DRAWBAR POWER REQUIREMENTS AND SOIL DISRUPTION OF IN-ROW SUBSOILER POINTS FOR CONSERVATION TILLAGE

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ABSTRACT

Soil compaction can reduce crop yields by restricting root development. In-row subsoiling is a common tillage practice for disrupting the compacted soil profile, allowing roots to proliferate downward to obtain adequate soil moisture. The subsoiler system is composed of many important components, but the point assembly is the first element to contact the soil and can largely determine the draft requirement and soil disruption of the subsoiler. Two points were evaluated in a soil bin experiment at the USDA-ARS National Soil Dynamics Laboratory in Auburn, AL. A standard ripper point was compared with a 'splitter point' which is designed to fracture the soil and reduce above-ground soil disruption, especially in dry conditions. The subsoiler system was mounted on a three-dimensional dynamometer where measurements of draft force, vertical force, side force, speed, and depth of operation were determined and tillage power requirements were calculated. Measurements of soil disruption including spoil cross-sectional area, trench cross-sectional area and trench specific resistance were determined. Results showed that the splitter point required significantly greater drawbar power (28%) compared to standard ripper point the while disturbing similar amounts of below-ground soil. However, the splitter point did reduce the above-ground soil disruption by more than 10%. The splitter point was helpful in reducing above-ground disruption but the added energy cost could be prohibitive for many producers.

Keywords. Tillage, Subsoiling, Soil compaction, Draft force, Ripper Point

INTRODUCTION

Soil compaction can reduce crop yields by restricting root development as well as water and air movement in the soil (Petersen et al., 2004; Wells et al., 2005). Deep soil compaction is difficult to alleviate by tillage and may have long-lasting implications for crop production (Hamlett et al., 1990; Raper et al., 1994; Petersen et al., 2004; Wells et al., 2005). One of the most common methods used to remove compacted soil conditions is subsoiling (Saveson and Lund, 1958; Box and Langdale, 1984; Busscher et al., 1986; Mullins et al., 1992; Vepraskas et al., 1995). Subsoiling disrupts compacted soil profiles, improves infiltration, increases soil moisture storage, and allows roots to proliferate downward to obtain adequate soil moisture and potentially improve crop yield (Raper, 2005b; Wells et al., 2005).

Because of the significant draft force required to subsoil compacted profiles, many different types of subsoilers have been designed and tested. The shape of the subsoiler shank can have a large effect on the required draft and soil disruption. Raper (2005a) reported that bentleg shanks had the lowest aboveground soil disruption when compared to several straight shanks for non-inversion in-row subsoiling. This type of shank was found to be suitable for a conservation tillage system. Smith and Williford (1988) reported that a parabolic subsoiler required reduced draft compared to a conventional subsoiler and a triplex subsoiler.

The subsoiler's point configuration has a large effect on the required draft and soil disruption. Some producers have reported that their draft force and their soil disturbance have been reduced by using a 'splitter point' on their subsoiler. This point, manufactured by Kelley Manufacturing Company[1] (Tifton, GA) has a dramatically raised ridge near the center of the point that 'splits' the soil as the shank travels forward.

Therefore, the objectives of this study were to:
- determine required draft forces for a standard ripper point and a splitter point at different depths of operation, and
- determine the amount of soil disruption caused by the different points at each depth of operation.

MATERIALS AND METHODS

The experiment was conducted in Nov. 2006 in the soil bins at the USDA-ARS National Soil Dynamics Laboratory in Auburn, Alabama. The soil bin is 20 ft wide, 190 ft long and 5 ft deep. The soil chosen for the study was a Norfolk sandy loam soil (sand 72%, silt 17%, and clay 11%) from the southeastern United States. A hardpan was formed in the soil bin to simulate a condition that is commonly found in this region. The hardpan condition was created in the soil bin by using a moldboard plow to laterally move the soil followed by a rigid wheel to pack the soil left exposed in the plow furrow. A small amount of soil was packed at a time and the entire procedure was repeated until the entire bin had been traversed.

The shanks used for this experiment were manufactured by Kelley Manufacturing Company and are commonly referred to as Generation I shanks. They are 1.25 in thick and have a forward angle of 52 degrees. Each point is 2.25 in wide and has an angle of 30 degrees with the horizontal. The splitter point has a 0.375 in thick fin attached to the top that extends back at an angle of 56 degrees with the horizontal and is 3.75 in high at the rear of the point (fig. 1).

Figure 1. Points used in the soil bin experiment. On the left is the splitter point (SP) and on the right is the standard ripper point (P).

[1]The use of company names or tradenames does not indicate endorsement by Agriculture University of Hebei or USDA-ARS.

The subsoiler system which included shank, point, and coulter were mounted on a three-dimensional dynamometer on a soil bin car at the NSDL (fig. 2). Draft force, vertical force, side force, speed, and depth of operation were recorded continuously for the shank for each test. The speed of tillage for all tests was held constant at 1 mph.

Figure 2. Subsoiler system mounted on the three-dimensional dynamometer in the NSDL soil bins.

Three depths of operation were evaluated for each point: 9, 12, and 15 in with the depth of the coulter remaining constant at 3 in (see table 1). The soil bin was partitioned into four blocks along the length of the bin. Six plots of dimensions 5 ft wide by 16.4 ft long were created within each block. A total of 24 plots were arranged in a randomized complete block design with two subsoiler points, three tillage depths, and four replications.

Table 1. Experimental treatments used for the soil bin experiment.

Treatments	Point	Depths of operation (in)
SP9	Splitter Point	9
SP12	Splitter Point	12
SP15	Splitter Point	15
P9	Standard Ripper Point	9
P12	Standard Ripper Point	12
P15	Standard Ripper Point	15

Before the tests were conducted in each plot, a set of five cone index measurements were acquired with a multiple-probe soil cone penetrometer measurement system (Raper et al., 1999). This set of measurements was taken with all five cone index measurements being equally spaced at an 8 in distance across the soil with the middle measurement being directly in the path of the shank. As soon as the subsoiler system had been tested in each plot, another set of five cone index measurement was also taken in the disturbed soil in close proximity to the original cone index measurements.

Measurements of bulk density and moisture content were taken in undisturbed regions of each replication for analysis. Values were collected from each plot using the soil measurement system (Raper et al., 1999) in increments of 2 in down to a depth of 20 in.

After each set of tillage operations was conducted, a laser profile meter (Raper et al., 2004) was used to determine the width and volume of soil disturbed by each tillage event. Disturbed soil was manually excavated from each subsoiled zone for approximately 3 ft along the travel path to allow five independent measurement of the subsoiled zone. Care was taken to ensure that only soil loosened by tillage was removed. The trench specific resistance was then calculated by dividing the drawbar power by the trench cross-sectional area to determine the relative efficiency of the tillage operation (Raper, 2005a)

A 2 (points) x 3 (depths) factorial design was used to evaluate the treatment effects and Fisher's protected least significant difference (LSD) was used for mean comparison using PROC MIXED (SAS; Cary, North Carolina). A probability level of 0.1 was chosen to test the null hypothesis that no differences existed between points or tillage depths.

RESULTS AND DISCUSSION

INITIAL SOIL CONDITIONS

Initial soil moisture content and bulk density for 0-20 in depth are shown in figs. 3 and 4. The gravimetric moisture content (dry basis) was approximately 7.9% near the surface and 8.4% at the 10-to 12-in depth. Bulk density values showed that the approximate location of the hardpan that was created in the soil bin started at a depth of 7.5 in. The soil within the hardpan, at a depth of 6 to 8 in and a depth of 16 to 18 in, had higher bulk density values [116.7 lb ft^{-3} and 118.0 lb ft^{-3} (1.87 Mg m^{-3} and 1.89 Mg m^{-3})] compared to the shallower layer of bulk density [100.5 lb ft^{-3} (1.61 Mg m^{-3})] at a depth of 4 to 6 in. Initial values of cone index increased gradually from the depth of 6 in to beneath the hardpan layer and increased again from 14 in (Fig. 5). These values indicated a similar pattern in soil compaction to the bulk density values. The different depths of tillage are also seen in figure 5 with extremely low cone index values being found down to the tillage depth.

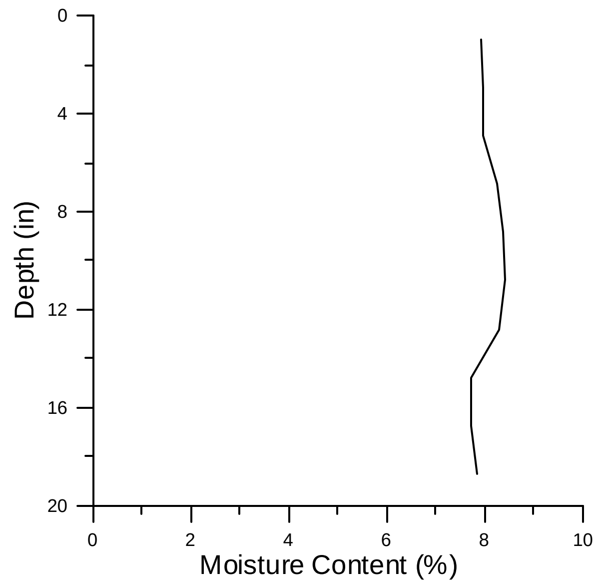

Figure 3. Initial soil moisture content of the soil bin.

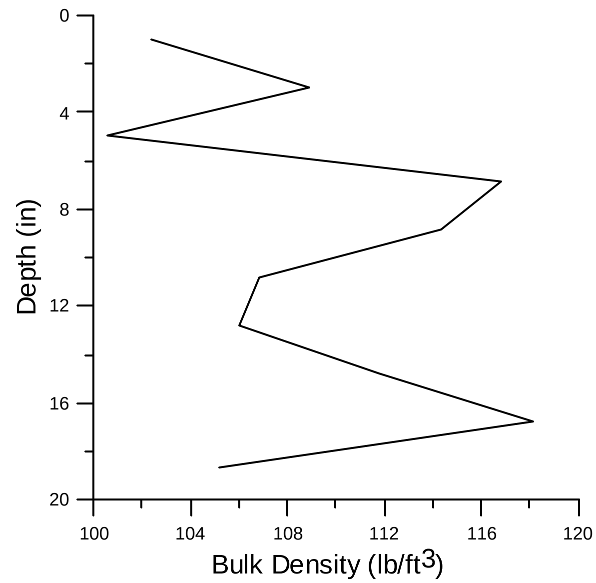

Figure 4. Initial bulk density of the soil bin.

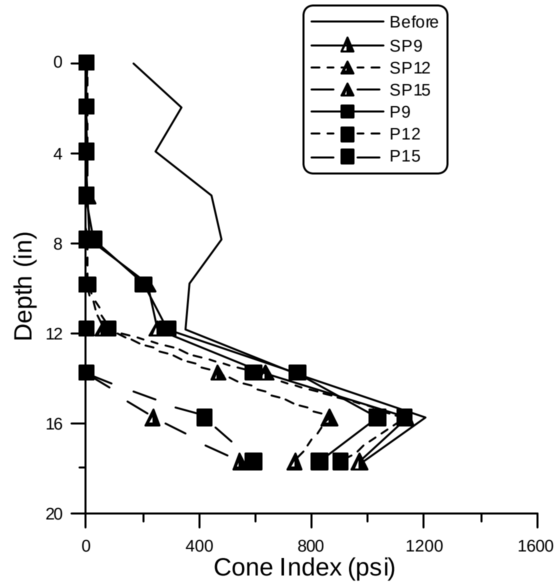

Figure 5. Cone index values obtained prior to tillage operations and after each tillage treatment in the center of the subsoiled zone.

DRAWBAR POWER

Values of drawbar power measured in soil bin experiments are typically reduced from typical field measurements due to the soil contained in the soil bin facility and the slow speed of operation at which experiments are conducted. The main effect of tillage depth was found to be highly significant ($p = 0.01$) on drawbar power (fig. 6). Minimum values of drawbar power (2.91 hp) were found at the shallowest tillage depth (9 in) and maximum values of drawbar power (10.6 hp) were found at the deepest tillage depth (15 in). Drawbar power increased almost 100% between each of the equally spaced depths of 9, 12, and 15 in.

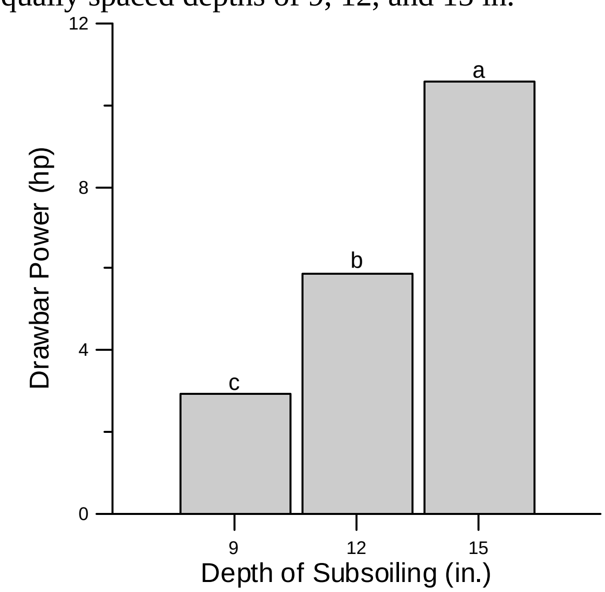

Figure 6. Drawbar power of subsoiler points averaged across points. Letters indicate differences at $LSD_{0.1}$.

The main effect of the subsoiler point was also found to be highly significant ($p = 0.01$) on drawbar power (fig. 7). The splitter point required 28% greater drawbar power (7.38 hp) compared to the standard ripper point (5.76 hp). No significant interactions were found between the two main effects of tillage depth and ripper points.

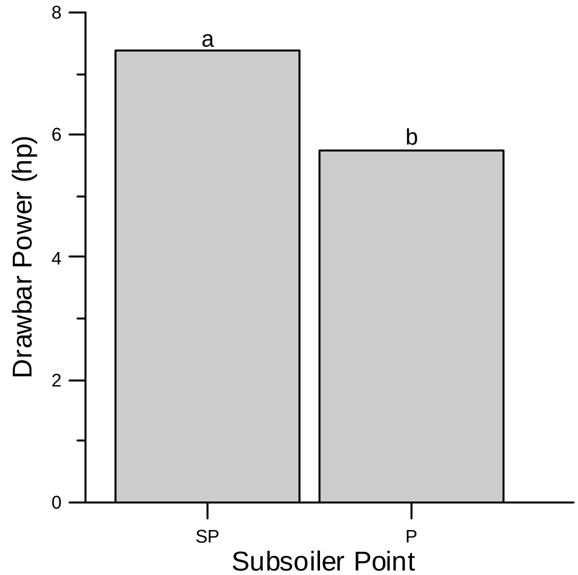

Figure 7. Drawbar power of subsoiler points averaged across depths. Letters indicate differences at $LSD_{0.1}$.

SOIL DISRUPTION

Spoil cross-sectional area was significantly affected by the main effect of tillage depth ($p = 0.01$; table 4) and ripper point ($p = 0.01$; table 5). Spoil gradually increased with tillage depth with minimum values occurring nearest the soil surface and maximum values occurring at the deepest depth. Also, the splitter point significantly reduced the spoil compared to the standard ripper point.

The trench cross-sectional area was significantly affected only by the tillage depth ($p = 0.01$; table 4) with maximum values of disruption occurring at the two deepest depths of 12 and 15 in and minimum values of trench disruption occurring at the shallowest depth of 9 in. The ripper point had no significant affect on below-ground disruption (table 5).

The trench specific resistance was also significantly affected by both tillage depth ($p = 0.01$; table 4) and ripper point ($p = 0.01$; table 5). Smaller amounts of trench specific resistance are advantageous because they indicate reduced amounts of power required to disrupt a specific volume of soil. Based on this parameter, the shallowest depth of operation required the minimum trench specific resistance while the deepest depth of operation required the maximum trench specific resistance (table 4). The standard ripper point also had minimum values of trench specific resistance as compared to the splitter point (table 5).

Table 4. Soil disruption parameters averaged across ripper points resulting from the soil bin experiments. Letters indicate differences $LSD_{0.1}$.

Treatments	Spoil Cross-Sectional Area (in^2)	Trench Cross-Sectional Area (in^2)	Trench Specific Resistance (hp/in^2)
9	46.08 c	64.47 b	0.047 b
12	54.31 b	104.18 a	0.058 b
15	67.65 a	112.20 a	0.096 a

Table 5. Soil disruption parameters averaged across tillage depths resulting from the soil bin experiments. Letters indicate differences $LSD_{0.1}$.

Treatments	Spoil Cross-Sectional Area (in^2)	Trench Cross-Sectional Area (in^2)	Trench Specific Resistance (hp/in^2)
P	59.02 a	98.16	0.056 b
SP	52.86 b	90.00	0.076 a

CONCLUSIONS

- Subsoiling conducted with the splitter point required significantly increased drawbar power than with the standard ripper point. The results showed that 28% more drawbar power was required to subsoil with splitter points than with standard ripper points.
- To reduce energy use and minimize above-ground soil disruption, reduced tillage depths should be considered. Tilling deeper than necessary wastes energy and excessively disturbs the soil surface.
- The splitter point reduced the amount of above-ground soil disturbance compared to the standard ripper point by more than 10%. However, the standard ripper point was more efficient using the trench specific resistance compared to the splitter point.

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