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FIELD PERFORMANCE OF TRELLEBORG AND SIMILAR SIZE RADIAL TIRES

By

Reed J. Turner
Project Engineer
Alberta Farm Machinery Research Centre
Lethbridge, Alberta, Canada

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Summary:

The field performance of a set of Trelleborg dual 750/65-38 tires was compared to three sets of similar capacity radial tires. Comparisons were done at various ballasted weights and inflation pressures in both wet and dry conditions in primary and secondary tillage. The Trelleborgs showed lower performance than radials in power delivery efficiency, drawbar power delivered and pull. They showed equivalent flotation and ground pressure to radials, had no power hop problems and were subjectively judged to produce a more comfortable ride. Durability of the tires was not addressed.

Keywords:

Machinery Management, Measurement, Performance, Power Delivery Efficiency, Power Hop, Power Transmission, Rubber, Slip, Tires, Traction, Tractive Efficiency, Tractors

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ASAE, 2950 Niles Rd., St. Joseph, MI 49085-9649 USA
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INTRODUCTION

During the 1998 field test season, the Alberta Farm Machinery Research Centre (AFMRC) in Lethbridge, Alberta, compared the performance of a set of Trelleborg tires to several similar capacity radial tires. Two identical 360 hp (270 kW) tractors were used for the comparisons. One tractor was equipped with dual 750/65-38 Trelleborg tires and the other was switched between dual 710/70 R38 radials and dual and triple 20.8 R42 radials. Comparisons were made in several different soils in both early spring conditions (wet) and late summer conditions (dry) in primary and secondary tillage. Three ballast weight setups, at least two tire pressure setups, three gears and a full range of drawbar loads were evaluated. All tests were repeated twice. The resulting data and observations were used to compare power delivery efficiency; traction and pull parameters; load and torque capacity; power hop control; flotation; ground pressure; ride quality and cost. The durability of the various tires was not addressed in the tests.

LITERATURE REVIEW

Previous researchers have reported laboratory and field comparisons between radial and bias ply tires and the relationship between soil compaction and tire inflation pressure.

Bohnert and Kenady (1) compared the tractive efficiency of conventional bias ply and radial tires in several different soil conditions. They reported tractive efficiencies some 7% higher and pulls some 14 to 18% higher for radial tires. They discussed torque buckling or wrinkling in the sidewalls of bias tires and presented an analysis of why it occurred in bias and not in radial tires.

Mueller and Treanor (2) reported a 5 to 13% increase in drawbar power and a 20 to 30% reduction in wheel slip in a comparison of similar size radials to bias tires. They also reported maintaining the same power and slip between radial and bias while reducing the ballasted weight on the radial by 15%.

Munson et al. (3) reported on the effect of tire inflation pressure on soil compaction. They concluded tire inflation pressure had a large influence on soil compaction, reduced tire inflation pressure produced less soil compaction and draft load also contributed to soil compaction.

Little published information was found comparing the performance of the bias belted Trelleborg design to either conventional bias or radial tires. While Trelleborg advertising literature mentioned comparisons between 20.8 R42 tires and Trelleborg Twin 850/55-42 tires done at IMAG-DLO in Holland, the literature did not give percentage increase numbers or any background information. Representatives at IMAG-DLO confirmed that confidential tests had been run for Trelleborg in 1992, which have not been published.

A Firestone Farm Tires advertising brochure (4) presented Firestone test results comparing dual 710/70 R38 tires to dual Trelleborg Twin 750/65-38 tires in tests on primary and secondary tillage. Their graphs show 19% more drawbar pull and about 2% more tractive efficiency in primary tillage and 14% more drawbar pull and about 4% more tractive efficiency in secondary tillage for radials over Trelleborgs.

SCOPE OF THE TESTS

The AFMRC tests were designed to evaluate the performance of Trelleborgs in a typical Western Canadian farm traction system. Tests were run in moderate clay loam soils typical of southern Alberta in two general field conditions. The first was a soft wet condition typical of early spring work where traction and flotation were limits, and the second was a hard dry condition typical of late summer and early autumn work where power hop and ground penetration were limits. Where possible, two soil tillage treatments were tested in each of these conditions; primary or first time tillage after cropping, and secondary or retillage after initial tillage. In each condition, tests were run across a range of settings covering the typical usage spectrum of the tires.

Two New Holland 82 Series Versatile tractors, Model 9682, were used for the evaluation. These articulated four-wheel-drive tractors were equipped with Cummins N14 inline 6 cylinder 360 hp (269 kW) engines and 12 speed power shift transmissions. AFMRC instrumentation was installed on the tractors and used to measure performance values as follows:

Engine Torque was measured by a torquemeter and slip ring set installed in the driveline behind the engine and in front of the transmission.

Engine Speed was measured by a magnetic pickup on the driveline from the engine to the transmission.

Ground Speed was measured by a radar gun mounted at the front of the tractor.

Axle Speed was measured by a magnetic pickup on the output shaft from the rear of the transmission to the rear drive axle.

Drawbar Pull was measured by a horizontal load cell mounted between the tractor drawbar and implement.

Inlet Fuel Temperature was measured by a thermocouple in the fuel line between the filter and the fuel pump.

Ambient Temperature was measured by a thermistor positioned in front of the front tractor grille.

Vertical Acceleration was measured by a single axis accelerometer positioned vertically over the rear axle centerline.

Additional tractor performance parameters, including Engine Power, Drawbar Power, Power Delivery Efficiency as defined by Turner (5), Percent Wheel Slip and Pull-to-Weight Ratio were computed from the measured values.

A floating hitch chisel plow was used as a load unit for all tests. The pull was assumed to act horizontally from the tractor drawbar and was measured with a horizontal load cell. This pull was then used to represent net traction, NT, while the total vehicle weight was used to represent dynamic load. With this simplification, the pull-to-weight ratio became the same as net, dynamic and vehicle traction ratio and is referred to as vehicle traction ratio, VTR, throughout the results. Since this same setup and assumption was used for all tests, any inaccuracies in the assumption would be equivalent for all the tire sets and should not affect comparisons.

Test comparisons followed the standard AFMRC field test procedure, Turner (6), and determined the entire range of performance for a given tractor setup. A given tractor and tire combination was set to a specific tire, ballast and tire inflation combination and the instrumentation was calibrated. The tractor was operated in the field using a chisel plow as a variable load and tested in at least three different gears. One was a gear low enough to allow overloading the traction system to produce excessive slip (40 to 50%). A second gear was in the normal operating range. A third was a gear high enough to overload the engine at low (5 to 10%) slip levels. In each of these gears, the test was started with the implement out of the ground. Draft was then increased from zero to the maximum in a series of small increments. Once the tractor reached equilibrium at a given draft, a 10 to 30 second data snapshot was recorded, representing some 100 to 300 individual readings on each data channel. Once a maximum for a gear was reached, whether slip or engine load, additional data was taken around the 10% slip level and around engine rated speed, when either or both points could be reached. All data points were saved to disk. In processing following the test, each snapshot of data was averaged to form a single point on the overall performance curve.

TEST VARIABLES AND ANALYSIS PROCEDURES

Because of the difficulty in providing constant soil and weather conditions over the entire test period, the test was blocked as three separate tire comparison sets. Tire Set 1 was composed of 20.8 R42 Triples and the Trelleborg Duals, Tire Set 2 was 710/70 R38 Duals and Trelleborg Duals, and Tire Set 3 was the 20.8 R42 Duals and Trelleborg Duals. Within each tire comparison set, both sets of tires were run in the same soils and under as similar as possible weather and ground conditions. Between tire comparison sets the soils and weather conditions varied.

There were six independent variables controlled and adjusted during the tests. Five were discrete or categorical: soil condition (6 levels but not each of them in all tire comparison sets), tire type (4 levels, two for each tire comparison set and one of them the same in all sets), tire pressure (2 or 3 levels in all tire comparison sets), tractor weight (3 levels in all tire comparison sets) and tractor gear (3 levels in all tire comparison sets). One variable, horizontal load or pull was continuous in all tire comparison sets. The total number of test combinations that could have been run for a single tire comparison set was 6x3x3x3x2 or 324 runs. While not all these runs were made within a tire comparison set, each run made was replicated and the same runs were made on each set of tires within a given tire comparison set.

The setting or adjustment levels for the six independent variables were as follows:

1. Soil condition

The wet secondary tillage condition (Sec0) was a clay loam that had been harvested and tilled the previous fall. While it had little standing stubble, it was 70% covered with tall green weeds. It had been tilled again in the spring and was extremely wet. The soil averaged 18 to 20% moisture (dry base) throughout the first 10 inches (250 mm) during all tests.

The first dry primary tillage (Pri1) was a clay loam that had produced a crop of barley silage. It had been tilled in the spring prior to planting and had not been tilled after harvest. Moisture during the tests was 6% at surface and 12% at 8 to 10 inches (200 to 250 mm).

The first dry secondary tillage (Sec1) was the dry primary tillage condition (Pri1) tilled to a uniform depth at least twice. Moisture during the tests was 4% at surface and 11% at 8 to 10 inches (200 to 250 mm).

The second dry primary tillage (Pri2) was an irrigated clay loam that produced alfalfa and barley silage. The ground had been in alfalfa for several years and had been direct-seeded to barley in the spring of 1998. The barley and alfalfa had been harvested together as silage. The soil was extremely packed and compacted. Moisture during the tests was 5% at surface and 13% at 8 to 10 inches (200 to 250 mm).

The second dry secondary tillage (Sec2) was an irrigated clay loam that had produced a crop of barley silage. The ground had been direct-seeded to barley in the spring of 1998. The soil was packed and compacted but had been tilled once just before the tests. This tillage broke the ground into large hard clods and left a very rough surface. Moisture during the tests was 5% at surface and 13% at 8 to 10 inches (200 to 250 mm).

The last primary tillage (Pri1w) was an irrigated clay loam that had produced a crop of barley silage. It was tilled in the spring of 1998 prior to planting and not tilled after harvest. It had been irrigated about two weeks before the tests and then allowed to dry again. Moisture during the tests was about 7% at surface and 18% at 8 to 10 inches (200 to 250 mm).

Surface and subsoil moisture samples were taken in each of the test sites. Surface moisture was determined as the dry basis average of the top 2 inches (50 mm), or the tilled area of soil. Subsoil moisture was sampled at the 4 to 6 inch (100 to 150 mm) depth and the 8 to 10 inch (200 to 250 mm) depth. Table 1 lists the various soils and their moisture levels.

Table 1. Soil Moisture (Dry Base).

Soil Type	Depths			Average
	0-2 inch	4-6 inch	8-10 inch	
Sec0	20%	21%	20%	20%
Pri1	6%	11%	12%	10%
Sec1	4%	10%	11%	8%
Pri2	5%	11%	13%	10%
Sec2	5%	13%	14%	11%
Pri1w	7%	15%	18%	13%

2. Tire type

The four sets of tires used in the tests were as follows:

Trelleborg "Twin" 414 Tubeless 750/65-38 Duals
Firestone Radial All Traction 23° R1 Tubeless 20.8 R42 Triples
Goodyear DT820 Radial R1W Tubeless 710/70 R38 Duals
Firestone Radial All Traction 23° R1 Tubeless 20.8 R42 Duals

The Trelleborg tires remained on the first tractor for all tests. The second tractor was switched between the other three tire sets. Because of this switching, not all tire sets were run in all soil conditions but the Trelleborg tractor was used as a base machine to enable comparisons with all tire sets. Table 2 shows the tire combinations that were run in each soil condition.

Table 2. Tire and Soil Combinations.

Soil Type	Tire Sets Tested			
Sec0	Trelleborg Duals	20.8 Triples	710 Duals	--
Pri1	Trelleborg Duals	--	710 Duals	--
Sec1	Trelleborg Duals	20.8 Triples	710 Duals	20.8 Duals
Pri2	Trelleborg Duals	20.8 Triples	--	20.8 Duals
Sec2	Trelleborg Duals	20.8 Triples	--	20.8 Duals
Pri1w	Trelleborg Duals	20.8 Triples	--	20.8 Duals

3. Tire Pressure

Tests were run using at least two and sometimes three tire inflation pressure settings. The first setting was the "100%" setting and was the manufacturer's recommended inflation pressure for the ballasted weight of the tractor. The second was the "200%" setting and was double the recommended inflation pressure. Tractors that hopped or wrinkled were tested at a third setting, the "As Required" setting, which was the smallest inflation pressure increase necessary to control either hop or wrinkle.

4. Tractor Weight

All tires were tested with the tractors set at three different ballasted weights, representing low, medium and high ballast. At each weight a 55/45% front/rear weight split was maintained. In all cases, tractor ballast included 3500 lbs (1590 kg) (350 imperial gallons) of water equally distributed in the rear tires. Additional ballast was added as cast weights, located as required to maintain the correct weight distribution. Low ballast was as close as possible to 98 lbs/engine hp (60 kg/engine kW), a total weight of 35,200 lbs (16,000 kg). With 20.8 R42 triples, it was not possible to maintain the 55/45 weight split at that low a total weight so the low weight for those tires was actually 100 lbs/engine hp (61 kg/engine kW) or 36,000 lbs (16,360 kg). Medium ballast was 110 lbs/engine hp (67 kg/engine kW), a total weight of 39,600 lbs (18,000 kg). High ballast was 122 lbs/engine hp (74 kg/engine kW), a total weight of 44,000 lbs (20,000 kg).

5. Tractor Speed

All tractor setups were tested in three different gears, 3rd, 5th and 7th. Third gear was nominally 4 mph (6.4 km/h) and was on the low side of the working range, allowing tests at high slip and low engine load. Fifth gear was 6 mph (9.6 km/h), in the middle of the working range, and allowed tests at correct engine load and slip. Seventh gear was 8 mph (12.8 km/h), on the high side of the working range, and allowed tests at low slip and high engine load.

6. Pull

Pull or horizontal load was a continuous variable and was adjusted from none to maximum during a test series. Pull was provided by a 45 ft (14.6 m) floating hitch chisel plow. Cultivation depth was adjusted to vary pull. With the floating hitch, draft angle was assumed to be zero and pull was measured using a horizontal load cell.

After runs were completed, performance curves were plotted and values for four dependent variables (Maximum Drawbar Power, Maximum Power Delivery Efficiency, Drawbar Power at Maximum Power Delivery Efficiency and Pull-to-Weight Ratio (VTR) at Maximum Power Delivery Efficiency) were extracted. These values were then grouped into three separate test blocks by Tire Comparison set. Each block was analyzed using the ANOVA and General Linear Model procedures of Systat to determine significant effects and interactions. The Bonferroni Pairwise Mean Comparison procedure was used to determine significance or confidence levels that are reported for differences in means. Overall averages of radial and Trelleborg values were also computed and are reported.

RESULTS AND DISCUSSION

• **Traction Performance Parameters** (measures of the effectiveness of power transfer to the ground)

For the traction performance parameters, comparisons are based on the averages of all gear and weight runs in all soil conditions. Any significant effects within the comparison resulting from changes in weight, gear or soil are also discussed. Comparison values are at 99.9% confidence level or above unless otherwise noted.

1. **Maximum Drawbar Power** (maximum power produced at the tractor drawbar)

   Radial tires produced higher Maximum Drawbar Power than the Trelleborg tires. The Average Maximum Drawbar Powers over all soil conditions, gears and ballast weights are shown in Figure 1. At correct inflation pressures, the 20.8 R42 triple radial tires delivered 14.4 hp (10.7 kW) or 6.6% more power than the Trelleborg tires. The 710/70 R38 duals delivered 8.9 hp (6.6 kW) or 4.33% more and the 20.8 R42 dual radials delivered 117.6 hp (13.1 kW) or 8.2% more. At double the correct inflation pressures, the 20.8 R42 triple radials delivered 16.5 hp (12.3 kW) or 7.9% more power than the Trelleborgs, the 710/70 R38 duals delivered 3.6 hp (2.7 kW) or 1.8% more (at 70% confidence level), and the 20.8 R42 dual radials delivered 7.2 hp (5.4 kW) or 3.4% more (at 98% confidence level).

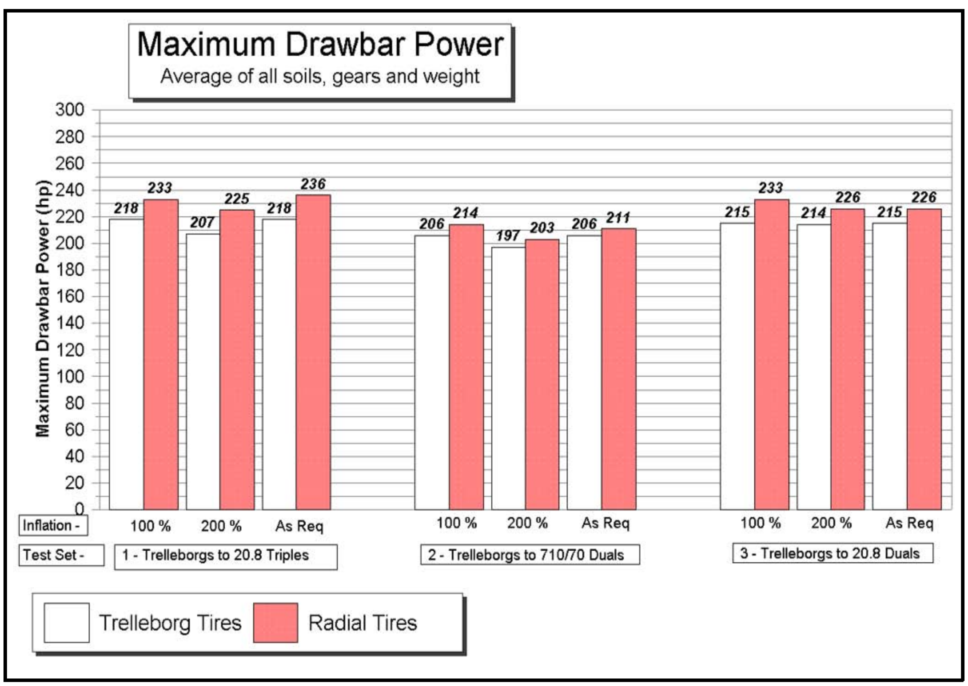

Figure 1. Maximum Average Drawbar Powers

For all tires, Maximum Drawbar Power increased as tractor transmission gear increased. Increasing the gear increased speed and reduced pull and slip at a given power level. This power increase was larger for the Trelleborgs than for radials, possibly because they started at a lower level than the radials. In effect, the increase in Maximum Drawbar Power of radials compared to Trelleborgs decreased as tractor gear increased. As shown in Figure 2, for the comparison of 20.8 R42 triples to the Trelleborgs, in 3rd gear, nominally 4 mph (6.4 kph), the radials showed an average increase over the Trelleborgs of 21.2 hp (15.8 kW) or 12.2%. In 5th gear, nominally 6 mph (9.6 kph), the increase was 17.7 hp (13.2 kW) or 8.0%; and in 7th gear, nominally 8 mph (12.8 kph), the increase was only 5.4 hp (4.0 kW) or 2.2% (at 83% significance level).

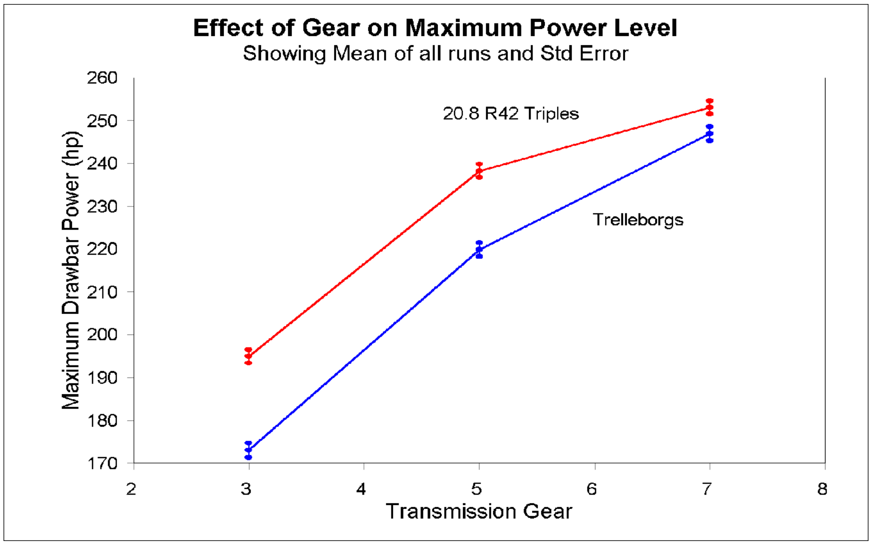

Figure 2. Effect of Transmission Gear on Maximum Drawbar Power

For all tires Maximum Drawbar Power increased as tractor weight increased. Increasing weight reduced the slip at a given pull and power level. This effect was also larger for the Trelleborgs than for radials. In effect, the increase in Maximum Drawbar Power of radials compared to Trelleborgs decreased as tractor weight increased. As shown in Figure 3, for the comparison of 20.8 R42 triples to the Trelleborgs, at 98 lbs/engine hp (60 kg/engine kW) radials showed an average increase of 20.2 hp (15.1 kW) or 10.1%. At 110 lbs/engine hp (67 kg/engine kW) the average increase was 13.5 hp (10.1 kW) or 6.3% and at 122 lbs/engine hp (74 kg/kW), the average increase was 10.7 hp (8.0 kW) or 4.7%. In general, the Trelleborg-equipped tractor performed like a 5000 lb (2272 kg) lighter radial-equipped tractor.

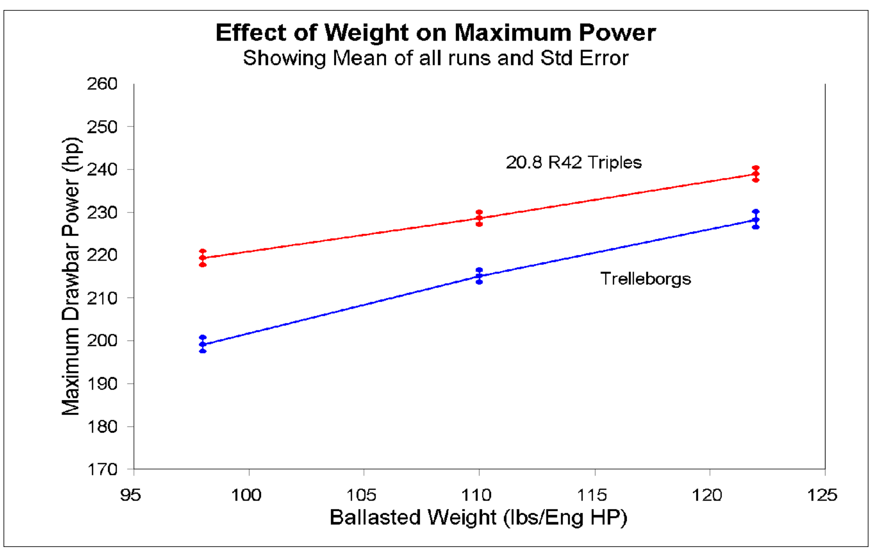

Figure 3. Effect of Ballast Weight on Maximum Drawbar Power

For all tires Maximum Drawbar Power decreased as tire inflation pressure increased above the manufacturers recommended level. The magnitude of this effect was similar for radials and the Trelleborgs. For the comparison of 20.8 R42 triples to the Trelleborgs, at 100% inflation pressure the radials showed an average increase over the Trelleborgs of 14.4 hp (10.7 kW) or 6.6%. At 200% inflation pressure, the average increase was 16.5 hp (12.3 kW) or 7.9%.

One tire factor not well examined that may have affected performance was tire lug height. The Goodyear 710/70 R38 tires were R1W tires while the Firestone 20.8 R42 tires were standard R1 tires. R1W tires have lugs some 25% deeper than standard R1 tires. The Trelleborg duals effectively had an R1W lug design. In previous work done at AFRMC, additional lug height had a slight negative effect on performance. Accounting for this variable might have slightly increased performance of the Trelleborgs relative to 20.8R42 tires and may also explain the lower performance of 710/70 R38 tires compared to 20.8 R42 tires.

2. Power Delivery Efficiency (ratio of power developed at the tractor drawbar to power developed by the engine)

Radial tires showed equal to higher Power Delivery Efficiency than the Trelleborg tires at the maximum efficiency point and any point beyond. Average Maximum Power Delivery Efficiencies over all soil conditions, gears and ballast weights are shown in Figure 4. At correct inflation pressures, 20.8 R42 triple radials were 2.1 percentage points or 3% more efficient than the Trelleborgs. The 710/70 R38 duals were not significantly different than the Trelleborgs and the 20.8 R42 dual radials were 2.9 percentage points (4.2%) more. At double the correct inflation pressure, 20.8 R42 triple radials were 2.3 percentage points (3.4%) more efficient than the Trelleborgs, and 710/70 R38 and 20.8 R42 dual radials were not significantly different.

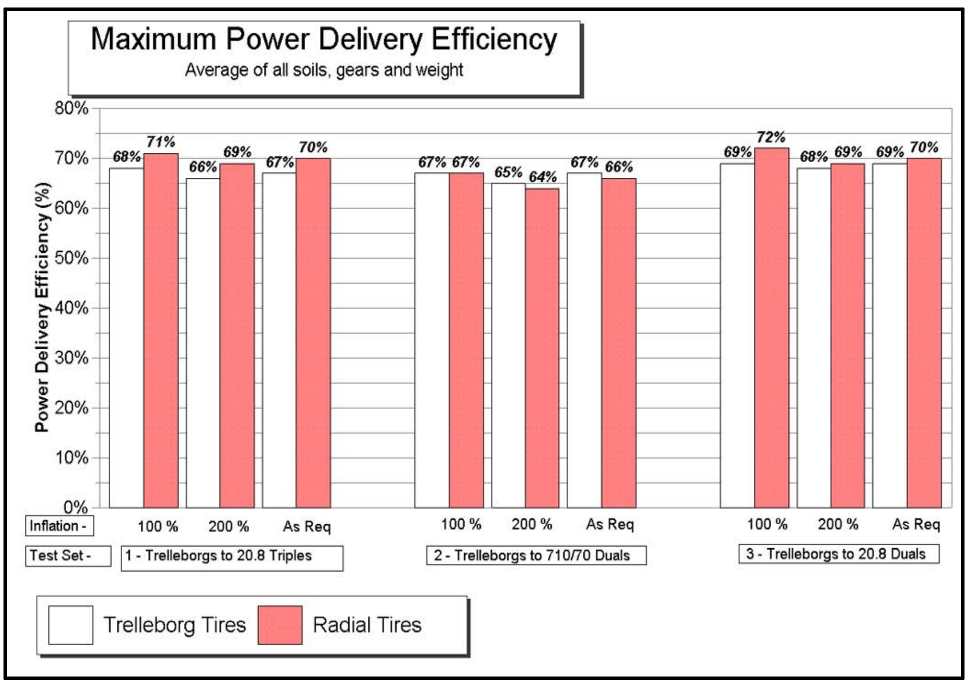

Figure 4. Average Maximum Power Delivery Efficiencies

For all tires, Power Delivery Efficiency increased as tractor speed increased. There was no significant difference in this effect between the different tires.

For all tires, Power Delivery Efficiency increased slightly as tractor weight increased. There was no significant difference in this effect between the different tires.

For all tires, maximum power delivery efficiencies increased as soil moisture decreased and soil firmness increased. There was no significant difference in this effect between tire sets. Maximum efficiencies ranged from a low of 58% in wet secondary tillage conditions to a high of 80% in dry primary tillage conditions.

Power Delivery Efficiency reached a maximum at a lower VTR for the Trelleborgs than for radial tires and decreased more rapidly than it did for radials as pull increased. Figure 5 is a plot of Power Delivery Efficiency vs. VTR for 20.8 R42 triples and 750/65-38 Trelleborgs. The graph shows the typical early peak in efficiency for the Trelleborgs followed by a more rapid decrease at higher pulls.

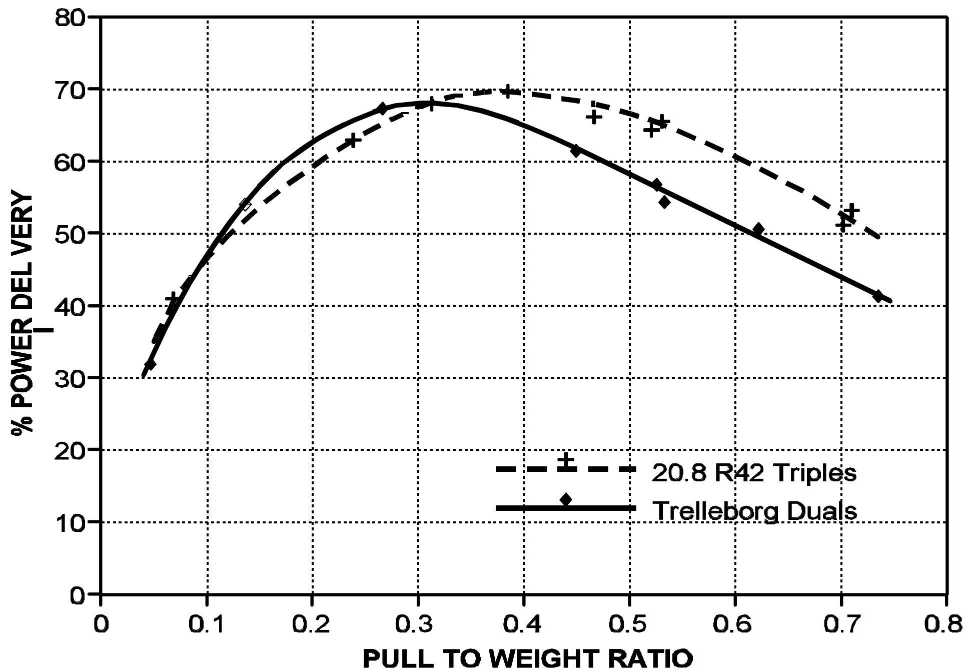

Figure 5. Power Delivery Efficiency

When the Trelleborg-equipped tractor was operated near its most efficient power delivery point, it was at lower drawbar horsepower and VTR than would be normally expected for a typical tractor. Since wheel tractors are commonly operated around .35 to .45 VTR, a Trelleborg-equipped tractor would often be operating beyond and below its maximum efficiency point.

3. Drawbar Power at Maximum Efficiency (drawbar power at the point of maximum power delivery efficiency)

Drawbar Power at Maximum Efficiency was higher for radial tires than for the Trelleborg tires. Average Drawbar Powers at Maximum Efficiency over all soil conditions, gears and ballast weights are shown in Figure 6. At correct inflation pressures, 20.8 R42 triple radials were 20.9 hp (15.6 kW) or 10.6% higher power at maximum efficiency than the Trelleborgs. The 710/70 R38 duals were 19.7 hp (14.7 kW) or 10.7% higher and the 20.8 R42 dual radials were 22.3 hp (16.7 kW) or 11.5% higher. Increasing inflation pressures changed the values but not the effect. At double the correct inflation pressures, 20.8 R42 triples were 24.9 hp (18.5 kW) or 13.3% higher, 710/70 R38 duals were 8.1 hp (6.0 kW) or 4.5% more and 20.8 R42 dual radials were 8.9 hp (7.4 kW) or 4.7% higher.

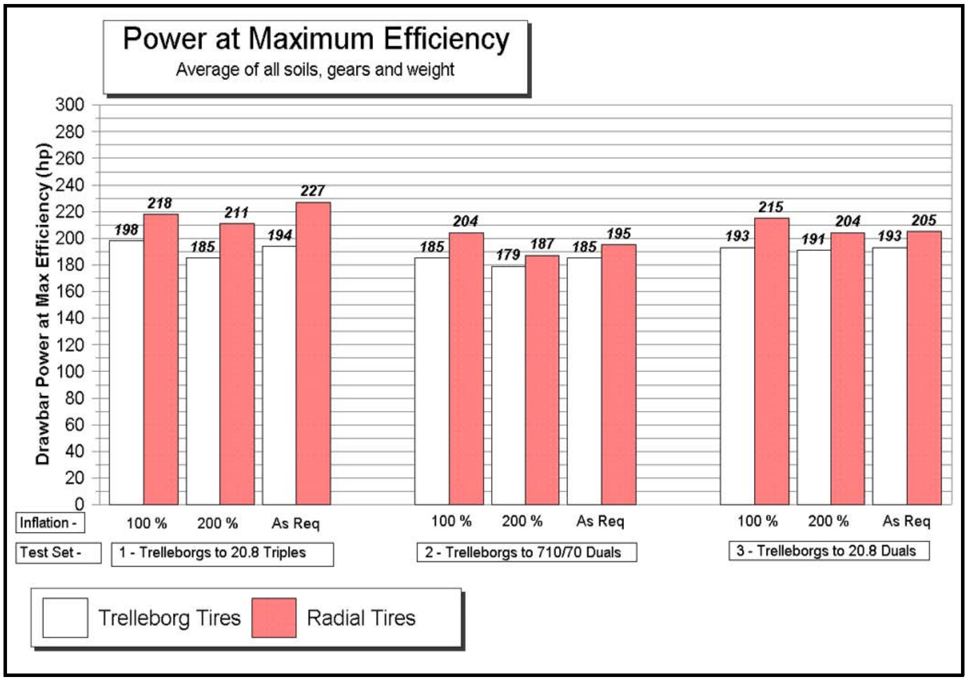

Figure 6. Power Levels at Maximum Efficiency

The same secondary conclusions are true for Drawbar Power at Maximum Efficiency as were true for Maximum Drawbar Power. For all tires, Drawbar Power at Maximum Efficiency increased as tractor speed and weight increased, and decreased as pressure increased. Again for increases with speed and weight, results from Trelleborgs were slightly more responsive to the variable than results from radials.

4. VTR at Maximum Efficiency (ratio of pull divided by tractor weight at the point of maximum power delivery efficiency)

Radial tires had a higher VTR at Maximum Efficiency than the Trelleborg tires. Average VTR's at Maximum Efficiency over all soil conditions, gears and ballast weights are shown in Figure 7. At correct inflation pressures, all three sets of radials had VTR's that were 6 percentage points or 17% higher at maximum efficiency than the Trelleborgs. At double the correct inflation pressure, 20.8 R42 triple radials were still 6 percentage points or 17% higher than the Trelleborgs while 710/70 R38 and 20.8 R42 dual radials were each 3 percentage points or 9% higher.

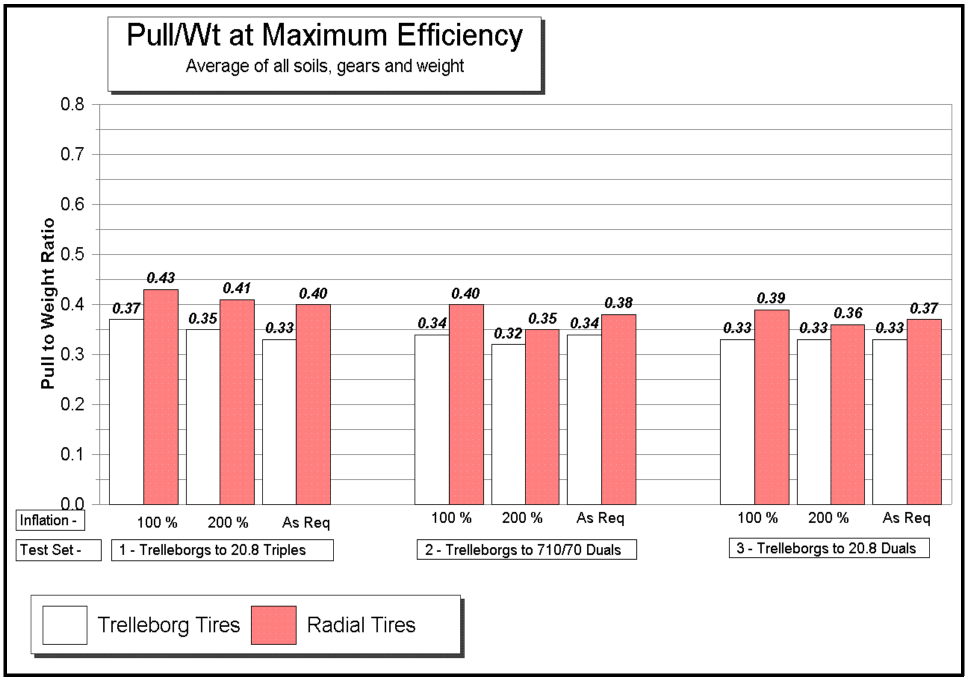

Figure 7. VTR at Maximum Efficiency

VTR at Maximum Efficiency did not vary significantly with speed or weight but did decrease as tire inflation pressure increased. There was no significant difference in these effects between the various tires.

5. **Drawbar Pull** (horizontal force developed at the drawbar)

For equal ballasted weights and equal tire slip, radials developed greater pulling force than the Trelleborgs. This meant that a radial-equipped tractor could pull more for the same ballasted weight or could weigh less for the same pull and thus produce less ground pressure. Figure 8 shows a plot of Drawbar Pull vs. Percent Slip for 20.8 R42 triples and 750/65-38 Trelleborgs. At 10% slip, the Trelleborg tractor pulled 13,000 lbs (58 kN) while the radial tractor pulled 16,500 lbs (73.6 kN), an increase of 27%. Looking at the data another way, at a pull of 16,500 lbs (73.6 kN) the radial tractor operated at 10% slip while the Trelleborg tractor operated at 18% slip.

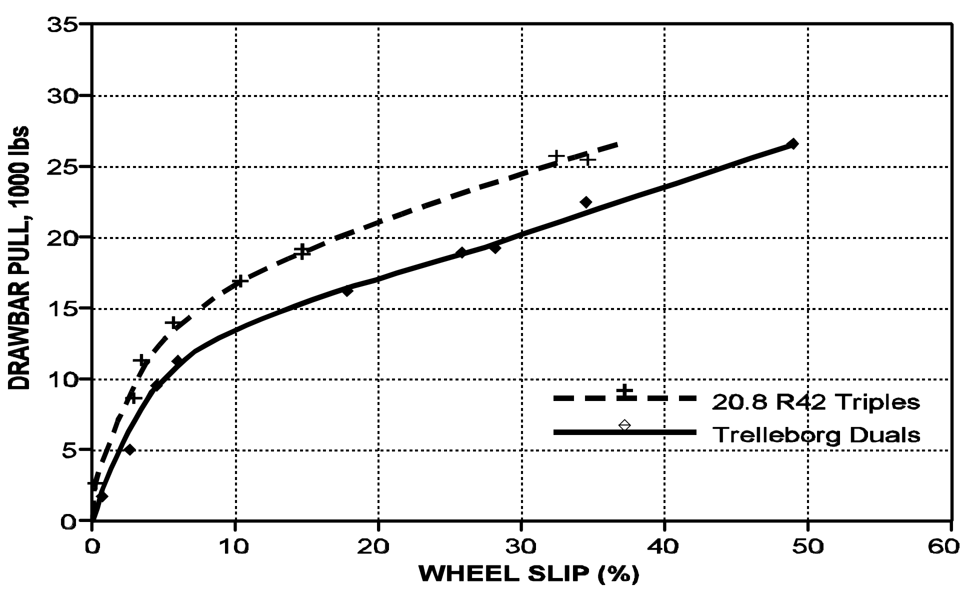

Figure 8. Drawbar Pull

• **Weight and Torque Capacities** (ability to carry weight and transmit torque)

The Trelleborg tires could not transmit as much torque as radials at the same settings without experiencing sidewall wrinkling. In dry soils, the Trelleborgs exhibited significant sidewall wrinkling at normal operating weights and correct inflation pressures, as shown in Figure 9. Raising inflation pressure reduced this wrinkling. The wrinkling was typically more significant on the rear tires than on front ones. While sidewall wrinkling could not be seen by the operator in the tractor, it was obvious to someone viewing the tractor from the side. In wetter soil conditions where torque loads were lower, wrinkling was not a problem for the Trelleborgs at the ballasted weights tested. Wrinkling was never a problem for radials. Table 3 shows ballasted weights and pulls where sidewall wrinkling became a problem and inflation pressures required to control it.

Figure 9. Trelleborg Sidewall Wrinkling under Load

Table 3. Trelleborg Tire Wrinkling Points - Dry Secondary Tillage (Sec1).

	Imperial Units			**Metric Units**		
	Light	**Medium**	**Heavy**	**Light**	**Medium**	**Heavy**
Ballasted weight	98 lbs/hp	110 lbs/hp	122 lbs/hp	60 kg/kW	67 kg/kW	74 kg/kW
Correct inflation pressure	7 psi	7 psi	9 psi	48 kPa	48 kPA	62 kPa
Pull where wrinkling became noticeable (VTR)	did not	14-16,000 lbs (.35-.40)	10-12,000 lbs (.23-.27)	did not	60-70 kN (.35-.40)	45-55 kN (.23-.27)
Pull where wrinkling became severe (VTR)	did not	18-20,000 lbs (.45-.50)	16-18,000 lbs (.36-.41)	did not	80-90 (.45-.50)	70-80 kN (.36-.41)
Pressure required to control wrinkling	7 psi	11 psi	14 psi	48 kPa	76 kPa	97 kPa

• **Power Hop** (resonant fore/aft bouncing or porpoising of a tractor under load)

The Trelleborg tires did not power hop at optimum settings. All the radial tire sets showed some tendency to power hop at optimum settings, in both wet and dry conditions. In particular, the 20.8 R42 duals exhibited severe hop in dry secondary tillage conditions. The Trelleborg tires could not be made to hop in wet soil. While they could be made to hop in dry secondary tillage, hop was difficult to start and occurred only in conditions and at settings beyond reasonable operation.

Tractor total weight affected the amount and severity of power hop. As tractor weight increased, there was less tendency for hop to occur and when it did, it was less severe and easier to control.

It was always possible to control power hop in radial-equipped tractors by raising pressure in the rear tires. Control usually required an increase of less than 50% above correct inflation pressure.

• **Ground Pressures (average pressure ex**erted on soil surface)

The Trelleborgs produced similar ground pressures to 20.8 R42 triples and 710/70 R38 duals. This was true both at manufacturers rated inflation pressures and at inflation pressures required for wrinkle-free and hop-free operation. These pressure similarities suggest there was no advantage in the reduction of soil compaction for Trelleborgs over large radials. The 20.8 R42 duals developed higher ground pressures and were at a soil compaction disadvantage.

This conclusion uses the assumption that average ground pressure under a tire is proportional to tire inflation pressure. While there are other measures of soil compaction and little consensus about what is best to use, ground pressure is one straightforward measurement related to compaction. Table 4, Section 1 shows the manufacturers correct tire inflation pressures required for each of the tractor ballasted weights. Section 2 shows tire inflation pressures that were actually required to ensure proper function, either to control power hop or sidewall wrinkling.

Table 4. Tire Inflation Pressures (Approximate Ground Pressures) in psi (kPa).

Tire	Ballasted Weight/Engine Power								
	Light - 98 lbs (60 kg)			Medium - 110 lbs (67 kg)			Heavy - 122 lbs (74 kg)		
	Front	Rear	Rank	Front	Rear	Rank	Front	Rear	Rank
Section 1	**Manufacturer Recommended**								
Trelleborg Duals	7(48)	7(48)	1	9(62)	9(62)	2	9(62)	9(62)	1*
20.8 R42 Triples	7(48)	6(42)	1	8(51)	6(42)	1*	10(69)	7(48)	2
710/70 R38 Duals	6(42)	6(42)	1*	8(51)	6(42)	1*	10(69)	7(48)	2
20.8 R42 Duals	11(76)	8(51)	2	14(97)	10(69)	3	17(117	12(83)	3
Section 2	**As Set for Best Operation**								
Trelleborg Duals (wrinkle control)	7(48)	7(48)	1	9(62)	11(76)	1*	9(62)	14(97)	2
20.8 R42 Triples (hop controlled)	7(48)	6(42)	1	8(51)	12(83)	1	10(69)	7(48)	1*
710/70 R38 (hop controlled)	6(42)	6(42)	1*	8(51)	12(83)	1	10(69)	14(97)	2
20.8 R42 Duals (hop controlled)	11(76)	16(110)	2	14(97)	20(138)	2	17(117)	24(165)	3

*Lowest pressure setups

• **Flotation** (ability to keep a vehicle on the surface and moving on wet ground)

The Trelleborg tires showed the same flotation as equivalent-sized radials. Flotation rankings were determined subjectively and were based on the ability of tractors to recover after being bogged down by a draft overload.

In wet soil, the 20.8 R42 triples showed higher flotation than 710/70 R38 duals or the 750/65-38 Trelleborgs. The 710/70 R38 duals and the 750/65-38 Trelleborgs were equivalent in flotation. The 20.8 R42 duals were not tested in wet soil but would be expected to show lower flotation than Trelleborg 750/65-38's.

In dry soils, there was no noticeable difference in flotation among any of the tires.

• **Ride Quality** (motion the operator experienced in the cab)

The ride produced by the Trelleborgs was subjectively judged to be better than the radials. Frequency and magnitude of vertical acceleration over the rear axle was measured during the tests. This data showed no differences between various tires as long as power hop was controlled. Even so, operators tended to prefer the ride in the Trelleborg-equipped tractor. Although it was not measured, there appeared to be less side-to-side motion in the cab of the Trelleborg tractor. This was possibly because of stiffer tire sidewalls and may have been the effect preferred.

• **Costs** (price for the tires)

The Trelleborgs cost more than similar radials. Table 5 shows price quotes obtained for various tire sets from dealers in the Lethbridge, Alberta area (November, 1998). All quotes are for tires only, delivered to Lethbridge, unmounted and excluding rims. As the table shows, Trelleborgs were about 160% the cost of 20.8 R42 triples and 710/70 duals and about 240% the cost of 20.8 R42 duals.

Table 5. Tire Costs in Canadian Dollars, Delivered to Lethbridge, Unmounted and Without Rims.

Tire	Quote 1	Quote 2	Quote 3	Quote 4	Mean	%
Trelleborg 750/65-38 Duals (8 tires)	$22,400	$22,048	--	--	$22,224	100.0
20.8 R42 Triples (12 tires)	$13,548	$13,944	$14,196	$13,476	$13,791	161.1
710/70 R38 Duals (8 tires)	$11,152	$18,704	--	$12,088	$13,981	159.0
20.8 R42 Duals (8 tires)	$ 9,032	$ 9,296	$ 9,464	$ 8,984	$ 9,194	241.7

CONCLUSIONS

Overall, Trelleborg tires did not perform as well as radial ply tires and in many ways performed similarly to conventional bias ply tires (1, 2). On the negative side, their power delivery performance was lower than radials, they pulled less at the same ballasted weight and slip and their sidewalls tended to wrinkle under torque load at inflation pressures near radial tire inflation pressures. They also cost substantially more than equivalent-sized radial tires. On the positive side, they showed no tendency to power hop, showed flotation that was equivalent to radial tires of similar size and had a more pleasing ride quality.

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