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Traction Characteristics of Prepared Traffic Lanes

Eddie C. Burt
USDA Agricultural Research Service

James H. Taylor
USDA Agricultural Research Service

Larry G. Wells
University of Kentucky, larry.wells@uky.edu

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E. C. Burt, J. H. Taylor, L. G. Wells
MEMBER ASAE SENIOR MEMBER ASAE MEMBER ASAE

ABSTRACT

TRACTION characteristics of lugged and smooth tires were compared on prepared traffic lanes and on conventional seedbed conditions. Results indicated that elevated traffic lanes offer important traction advantages over seedbeds in wet soil conditions. In dry soil conditions, traction on elevated traffic lanes was sometimes less than on the seedbed conditions. A timeliness advantage in mobility for the elevated traffic lanes was found to be up to 2 days in extremely wet conditions. A non-elevated traffic lane showed no traction advantage in wet conditions.

INTRODUCTION

The potential advantages of the controlled traffic concept have been widely discussed. When "rootbed" and "roadbed" zones are distinctly separated, the desirable characteristics of each zone can be maintained. With this system of crop production, the detrimental effects of soil compaction on production can be minimized.

The agronomic advantages of the uncompacted rootbed in the controlled traffic concept are not the only benefits. Prepared compacted traffic lanes offer potential for improved flotation, traction, and timeliness. The potential for traffic-related benefits has not been fully explored.

PRIOR RESEARCH

Various approaches to the controlled traffic concept have been investigated by many researchers (Taylor, 1983). Advantages of controlled traffic frequently cited include increases in crop yields of 20 to 50%, reduced requirements for deep tillage, reduced power and fuel requirements for crop production, and increased soil water holding capacity. However, references to the traffic-related benefits of controlled traffic are few. Several researchers have explored the controlled traffic concept using traffic lanes made from reinforced concrete (Kisu, 1971; Kisu, 1976; Kereselidze et al., 1974). These authors reported significant improvement in the operation of tea harvesting equipment on the concrete treadways.

Pollard and Elliott (1978) used a concrete treadway technique to evaluate the effects of soil compaction on barley production. They emphasized the increase in barley yield which resulted from the absence of soil compaction, but did not discuss traction or timeliness advantages.

Taylor (1982) discussed the potential improvement in traction resulting from operation of pneumatic tires on compacted soil. He mentioned the lack of research results which directly address the traction, flotation, and timeliness of operations on controlled traffic lanes. Therefore, the objectives of the research reported in this paper were to:

1. Determine the net traction and tractive efficiency of pneumatic tires operating on elevated and non-elevated traffic lanes and on a simulated seedbed condition for selected soil types and soil moisture conditions.
2. Determine the time delay following a flooded soil condition for adequate mobility on elevated and non-elevated traffic lanes and on the simulated seedbed.

PROCEDURES

This research was conducted in the soil bins at the National Soil Dynamics Laboratory. Soils used for the elevated traffic lane tests were Decatur silt loam, Davidson clay, and Hiwassee sandy loam (Batchelor, 1968). The Decatur silt loam soil was subsequently prepared with a non-elevated traffic lane. Soils were prepared using soil bin preparation equipment to simulate a traffic lane and seedbed condition. The prepared seedbed condition had approximately 25 cm of soil over a plowpan, simulating a field that had been plowed and subsequently disked. Traffic lanes were built by placing soil on the lane area, leveling the surface, and then compacting the soil in approximately 8-cm layers. The final compacted elevated traffic lane was approximately 15 cm higher in elevation than the surrounding seedbed. Final surface elevation for the non-elevated traffic lane was the same as for the surrounding seedbed.

All tests for this study were conducted using a single wheel agricultural tire test machine. This machine operates a test tire under computer control and has provisions for measuring the variables needed to evaluate the tire performance (Burt et al., 1980; Lyne et al., 1983).

Tires used for this study were a commercially available 18.4-38 bias-ply tire with R-1 tread supplied by Firestone Tire and Rubber, and a 18.4-38 smooth tire modified and furnished by Caterpillar Tractor Co.* The smooth

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The authors are: EDDIE C. BURT, Agricultural Engineer, and JAMES H. TAYLOR, Research Leader and National Technical Advisor, Traction and Controlled Traffic, National Soil Dynamics Laboratory, USDA-ARS, Auburn, AL; and LARRY G. WELLS, Associate Professor, Agricultural Engineering Dept., University of Kentucky, Lexington, KY.

*Use of a company name does not imply USDA or University of Kentucky approval or recommendation of the product or company to the exclusion of others which may also be suitable.

tire had been buffed smooth and recapped to original lug dimensions with solid tread rubber (no lugs). Each tire was operated at an inflation pressure of 110 kPa and at a dynamic load of 23.3 kN.

The rolling radius needed for travel reduction calculations for each tire was determined at zero net traction on a rigid surface. Inflation pressure and dynamic load were controlled at the desired levels during the radius tests.

All tests on soil were run as continuously varying travel reduction tests. The travel reduction was initially set at approximately negative 5% and was then slowly and continuously increased through zero to approximately 40%. Dynamic load and inflation pressure were held constant during each test. Variables needed to determine net traction and tractive efficiency were recorded throughout each test run. The same test procedure was followed for both the traffic lane and the seedbed areas.

Tire performance was evaluated on each test soil condition at three different soil moisture conditions. A saturated condition was developed by adding water for several hours from overhead until the soil bin was flooded. In bins prepared with elevated traffic lanes, the traffic lane extended 5 cm above the surface water level. For this condition, the elevated traffic lane was also saturated up to about 5 cm below the surface. Traction performance tests were conducted at this moisture condition to simulate field conditions immediately following a heavy rainfall.

The second and third moisture conditions resulted from a delayed time period for drainage and drying following the flooded condition. The time delay period was adjusted for the different soils based on the drainage and drying rate. Soil moisture content at each test condition is given in Table 1. Approximately one-third of each soil bin was tested at each moisture condition.

Accumulation of mud on the surface of the tires operated in wet soil conditions causes wide variations in tire performance. These variations presented difficult problems in the analysis of data. Therefore, the curves presented in this paper were drawn to best represent the overall trends in performance.

RESULTS

Decatur Silt Loam—Elevated Lane

Fig. 1(a) shows net traction vs. travel reduction for the lugged tire run on Decatur silt loam on the elevated traffic lane and on the seedbed areas. This test was run

TABLE 1. SOIL MOISTURE CONTENT FOR EACH NONFLOODED TEST CONDITION

Soil type	Time after flooded condition	Moisture content at surface, %*	
		Traffic lane	Seedbed
Decatur silt loam—	3 hours	16.7	19.1
Elevated lane	2 days	16.2	15.4
Davidson clay	1 day	18.5	20.5
Elevated lane	2 days	17.1	13.5
Hiwassee sandy loam	2 days	17.1	19.1
Elevated lane	6 days	4.0	8.0
Decatur silt loam—	2 days	20.8	21.3
Non-elevated lane	5 days	10.9	9.9

*Dry weight basis

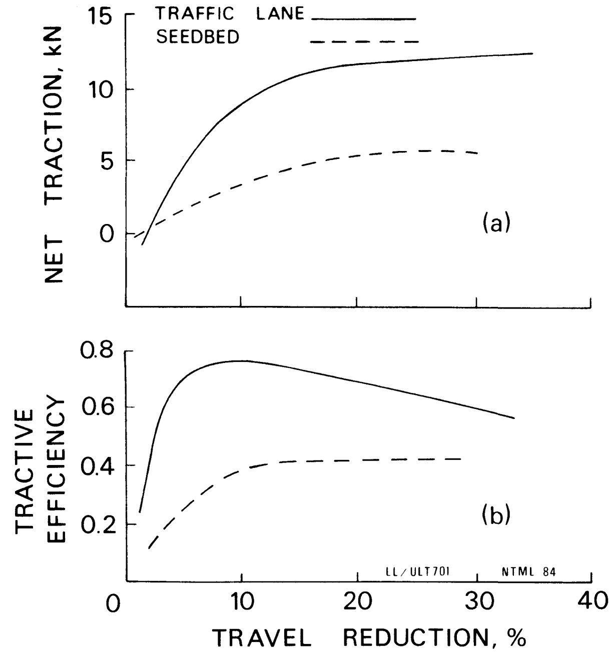

Fig. 1—Net traction and tractive efficiency vs. travel reduction for the lugged tire operating on an elevated traffic lane on saturated Decatur silt loam. Dynamic load was 23.3 kN. (NTML Photo No. P10,369a)

approximately 3 h following the flooded seedbed condition. At this condition, the seedbed area was saturated but was not completely covered in water. The results show a consistent improvement in net traction on the elevated traffic lane as compared to the seedbed condition, especially at the higher travel reduction levels. This same trend is evident in tractive efficiency, Fig. 1(b).

Fig. 2, (a) and (b), shows net traction and tractive efficiency vs. travel reduction for tests run on Decatur silt

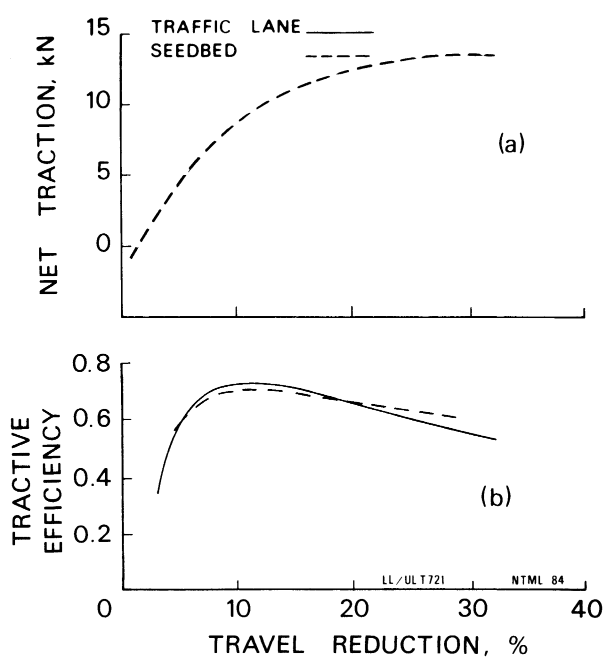

Fig. 2—Net traction and tractive efficiency vs. travel reduction for the lugged tire operating on an elevated traffic lane on Decatur silt loam 2 days after flooding. Dynamic load was 23.3 kN. (NTML Photo No. P10,369b)

loam with the lugged tire on a dry soil condition. These tests were run approximately 48 h following the flooded seedbed condition. It is evident from Fig. 2 that there was no significant difference in lugged tire performance between the elevated traffic lane and the seedbed areas for this soil condition. The advantage of the elevated traffic lane perhaps disappeared due to moisture content differences between the traffic lane and the seedbed. After 2 days of drainage and drying, the traffic lane appeared to be too dry at the surface for maximum traction, i.e., the lugs of the tire could not penetrate the dry surface soil to reach moist soil of higher strength. Two days of drainage and drying in the seedbed produced a moist soil that permitted good lug penetration.

An estimate of the timeliness advantage of elevated traffic lanes can be obtained by comparing net traction from the traffic lane at the wet soil condition and from the seedbed area at the dry soil condition. At common travel reduction values of 10% or greater, the net traction from the wet elevated traffic lane is close to the net traction from the dry seedbed area. This comparison indicated that, on the wet soil condition, mobility on elevated traffic lanes can be obtained with a vehicle approximately 2 days earlier following a heavy rainfall, as compared to mobility on the seedbed. The tractive efficiency from the wet elevated traffic lane was slightly higher than from the dry seedbed throughout the travel reduction range of 10 to 30%.

Fig. 3, (a) and (b), presents net traction and tractive efficiency vs. travel reduction results from the smooth tire operating on the wet Decatur silt loam. These results show that the smooth tire was able to generate up to 11 kN net traction on the elevated traffic lane, but was immobilized in the seedbed zone at travel reduction levels below 25%. The tractive efficiency on the elevated traffic lane was reasonably high, but was extremely low in the seedbed zone.

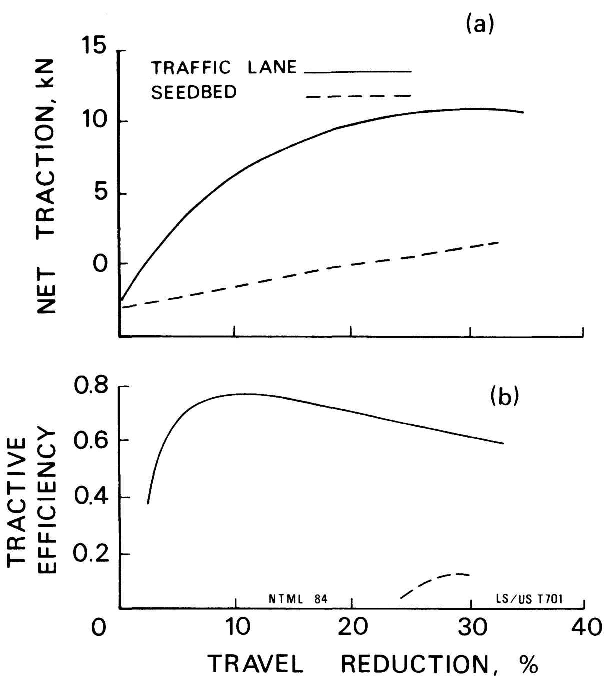

Fig. 3—Net traction and tractive efficiency vs. travel reduction for the smooth tire operating on an elevated traffic lane on saturated Decatur silt loam. Dynamic load was 23.3 kN. (NTML Photo No. P10,369c)

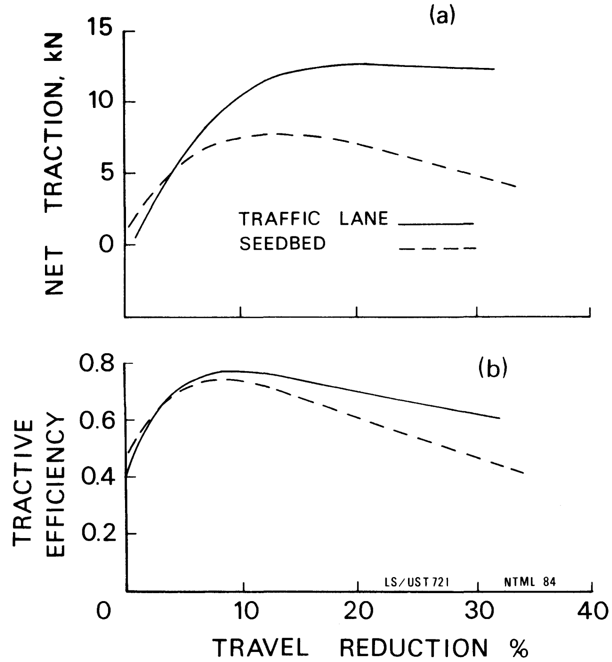

Fig. 4—Net traction and tractive efficiency vs. travel reduction for the smooth tire operating on an elevated traffic lane on Decatur silt loam 2 days after flooding. Dynamic load was 23.3 kN. (NTML Photo No. P10,369d)

The elevated traffic lane offered a significant traction advantage for the smooth tire even in the dry soil condition. Fig. 4, (a) and (b), shows traction results from the Decatur silt loam soil at the dry soil condition (2 days after flooding). Both net traction and tractive efficiency for the smooth tire were consistently higher for the elevated traffic lane as compared to the seedbed zone throughout the travel reduction range of 10 to 30%. A comparison of Figs. 3 and 4 indicate that for a smooth tire the timeliness advantage for the traffic lane is greater than 2 days.

Davidson Clay—Elevated Lane

Results from tests on Davidson clay were considerably less consistent than from the Decatur silt loam. At 20% travel reduction at the flooded condition, the lugged tire operating on the elevated traffic lane (Fig. 5, (a) and (b)) offered a 25% increase in net traction and an increase in tractive efficiency of 0.26, as compared to the seedbed zone. However, after either 1 day (Fig. 6, (a) and (b)) or 2 days (Fig. 7 (a) and (b)) drainage and drying, the seedbed zone offered 20 to 25% higher net traction than did the elevated traffic lane for the lugged tire. This reversal could have resulted from the surface soil condition in the elevated traffic lane being too dry to permit adequate lug penetration for maximum traction. A comparison of tire performance on this soil condition from the elevated traffic lane and from the seedbed zone (Figs. 6(a) and 7(a)) shows no timeliness advantage for the lugged tire operating on the traffic lane.

The smooth tire, when operating on the flooded condition, was immobilized in the seedbed and barely mobile on the elevated traffic lane. However, the elevated traffic lane offered an important traction advantage for the smooth tire after 1 and 2 days drying time. When the smooth tire was operating at 20% travel reduction on the elevated traffic lane 1 day after the flooded condition, net

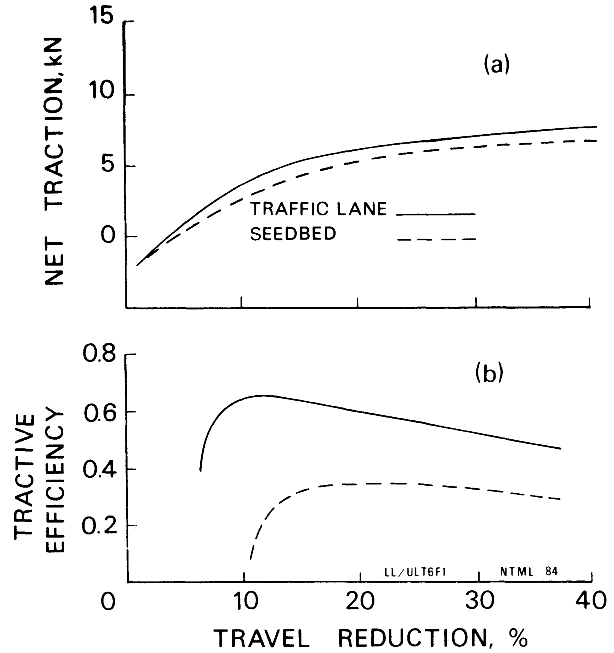

Fig. 5—Net traction and tractive efficiency vs. travel reduction for the lugged tire operating on an elevated traffic lane on saturated Davidson clay. Dynamic load was 23.3 kN. (NTML Photo No. P10,369e)

traction was 55% greater for the traffic lane than for the seedbed zone. After a 2-day drying period, the net traction advantage for the elevated traffic lane was 17%. Tractive efficiency advantage for the elevated traffic lane as 0.07 to 0.1. Timeliness advantage for the smooth tire operating on the elevated traffic lane was slightly greater than 1 day.

Hiwassee Sandy Loam—Elevated Lane

At the flooded seedbed condition in the Hiwassee sandy loam, the elevated traffic lane offered no

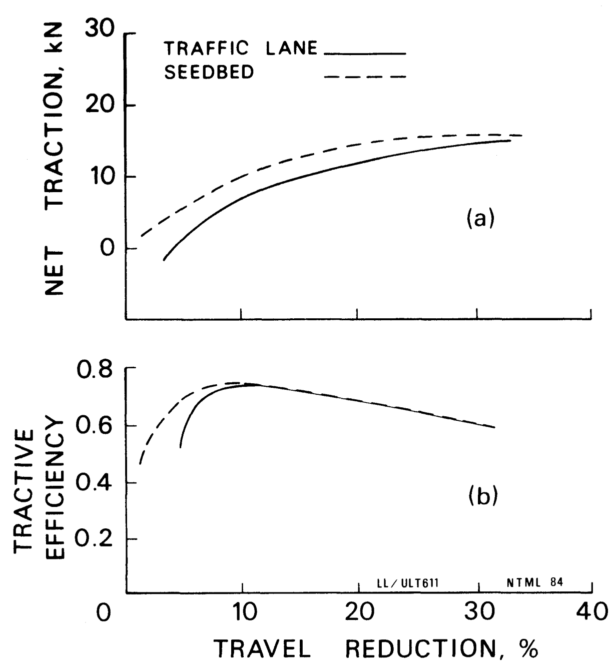

Fig. 6—Net traction and tractive efficiency vs. travel reduction for the lugged tire operating on an elevated traffic lane on Davidson clay 1 day after flooding. Dynamic load was 23.3 kN. (NTML Photo No. P10,369f)

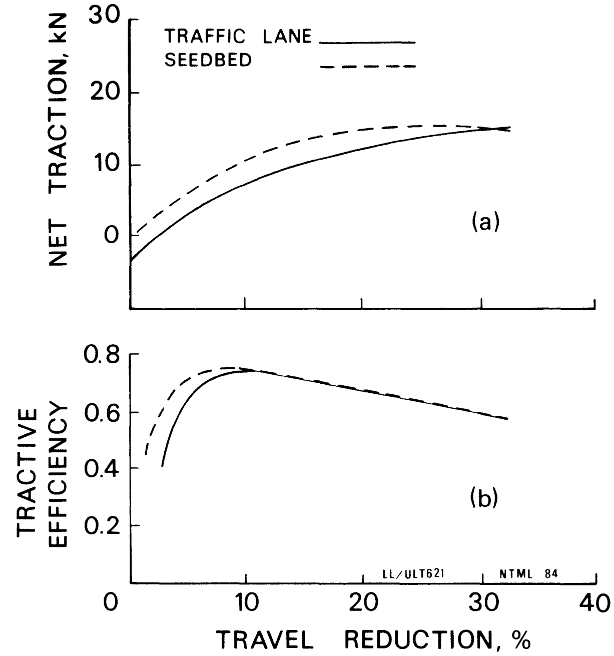

Fig. 7—Net traction and tractive efficiency vs. travel reduction for the lugged tire operating on an elevated traffic lane on Davidson clay 2 days after flooding. Dynamic load was 23.3 kN. (NTML Photo No. P10,369g)

important traction advantage. However, Fig. 8(a) shows that after 2 days drying time the lugged tire operating on the elevated traffic lane provided slightly higher net traction at low values of travel reduction than did the same tire operating on the seedbed zone. Fig. 8(b) shows an important tractive efficiency advantage for the elevated traffic lane. At this moisture condition, there was significant sinkage and rutting, especially in the seedbed zone.

Fig. 9, (a) and (b), shows the net traction and tractive efficiency comparison after 6 days of drying time. This figure shows an important net traction and tractive efficiency advantage for the elevated traffic lane. In this poorly drained soil, at least 6 days drying time is required in the seedbed zone before soil strength is sufficient for operation of a traction device without significant sinkage and rutting.

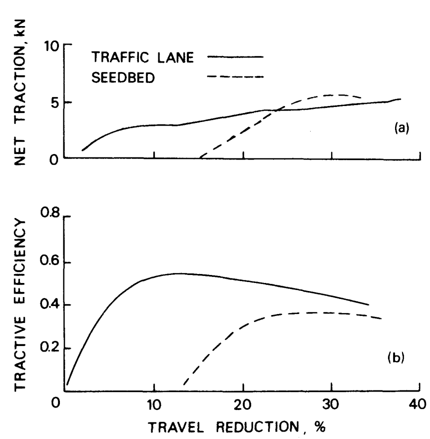

Fig. 8—Net traction and tractive efficiency vs. travel reduction for the lugged tire operating on an elevated traffic lane on Hiwassee sandy loam 2 days after flooding. Dynamic load was 23.3 kN. (NTML Photo No. P10,386a)

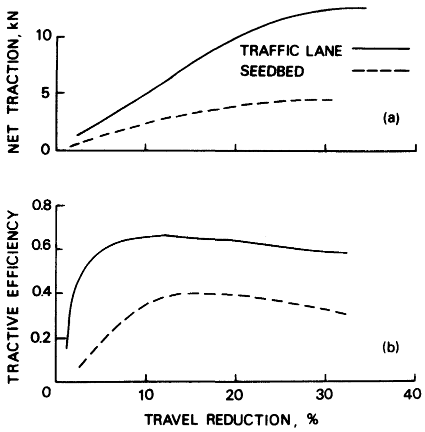

Fig. 9—Net traction and tractive efficiency vs. travel reduction for the lugged tire operating on an elevated traffic lane on Hiwassee sandy loam 6 days after flooding. Dynamic load was 23.3 kN. (NTML Photo No. P10,386b)

A comparison of Figs. 8(a) and 9(a) shows that net traction in the seedbed zone did not greatly improve during the drying period between 2 and 6 days. However, net traction at 30% travel reduction for the elevated traffic lane improved approximately 250% during this same period. The timeliness advantage when developing low net traction at a reasonably high tractive efficiency on the elevated lane is up to 4 days.

Decatur Silt Loam—Non-elevated Lane

Fig. 10, (a) and (b), presents net traction and tractive efficiency results from tests conducted with the lugged tire operating on a non-elevated traffic lane on saturated Decatur silt loam. During these tests, the entire soil bin, including the non-elevated traffic lane, was covered with water. Even though sinkage on the non-elevated traffic lane was much less than on the seedbed condition, there was no important difference in either net traction or tractive efficiency. At the 20 to 30% travel reduction range, net traction as well as tractive efficiency for the seedbed zone was slightly higher than for the non-elevated traffic lane. Results from tests on the non-elevated traffic lane after 2 days drying time showed no important differences in tractive performance between the traffic lane and the seedbed zone.

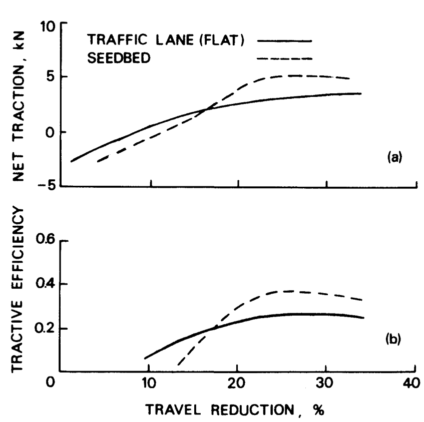

Fig. 10—Net traction and tractive efficiency vs. travel reduction for the lugged tire operating on a non-elevated traffic lane on saturated Decatur silt loam. (NTML Photo No. P10,386c)

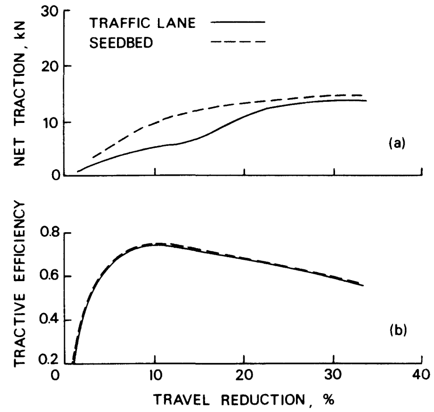

Fig. 11. Net traction and tractive efficiency vs. travel reduction for the lugged tire operating on a non-elevated traffic lane on Decatur silt loam 5 days after flooding. Dynamic load was 23.3 kN. (NTML Photo No. P10,386d)

Fig. 11, (a) and (b), presents net traction and tractive efficiency results from the non-elevated traffic lane and the seedbed after 5 days drying time. These results show that the seedbed zone provided slightly higher net traction than did the non-elevated traffic lane. Tractive efficiency was the same for the two conditions. At this condition the compacted traffic lane was fairly dry with a thin crust, while the seedbed zone contained a higher moisture content. The inability of tire lugs to penetrate the traffic lane to reach soil of greater strength perhaps could explain the higher developed net traction on the seedbed zone.

The smooth tire, operating on this soil at the flooded condition, was immobilized on the non-elevated traffic lane as well as on the seedbed zone. After 2 days drying time, the smooth tire operating on the non-elevated traffic lane offered slightly higher net traction as well as tractive efficiency than did the seedbed zone. However, after 5 days drying time, the seedbed zone offered slightly higher net traction than did the non-elevated traffic lane. Tractive efficiency was the same on the lane and on the seedbed zone after 5 days drying time for the smooth tire.

The results from this one soil condition indicates that a non-elevated traffic lane may offer little advantage for traction. The non-elevated traffic lane did have less rutting than did the seedbed zone, which could be an advantage from the point of view of soil preparation for subsequent crops.

CONCLUSIONS

Based on the results of this study on a limited range of soils and soil conditions, the following conclusions can be drawn.

1. In extremely wet soil conditions, elevated traffic lanes offer an important advantage in traction and mobility, as compared to "normal" seedbed condition. The lugged tire offered adequate mobility in all conditions tested, even when the seedbed areas were flooded.

2. On dry soil conditions, traction advantages of an elevated traffic lane can disappear. In some cases, the compacted traffic lane was dry at the surface and prevented penetration of lugs into the soil, therefore reducing traction performance.

3. Except in extremely wet soil conditions, a smooth

(continued on page 401)

Traction in Traffic Lanes

(continued from page 397)

tire (no aggressive lugs) offers reasonably good traction and high efficiency on elevated traffic lanes.

4. The timeliness advantage of traffic lanes is dependent on the soil type and conditions. Results from this study indicate that, following a flooded condition, elevated traffic lanes provide mobility up to 1 to 4 days earlier than a flat seedbed.

5. A non-elevated traffic lane appears to offer little traction advantage.

6. Additional research is needed to determine traction and mobility effects on more soil types and conditions and on traffic lanes of different configurations.

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