SHANK OPERATING DEPTH FOR ZONE TILLAGE

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Introduction

Zone tillage, a variation of "strip tillage", has become a popular tillage system for sugarbeets in certain sugarbeet growing areas of the U.S. including Nebraska, Colorado, Idaho, and Montana. This system maintains residue on the soil surface to control soil erosion and reduce soil evaporation. The system reduces trips across the field, provides a means to apply fertilizer, and reduces input costs compared to more intensive, broadcast tillage systems. Evans et al. (2010) compared zone tillage and a conventional broadcast tillage for sugarbeets and found that sugarbeet yields were comparable, but that zone tillage had a considerable savings in input cost and time. These authors also described the overall zone tillage system including equipment and associated field operations.

A question producers frequently ask is how deep should they adjust the shanks on the zone tillage machine when used for sugarbeet production? If the shank is operated too deeply, input energy is wasted, an excessively large tractor is required, and input costs are increased. In addition, the deeper the shanks, the more difficult it will be to break up clods displaced from deep in the soil, and it will be more difficult to completely close the shank mark at the bottom of the shank. On the other hand, if the shank is not operated deeply enough, any undisturbed soil compaction might limit root development or water and nutrient uptake by the plant, and thus limit crop yield potential. There is a need to develop data in field studies to provide recommendations for shank depth in zone tillage for sugarbeet production.

Objective

Determine sugarbeet yield response to different zone tillage shank depths within a range of soil compaction levels to help provide a recommendation for shank depth.

Procedure

This study was conducted in 2008, 2009, and 2010 at the University of Nebraska Panhandle Research and Extension Center, near Scottsbluff, NE. The soil type at this location is generally described as a fine sandy loam with 1.0% O.M. and 8.0 pH. The previous crop was corn each year. The stalks were shredded, disked twice, and moldboard plowed (11-12 in. depth) in the spring of each study year. After moldboard plowing, the field was roller harrowed two times to firm the soil. Granular fertilizer (rate based on soil test) was applied between rollerharrow operations. The roller harrowing operations were made using a tractor equipped with floatation tires and when the soil was relatively dry – intending to create no significant surface applied soil compaction.

Four zone tillage shank depths (0, 5, 10, 15 in.) and three "levels" of soil compaction (no applied soil compaction, moderate soil compaction, high soil compaction) were applied after the second rollerharrow operation but before zone tillage. Note that the soil compaction was applied to the soil surface, meaning the magnitude of soil compaction would be expected to decrease with distance from the soil surface within at least the top 12 in. of soil. The soil compaction treatments were applied in a randomized complete block statistical design, with the four shank depth treatments split on each of six replications of each soil compaction treatment. The compaction treatments were applied to an individual compaction plot size of 44 ft. wide by 60 ft. long. The moderate soil compaction treatment was made by making one pass over the entire compaction plot area with a tandem axle truck with no load (total truck weight = 21,000 lbs). The high compaction treatment was made with the same truck with near rated maximum load (52,000 lbs gross weight). Both applied compaction treatments were made when the soil was relatively dry. After the moderate and high compaction treatments were applied, the entire plot area (including the no compaction treatment plots) was tilled to a 2 in. depth with a German made BBG precision tillage implement to loosen the top 2 in. of soil in all plots to achieve uniform seed depth with the planter.

The zone tillage machine was a six row wide, 22 in. row spacing, three point mounted, Till-N-Plant model manufactured by Schlagel Manufacturing Co. of Torrington, WY. This machine used a ¾ in. wide, parabolic shaped shank with shank tip point. Field speed was 3.5 mph. Shank depth was adjusted by moving the shanks up or down within the machine to maintain correct operating functions for the advance coulter, the wavy closing coulters behind the shank, and for the rear rolling baskets. The machine was not operated in the "0" depth plots. After the zone tillage operation, all plots received one pass with a machine that had individual rows of two rolling baskets (no shanks or disks) to break any large clods left by the zone tillage machine (especially in the high compacted plots) and to firm the seedbed. The intent was to focus on shank depth and not irregularities of seedbed that might be caused by the zone tillage shanks.

The plots were planted with a six row Deere 71 Flexi-planter on May 5, 2008, May 1, 2009, and April 29, 2010, using Betaseed variety 66RR70 in regular pellet form. The field was sprinkler irrigated as needed to provide high emergence. The field was roughened with a "rotary hoe" implement between rows as needed to prevent wind erosion but was not cultivated. Weeds were controlled with three applications of Roundup herbicide. Quadris was applied to help control Rhizoctonia. The plots were sprinkler irrigated for the duration of the crop season.

Plant stand counts in the center 30 ft length of the center two rows of each plot were made on May 28, 2008, May 28, 2009, and June 1, 2010 when emergence was considered complete. Soil cone penetrometer resistance measurements were made in one random location within both center two rows of each plot on August 21, 2008 three days after applying 1 in. of irrigation water and on August 3, 2010, two days after a ¾ in. sprinkler irrigation event. The penetrometer was a manual instrument with a proving ring force measuring system and a standard 0.500 in. diameter cone. The maximum cone penetration resistance was measured within four soil depth ranges: 0-3 in., 3-8 in., 8-13 in. and 13-18 in. These depth zones were selected to include the bottom of the shank within the four shank operating depths.

A 50 ft. length of the center two rows of each six row wide plot was harvested with the University of Nebraska two row plot harvester on October 20, 2008, October 5 & 6, 2009, and October 9, 2010. Roots from the entire 2 row by 50 ft length harvest area were weighed for root yield. Root shape was rated visually in the weigh basket of the harvester for each plot using a scale of 1 to 3 (1=normal root shape; 2=somewhat shortened root and/or some sprangling; and 3=definite sprangling and shortened root shape). Two tare samples were collected from each plot and taken to the Western Sugar Cooperative tare lab for analysis of tare, percent sugar, and SLM. The root weight from each plot was adjusted by the average tare from the respective plot to calculate plot root yield.

Results

The field plots had good growing conditions all three years with no major issues from hail, insects, or disease. The high compaction plots contrasted visually with the no compaction plots during the period of emergence and early plant growth. Irrigation water tended to run off or "puddle" in the high compaction plots. Until mid-July of each year, the plants in particularly the high compaction plots with zero depth shank were very stunted with yellowish leaves. In June and early July it appeared that these plants might die or would certainly have no or little harvestable root yield. Surprisingly, by mid-July these plants began to grow and had better leaf color. At harvest, the roots from the high compaction, zero depth shank plots had very short, sprangled roots. Evidently as the season progressed, the roots were able to penetrate the compacted soil layer and develop higher than expected root yield, even though the roots were very short and sprangled.

Plant population. There were statistical differences in plant stand within both factors of soil compaction and shank depth as shown in Tables 1 and 2 when combined over the three years of the study. It is likely that these differences in plant population were caused by differences in the seedbed condition during the emergence period. Results in Table I suggest that even moderate surface applied soil compaction reduced sugarbeet emergence, and in Table 2 that operating the shank at 15 in. depth also reduced sugarbeet emergence. The machine shank tended to bring hard clods from the compacted soil to the surface. These clods were not completely broken by the press wheel behind the shank or by the two rolling baskets of the machine that followed the zone tillage operation.

Table 1. Plant population for compaction treatments averaged over shank depths and combined over three years.

Compaction Treatment	Plant Population Averaged Over Shank Depths (plants/A)
None Applied	40,500
Moderate	37,900
High	36,500

Population values that differ by more than 1100 plants/A are statistically different (p=0.05).

Table 2. Plant population for shank depth treatments averaged over compaction treatments and combined over years.

Shank Depth (in.)	Plant Population Averaged Over Compaction Treatments (plants/A)
0	38,900
5	39,000
10	38,200
15	37,000

Population values that differ by more than 1200 plants/A are statistically different (p=0.05).

Soil cone penetrometer resistance. There were statistically significant interactions between the factors of soil compaction and shank depth for the measure of soil cone penetrometer resistance within depth ranges when combined over the two years the measures were taken, 2008 and 2010. Thus shank depth results are reported for each soil compaction level.

Nominal soil cone penetrometer resistance values in plots where the zone tillage machine had not operated (zero depth) are listed in Table 3 for each measured soil depth zone. These values reflect mechanical resistance of the soil in plots where zone tillage was not used. As a point of reference, a soil cone penetrometer resistance of approximately 300 psi is often considered the level of compaction where crops such as corn and soybeans begin to exhibit a measurable yield reduction, if the compaction layer is within the critical root depth and if soil water is limited.

The values of cone penetrometer resistance in Table 3 suggest several soil compaction related issues during mid-summer. First, there was significant soil compaction at the 8-13 in. range even with no additional compaction applied, perhaps from an existing tillage or plow layer. Second, the high surface applied compaction extended down into the 8-13 in. range.

Table 3. Maximum soil cone penetrometer resistance within the four measured depth ranges where no zone tillage shank had been operated, combined over two years.

Depth Range of Soil Cone Penetrometer Measurement (in.)	Soil Cone Penetrometer Resistance (psi)		
	Soil Compaction "Level"		
	None Applied	Moderate	High
0 - 3	150	440	480
3 - 8	240	710	810
8 - 13	630	690	840
13 - 18	730	630	680

Soil cone penetrometer resistance results for each measured depth range are shown in Tables 4-7. Effect of the zone tillage shank was clearly evident where the shank was operated below the cone penetrometer resistance measurement. In Table 4 all penetrometer resistance values below the 3 in. measurement zone are less than 100 psi except for the 0 in. shank depth where the shank did not penetrate this 0-3 in. depth zone. In Table 5 the shank depth needed to be either 10 or 15 in. to have loosened the compacted layer within the 3-5 in. measurement zone. In Table 6, where the maximum soil cone resistance was measured in the 8-13 in. zone, the penetrometer resistance was substantially reduced where the shank was operated at 15 in. Since the 15 in. shank depth in Table 7 was not below the 13-18 in. measurement zone, the penetrometer resistance was still very high. This series of measurements in Tables 4-7 does show that operating a shank below the compacted layer prior to planting time substantially reduced the mechanical resistance of the soil in the crop row when measured in mid-summer.

Table 4. Maximum soil cone penetrometer resistance within the **0-3 in. soil depth range** combined over two years, 2008 and 2010.

Shank Depth (in.)	Soil Cone Penetrometer Resistance (psi)		
	Soil Compaction "Level"		
	None Applied	Moderate	High
0	150	440	480
5	60	90	100
10	60	110	120
15	80	140	100

Cone penetrometer values within a column that differ by more than 60 psi are statistically different. Values within a row that differ by more than 70 psi are statistically different (p=0.05).

Table 5. Maximum soil cone penetrometer resistance within the **3-8 in. soil depth range**, combined over two years, 2008 and 2010.

Shank Depth (in.)	Soil Cone Penetrometer Resistance (psi)		
	Soil Compaction "Level"		
	None Applied	Moderate	High
0	240	710	810
5	170	530	660
10	90	160	210
15	120	190	160

Cone penetrometer values within a column that differ by more than 100 psi are statistically different. Values within a row that differ by more than 90 psi are statistically different (p=0.05).

Table 6. Maximum soil cone penetrometer resistance within the **8-13 in. soil depth range**, combined over two years, 2008 and 2010.

Shank Depth (in.)	Soil Cone Penetrometer Resistance (psi)		
	Soil Compaction "Level"		
	None Applied	Moderate	High
0	630	690	840
5	540	660	890
10	340	520	690
15	190	240	250

Cone penetrometer values within a column that differ by more than 140 psi are statistically different. Values within a row that differ by more than 150 psi are statistically different (p=0.05).

Table 7. Maximum soil cone penetrometer resistance within the **13-18 in. soil depth range** combined over two years, 2008 and 2010.

Shank Depth (in.)	Soil Cone Penetrometer Resistance (psi)		
	Soil Compaction "Level"		
	None Applied	**Moderate**	**High**
0	730	630	680
5	710	750	800
10	590	580	700
15	580	590	520

Cone Penetrometer values within a column that differ by more than 130 psi are statistically different. Values within a row that differ by more than 180 psi are statistically different (p=0.05).

Root shape rating. Root shape ratings averaged over three years are shown in Table 8. Root shape rating was influenced by both level of soil compaction and by shank depth. Where no soil compaction was applied, there was not a difference in shape rating among shank depths. Where moderate soil compaction was applied, roots exhibited some shape difference for zero shank depth (no zone tillage) compared to the other three shank depths. Where high surface compaction was applied, each of the shank depths exhibited different levels of root distortion. The roots from the plots of zero shank depth with both moderate and high soil compaction exhibited extreme sprangling.

Table 8. Visual root shape rating (1=normal root shape; 2=somewhat shortened root and/or some sprangling; and 3=definite sprangling and shortened root shape) taken from the basket of the plot harvester during harvest, combined over three years.

Shank Depth (in.)	Visual Root Shape Rating		
	Soil Compaction "Level"		
	None Applied	**Moderate**	**High**
0	1.2	2.7	2.9
5	1.1	1.5	1.9
10	1.1	1.4	1.3
15	1.3	1.6	1.6

Root shape rating values within a column or within a row that differ by more than 0.3 are statistically different (p=0.05).

Sugarbeet yield response to soil compaction and shank depth. There were no differences in sugar content or root tare caused by either factor of soil compaction level or shank depth when averaged over the three years of the study. SLM was higher for zero shank depth in all three levels of soil compaction compared to all other shank depths when data was combined over all three years (Table 9). An explanation for this consistent difference is not obvious. SLM was not different for different levels of soil compaction.

Table 9. Sugar Loss to Molasses, combined over compaction levels, and combined over three years.

Shank Depth (in.)	SLM (%)
0	1.32
5	1.23
10	1.23
15	1.23

SLM values that differ by more than 0.09 are statistically different (p=0.05).

Table 10. Sugarbeet root yield, combined over three years.

Shank Depth (in.)	Sugarbeet Root Yield (ton/A)		
	Soil Compaction "Level"		
	None Applied	Moderate	High
0	34.5	30.2	18.5
5	32.3	32.8	27.5
10	33.8	33.7	32.1
15	31.4	32.7	32.1

Root Yield values within a column that differ by more than 2.5 ton/A are statistically different. Root yield values within a row that differ by more than 2.7 ton/A are statistically different (p=0.05).

Sugarbeet root yields combined over three years for each combination of applied soil compaction and shank depth are listed in Table 10. Root yield responded to shank depth differently for each compaction level. Where no soil compaction was applied, root yield was lowest for the 15 in. shank depth. Where moderate soil compaction was applied, root yield was lowest for the zero shank depth. Root yields were lowest for the zero and 5 in. shank depth where high compaction was applied. Comparison of root yields among compaction levels within a shank depth also suggests that root yield tended to be suppressed by added levels of soil compaction even when zone tillage was used.

Sugar yield, a simple product of root yield and root sugar content, for each combination of soil compaction level and shank depth, is provided in Table 11. Since sugar content was not statistically different among compaction levels or among shank depths, relative sugar yield was a near mirror image of relative root yield.

Table 11. Sugar yield for combinations of shank depth and soil compaction treatment, combined over three years.

Shank Depth (in.)	Sugar Yield (lb/A)		
	Soil Compaction "Level"		
	None Applied	Moderate	High
0	10,900	9,700	5,800
5	10,400	10,500	8,800
10	10,900	10,700	10,300
15	10,100	10,400	10,300

Sugar yield values within a column that differ by more than 900 lb/A are statistically different.
Sugar yield values within a row that differ by more than 1000 lb/A are statistically different (p=0.05).

Relationship of yield and soil compaction. During the first half of the growing season the plants in the plots with high compaction and zero shank depth appeared that they would die, or at best have very little root yield. By mid summer these plants had begun to grow and by harvest time this treatment had a root yield of 18.5 ton/A compared to 34.5 ton/A in the treatment with no added soil compaction (Table 10). This was very surprising. Evidently, the sugarbeet plant root could not effectively penetrate or function in the compacted soil layer early in the season, but by later in the season, the roots were more functional.

Even though the zone tillage shank reduced the soil cone penetrometer resistance in the row where moderate or high soil compaction was applied, root yield did not equal yield in treatments where no soil compaction had been applied. Thus, zone tillage did not completely alleviate the effect of soil compaction. Perhaps it was because all the soil within the tillage zone was not completely "relieved" of the destructive effect of the compaction. Or, yield might have been suppressed because the soil area between rows, not "tilled" by the zone tillage machine shanks, was still compacted. This may have implications for whether the shank should be positioned in the old rows or between old rows when zone tillage follows zone tillage from year-to-year.

An observation of cone penetrometer resistance (Tables 3-7) with root yields (Table 10) suggests that in-row cone penetrometer resistance of about 400 psi in the top 12 in. of soil began to suppress sugarbeet root yield. Surprisingly, the high soil compaction in the 8-13 in. depth range did not seem to substantially reduce sugarbeet yield as indicated by the lack of difference in yield between the 10 and 15 in. shank depth in the moderate and high compaction treatments.

Conclusions

Plant response to soil compaction and to tillage systems is notorious for having high variability. This study which included four zone tillage shank depths in previously moldboard plowed soil with no applied soil compaction, and moderate and high surface applied soil compaction, was not an exception. But, there are several clear messages from this study about how surface applied soil compaction and zone tillage shank depth affected sugarbeet yield:

- Even moderate soil compaction reduced sugarbeet yield. 'High' soil compaction reduced yield by almost half.
- A shank depth of 10 in. improved sugarbeet yields in 'moderate' and 'high' soil compaction treatments. A shank depth of 15 in. did not improve yields compared to 10 in. shank depth even though there was highly compacted soil below 10 in.
- A shank operating depth of 10 in. is recommended as a starting depth for zone tillage where some surface applied soil compaction is present. The particular fields should be inspected for presence and depth of any soil compaction and the shank depth adjusted accordingly.

Reference

Evans, R.G., W.B. Stevens and W.M. Iversen. 2010. Development of Strip Tillage on Sprinkler Irrigated Sugarbeet. Applied Eng. in Agric. 26(1):59-69.