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EFFECT OF SOIL COMPACTION FROM WHEEL TRAFFIC ON CORN CROP PERFORMANCE

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Abstract

A compaction demonstration experiment was established at the Central Experimental Farm in Ottawa, ON in 2002 to demonstrate the effects of field traffic on wet soil on soil structure and crop performance. Compaction treatments were applied under wet soil conditions with wheel-beside-wheel traffic with a heavy tractor in spring 2002 and 2003. Four N fertilizer treatments were applied and a corn crop was grown following normal agronomic practices. Plant population, numbers of cobs, and corn yield measurements were taken at harvest.

The compaction treatment had a highly significant effect on all three crop performance measurements. Average yield for plots compacted in spring, 2003 was 6.2 Mg ha⁻¹ compared with 9.3 Mg ha⁻¹ for the non trafficked plots. There did not appear to be a residual effect of compaction treatments from the previous year. Surprisingly, the N fertilizer treatments did not have a significant effect on any of the three performance measurements. Further analyses are required to determine if residual soil N may have masked N fertilizer effects. The results clearly indicate the consequences of heavy field traffic under wet soil conditions. They also suggest that a copious amount of N fertilizer is not an effective remedy when the underlying cause of poor crop performance is degraded soil structure resulting from heavy field traffic.

Key Words: soil compaction, field traffic.

Introduction

Soil compaction is a leading cause of poor crop performance in the fine textured soils in eastern Canada. Soil compaction is the consolidation of soil particles which results in an increased in soil strength. In road building, soil is intentionally wetted, and compacted with specialized heavy machinery to increase the strength of the road bed to support subsequent road traffic. In agriculture, soil is also compacted by wheel traffic from agricultural field machinery, but the resulting increase in soil strength is undesirable. Compaction results in poor drainage characteristics, low air filled porosity, and reduced ability for the plant roots to penetrate the soil to reach nutrients (Hamza and Anderson 2005). These factors all lead to reduced crop performance.

Most producers know about soil compaction issues, but often, they are not aware of the magnitude of the problem. Most producers know that field operations in wet conditions will cause soil damage. Rutting from tires is a very visible consequence of traffic on very wet soil. Of then though, the rutting problem disappears, at least on the surface, after a few tillage operations. The deeper effect on the subsoil is more difficult to detect (McBride et al. 1988), and is sometimes ignored. While producers know that it is bad management to do field operations in wet soil conditions, sometimes they have little choice. Full season crops such as corn require field operations in early spring for planting, and late fall for harvest. These are often the times when the weather is bad and soil is very wet. Sometimes a choice has to be made: stay off the field in the fall and loose the crop, or harvest under wet soil conditions and potentially damage the soil.

A compaction demonstration experiment was established in 2002 at the Central Experimental Farm in Ottawa, ON to demonstrate the effects of soil compaction at a producer field day. An evaluation of the demonstration aspects of the experiment was presented by McLaughlin et al. 2003. A lot of interest was shown in the experiment and it was decided to continue the experiment and expand the suite of measurements. This paper presents the yield data from 2003.

Materials and Methods

The field site was at the Central Experimental Farm in Ottawa, ON. The soil was a North Gower Clay Loam (Ortho Humic Gleysol). The field had been in corn in 2001, and was chisel plowed and disced in fall 2001.

For the demonstration experiment in 2002, the field was divided into nine parallel strips, each 6 m wide by 90 m long (Fig. 1). Four of the strips were compacted by wheel beside wheel traffic with a tractor with a mass of approximately 10 Mg. The tractor had single front and rear wheels with 18.4R38 tires on the rear, and 16.9-26 bias ply tires on the front. Inflation pressure in the front and rear wheels were 140 and 150 kPa respectively. Water tanks were mounted front and rear and each were filled with 2000 litres of water creating an additional ballast of nearly 4 Mg for a total tractor mass of approximately 14 Mg (Fig. 2). This total tractor mass was well above the recommended maximum load for the tire sizes used. However, the ground pressure was below that which is often exerted

by agricultural equipment. For example, liquid manure spreaders with a total mass of over 25 Mg are sometimes fitted with tandem axles and 445/65R22.5 truck tires inflated to 560 kPa (McBride et al. 2000). Total axle weight and ground pressure for this configuration is well above that for the tractor used to apply the compaction treatments.

The trafficking was done when the soil was very wet after a heavy rain in May, 2002. The plots were 6 m wide, and the tractor was about 3 m wide, and consequently, the wheel-beside-wheel traffic resulted in double compaction in the centre part of the plots, and single compaction near the plot borders. An extreme degree of compaction was intentionally applied. The intent was to simulate a worst case field operation such as applying liquid manure with a heavy liquid manure spreader under early spring wet soil conditions.

In 2003, the field was subdivided into four replicates, each with four 6x30 m plots corresponding to the strip plots from the previous year (Fig. 3). Compaction treatments were applied to half of the plots. A procedure similar to the previous year was used where the compaction was done with wheel-beside-wheel passes with a heavy tractor when the soil was very wet after a heavy rain (Fig. 4). Two separate compaction treatments were applied, one on May 16, 2003 when the soil was dry on the surface, and one on May 26, 2003 during a rain when the surface soil was very wet (Fig. 4). After the soil had dried, normal spring tillage operations were done, and the field was planted with corn perpendicular to the direction of the strip plots. Nitrogen fertilizer was applied at four rates, 0, 75, 150 and 300 kg N ha⁻¹ (Fig. 3).

A 4x4 factorial experimental design was employed with four compaction treatments, four levels of fertilizer. Four replicates were used. The compaction treatments represented all combinations of compacted and non-compacted in both 2002 and 2003. Nitrogen fertilizer was applied in strip plots perpendicular to the compaction treatments. Four rates of N fertilizer were used, 0, 75, 150 and 300 kg N ha⁻¹. A diagram of the field plot layout is given in Fig. 3, and the levels of the compaction and fertilizer treatments are given in Tables I and II.

Normal crop husbandry practices were followed. There was a problem with weeds, although it was not considered severe, and likely had moderate detrimental effect on crop performance.

Yield data were obtained by hand harvesting a two meter length of the centre four rows in each plot in November, 2003. The two meter length corresponded to the central part of the plot that received double compaction in the wheel-beside-wheel compaction. Cobs were removed by hand, shelled, and weighed. A sub sample of the grain was oven dried to determine moisture content.

Results and Discussion

The first compaction treatment on May 16, 2003 when the soil surface was relatively dry did not create noticeable rutting by the tractor tires. However, as the tractor was very

heavy, and as the subsoil was still quite wet, it is likely that subsurface compaction resulted. McBride et al. (1988) presented diagrams of the subsurface stress field calculated with the Boussinesq equations for elastic media. Compressive stresses can extend deep into the subsoil when the surface is loaded with heavy machinery.

The second compaction treatment was conducted on May 26, 2003 while it was raining. Rutting was only moderate, but the imprints of the tire grousers were clearly visible. The differences between compacted and non compacted plots were clearly visible in the surface sheen of the soil. Water ponded in the imprints left by the tire grousers, and the soil surface between the grouser imprints had a sheen indicating a water film sitting on the soil surface (Figs. 4 and 5). McLaughlin et al. (2003) presented a photograph the soil surface in and beside a wheel track which clearly showed the difference in surface water infiltration in and beside a wheel track.

Normally, one would expect tractor tire marks to be clearly visible in soil, even if it was not wet. The plot area had not been tilled the previous fall, and the soil surface was quite firm, even when the soil water content was high.

Severe rutting occurred when the tractor was turned in the buffer zone between reps 3 and 4, and reps 1 and 2 (Fig. 4 centre, Fig. 5 bottom). Skidding occurred when the tractor rear brakes were used to aid in turning, and this piled the surface soil. It is likely that the resulting smearing caused severe soil damage, but this area was outside of the plots, and yield measurements were not made in this zone. No turns were made in the plot area, and any smearing that occurred was the result of the soil deformation under the axle weight.

Data for plant population density, numbers of cobs, and grain yield for the various compaction and fertilizer treatments are given in Tables I and II. The effect of the 2003 compaction treatment is clearly evident in all of measured crop parameters (Table I). Plant population was significantly lower in the compacted plots. This is likely mainly due to poorer initial crop establishment. Plant population counts made in spring 2002 showed poorer crop establishment in the compacted plots. The lower cob count in the plots compacted in 2003 may be a combination of lower plant population, and poorer performance of those plants that did achieve initial establishment.

The differences in yield between compacted and non-compacted plots were much more dramatic than differences in either the plant population or cob count. This indicates that plants in the compacted plots that did establish themselves and did produce cobs, were not as vigorous as those in the non-compacted plots. Cobs in the compacted plots did not produce as much grain. The average grain per cob in the non-compacted plots was 138 grams/cob while that in the compacted plots was 109 grams per cob. Differences in vigour of the plants between the compacted and non-compacted plots were clearly visually evident, particularly early in the growing season.

Residual effect of compaction from 2002 was not as pronounced as the compaction in 2003. Some residual effect was expected, but spring tillage and natural processes such as

soil biology (root growth and soil micro flora and fauna), and the freezing in the winter appear to have largely relieved the previous year's effects.

The effect of N fertilizer was not as dramatic as was expected. Mean yield for the Range in mean yield for the four N fertilizer treatments of 0, 75, 150 and 300 kg N ha⁻¹ ranged from 7.43 to 8.24 Mg ha⁻¹. Sometimes producers think that crop performance problems can be remedied with copious amounts of N fertilizer. These data suggest though that poor crop performance due to an underlying compaction problem is not readily fixed by additional N fertilizer. N use efficiency was not calculated, but a cursory evaluation of the data suggests that the differences in N use efficiency could be quite substantial.

The fertilizer data in Table II are the result of a preliminary analysis. There may have been a considerable residual effect of N fertilizer from 2002 when half of the field area received 300 kg N ha⁻¹, while the other half only received 150 kg N ha⁻¹ (Fig. 1). Any residual N from 2002 would have a confounding effect on the N response in 2003. More detailed statistical analysis is required. Residual soil N from spring soil cores may provide a means to delineate the interactions of compaction and N fertilizer.

Conclusions

Preliminary analysis of the results from the compaction demonstration experiment show that field traffic under wet spring soil conditions has a substantial detrimental effect on corn yield. The response of compacted plots to additional N fertilizer is only minimal. Further analysis of data is required to determine the effects of residual N fertilizer.

Acknowledgements

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Table 1. Plant density, cob count, and corn yield for various compaction treatments in 2002 and 2003.

Compaction Treatment		Plant Population (plants ha ⁻¹)	Cobs (Number ha ⁻¹)	Grain Yield (Mg ha ⁻¹)
2002	2003			
C	C	64200 a,b	59200 a,b	6.40 a
C	N	69000 b	66800 c	8.99 b
N	C	61500 a	54800 a	6.00 a
N	N	66900 b	65100 b,c	9.60 b

Table II. Plant density, cob count and yield for various nitrogen treatments in 2003.

2003 Nitrogen Treatment (kg ha ⁻¹)	Plant Population (plants ha ⁻¹)	Cobs (Number ha ⁻¹)	Grain Yield (Mg ha ⁻¹)
0	64100 a	63800 a,b	7.53 a
75	64100 a	58000 a	7.43 a
150	68800 a	65500 b	8.24 a
300	64600 a	58500 a,b	7.80 a

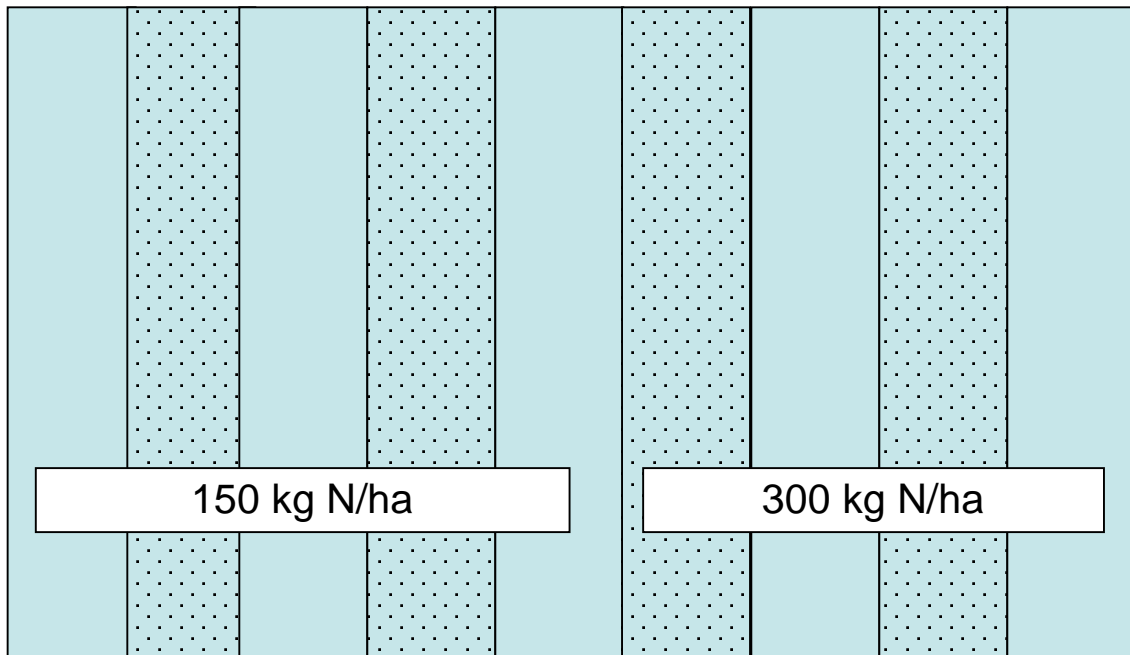


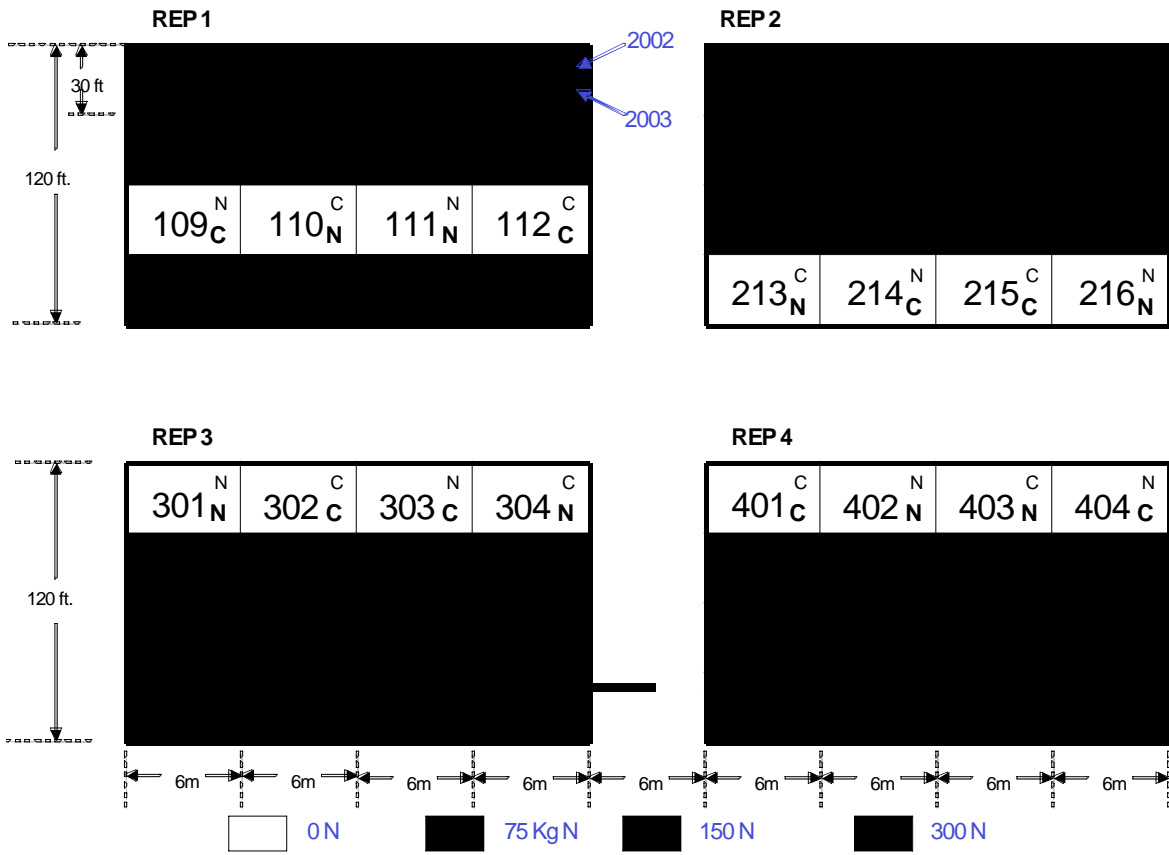
Fig. 1. Diagram of field plan for 2002 Compaction Demonstration Experiment. The strip plots were each 6 m wide by 90 m long. Shaded plots were compacted in 2002, and non-shaded plots were not compacted in 2002. Fertilizer was applied at 150 kg N/ha to the five plots on the left, and at 300 kg N/ha to the four plots on the right.



Fig. 2 Tractor used to compact plots in a wheel-beside-wheel manner. The large tanks mounted on front and rear of the tractor were each filled with 2000 litres of water for increased ballast. Total tractor mass including water ballast was about 14 Mg.

CEF Compaction Demonstration 2003 Plot Plan

Notes : N=Non -compacted
C=Compacted



May 22/03

Fig. 3. Field plan for 2003 compaction and N fertilizer treatments in compaction demonstration experiment.

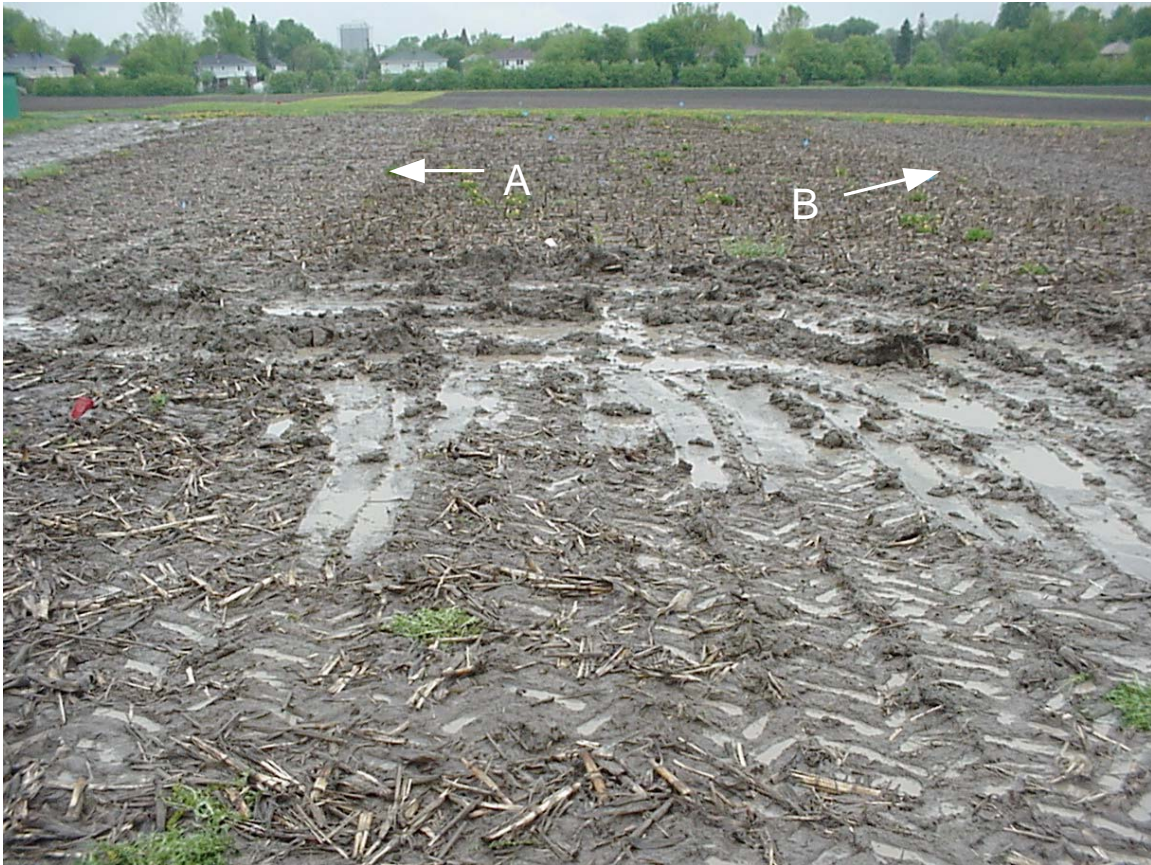


Fig. 4. Compacted plot. The foreground in the lower section of the photograph shows water laying in the wheel tracks in a compacted plot. The central section of the photograph shows skid marks where the tractor was turned in the buffer zone between reps 1 and 3 (Fig. 3) using a combination of front wheel steering and rear wheel brakes. The background in the upper section of the photograph shows two compacted plots, one on the left and one on the right, and a non compacted plot in the center. The arrows, A and B point to the border of the non-compacted and compacted plots.



Fig. 5. Photograph of compacted plot. The A and B arrows point to the border between the compacted plot and adjacent non-compacted plots. Note rutting and skidding in foreground at the bottom of the photograph resulting from turning the tractor in the buffer zone between reps 3 and 4 and reps 1 and 2 (Fig. 3).