Drs. Richard P. Wolkowski and Larry G. Bundy

Compaction Reduces Alfalfa Yield

Two-year study shows effects of wheel compaction on yield and nutrient uptake.

Summary: *A relationship between wheel-traffic induced soil compaction and K fertility of corn has been demonstrated, but little is known about compaction problems in forages. The results of this study demonstrate the deleterious effect of soil compaction on the growth and yield of alfalfa. Wheel traffic compaction with a 14-ton vehicle produced detectable increases in soil bulk density and penetration well below the depth of tillage. Compaction signifiantly decreased the yield and K concentration of alfalfa tissue. Because of dry weather, these differences were not observed in the second cut, which may have actually favored growth on the compacted soil A favorable response to K fertilization, as measured by soil test K, was found. Even though a significant response to annual K fertilization was not observed in 1992, the trend of yield response and the effect on soil test demonstrated that rate was more important than placement. An interaction between soil test K and compaction was observed, suggesting that alfalfa is more responsive to K fertility on compacted soils.*

Plots were established in April of 1991 on a Piano silt loam near Arlington, Wisconsin. Treatments were arranged in a split-split plot design containing four replications. Compaction was established as the main plot treatment as either none or a double wheel-tracking over the entire plot with a 14-ton payloader. Soil moisture at compaction ranged from 22 to 25 percent by weight to a depth of two feet. Following compaction, plot area was disked twice to prepare a seedbed, treated with Eptam and seeded with alfalfa (Garst 636). Soil test K was established as the subplot treatment at anticipated levels of the indigenous (90 ppm), *150* ppm and 225 ppm. Sub-subplot treatments were none, 1 *50* or 300 lbs/A K_2O broadcast, or 75, 150 or 300 lbs/A K_2O handed on 15-inch centers. All sub-subplot treatments were applied with liquid 0-0-62.

Favorable growing conditions were experienced at Arlington both years. The season was warmer than usual in 1991 and cooler than usual in 1992. Rains were timely except for dry periods in August of 1991 and June of 1992. Dryness affected the growth of the second hay crop in each year. Precipitation is shown in Table 1.

Yield reduction substantial

Figure 1 shows the effect of compaction on yield. Note how compaction decreased yield substantially at all cuttings except the second cut in 1991 when it was dry. Other research has suggested that compaction can increase yield in dry

Table 1. Precipitation during growing season, Arlington, WS.

Year	April	May	June	July	Aug	Sept	Oct
	- - - - - - - - - - - - inches - - - - - - - - - - - -						
1991	4.52	1.91	2.63	3.75	1.78	4.37	6.75
1992	3.96	1.22	1.19	5.80	1.91	7.46	1.26

Table 2. Soil bulk density measured June 19, 1991 and October 13, 1992 at Arlington, WS.

Depth (in.)	Compaction (tons)	Soil Bulk Density - - - - - - - - g/cc - - - - - - - - 1991	1992
0-6	<5	1.19 (0.10)	1.30 (0.05)
	14	1.36 (0.06)	1.41 (0.03)
6-12	<5	1.31 (0.06)	1.33 (0.04)
	14	1.59 (0.05)	1.50 (0.13)
12-18	<5	1.19 (0.09)	1.35 (0.01)
	14	1.45 (0.08)	1.44 (0.08)
18-24	<5	1.40 (0.07)	1.34 (0.03)
	14	1.40 (0.07)	1.34 (0.03)

Numbers in parentheses are standard deviations. n = 8 seasons because of the increased waterholding capacity of a soil caused by a greater number of pores.

Total yield was reduced to 58 and 81 percent of the noncompacted treatment in 1991 and 1992, respectively. A yield response to soil test K was observed for the first cutting in both years; however, these responses were relatively small (0.09 and 0.17 ton/A in 1991 and 1992, respectively). This response was not significant for the later cuttings in either year. The response to soil test K for total yield was significant at the 18 and 13 percent level for 1991 and 1992, respectively. There did not appear to he a benefit from banding (versus broadcasting) K treatments. Higher rates of annual K application tended to increase yield. These differences, however, were not significant (data not shown).

Table 2 shows the effects of compaction treatments on soil bulk density. It's apparent that wheel traffic with the 14-ton payloader increased bulk density to a depth of 18 inches. Bulk density was especially high in the 6- to 12-inch depth increment where 1.59 g/cc bulk density measured in 1991 translated into a 10 percent reduction in soil porosity by compaction. Visible observation of several plants pulled from the compacted area showed kinked roots at depths of three to four inches. Measurements in 1992 show that bulk density increased somewhat in the uncompacted treatments at the 0 to 6-inch depth increment. This is most likely a result of harvest traffic, which, while maintained at a load of less than five tons, was not controlled.

Alfalfa stand count was higher in the compacted treatments in both years of the study. Many of the crowns in the compacted plots were poorly developed and contained only a few stems. This effect may be a result of reduced growth on compacted plots and less competition for space between adjacent plants. Soil test K and annual K treatments did not affect stand.

A significant interaction between soil test K level and total yield was observed for the first cut in 1992 (Figure 2). In this case, a small yield response to soil test K (0.04 ton/A)

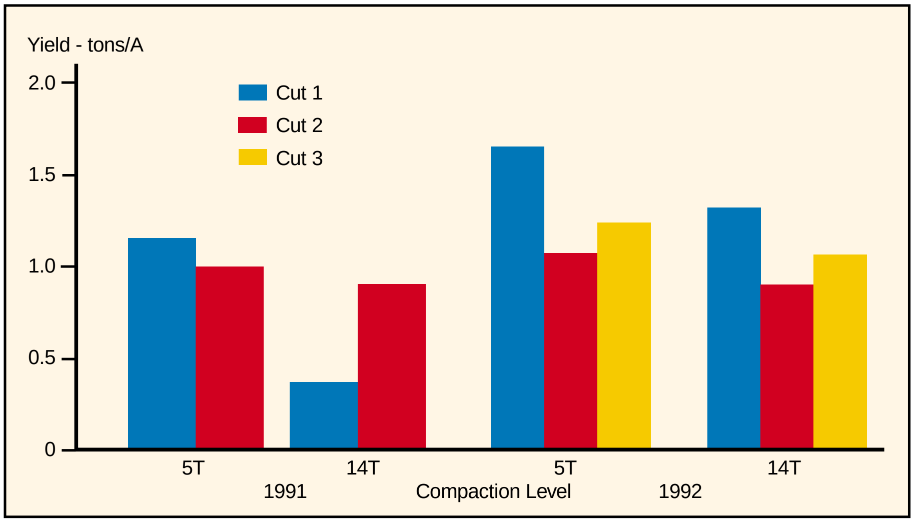

Figure 1. Effect of compaction and K fertilization on alfalfa yield, Arlington, WI, 1991-1992.

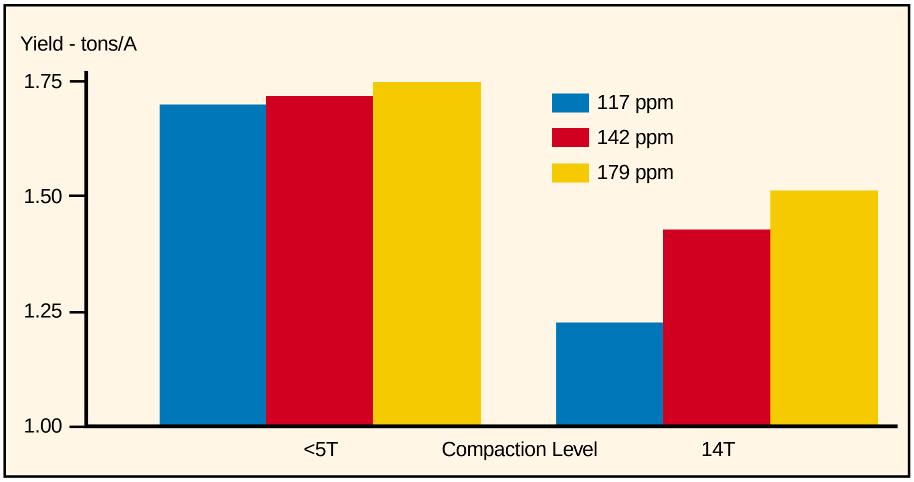

Figure 2. Interaction between woil test K and alfalfa yield, Arlington, WI, first cut, 1992.

Table 3. Effect of compaction on alfalfa forage K concentration. Arlington, WS, 1991-1992.

Compaction Level	1991		1992		
	Cut 1	Cut 2	Cut 1	Cut 2	Cut 3
5 tons	4.21	2.81	2.68	2.50	2.47
14 tons	2.96	2.73	2.42	2.39	2.36
Pr > F	0.01	0.42	0.07	0.19	0.03

Average over soil test K and annual K treatments.

occurred in the uncompacted treatment, whereas response in the compacted treatment was 0.28 ton/A. While this effect was not significant at other cuttings, a similar trend was observed, suggesting that alfalfa is more responsive to K fertility on compacted soils. Recognize that even though yield was increased at higher soil test K levels, yield was considerably lower than yield measured in the uncompacted treatment at low soil test K. It should be obvious that compaction should be avoided.

The effect of compaction on forage K concentration is shown in Table 3. Compaction consistently reduced K concentration in the forage, except in cases where dry conditions limited growth (second cut each year). This is interesting to note in light of the fact that soil test K was apparently increased by compaction and that less dry matter (which would dilute tissue K) was produced in compacted treatments. This finding is consistent with other research, which demonstrated that inadequate soil aeration from reduced soil porosity caused by compaction reduced plant uptake of monovalent cations, such as rubidium and potassium.

Bulk density measurements were taken each season from the main plots with a 1.3-inch diameter probe, spaced at six-inch increments to a depth of 24 inches.

Yield measurements were taken with a three-foot flail mower mounted on a small tractor. A subsample of the harvested material was taken to determine dry matter and nutrient content. Surface soil samples were taken to a depth of six inches following the second harvest. Stand counts (three per plot) were also taken following the second cut.

Plant tissue and soil analyses were conducted by the UW Soil and Plant Analysis Laboratory, according to standard procedures. Data were analyzed using SAS statistical procedures (SAS Institute. Cary, NC). Significance is expressed as the probability that tabular value is greater than that determined by the analysis of variance (Pr>F).

Traffic main culprit

Soil compaction long has been recognized as a yield limiting factor in crop production. Researchers have described the causes of soil compaction and its negative effects on crop production. Most compaction research has been on row crops, with relatively little reported on the relationship between soil compaction and legume forage production.

The most significant cause of soil compaction is the use of heavy equipment, with little regard to controlling traffic patterns on wet soils. Negative effects include: reduced porosity and aeration, increased resistance to root penetration, reduced nutrient uptake and yield reductions.

In perennial crops, such as alfalfa, compaction problems may exist before stand establishment or develop after seeding because the soil is subjected to many traffic passes (e.g., topdressing, cutting, raking, baling, or chopping). Yield stand and loss may also be caused by physical damage to the alfalfa crown from wheel traffic. Researchers in California have shown a 26 percent reduction in alfalfa, related to both situations. Researchers in Wisconsin found that preplant compaction consistently reduced K concentration in alfalfa, but inconsistently affected yield. Over several years of this study, the volume of soil having an increased penetration resistance decreased, suggesting that long-term forage production may ameliorate compaction effects.

Dr. Wolkowski is extension soil specialist and Dr. Bundy is professor in the Department of Soil Science at the University of Wisconsin, Madison. **J**

Acknowledgment: The Fluid Fertilizer Foundation and PPI provided partial funding for this research as a grant.