WHEEL EFFECTS ON TILLAGE ENERGY

J.N.Tullberg and L.Victor-Gordon.
Farm Mechanisation Centre, University of Queensland, Gatton College, Queensland 4343, Australia

1. INTRODUCTION

Tractor and/or implement wheels precede tines, and compact the soil immediately before it is loosened in most tillage and planting operations. Soil compaction effects generally ameliorate with time, so the most severe wheeling should be observed in the performance of tillage tools following immediately behind wheels. This aspect of tractor/implement system efficiency appears to have received little attention in the literature, which is surprising when wheels usually cover 15% --30 % of implement width. Tractor drive wheels are likely to be most important in this respect, although the implement wheels providing depth control and frame support will have some effect.

In controlled traffic farming this effect is avoided as all field traffic is confined to permanent laneways, and all crops grown in permanent unwheeled beds. This should have a direct effect on the energy requirement of tillage because unwheeled soil requires less tillage energy than wheeled soil. Traction should also be more efficient when tyres are working on compacted permanent tracks.

The severity of compaction has been found to be dependent on wheel load (Ronai *et al.*, 1993) and tyre pressure (Raper *et al.*, 1993). This has lead to the widespread adoption of dual and triple tyres by producers in an attempt to reduce compaction. Although dual and triple tyres reduce the severity of compaction, the increased wheel width causes an increase in the area of soil compacted. It is debatable whether or not these measures actually reduce the overall effect of compaction on factors such as tillage energy.

Trials have been undertaken to assess the effect of tractor and implement wheels on the draft of the tillage tools following immediately behind them, and to determine the effect of tyre pressure and wheel load. The results will be used to quantify the impact of field traffic, and its control, on tillage energy requirements.

2. MATERIALS AND METHODS

2.1 Instrumented Plough

Draft-sensing tines were designed using 450 mm chisel plough shanks attached to parallel link assemblies. Rearward movement of the tines was restricted by shear beam force transducers connected to a data logger which scanned transducer outputs at 0.1s intervals, and recorded the mean draft force measurement for all tines at 10 s intervals. The draft-sensing tines could be fitted with 50mm chisels, normally used for primary tillage, or 450mm sweeps, normally used for weedkill and seedbed preparation.

The draft sensing tines were mounted on a 4 m wide three-point linkage toolbar fitted with adjustable depth control wheels at its extremities.

2.2 Overall Wheeling Effect

The initial series of tests were carried out in order to determine the overall effect of tractor and implement wheels on tillage energy. The toolbar was attached to a tractor modified for work in permanent wide beds, with front and rear wheel track centres set to 3 m, and stabilizers to prevent lateral movement of the toolbar relative to the tractor. Four draft-sensing tines were fitted to the toolbar at 1 m centres so the two outer 'wheeltrack' tines operated directly behind the tractor wheel centrelines, and tilled soil immediately after wheeling by the tractor. The two inner 'control' tines worked in soil not previously wheeled by the tractor.

An implement wheel was mounted on a frame on the front of the tractor to simulate the action of a trailed implement depth control/frame support wheel. This was fitted with a 10x16 implement tyre and carried a load of 9.0 kN. The tractor was a 2WD John Deere 4040, total weight 65 kN. The rear axle was fitted with two 16.9x38 R1 tread bias ply tyres, operated at a pressure of 120 kPa.

Chisel points were used in test A, where a relatively loose and dry surface soil mulch overlay a moist, compact layer. The implement wheel was not available during this test, representing primary tillage effects to a depth of 220 mm. Subsequent tests with sweeps in secondary tillage and planting conditions rarely exceeded 125 mm depth. Tests B and C were carried out under conventional secondary tillage and planting conditions respectively. Test D was carried out in sorghum stubble with some weed growth, to represent reduced tillage planting or weed control, and test E, with dry surface soil, represented a secondary tillage operation delayed until soil moisture was sub-optimal.

2.3 Wheel Load and Tyre Pressure Effects

A further three tests were undertaken to determine the effects of wheel load and tyre pressure on tillage energy, using same instrumented plough with different tractors.

Both pressure and load effects were investigated in trial F and H. Differences in wheel load were obtained by fitting a dual wheel to one side of a tractor in trial F and extending the rear axle on one side in trial H. Trial G was limited to pressure treatments as the dual wheel was not available. Tractor and treatment details are shown in Fig. 1.

Trial	Tractor	Weight	Tyre Pressures	Depths
F	2WD Ford 6640	40.7 kN	55, 83, 110 kPa	5, 10, 15(cp) cm
G	2WD Ford 5640	46.7 kN	83, 93, 124 kPa	10, 15, 20(cp) cm
H	2WD J.Deere 3120	40.2 kN	69, 138 kPa	10(sw), 20(sw) cm

Figure 1. Experimental Details of Trial F-H. (cp = Chisel Points, sw = Sweeps).

2.4 Sites and Layout

All tests except trial F were carried out at the University of Queensland Gatton College farm, on self-mulching alluvial black earth of the Lawes or Blenhiem profile classes (ug

5.15, clay~55 %, silt~25 %, sand~25 %). Trial F was conducted on a non-cracking Ferisol in Crawford. Soil conditions approximating those of Australian dryland grain production were obtained by selecting plot areas from fields at the appropriate stage of land preparation. No special preparation was involved other than the choice of areas which appeared to be uniform. Before each set of tests, core samples were taken for gravimetric moisture determination.

Mean tine draft for each treatment was measured while traversing two plots orientated at approximately 30° to the longer dimension of field. The purpose of this angle was to minimize the possibility of systematic error due to tines following pre-existing wheel tracks. The toolbar depth wheels were set using a 2m straight edge laid across undisturbed soil surface. The actual depth of wheeltrack tines was always smaller due to the wheel rut.

3. RESULTS

3.1 Overall Wheeling Effect

Relatively smooth draft:depth characteristics were obtained for wheeltrack and control tines in all cases except test C, where some inconsistency occurred at 75 mm depth. In all cases the draft of tractor and implement wheeltrack tines was less than that of control tines at depths <50 mm. This effect occurred because wheeltrack tines did not engage the soil until tillage depth exceeded wheeltrack depression (ie rut depth). When wheeltrack tines did engage the soil, tractor and implement wheeltrack tine draft always increased more rapidly with depth than control tine draft.

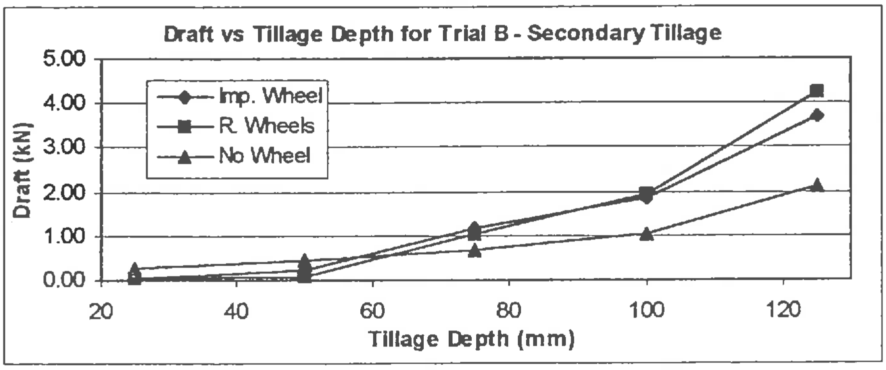
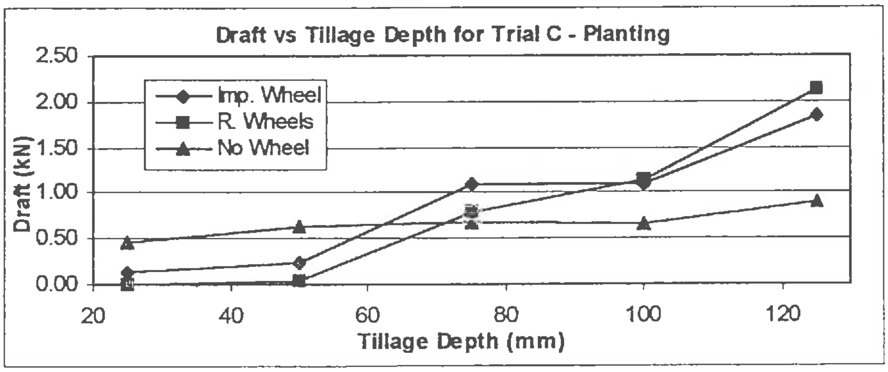


Figure 2.



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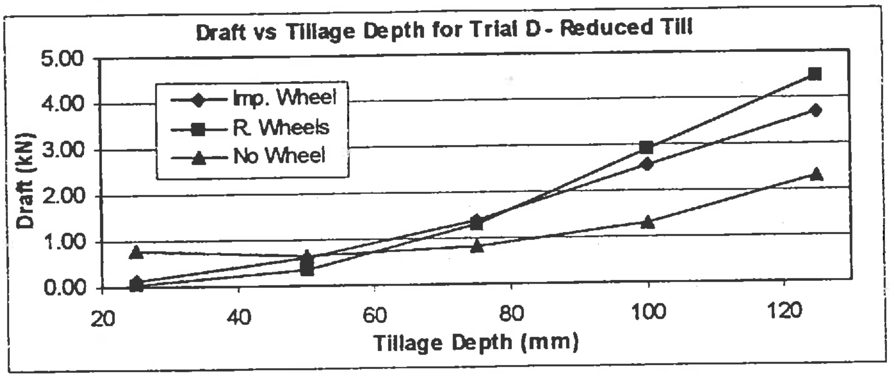

Figure 4.

In all cases except test E (secondary tillage in dry conditions) the draft of wheeltrack tines was significantly greater than that of control tines at normal operating depths. For chisel tines in primary tillage at depths >150 mm, the mean draft of wheeltrack tines was greater than that of control tines by a factor of approximately 2.2. For sweeps in secondary tillage (Fig. 2) at depths >75 mm, tractor and implement wheeltrack tine draft was greater than control tine draft by factors of approximately 2.0 and 1.8 respectively.

When surface soil was drier, the wheeltrack effect was different. In test E with sweeps, and in test A with chisels, wheeltrack tine draft appeared similar, or less than the control tine draft at depths <100 mm. Tillage of dry surface soil in these conditions appeared to simply rearrange the existing aggregates, while producing little effect on aggregate size distribution. There is rarely any useful purpose for tillage in these conditions. In both cases, however, at depths >100 mm, wheeltrack tine draft appeared to increase relative to control tine draft when the tine started to work in more moist soil.

At normal soil moisture content and operating depth (100 mm) for secondary tillage with sweeps, these results indicate an overall mean control tine draft of 1.07 kN (Fig. 2). If these tines were at their normal spacing of 305 mm this is equivalent to a unit draft of approximately 3.5 kN/m implement width (ignoring any between-tine interaction effects). In a typical extensive tillage situation, tractor and implement wheeltracks might represent 20 % and 15 % of implement width. If tine draft in these wheeltracks increased by factors of 2.0 and 1.8 respectively, the overall unit draft would be 4.6 kN/m, or > 30% greater than control tine draft.

3.2 Wheel Load and Tyre Pressure Effects

Although increased wheel load was found to significantly increase tillage energy at all tested depths, it can be seen in that higher wheel loads (single) had a greater effect at depth than lower wheel loads (duals) (Fig. 5). This effect was also found in trial H and is consistent with previous research which has found wheel load to be the major determinant of compaction depth (Adawi and Reeder, 1996).

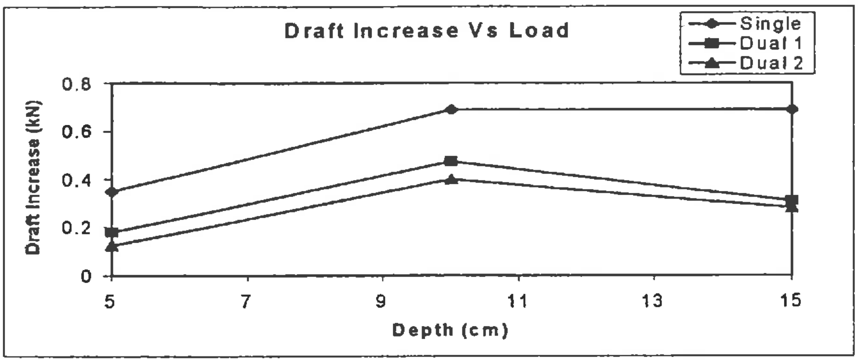

Figure 5. Draft Increase With Depth and Load – Trial F.

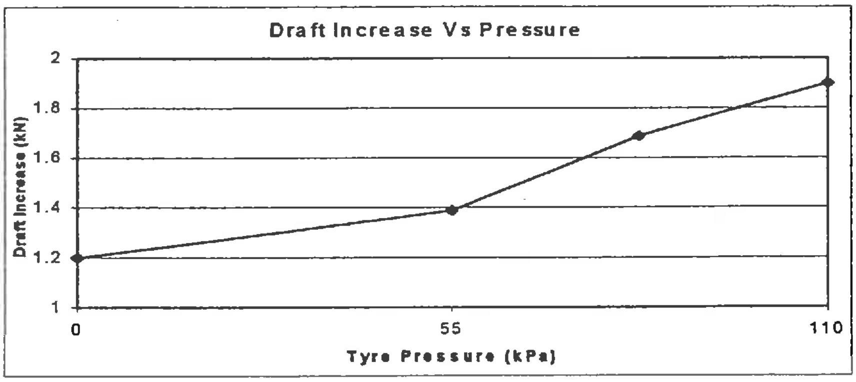

Figure 6. Draft Increase With Tyre Pressure – Trial F.

It was difficult to demonstrate a significant difference between different tyre pressures at the same depths but when all depths were considered, tillage energy was found to increase significantly with increasing tyre pressure (Trials F and H - Fig. 6). The results from trial G were erratic due to variation in soil moisture. No consistent relationship was found between tyre pressure and depth of compaction.

The comparison between dual and single wheels in trial F revealed that duals have little or no advantage over singles in terms of tillage energy. Even when the dual wheels were inflated to half the pressure of the single (55kPa vs 110kPa) there was no significant difference in draft. The draft of tines immediately behind the dual wheels was considerably lower than that of the single wheel, but the increased area of compaction caused by the duals meant that the overall draft increase was approximately the same.

4. DISCUSSION

The simple analysis presented here demonstrates that >30 % of implement input energy was used to undo wheeltrack effects. When tractive efficiency is ~ 80 %, however, at least 25 % of implement input energy (= 20% of tractor axle output energy) has already been dissipated by the tractor in the soil/tyre interaction. Total energy input to the creation and removal of wheeltracks is thus >55 % of implement input energy under very good tractive conditions. A mean tractive efficiency level of 75% was found in a survey of 4WD tractors on Queensland grain farms. At this tractive efficiency approximately 65 % of implement input energy, or almost half the tractor's output energy will be dissipated in the creation and removal of wheeltracks. In a controlled traffic situation where tractor and implement wheels would be repositioned to the permanent laneways and the wheeltrack tines removed, drawbar pull would be >65 % of an equivalent conventional system.

Increasing wheel load and tyre pressure were both found to have a positive correlation with tillage energy. However, attempting to overcome compaction by lowering tyre pressure and spreading axle load over dual wheels would appear to be ineffective if tillage energy can be taken as an indication of compaction. The measurements taken did not consider the compaction caused below the tillage depth and as wheel load has be correlated with compaction depth, it is likely that the single wheel caused greater compaction below the tillage layer.

5. CONCLUSIONS

Investigation of the impact of tractor and implement wheels on the performance of tined tillage equipment operating at normal soil moisture and depth in a clay soil has demonstrated that:

- The draft of sweep and chisel tines operating in the wheeltracks left by a 2WD tractor of approximately 6t was increased by more than 100% compared to tines in non-wheeled soil.
- The draft of sweep tines following an implement tyre carrying approximately 0.9t was increased by approximately 80% compared to tines in non-wheeled soil.
- Under these conditions, almost 50% of the power output of the tractor can be absorbed in the creation and partial removal of wheel tracks.
- The use of dual wheels causes little or no reduction in tillage energy.
- Controlled traffic operations can reduce tillage energy requirements by > 50%, although the change in tillage objectives might be equally significant in terms of reduced energy requirement.

These phenomena did not occur during tillage of dry soil, and different effects might occur with varying soil type, implement type tyre type and pressure.

7. REFERENCES

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