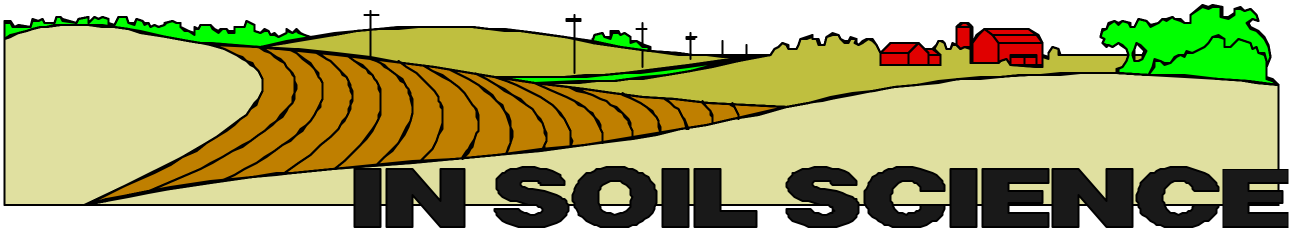
NEW HORIZONS IN SOIL SCIENCE



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Soil Management and K Availability[1]

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The 2000 crop year was very challenging because of the variety of weather that was experienced and the effect it had on growing conditions. Low over-winter and early spring precipitation had many of us discussing management for a major drought. The drought issue quickly became moot as frequent, heavy late spring and early summer rains drowned the landscape. As the season progressed, we began to receive numerous questions regarding crop conditions. There were many concerns associated with the precipitation and its effect on N, but surprisingly there were also reports of occurrences of K deficiencies. Many were reported in no-till and/or low soil test K fields, although this was not exclusively the case. This paper will discuss some of the soil management issues that can interact to cause problems with K uptake by crops.

Potassium is a relatively immobile nutrient in soils. Available K is held on cation exchange sites and leaching from the rootzone is unusual except on sandy, low CEC, and organic soils. Therefore, with the assumption that soil test K levels were optimum, a K deficiency problem observed on medium-textured soils was likely the result of a plant/soil interaction and not the loss of available K.

Most of the K absorbed by crops is brought to the root surface by diffusion where it is absorbed into the root by an active uptake mechanism. Diffusion is the movement of an ion from an area of higher concentration to an area of lower concentration by the random activity of atoms. The simplified equation shown below describes how soil properties affect the rate of ion diffusion (Barber, 1984).

$$D_e = \frac{D_l \ ? \ f}{b}$$

where D_e = effective diffusion coefficient in soils; D_l = effective diffusion coefficient in water ($1.98 \times 10^{-5} cm^2 s^{-1}$); ? = soil water content; f = soil impedance factor (low value means greater impe-dance); b = soil buffer power.

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According to this equation, phenomena in the soil that slow the rate of diffusion would include a decrease in the soil water content or the impedance factor and an increase in the soil buffer power. Low soil water content reduces diffusion because ions must travel along moisture films coating soil particles, increasing travel time (much like driving a boat along a shoreline vs. cutting across the bay). Impedance, or an increase in the tortuosity of the pathway, can be the result of an increase in bulk density that affects the “straightness” of the path an ion will travel (i.e., more soil in the way). Finally, the buffer power is an expression showing the amount of fertilizer K that must be added to change the K in the soil solution. Thus, soils with higher CEC (medium- and fine-textured soils) will require more K fertilizer than sands to change the soil solution K.

What has been described so far is just the soil chemistry part of the story. Other factors that are important are the plant and its uptake capacity, as well as the soil physical condition as it relates to porosity and the distribution of water in the rootzone. As mentioned, K is absorbed across the root cell membrane by an active process. An active process requires energy that the root provides by respiration, and respiration requires oxygen. If oxygen is restricted, K uptake is reduced. Lawton (1945) demonstrated early the effect that poor aeration has on reducing the K concentration in young corn. This study showed a large reduction in corn seedling K concentration when grown in an aerated vs. a non-aerated system. Subsequent research by Danielson and Russell (1957) demonstrat-ed reduced monovalent cation uptake when the soil oxygen content dropped below 10% (the atmosphere has an oxygen content of about 20%). Aeration is related to the soil porosity that must decrease if the soil bulk density (compaction) increases. Furthermore, even moderate compaction, while not dramatically affecting total porosity, has a significant impact on the pore size distribution as shown in Table 1 (Tahla et al., 1979). These changes in porosity block soil air exchange with the atmosphere because oxygen diffuses very slowly through the water-filled pores. Additionally, micro-organisms compete with roots and can rapidly deplete soil oxygen.

Table 1. Porosity and pore size distribution of a clay loam soil as affected by compaction† (adapted from Tahla et al., 1979).

			Percent by pore size (inch)			
Compaction	Depth	Total porosity	Large >0.002	Medium 0.002 to 0.0004	Small 0.0004 to 0.00008	Very small <0.00008
	inch					
No	1 to 4	53.3	27	7	36	30
	6 to 9	52.5	24	5	39	32
Yes	1 to 4	47.9	5	13	43	39
	6 to 9	47.9	5	9	48	38

† Compaction with a 5-ton tractor.

If soil compaction reduces K uptake because of reduced aeration, will increasing available K by fertilization offset growth and yield decreases? Greenhouse studies by Hallmark and Barber (1981) found that K fertilization did partially offset the growth reducing effect of compaction, but did not completely make up for compaction (Table 2). Their study showed substantially lower root surface area in soybean grown under a higher bulk density and a reduced K concentration in the leaf. It is interesting that the relative K influx (K uptake per unit surface area) in the compacted, unfertilized treatment is greater than that in the uncompacted, unfertilized treatment. The compaction of the soil likely improved the diffusion of K to the root surface, but growth was limited because of the overall decrease in root growth.

Table 2. Effect of soil bulk density on the growth, root surface area, and K concentration of soybean seedlings (adapted from Hallmark and Barber, 1981).

Bulk density	K added	Shoot weight	Root area	Shoot K	K influx
g/cc	ppm	oz/pot	$inch^2$/pot	%	rel. %
1.25	0	0.086	85	1.68	100
1.25	100	0.092	84	1.91	133
1.45	0	0.081	57	1.48	121
1.45	100	0.087	67	1.79	125

Wolkowski (1991) evaluated the effects of compaction on the growth and K concentration in corn seedlings on three Wisconsin soils. Compacting a greenhouse soil to 1.25 times its initial bulk density decreased both root growth and the total amount of K in the harvested leaves. Plant dry weight, however, was not reduced by compaction (it actually increased on the Kewaunee soil) under these controlled conditions because in each case a slightly higher K influx was observed (Table 3). The enhancement in K influx was greater on the sand, presumably because compaction improved diffusion characteristics in that soil. In other words, roots encountered more soil on their surfaces, increasing uptake.

Table 3. Corn seedling growth as affected by soil compaction on three Wisconsin soils.

	Kewaunee silty clay loam			Plainfield sand			Plano silt loam		
Bulk density†	Root g/plt	Leaf K	Root mg K/g	Root g/plt	Leaf K	Root mg K/g	Root g/plt	Leaf K	Root mg K/g
		mg/plt			mg/plt			mg/plt	
Initial	1.12	39.6	35.4	0.72	32.0	44.0	1.00	42.3	42.3
1.25X	0.98	35.7	36.4	0.60	30.8	51.3	0.92	39.21	42.6

† Bulk densities: Kewaunee 1.17, 1.50; Plainfield 1.36, 1.70; Plano 0.88, 1.15 g/cc in the initial and 1.25 X compaction treatments, respectively.

Compaction in field conditions seldom results in the uniform compaction of the rootzone. Root growth may be physically restricted in part of the soil, but relatively unaffected in other areas. Potassium fertilization of a compacted soil, either by broadcast fertilization or the placement of a localized band, may induce roots to increase K uptake to compensate for the loss of root volume. Claassen and Barber (1977) found exactly that response in a split plot experiment where corn roots were divided between a media with and without adequate K. Roots from plants grown in this split root system had a K uptake rate that was 2.6 greater than plants grown entirely in a K-containing media. Clearly plants have the capacity to "turn on" switches to absorb nutrients when the demand exists.

The interaction between compaction and K fertility has been evaluated by this author in several studies. Research conducted at Oshkosh in 1985-1987 on a Kewaunee silty clay loam soil demon-strated an increased corn yield response to K on a soil that was intentionally compacted (Wolkowski, 1989). This research clearly shows the increased response to K fertilization, both in the row or as increased soil test K. Note, however, that K fertilization did not allow the corn crop to totally overcome the compaction effects.

Table 4. Effect of row applied K fertilizer† on corn yield at two compaction and soil test K levels at Oshkosh, WI, 1985-1987.

Compaction	Soil test K	Row	1985	1986	1987
< 5 T	Optimum‡	No	132	169	124
		Yes	161	175	137
	Ex. High	No	164	172	123
		Yes	161	175	137
19 T	Optimum	No	112	147	120
		Yes	159	169	145
	Ex. High	No	147	150	126
		Yes	143	159	134

† Row fertilizer = 45 lb K_2O/acre.

‡ Optimum and Ex. High soil test K = 115 and 214 ppm, respectively

A similar response was noted for alfalfa in a study conducted at Arlington from 1992-1994. This study had levels of soil test K and annual K applications superimposed on uncompacted and heavily compacted plots. Compaction was conducted prior to seeding in 1991 and forage was grown for three additional years. Compaction reduced yield the most in the seeding year and the first hay year, with the yield reduction diminishing over time. As expected, responses were observed to K fertility as either soil test level or annual application. The data shown in Table 5 show the relation-ship between total yield compaction and soil test K, and compaction and annual K treatment for the three hay-years. The interactive effect between annual K and compaction was statistically significant. These data show that alfalfa yield is negatively affected by compaction and, like the corn study, the K fertility management can partially overcome the yield limitation. Soil bulk density changes were noted down to 18 inches, but the increases were probably not great enough to reduce air-filled porosity below 10%. Therefore, the yield decrease is attributed to a poorly distributed rootzone under compacted conditions.

Table 5. Interactive effects between soil compaction and K fertility on alfalfa yield, Arlington, WI, 1992-1994. †

K fertility treatment	< 5 T	14 T
	tons dry matter/acre	tons dry matter/acre
Annual K = 0	11.1	9.2
Annual K = 300 lb K_2O/year	11.3	10.3
Soil test K = Optimum	11.1	9.2
Soil test K = High	10.7	9.8
Soil test K = Very high	11.5	10.3

† Total of nine cuttings

What happened in 2000? Nearly 18 inches of rain were recorded at the Arlington Agricultural Research Station in the months of May and June. Soils were extremely wet and, in some cases, crops were lost or replanted. It is speculated that the high soil moisture conditions may have encouraged shallow root distribution in corn for which the plant never compensated as the season progressed. As soils began to dry out in July, the shallow root system was unable to provide K from the subsoil. Recent harvest efforts in on-farm studies conducted by this author have shown substantial blow down of corn, minimal brace root formation, and shallow rooting; however, similar management in drier years did not produce the same result. It is difficult to relate K nutrition to these problems. The farmer-cooperators in each case indicated that they had applied some K fertilizer.

Many of the potassium deficiency complaints were noted in reduced tillage fields. Historically, K problems have been seen in no-till fields presumably because of their higher soil bulk density, lower porosity, and root penetration problems. Row K application is strongly recommended for corn grown in no-till and other high residue systems. Broadcast K should be applied prior to the installation of the high residue systems to adjust the soil test K level in the optimum category.

Finally, several questions were related to situations where corn was no-tilled into fall-killed alfalfa. Problems in this system are somewhat surprising; however, it is possible that K fertilization was not made in the final hay year, thereby reducing plant available K to the succeeding crop. Producers should be made aware that the large amount of potash removed by an alfalfa crop (50 to 60 lb K_2O/ton/acre) should be applied in the final year of the forage rotation to maintain soil test levels.

Summary

There clearly appears to be a relationship between K fertility management and soil compaction on crop growth and yield. Soils that are compacted may respond to higher levels of soil test K or banded K, but yields are still typically lower than a soil that is not compacted. Therefore, avoiding compaction is the first step. Growers should use row K (~ 20 lb K_2O/acre) for corn grown on corn in high residue systems, even at high soil test levels. Producers should replace K removed by the last hay crop in the rotation.

It is suspected that much of the problems that were noted in 2000 relative to K fertility were in response to the very wet conditions experienced in the early weeks of the growing season. Shallow rooting likely reduced the volume of soil explored by roots and the ability of the plant to absorb nutrients during the early rapid growth period.

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