

THE EFFECT OF GEAR RATIO AND IMPLEMENT SIZE ON THE INFIELD PERFORMANCE OF A 58 kW TRACTOR

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Abstract

The performance of a 58 kW tractor was measured for different gear ratios and implement sizes and a performance index was established. The productivity and fuel consumption were determined and results indicated that considerable savings in fuel consumption and improvements in productivity could be achieved by simple changes in the operating technique.

Introduction

A project was initiated to measure the effect of different machinery management on the productivity (h/ha) and fuel consumption (l/ha) of a 58 kW tractor. The factors that were investigated were different gear ratios and implement sizes, alternative throttle positions, and two wheel drive (2WD) or two wheel drive plus front wheel assist (4WD).

All tests were carried out on a Ford County 6600/4 tractor. Since the front and rear wheels were not the same size, it was classed as a front wheel assist tractor. The tractor was ballasted in the front and rear and also had water in the tyres. The mass of the vehicle, including 795 kg of ballast in the rear and 328 kg in front, was 4 237 kg (see Appendix A).

Materials and Methods

Disc, mouldboard and chisel ploughs and a disc-harrow were used in the tests and the parameters that were measured were speed (km/h), width of cut (m), wheel slip (%) and fuel consumption (l/h).

5th wheel distance transducer

Initially an electronic transducer was used to indicate the distance travelled in a pre-determined time (see Figure 1). This instrument was based on a photo-electric sensor which picked up signals from a toothed sprocket inside a motorcycle's front wheel which was mounted on the tractor. It was suitably modified, but was sensitive to environmental electronic noise and it proved to be unreliable. A much simpler and effective transducer was made from a set of automotive ignition contact breakers running on a cam that was driven off the surface of the 5th wheel and it gave a signal every time the contacts closed. This transducer is illustrated in Figure 2.

Rear wheel distance transducer

A transducer which operated similarly to the 5th wheel transducer was designed to run on the inside of the rim of the rear wheel so that wheel slip could be measured. This was done by comparing the distance covered by the 5th wheel with that travelled by the rear wheel of the tractor.

Fuel flowmeter

Fuel consumption during a fixed period was measured by means of a batch type flowmeter in which fuel was drawn from a graduated reservoir. Bypass fuel from the injector and injection pump was returned to the top of the reservoir so that only the amount of fuel used was measured. Two three-way solenoid valves interrupted the normal fuel delivery system to engage the fuel flowmeter as illustrated in Figure 3.

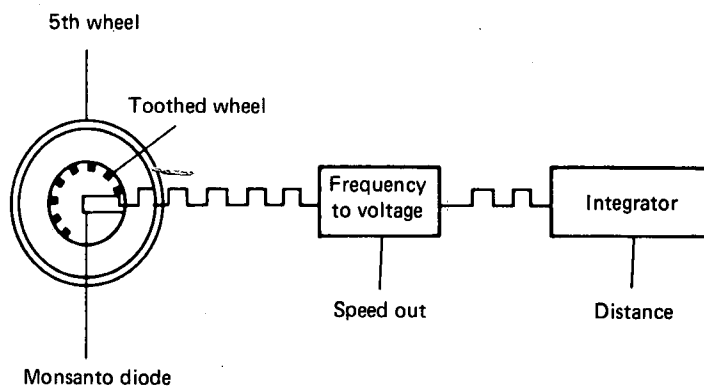


FIGURE 1 Layout of 5th wheel and electronic components.

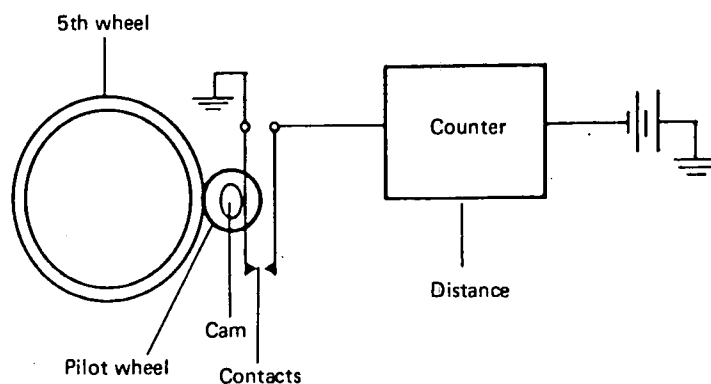
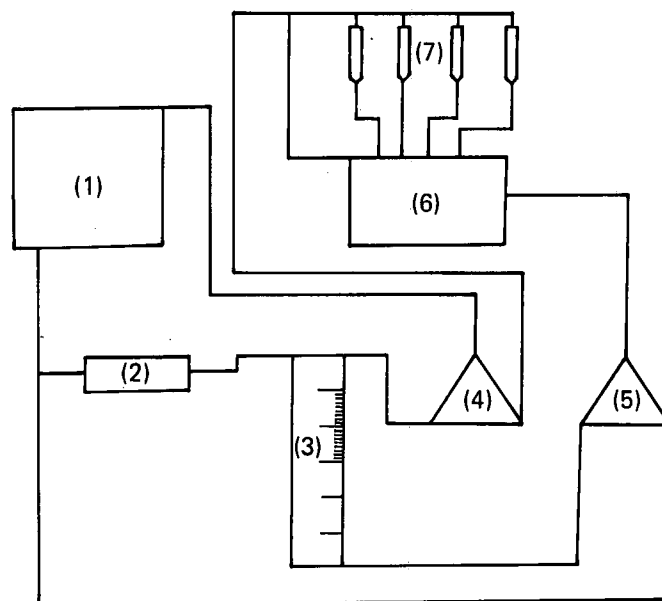


FIGURE 2 Layout of 5th wheel and electro-mechanical counter.



KEY
1 Main fuel tank, 2 Flask priming pump, 3 Fuel flask, 4, 5 3 way solenoid valves, 6 Injector pump, 7 Injectors.

FIGURE 3 Layout of fuel flowmeter.

All the recording mechanisms of the transducers were controlled by a single switch mounted on the dashboard of the tractor and it was used to activate the three transducers for 30 seconds. Each test was repeated four times.

The width of cut made by the implement was measured after each test and productivity, fuel consumption and wheel slip were calculated as follows:

$$\text{Speed (km/h)} = \frac{\text{5th wheel distance (m)}}{60} \times 0,12$$

$$\text{slip (\%)} = \left(\frac{\text{rear wheel distance} - \text{5th wheel distance}}{\text{5th wheel distance}} \right) \times 100$$

$$\text{Productivity (h/ha)} = \frac{10}{\text{speed (km/h)} \times \text{width of cut (m)}}$$

$$\text{Fuel consumption (\$/ha)} = \frac{\text{productivity (h/ha)} \times \text{volume of fuel consumed (ml)}}{1000}$$

$$\text{Performance index (ha}^2\text{/h)} = \frac{1000}{\text{productivity (h/ha)} \times \text{fuel consumption (\$/ha)}}$$

When wheel slip was greater than 30%, the combination of implement size and gear ratio was not tested.

While each implement was being tested, soil variability was small but it was considerable between tests. Tests were done only when the moisture content of the soil was satisfactory for tillage. The soil type on one of the sites where the tests were conducted was a Lower Ecca shale while on the other it was a Recent Sand. It was unfortunate that no areas of heavy soils, which were large enough and sufficiently uniform in texture could be found for the trials.

Results

The different gear ratios were compared with each other, as were the implement sizes, 2WD or 4WD and part and full throttle settings. Their relationships were expressed as ratios. Results of the trials involving implement sizes are presented in Table 1 while the results of the gear ratio trials are listed in Table 2.

The comparisons of 2WD and 4WD performances and of part and full throttle are shown in Tables 3 and 4 respectively.

TABLE 3

Comparison of 2 and 4 wheel drive performance in soils of medium texture

Implement	Gear ratio	% improvement of 4WD over 2WD		
		h/ha	\$/ha	Performance index
Chisel plough (7 tines)	4	3	3	6
	3	1	3	4
Mouldboard plough (3 furrow)	4	0	2	2
	5	2	14	15
Mounted disc harrow	4	1	2	1

TABLE 4

Comparison of performance resulting from setting high idle 400 rpm lower than standard operating on a soil of medium texture

Implement	Gear ratio	Reduction in performance resulting from 400 rpm drop in high idle (%)		
		h/ha	\$/ha	Performance index
Chisel plough (7 tines)	4	19	4	22
Mouldboard plough (3 furrow)	4	21	10	9
	5	20	8	28
Mounted disc harrow	4	23	9	12
	5	24	16	6

Discussion

The effect of increasing implement size on productivity is shown in Table 1 and in all cases the increase was considerable, provided a change to a lower gear was not required for the tractor to pull the implement. A change between gear ratios 3 and 4 had less effect on productivity, fuel consumption and the performance index than did a change between gear ratios 2 and 3 (see Table 2). This is explained in Appendix B where the difference between ratios 2 and 3 was 76%, whereas between ratios 3 and 4 it was 36% and between ratios 4 and 5 it was 20%. If a change to a lower gear ratio is required, there will be a gain in performance only if the effect of an increase in width of cut is greater than that of the decrease in speed which results from the gear change.

In five cases, larger implements caused an increase in the amount of fuel consumed per hectare. A possible explanation for this is that the substantial increase in draught resulted in greater wheel slip

TABLE 1

Performance as affected by change in implement size

Implement	Implement size change from/to	Gear	Percentage improvement in productivity (h/ha)	Percentage improvement in specific fuel consumption (\\$/ha)	Percentage improvement in performance index
Light soil: Mouldboard ploughs	2 furrow to 3 furrow	3	102	56	211
		4	73	29	127
Disc ploughs	2 furrow to 3 furrow	3	24	- 22	2
		4	29	- 14	12
Disc harrows	mounted to trailed	3	16	- 5	16
		4	36	- 10	42
Chisel ploughs	5 tine to 7 tine	3	41	35	90
		4	44	44	112
Chisel ploughs	3 tine to 5 tine	3	65	86	207
		4	48	53	130
Medium soil: Mouldboard ploughs	2 furrow to 3 furrow	3	93	39	168
		4	90	38	162
Disc ploughs	2 furrow to 3 furrow	3	42	- 5	35
		4	50	31	90
Disc harrows	mounted to trailed	3	16	9	7
		4	16	5	11
Chisel ploughs	5 tine to 7 tine	3	50	42	113
		4	43	34	92
Chisel ploughs	3 tine to 5 tine	3	59	37	118
		4	55	50	132

TABLE 2
Improvement in performance due to change in gear ratio

Performance parameter	Productivity (h/ha)					Fuel consumption (l/ha)					Performance index (ha ² /h)		
	1	2	3	4	5	1	2	3	4	5	1	2	5
Change from gear ratio	2	3	4	5	6	2	3	4	5	6	2	3	6
Implement													
Light soil:													
Mouldboard plough (3 furrow)		71	19	25			20	- 8	22				106
Disc plough (3 furrow)		57	40				9	13					71
Mouldboard plough (2 furrow)	21	65	39	15	23	9	36	12	- 3	15	27	130	59
Disc plough (2 furrow)		74	34	18	22		55	7	2	- 2		169	18
Shallow plough (2 furrow)			31	21	22			6	9	4			16
Mounted disc harrow		56	47				30	28				103	
Trailed disc harrow	13	46	72	14		-10	30	11	-22		3	82	
Chisel plough (7 tine)			40	10				13	- 6				
Chisel plough (5 tine)			33	18				2	10				
Chisel plough (3 tine)			48	16				26	0				
Medium soil:													
Mouldboard plough (3 furrow)	28	47	29			24	- 4	2			58	42	
Disc plough (3 furrow)	16	57	40	16		6	8	24	- 3		22	69	
Mouldboard plough (2 furrow)		70	31	17			28	3	- 3			119	
Disc plough (2 furrow)		64	32	16			40	-11	- 3			129	
Shallow plough (2 furrow)		50	39	12			11	10	- 7			65	
Mounted disc harrow			34	16				8	3				
Trailed disc harrow		61	34	14			-15	-18	0			99	
Chisel plough (7 tine)	21	63	32	13		9	9	16	- 8		33	77	
Chisel plough (5 tine)		58	32	17			2	19	- 3			61	
Chisel plough (3 tine)			34	12				5	- 1				

and that the engine may have been operating at a level where specific fuel consumption was high (Murray & de Beer¹). Although engine speed was not measured, attempts were made to prevent it from falling too far below the rated speed.

Although fuel consumption increased and the increase was substantial in some cases, the productivity index always increased which indicated that provided fuel consumption and productivity were rated equally, increasing the size of the implement was beneficial. This does not mean that these results can be applied to implements larger than those tested.

A tractor such as that used in the trials, would cost about R12,60* per hour (fixed and variable costs) if it worked for 1 000 h in a year. Of this, fuel would cost approximately R2,15 (7 l/h × R0,45/l) which indicates that the fuel consumption should probably influence the performance index less than it has been allowed to do.

Table 2 illustrates the improvement in performance which could result from increasing the forward speed of an operation provided the wheel slip is within acceptable limits and that the engine is not overloaded to the extent that its speed falls more than 20% below high idle. In some cases, changing from 4th to 5th gear caused an increase in fuel consumption, probably for reasons similar to those discussed previously. The performance index usually improves considerably with an upward change in gear ratio. In a commercial operation, gear ratios 3 to 5 are usually used, and for all implements and both soil types, there was an average improvement of 37% in productivity. By changing from 3rd to 4th and from 4th to 5th, productivity improves by 16%. Fuel consumption improved by 8% by changing from 3rd to 4th gear but there was no improvement when changing from 4th to 5th gear. The performance index improved by 94% in changing from 3rd to 4th and by 49% from 4th to 5th gear.

Considerable savings can therefore be made by the correct choice of gear ratio and implement size for tillage operations. Machinery costs are proportional to the time spent by a tractor performing a particular task and if the time can be reduced by 37%, the total cost per unit of area will be reduced by a similar proportion.

During the tests, conditions for tillage were favourable but the front wheel assistance never resulted in more than a 3% increase

in productivity. In one trial, there was a 14% saving in fuel but in other instances there was only a 2% or 3% saving (see Table 3). It appears that in these conditions the improvement in performance does not warrant the increased cost of operating these tractors. It is estimated that the operating costs of a 2WD, 58kW tractor are R12,60* per hour whereas a 58 kW front wheel assist tractor would cost R15,60* per hour. This represents an increase of 24%.

The use of either full or part throttle was also tested. Tests were conducted on three implements on a soil of medium texture to compare the performance of the tractor with the throttle set 400 rpm lower than high idle. The results showed that there was an average reduction of 21% in productivity and a 7,4% increase in the amount of fuel used. This was due primarily to the reduced power demand because of the slower speed, which meant that the engine used fuel less efficiently.

Conclusion

The choice of implement, gear ratio and throttle position are often neglected in the management of farm machinery. Considerable savings in tractor time and fuel can result from attending to the way in which a tractor is operated. It has also been shown that for good tractive conditions a 4WD tractor does not perform significantly better than a well-ballasted 2WD tractor.

* according to SASA Experiment Station standards.

REFERENCES

- Murray, T. J. and de Beer, A. G. (1978). Machinery selection based on machine costs. *SASTA Proc* 52: 174-177.

APPENDIX A

Ballast used on the Ford County 6600/4 during the trials	
Ford County 6600/4 ballast	Mass (kg)
Unballasted mass	3 114
Front ballast	
Wafer mass pieces	200
Wheel mass pieces	128
Rear ballast	
Water	522
Wheel mass pieces	273
Total additional ballast	1 123
Total mass	4 237

APPENDIX B

Ford County 6600/4 gear ratio differences

Change from gear ratio	% change in overall gear ratio
1 to 2	25
2 to 3	76
3 to 4	36
4 to 5	20
5 to 6	24