6-1988

Comparison of Bulk Density Beneath a Belt Track and Tire

Leonard L. Bashford
University of Nebraska - Lincoln, lbashford1@unl.edu

A. J. Jones
University of Nebraska - Lincoln

L. N. Mielke
University of Nebraska - Lincoln

Comparison of Bulk Density Beneath a Belt Track and Tire

L. L. Bashford, A. J. Jones, L. N. Mielke
MEMBER ASAE — AFFILIATE ASAE

ABSTRACT

WHEEL traffic is considered a major cause of soil compaction in production agriculture. Soil compaction depends on initial conditions, load, contact area and tire type and shape at the soil surface. The use of tractors equipped with tracks instead of tires has the potential of reducing soil compaction because of reduced surface contact pressure and difference in load distribution over a relatively long-narrow track. The introduction of a new agricultural tractor equipped with a rubber belt track permits a crawler tractor to compete with a large four-wheel drive tractor in both speed and mobility.

Soil bulk density was measured as an indication of compaction which results from trafficking with a rubber belt track tractor and a four-wheel drive tractor. The measurements were taken on three tillage treatments at three soil water contents. Most of the comparative differences in bulk density resulting from trafficking with the two tractors were non-significant at the 0.10 level. Bulk densities at the deeper depths were significantly higher for the tire than the rubber belt track for some tillage treatments. However, in all comparisons, bulk density resulting from the rubber belt track was numerically less than from the tire.

INTRODUCTION

The use of steel tracked crawler tractors for agricultural purposes has been, in many situations, replaced with large 4-wheel drive tractors. The faster travel speeds of the 4-wheel drive tractors permitted mobility not possible with the steel tracked crawler tractors. Track type tractors have the advantage of developing higher dynamic traction ratios than tire-type tractors. However, because the tire-type tractors travel at faster speeds, high dynamic traction ratios were not required to achieve high tractive efficiencies.

The introduction of a tractor equipped with rubber belt tracks, instead of steel tracks, permits operation of track type tractors at speeds equal to the large 4-wheel drive tractor. Therefore, the advantages of mobility and speed for the 4-wheel drive tractor are negated by the crawler tractor with rubber belt tracks.

Wheel traffic is considered a major cause of soil compaction in agricultural soils. Resulting compaction for a given soil condition depends upon the shape of the contact area, the surface contact pressure and the axle load. The larger and longer contact area of a track, as compared to a tire, has the potential of reducing soil compaction resulting from the use of large agricultural tractors.

LITERATURE REVIEW

Many differing points of view exist as to whether a tire or track causes the most compaction. Burger et al. (1983) compared a rubber-tired log skidder with a steel track crawler. They reported that neither soil density nor porosity were affected at the 15-cm depth. However, both soil water content and number of passes significantly affected the actual change in these soil properties.

For field experiments, Brixius and Zoz (1976) reported no significant differences between crawler and four-wheel drive tractors in soil compaction below the tillage zone. The crawler and the four-wheel drive tractor had static contact pressures of 61 and 75 kPa, respectively. The four-wheel drive had a slightly greater compaction effect in the top 100 mm of soil, while the crawler had a greater compactive effect in the 150 to 250 mm zone. Soil compaction was not evident beyond a 250 mm depth for either tractor.

Taylor and Burt (1975) evaluated compaction under a tire, pneumatic track and a steel track. They indicated bulk densities in the 0 to 5 cm depth, and soil pressures at the 20 cm depth, were significantly higher for the tire than for the two track devices.

Erbach et al. (1986) evaluated compaction caused by track and tire-type tractors during secondary tillage. Differences were not great, but soil trafficked by track-type tractors consistantly had lower bulk density, and lower cone penetration resistance than the tire-type tractors.

OBJECTIVE

The objective of the research reported in this paper was to compare the soil bulk density resulting from trafficking with a rubber belted track-type tractor and a similar size 4-wheel drive tractor.

Article was submitted for publication in July, 1987; reviewed and approved for publication by the Power and Machinery Division in February, 1988. Presented as ASAE Paper No. 87-1054.

Published as Paper Number 8405, Journal Series, Nebraska Agricultural Research Division.

Trade and company names are included in this paper for the benefit of the reader and do not infer endorsement or preferential treatment of the product named by the University of Nebraska and the U.S. Department of Agriculture, Agricultural Research Service.

The authors are: L. L. BASHFORD, Professor, Department of Agricultural Engineering; A. J. JONES, Assistant Professor, Department of Agronomy; and L. N. MIELKE, Soil Scientist, U.S. Department of Agriculture, Agricultural Research Service, University of Nebraska-Lincoln, Lincoln, NE.

Acknowledgment: The authors acknowledge the loan of the tractors from Caterpillar Inc.

TABLE 1. TRACTOR SPECIFICATIONS

Specifications		Belted track	Four-wheel drive
Mass, kg:	front		7543
	rear		5467
	total	13970	13010
Track/tire size		0.635 m wide 2.740 m long	20.8 x 38 duals
Inflation pressure			inner: 98 kPa outer: 85 kPa
Tread width:	inside	1.52 m	1.30 m
	outside	2.79 m	3.81 m

PROCEDURE

General

The bulk density comparisons were conducted at the University of Nebraska Agricultural Research Development Center at Mead, NE, on a silty clay loam soil. The research site was an oat stubble field on which three tillage treatments and three different soil water contents were established.

The three tillage treatments consisted of a non-tilled oat stubble, disked oat stubble and a plowed oat stubble. Depths of disking and plowing were 90 mm and 270 mm, respectively.

Three soil water conditions were established; dry, medium and wet. The dry plots were maintained by covering the area with 6-mil black plastic after tillage. The medium plots were left uncovered. Wet plots were established by adding, with a specially designed manifold, 33 mm of water depth to the soil after the tillage operations and then covering with plastic.

Tractors used to compact the soil were a crawler equipped with a rubber belted track and a standard full size four-wheel drive agricultural tractor. These tractors were similar in power and weight, Table 1. Differences in area trafficked by the two tractors is a function of the physical characteristics of the two tractors. The rubber belt track will traffic about 67% of the area that the 4-wheel drive will traffic because of the narrower total width of the track compared to the wheel.

Traffic patterns were established that would provide soil sampling to compare bulk density after one and two passes with the non-trafficked soil. The tractors were driven at a speed of 4.8 km/h and zero drawbar load over the designated areas. Plastic covering the plots was left in place during tracking.

Surface Bulk Density

Bulk density at the soil surface was evaluated on three blocks of the experimental plot. Samples were obtained from approximately the 0 to 15 mm and 15 to 30 mm depths by the compliant cavity method used by Bradford and Grossman (1982) which is similar to the sand refill method for determining bulk density (Blake, 1965). The sampling equipment consisted of a circular plexiglass plate with a 131 mm diameter opening in the center held in place on the soil surface by three threaded steel rods driven into the soil. The plate was leveled and maintained in that position by adjusting wingnuts that held the plate. A foam rubber ring between the plate and soil compressed and conformed to the irregular soil surface.

A piece of 0.002 mm plastic film (Saran wrap) placed in the center cavity of the plexiglass plate was molded against the soil surface and foam rubber sides. The cavity was filled with water from a preweighed container up to a reference level. Water not used to fill the hole was kept in the container and reweighed. The difference between the initial and final weights was the volume space above the undisturbed soil surface and the reference level.

Plastic film and water were then removed from the cavity. Soil was excavated from the cavity to a depth of 15 mm and placed in a soil can for detemination of dry soil weight. This cavity was lined with plastic wrap and filled with water from a second preweighed container to the reference level. Water remaining in the second container was reweighed. The difference in weight loss between the first and second containers was the volume of soil excavated. Bulk density was calculated by dividing the dry weight of soil by the volume difference.

Following the removal of the plastic wrap and water a second soil sample was excavated from the 15 to 30 mm depth. Procedures for determining dry soil weight and soil volume for this depth was the same as for the 0 to 15 mm depth.

Deep Bulk Density

Bulk density was sampled to a depth of 300 mm in 75 mm increments using a hand held sampler, (Doran and Mielke, 1984). The sampler consisted of a 348 mm long, 28.7 mm diameter metal tube with an acetate (cellulose acetate butyrate) cylinder 315 mm long by 25.4 mm diameter (23.8 mm i.d.) inserted inside. The 22.4 mm i.d. cutting tip provided 1.4 mm relief which reduced friction between the soil and acetate liner during sampling.

The acetate cylinders were cut to lengths corresponding to the desired sampling depth intervals (75 mm). The sampler tube was pushed into the soil with slow even pressure to avoid starts and stops that might fracture the soil core. A check for compaction was made before removing the sampler from the soil, by removing the handle and inspecting the relative height of soil inside the sampler as compared to surface level. Liners filled with soil were removed from the sampler tube and inspected for quality of sample. Soil was trimmed flush with the top and bottom ends of the 300 mm core. Each sampling interval was separated by slicing between the acetate cylinders with a spatula or thin-bladed knife. Sample volume was used to calculate bulk density based on tip diameter and length of acetate cylinders. Three samples were taken from each experimental unit and used to calculate dry bulk density. For some tillage-water combinations, compaction was a problem for the tube sampler. For those problem situations, a volume soil sample was obtained using a 50 mm diameter by 25 mm length cylinder at a depth representative of that increment.

Experimental Design

Soil water and tillage treatments were replicated four times in a split-split block design. Soil water contents were randomized within tillage treatments which were

TABLE 2. SOIL WATER CONTENTS OF THE TILLAGE TREATMENTS AT THE TIME OF TRAFFICKING, % OF DRY BASIS

Water conditions	No Till	Disk	Plow
Dry	21.0	19.5	15.5
Medium	25.0	24.0	22.0
Wet	26.5	24.0	29.0

stripped across the experiemental area. Trafficking was stripped perpendicular to the water-tillage experimental units. Results were analyzed for the split-split block design using analysis of variance.

RESULTS AND DISCUSSION

The soil water contents of the plots were determined prior to the density sampling but after the trafficking. The results are illustrated in Table 2.

Bulk Density Before and After Traffic

The resulting bulk densities, within each treatment, after one and two traffic passes were not significantly different from each other. This would imply that most compaction occurs during the first traffic pass and that subsequent traffic passes would increase bulk density very little. Therefore, data from the one and two passes were combined for all comparison purposes in the following discussion.

The bulk density difference between non-traffic and traffic areas were significant at all tillage and water treatments except for the no-till and disk treatment at the deeper depths. This suggests that bulk density changes from trafficking on some tillage treatments may be limited to the top 150 mm. However, for the plow tillage treatment, highly significant changes in bulk density due to trafficking occurred at all measured depths.

Bulk density differences were significantly different between non-traffic and the rubber belt track at all but the deepest depth. However, the bulk density differences between the non-traffic and tire were significant at all depths. There were no significant differences in bulk density between the rubber belt track and tire, when averaged over all tillage and water treatments, except at the two deeper depth ranges, 150 to 225 mm and 225 to 300 mm. This would again imply that compaction occurring from the tire goes deeper than from the rubber belt track.

Surface Bulk Density

A comparison of bulk density for traffic and non-traffic plots with the rubber belt track and tire averaged over all tillage and water contents is illustrated in Fig. 1. Differences in bulk density between the rubber belt track and tire were significant for the 0 to 15 mm depth at the 0.05 level, with the traffic from the tire causing higher surface densities. For each soil water content averaged over all tillage treatment, comparison of surface bulk density between the rubber belt track and tire were non-significant at the 0.10 level. A comparison of bulk densities for each tillage treatment averaged over all water contents was non-significant at the 0.05 level except for the plowed tillage treatment where the tire caused a higher bulk density than the rubber belt track. However, in all comparisons, the trend in surface bulk density from the rubber belt track was numerically less than from the tire. The increase in bulk density due to trafficking was approximately 14% and 18% respectively, for the 0 to 15 mm and 15 to 30 mm depths.

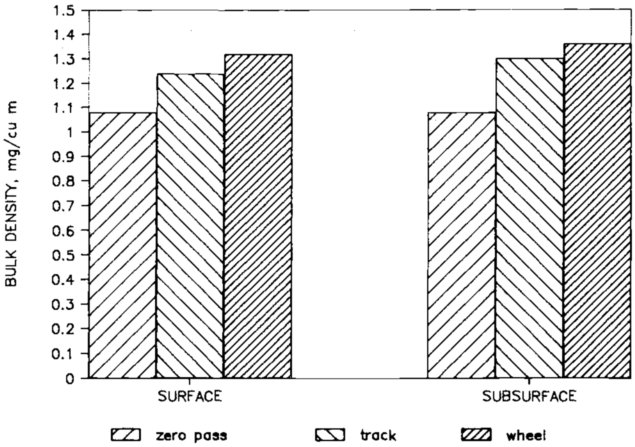

Fig. 1—Bulk density averaged over all tillage and water contents for the surface (0 to 15 mm) and subsurface (15 to 30 mm). Differences in bulk density between the rubber belt track and tire were significant for the surface at the 0.05 level.

Deep Bulk Density

The bulk densities for each depth range averaged over all water contents and tillage operations are illustrated in Fig. 2. The largest bulk density difference between non-traffic and traffic areas occurs in the first 0 to 75 mm of depth where bulk density increased 11% due to trafficking. This difference in bulk density then decreased as depth increased. Differences in bulk density between the rubber belt track and tire were significant at the 0.10 level for the 150 to 225 mm and 225 to 300 mm depths. The significant differences at the 0.10 level in bulk density between the rubber belt track and tire at the two deep depths indicate that compaction from the tire is transmitted deeper than from the rubber belt track.

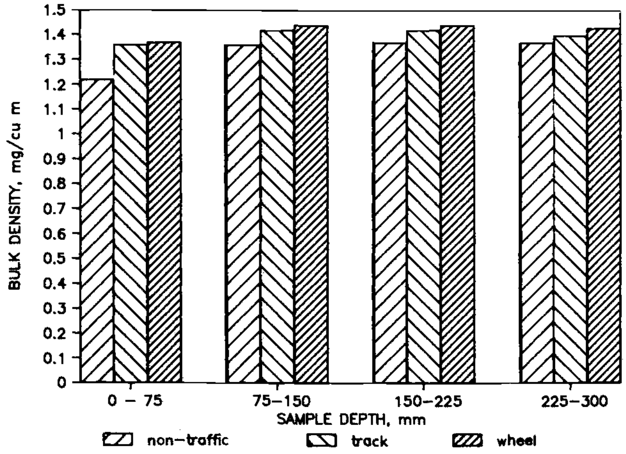

Fig. 2—Bulk density averaged over all tillage treatments and water contents for the different depth ranges. Differences in bulk density between the rubber belt track and tire were significant at the 0.10 level for the 150 to 225 mm and 225 to 300 mm depths.

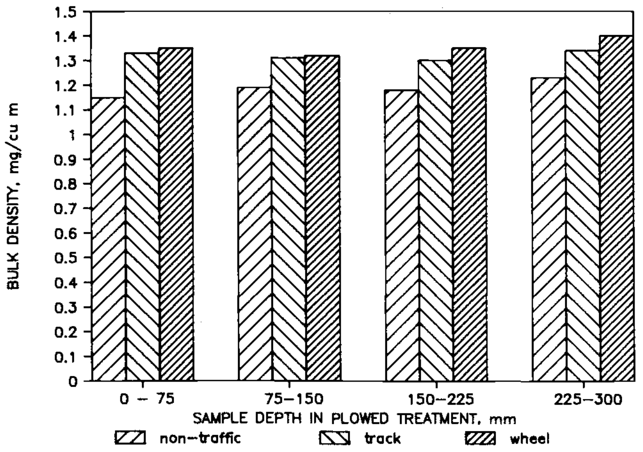

Fig. 3—Bulk density for the plow tillage treatment averaged over all water contents. Differences in bulk density between the rubber belt track and tire were significant at the 0.10 level only for the 225 to 300 mm depth.

The comparisons of bulk density before and after the rubber belt track and tire traffic for each depth range averaged over all water contents for the plow tillage treatment are illustrated in Fig. 3. Increases in bulk density due to trafficking were approximately 17 to 20% at all depths. Differences in bulk density resulting from trafficking with the rubber belt track and tire were significant at the 0.10 level only at the deepest depth. This result again indicates that compaction from the tire is transmitted deeper than from the rubber belt track.

Other comparisons in bulk density were made for each depth averaged over all tillage and water contents, and for each water content averaged over all depths and tillage treatments. In each of these comparisons, all differences in bulk density between the rubber belt track and tire were non-significant at the 0.10 level. However, in all instances the tire resulted in a higher bulk density than the rubber belt track.

It is certainly recognized that the experimental plots were trafficked with the tractors under no drawbar load. The results of a similar study with trafficking occurring with the tractors under a drawbar load would be most appropriate as a next step.

SUMMARY

Soil bulk densities resulting from trafficking with a rubber belt track tractor and a four wheel drive tractor were measured. The measurements were taken on three tillage treatments at three soil water contents. Bulk densities were measured after zero, one and two passes with each tractor. The bulk densities did not change significantly after the first pass. Therefore, most compaction occurs with the first pass of a tractor.

Most of the comparative differences in bulk density resulting from trafficking with the two tractors were non-significant at the 0.10 level. However, for the plow treatment at the deeper depth, 225 to 300 mm, traffic from the tire caused significantly higher bulk densities than traffic from the rubber belt track. This suggests that the tire causes compaction at a deeper depth than the rubber belt track. Certainly, deeper compaction requires greater effort to eliminate than surface compaction. In all comparisons the resulting bulk density from the rubber belt track was of a smaller magnitude than from the tire.

References

1. Blake, G. R. 1965. Methods of soil analysis. Part 1, Agronomy 9:374-390.
2. Bradford, J. M. and R. B. Grossman. 1982. In-situ measurement of near surface soil strength by the fall-cone device. Soil Sci. Soc. Amer. J. 46:685-688.
3. Brixius, W. W. and F. M. Zoz. 1976. Tires and tracks in agriculture. Transactions of the Society of Automotive Engineers 85(3):2034-2044.
4. Burger, J. A., J. V. Perumpral, R. E. Kreh, J. L. Torbet and S. Minaci. 1983. The effect of track and rubber-tired vehicles on soil compaction. ASAE Paper No. 83-1621, ASAE, St. Joseph, MI 49085.
5. Doran, J. W. and L. N. Mielke. 1984. A rapid, low-cost method for determination of soil bulk density. Soil Sci. Soc. Am. J. 48:717-719.
6. Erbach, D. C., S. W. Melvin, R. M. Cruse and D. C. Jnzen. 1986. Effects of tractor tracks during secondary tillage. ASAE Paper No. 86-1533, ASAE, St. Joseph, MI 49085.
7. Taylor, J. H. and E. C. Burt. 1975. Track and tire performance in agricultural soils. TRANSACTIONS of the ASAE 18(1):3-6.