MANURE SPREADING AND ITS EFFECTS ON SOIL COMPACTION AND CROP YIELD

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Abstract

With the increasing size of farm equipment, the potential for soil compaction has become a real problem. According to some grain farmers, compaction from manure spreading equipment is a factor limiting their acceptance of slurry as a soil building and soil fertility resource. To address the issue of compaction caused by manure spreaders, eight on-farm sites were set up in the fall of 2004 and spring of 2005. At each site three treatments were applied (manure, farmer's check, and tanker compaction only), and replicated three times. In addition to the on-farm trials, an on-station site was set up in Arlington. The on-station site examined the impact of multiple passes of heavy slurry equipment as might occur on field roads or headlands. After one year of field trials, it appears that compaction from manure spreaders does not adversely affect corn yields when it is applied in reasonably dry conditions. There was no significant difference between the three treatments in seven of the eight on-farm sites. Despite non-significant differences at the plot scale, hand harvests of the on-station trial showed a 10 to 15% reduction in corn yield for rows that were directly within the tire track when there were multiple passes.

Introduction

Despite the nutrient content of manure many grain farmers have indicated that they are hesitant to bring slurry onto their land due to concerns regarding soil compaction (pers. comm. Columbia County Crop Production Club, 2003). Their concerns are not unfounded as manure tankers commonly carry volumes ranging from 3,000 to 7,500 gallons and can weigh from 20,000 to 35,000 pounds per axle. These weights exceed the 20,000 lb/axle benchmark that has been shown to contribute to subsoil compaction, which is generally not alleviated by freeze/thaw cycles or tillage (Lowery and Schuler, 1991, 1994, Håkansson et al., 1987). However, slurry tankers are not that much heavier than some of the equipment already used by grain farmers. For example a single axle, 500 bu. grain cart has an axle weight of approximately 31,000 lbs full, and a combine with a hopper capacity of 250 bu can weigh over 27,000 lbs/axle when loaded with corn at 20% moisture.

Heavy equipment, especially on wet soils, can cause soil deformation, compaction, and destruction of soil structure resulting in anaerobic microbial buildup, denitrification, and reduced water use efficiency and nutrient uptake by the crop (Abu-Hamdeh, 2003, Håkansson et al., 1987, Lowery and Schuler, 1991, Wolkowski, 1990). Approximately 80% of potential soil compaction occurs during the first traffic pass, and subsequent passes lead to additional but progressively less compaction that is almost negligible by the fourth pass (Daum, 1996). Under certain conditions, these changes can result in yield reductions. For example, Lal and Ahmadi (2000), working in Ohio, found that compaction (16,500 pounds/axle) reduced corn yields (approximately 14%) in 2 out of 11 years on a fragic silt loam soil but in a six year companion study, axle weights up to 44,000 pounds had no effect on yield. In a similar type of study Lowery and Schuler (1991) found

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that axle weights of 17,600 lbs and 27,500 lbs reduced corn yields, in the first year of a four-year study, by 4 and 14% respectively on a Rozetta silt loam (fine-silty) and 14 and 43% respectively on a slightly heavier Kewaunee silt loam (fine). Much of the current research addressing compaction however, is focused on potential yield loss, and was conducted under extreme conditions (multiple passes with entire plot coverage). This probably does not represent actual yield losses since most of a production field is not directly under the tire tracks. When looking at some common manure spreading equipment, the percent of tire track to spreader width ranges from 10 to 40 % (Table 1). In addition, although there has been extensive research on machinery induced compaction (Alakukku et al., 1995, Evans et al. 1996, Håkansson et al., 1987, Lal and Ahmadi, 2000, Lal, 1996, Lowery and Schuler, 1991, 1994, Stewart et al., 1994, Wolkowski, 1990, 1991), very little has been done to address this issue in conjunction with the application of manure, which can positively effect soil structure and yield.

Two questions are posed in this study:

1. Does the compaction caused by the application of manure result in lower corn yields; and,
2. Does the manure itself, help to mitigate the effect of compaction due to the general benefits associated with manure (plant nutrients, increased porosity, water infiltration, nutrient uptake, increased organic matter and soil biological activity)

It was decided to address these issues as on-farm trials. The trial included three treatments:

1. **F**-farmer's check with fertilizer and no manure
2. **M**- where manure replaced some of the fertilizer requirement
3. **C**-compacted plot where loaded spreader traversed the plot without adding manure

Table 1. Spreader width and % field traffic.

Spreader	Tire specs	Application width	% of application width under the tire
Broadcast Truck[1]	11R-22.5	~30 ft.	13.3%
Broadcast Tank[2]	28L-26	~50 ft.	9.2%
Injection Tank[3]	30.5L-32	12 ft.	41.6%

[1]Husky 4,000 gallon truck mounted tank
[2]Waste Handlers by J-Star 4,600 gallon tractor-pulled slurry tank
[3]Balzer 5,700 gallon tractor-pulled slurry tank

On-farm Trials

Site Characterization and Trial Layout

Eight on-farm research sites were established in the fall of 2004 and spring of 2005 in Dane, Jefferson, Columbia and Walworth Counties. A characterization of these sites and the application of the treatments are outlined in Table 2. At each site fields were selected that had not received manure or bio-solids in the past 10 years. The experiment was set up as a randomized complete block design with three replications at each site. Plot sizes were determined based on manure spreading, corn planting and harvesting equipment and ranged from 30 to 45 feet wide and 300 to 480 feet long (0.2 to 0.5 acres/plot).

Table 2. Characterization of on-farm sites.

Site	Previous crop	Soil texture	% OM	Drainage[1]	Type of tanker	Axle wt. of tanker lbs.[2]	Manure incorporated Yes/No	Date of app.	Post-application tillage
1	Soybean	clay loam	2.8	PD	Tractor Pulled (Broadcast)	24,000	No	11/3/04	None
2	Wheat	Silt loam	3.5	WD	Tractor Pulled (Broadcast)	24,000	No	11/3/04	Field Cultivator
3	Soybean	Silt loam	3.7	WD	Truck Mounted (Broadcast)	19,880	Aerway	11/14/04	Zone till
4	Wheat	Silt loam	4.0	WD	Truck Mounted (Broadcast)	19,880	Aerway	11/14/04	Field Cultivator
5	Corn	Silt loam	1.3	MWD	Tractor Pulled (Injected)	26,400	Yes	5/4/05	Field cultivator
6	Alf.	Loam	2.6	WD	Tractor Pulled (Injected)	30,955	Yes	4/27/05	Field finisher
7	Wheat	Silt loam	2.2	WD	Tractor Pulled (Injected)	30,955	Yes	10/9/04	Field finisher
8	Wheat/ Clover/ Alfalfa	Silt loam	2.5	MWD	Tractor Pulled (Injected)	26,400	Yes	9/20/04	Field cultivator

[1] Drainage class: PD = poorly drained, MWD – moderately well drained, WD = well drained

[2] Axle weights are based on weights of loaded slurry tankers.

Manure Spreading and Compaction

Based on informal surveys with nutrient spreaders and extension personnel, the target spreading rate was 12,000 gal/a. Plots were designed to be long enough to empty the spreader in one pass in order to insure that all manured plots got an equal amount of manure. This resulted in the manured plots (M) having a changing axle weight across the plot, while the compacted plots (C) (without manure) had a constant full weight applied to the plot. As can be seen in Table 2, in four cases, the manure was applied using a tractor-pulled tank with an injection toolbar and at the remaining sites manure was broadcast. The former system required 3 passes across the plot and in the latter-- just one. The compaction treatment was applied by driving over the plot with a loaded slurry tanker using the same traffic pattern that was used for spreading. Conditions were generally good for field operations at all sites on the day of manure application. Rainfall ranged from 0.1 to 0.8 inches and fell from two to seven days prior to manure spreading.

Corn Phase

Corn was planted in the spring of 2005 at all sites. Selection of corn variety, seeding rate, herbicide program and other cultural practices were left up to the farmer-participant. Crop nutrient needs were met with fertilizer in the farmer check (F) and compaction only (C) treatments, and manure plus sidedressed nitrogen (according to the Pre-Sidedress Nitrate Test (Bundy and Andraski, 1995)) in the manured treatment (M). All the plots received starter fertilizer. At each site corn was harvested from the middle six rows of each plot using the farmer-participants' combine.

Headlands Project

Although most of the field is only trafficked once when manure is being spread, parts of the field (headlands, field entrance) receive multiple passes. In order to study the impact of this more extreme compaction due to manure spreading, a factorial experiment plus check plot was established using broadcast manure. The treatments include:

M1-Manured plot with one pass
M6-Manured plot, trafficked 5 times and the manure applied on the 6th pass
C1-Trafficked once but no manure added
C6 -Trafficked six times but no manure added.
F-farmer's check without manure added

The Headlands Project was established at the UW Madison Agricultural Research Station in Arlington. The field was a Plano silt loam (3.4% OM), had been in a no-till corn / soy rotation for the previous 5 years, and had no history of manure application. The experiment was set up as a randomized complete block design with four replications. Plots were 45 feet wide by 125 feet long. Manure was spread on April 15, 2005 at a rate of 12,000 gallons per acre using a 4,600-gallon Waste Handlers slurry tanker (24,000 lbs /axle) pulled by a Case IH 8920 tractor. Soil moisture (0 to 6 inches) at the time of spreading was 26 to 31% and tire tracks were clearly visible following application of treatments. Manure was incorporated within three days of application using a chisel plow.

Spring Practices

Selection of corn variety, seeding rate, herbicide program and other cultural practices at the research station were handled by the research station staff. Side-dressing with 28% UAN (Urea Ammonium Nitrate) was done according to UWEX PSNT recommendation on all plots.

Fall Harvest

Prior to whole plot harvest, hand harvested areas were taken in each plot to evaluate the impact of compaction on crop yield at varying distances from the tire tracks. Three sampling stations were randomly assigned to each plot. At each station a five-foot length of corn row was harvested from the row in the tire track, the row 30 inches from the tire track, and the row 60 inches from the tire track. Samples were shelled and analyzed for % moisture, test weight, and then weighed. Following hand harvests the middle six rows of each plot were harvested using a JD 9500 combine to determine plot yields.

Results and Discussion

On-Farm Trials

Combined analysis of corn yield at the 8 on-farm trials is shown in Table 3. Treatment was not significant ($p = 0.17$) (Manure=193 bu/a; Farmer check= 187 bu/a; Compaction only=189 bu/a). When linear contrasts were used to address our two research questions we found that compaction (C) did not significantly decrease corn yield when compared to our farmers' check (F) ($p = 0.67$), and manure did not "ameliorate" any negative effect of compaction ($p = 0.17$). Site was highly significant ($p<0.0001$) with much (>60%) of the site effect accounted for by location within the state (Table 3). There is a trend of reduction in yield from the sites in south-central Wisconsin (sites 1-4) to the sites in southeastern Wisconsin (5-8) (Fig 1). This difference in yields with location is likely the result of soil type and available water during the growing season. The 2005 growing season was dry with total rainfalls from May 1 to Sept 15 of 10.78, 12.14, and 7.31 inches for Columbia, Jefferson, and Walworth counties respectively[4]. In addition to site, there was a significant site by treatment interaction ($p = 0.0437$). At seven of our eight sites the manured treatment (M) yielded as well if not better than compaction only (C) and farmers' check (F) but at one site, it gave the lowest yield. It is important to note that farmers, based on the PSNT results, applied on average 50# less sidedressed N to the manured (M) vs. non-manured (C and F) plots.

Table 3. ANOVA table of combined on-farm analysis.

Source	d.f.	Sum of Squares	Mean Square	F value	p > F
Site	7	45,172.48	6,453.21	53.18	<0.0001
SC v. SE	*1*	*28,541.43*	*28,541.43*	*235.22*	*<0.0001*
Trt	2	412.17	206.10	1.87	0.1713
Site*Trt	14	3,215.92	229.71	2.08	0.0437
Block(Site)	16	1,941.97	121.34	1.10	0.3955
Error	31	3,418.31	110.27	--	--
Total	70	54,794.49	--	--	--

Note: contrast within site is for south central (SC) sites vs. south eastern (SE) sites.

Headlands Study

Whole plot yields

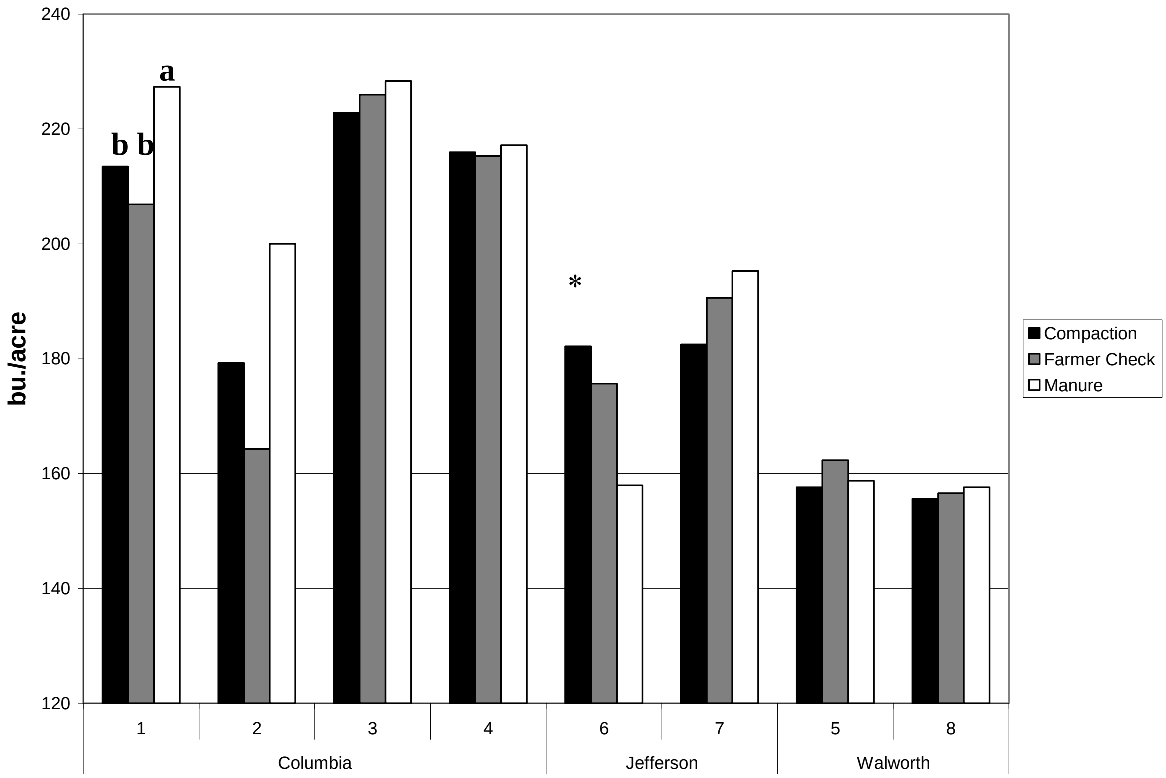
As with the on-farm trials, there was no effect due to treatment in the on-station trial. Looking specifically at our hypotheses: 1) the single compaction pass resulted in similar yields to the farmer check and 2) the manured plot did not ameliorate yields above the compacted plot. Surprisingly, even the heavily trafficked C6 had yields nearly equivalent to the farmer's check.

Hand harvests

A trend begins to appear with the hand harvests (Table 4). While distance from the tire track was not important with one pass, both M6 and C6 (six pass treatments) yields increased significantly from within the tire track to 60 inches from the tire track.

[4] Midwest Regional Climate Center http://mcc.sws.uiuc.edu/

Fig 1. Site by site on-farm yield summary.



Note: bars with different letters are significant at α = 0.05,
* mean value based on two data points rather than three

Table 4. Summary of 5-foot long hand harvest yields—estimated corn yield in bu/a.

	1 Pass		6 Pass	
Treatment	Manure	Compaction	Manure	Compaction
Within tire track	185	181	168[a]	146[a]
30 in. from tire track	187	188	166[a]	171[b]
60 in. from tire track	179	176	184[b]	176[b]

Note: Columns with differing letters are significantly different at α=0.10.

Conclusions

In this study we are asking two questions: 1) Does the compaction caused by the application of manure result in lower corn yields; and, 2) If lower yields do result, does manure itself, help to mitigate the effect of compaction. In our on-farm and on-station trials, although loaded axle weights were high (19,880 to 30,995 lb), plots that were driven across with a slurry tanker, but received no manure gave equivalent yields as non-trafficked farmer check plots. Furthermore, yields were not significantly improved from the addition of manure suggesting that there was no amelioration effect of manure. However, when rows were harvested individually, it appeared that rows within/ directly next to the tire tracks did produce less corn than those at 60" from the track. Within-track yields of multiple trafficked areas were reduced by 10% to 16% compared to rows 60" away from the tire tracks. These preliminary results suggest that, when driving on relatively dry soils, the compaction caused by manure spreaders does not significantly reduce corn yields on the majority of the field but headlands or field entrances will yield slightly less.

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