First, K can diffuse farther in soils than can P. That means a given plant root can take advantage of supplies farther from it for K compared to P. It also means that competition for uptake by other roots may be more important than for P, since roots can be farther away and still compete (Silburbush and Barber, 1983). Another important difference is that corn and soybean nutrient influx rates are much higher for K than for P (Figure 7). While the K influx rate of soybean roots is still much less than for corn early in the season, it is nearly as high as the P influx rate for corn early in the season and stays at elevated levels longer than does both the corn P and K influx rates. This implies that soybean may require higher volumes of soil enriched with K than it does with P.

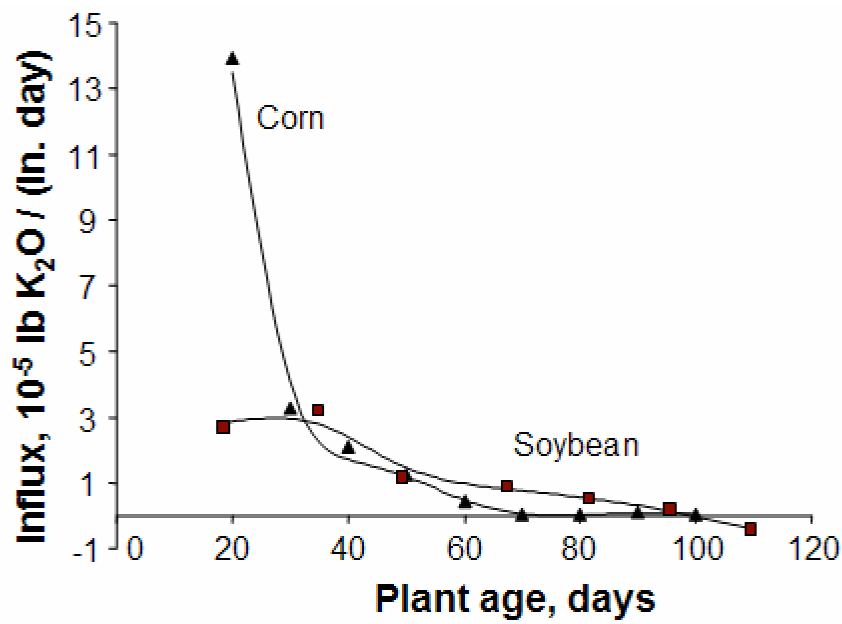

Figure 7. Changes in K influx with plant age for corn and soybean (Barber, 1978; Mengel and Barber, 1974).

Field research in conservation tillage systems is confirming the importance of subsurface banded applications of K for attaining higher yields (Bordoli and Mallarino, 1998; Borges and Mallarino, 2003; Borges and Mallarino, 2001; Yin and Vyn, 2003). While deep-banded K does not always result in improvements over broadcast applications, it is seldom inferior. The apparent agronomic need for K placed below the soil surface is consistent with the smaller soil volume that is enriched in K in reduced tillage systems utilizing only broadcast applications. Unlike broadcast applications, subsurface K applications actually end up fertilizing soil below and at the soil surface. Figure 1 demonstrates how crop uptake alone can redistribute K from lower to upper parts of the soil profile. Grain crops deposit back to the soil surface a significant amount of the total K they take up. For example, some studies have shown that soybean has approximately 54% of its total K in the grain while for corn, it is 31-44% (Hanway, 1962; Hanway and Weber, 1971). Potassium is leached from crop residues with precipitation. Unlike phosphorus and nitrogen, K is not immobilized in organic matter, so it is available much more quickly. So K below the surface ends up at the surface through leaching from crop residue as well as below the surface where it was originally placed. Over the long term, subsurface applications may lead to improved distributions of K in the soil profile, although this concept has yet to be tested in long-term studies.

References

Anghinoni, I., and S.A. Barber. 1980a. Phosphorus application rate and distribution in the soil and phosphorus uptake by corn. Soil Sci. Soc. Am. J. 44:1041-1044.

Anghinoni, I., and S.A. Barber. 1980b. Predicting the most efficient phosphorus placement for corn. Soil Sci. Soc. Am. J. 44:1016-1020.

Barber, S.A. 1978. Growth and nutrient uptake of soybean roots under field conditions. Agron. J. 70:457-461.

Bordoli, J.M., and A.P. Mallarino. 1998. Deep and shallow banding of phosphorus and potassium alternatives to broadcast fertilization for no-till corn. Agron. J. 90:27-33.

Borges, R., and A.P. Mallarino. 2003. Broadcast and deep-band placement pf phosphorus and potassium for soybean managed with ridge tillage. Soil Sci. Soc. Am. J. 67:1920-1927.

Borges, R., and A.P. Mallarino. 2001. Deep banding phosphorus and potassium fertilizers for corn managed with ridge tillage. Soil Sci. Soc. Am. J. 65:376-384.

Borkert, C.M., and S.A. Barber. 1985a. Soybean shoot and root growth and phosphorus concentration as affected by phosphorus placement. Soil Sci. Soc. Am. J. 49:152-155.

Borkert, C.M., and S.A. Barber. 1985b. Predicting the most efficient phosphorus placement for soybeans. Soil Sci. Soc. Am. J. 49:901-904.

Fixen, P.E., and A.E. Ludwick. 1983. Phosphorus and potassium fertilization of irrigated alfalfa on calcareous soils: I. Soil test maintenance requirements. Soil Sci. Soc. Am. J. 47:107-112.

Hanway, J.J. 1962. Corn growth and composition in relation to soil fertility: II. Uptake of N, P, K and their distribution in different plant parts during the growing season.

Hanway, J.J., and C.R. Weber. 1971. Accumulation of N, P, and K by soybean (*Glycine max* (L.) Merrill) plants. Agron. J. 63:406-408.

Mitchell, R.L., and W.J. Russell. 1971. Root development and rooting patterns of soybean (*Glycine max* (L.) Merrill) evaluated under field conditions. Agron. J. 63:313-316.

Mengel, D.B., and S.A. Barber. 1974. Rate of nutrient uptake per unit of corn root under field conditions. Agron. J. 66:399-402.

Moncrief, J.F., P.M. Burford, and J.B. Swan. 1985. The effect of tillage on interpretation and response to soil K. J. Fert. Issues 2:17-25.

Murrell, T.S. 2005. Average nutrient removal rates for crops in the Northcentral region [online]. Available at http://www.ppi-ppic.org/northcentral/nutrientremoval (verified 27 Dec. 2005).

Peterson, L.A., D. Smith, and A. Krueger. 1983. Quantitative recovery of alfalfa with time of K placed at different soil depths for two soil types. Agron. J. 75:25-30.

Silburbush, M., and S.A. Barber. 1983. Prediction of phosphorus and potassium uptake by soybeans with a mechanistic mathematical model. Soil Sci. Soc. Am. J. 47:262-265.

Weaver, J.E. 1926. Root development of field crops. McGraw-Hill, New York, NY.

Yin, X., and T.J. Vyn. 2003. Potassium placement effects on yield and seed composition of no-till soybean seeded in alternate row widths. Agron. J. 95:126-132.