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EVALUATION AND COMPARISON OF TRACTION PERFORMANCE OF TWO COMMON TRACTORS IN IRAN

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ABSTRACT

Traction performance of two commonly used tractors in Iran, namely, Massey Ferguson 285 and Universal 650 with 56 and 48.5 kw rated engine powers, respectively, were evaluated and compared. Because of the limited available instrumentations, among the operating parameters affecting tractive performance of tractors, only wheel slip, fuel consumption and field capacity in tillage operations were evaluated and compared.

For accurate measurement of fuel consumption, a fuel measuring device consisting of a graduated cylindrical reservoir, a six-way, two-position spool valve and an oil cooler was designed, fabricated and mounted between the main fuel tank and feed pump of each test tractor.

Analysis of the test results showed that for the same draft load, Massey Ferguson had higher wheel slip and fuel consumption and lower field capacity as compared to the Universal. Lower tractive performance of the Massey Ferguson could be attributed to its lower static weight, shorter wheel base, smaller drive wheel outer diameter and higher tire inflation pressure.

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ارزیابی و مقایسه عملکرد کششی دو تراکتور متداول در ایران

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به ترتیب دانشجوی سابق کارشناسی ارشد و استادیار بخش ماشین‌های کشاورزی، دانشکده کشاورزی دانشگاه شیراز، شیراز، ایران.

چکیـــده

عملکرد کششی دو تراکتور متداول در ایران به نام‌های مسی فرگوسن ۲۸۵ و یونیورسال ۶۵۰ به ترتیب با توان لگامی ۵۶ و ۴۸/۵ کیلووات مورد ارزیابی و مقایسه قرار گرفت. به علت در دسترس نبودن وسایل اندازه گیری، از بین پارامترهای کاری مؤثر بر عملکرد کششی تراکتورها تنها لغزش چرخ، میزان مصرف سوخت و ظرفیت مزرعه ای در عملیات خاک ورزی، ارزیابی و مقایسه گردید. برای اندازه گیری دقیق مصرف سوخت، وسیله‌ای شامل یک مخزن استوانه‌ای مدرج، یک شیر ماسوره‌ای دو وضعیتی ۶ راهه و یک خنک کننده طراحی و ساخته شد. این وسیله بین مخزن اصلی سوخت و پمپ تغذیه هر تراکتور آزمایشی نصب گردید. نتایج این آزمایش نشان داد که با بار کششی یکسان، تراکتور مسی فرگوسن در مقایسه با تراکتور یونیورسال دارای لغزش چرخ و مصرف سوخت بیشتر و ظرفیت مزرعه‌ای کمتری بود. عملکرد کششی ضعیف تر مسی فرگوسن می تواند ناشی از وزن کمتر، کوتاهتر بودن فاصلهٔ بین دو محور، کوچکتر بودن قطر خارجی چرخ محرک و فشار زیادتر باد لاستیکهای این تراکتور باشد.

INTRODUCTION

Transmission and conversion of tractor power to useful work is normally performed by three means; hydraulic system, power take-off shaft and drawbar pull, the later, being the most common while having the least efficiency (10). Research results throughout the world show that from 20 to 55% of the energy delivered to the drive wheels of tractors is wasted in the traction elements (5). This energy is not only wasted, but the resulting soil compaction by a portion of this energy may be detrimental to crop production.

As tractors are the main consumers of energy in the agricultural sector of the industry, it is necessary to aim for efficient utilization of tractor power on farms. One of the possible ways to improve the tractive performance of a tractor is to reduce power loss at the soil-tire interface.

The ability of a tractor to develop draft power depends upon soil type and condition, physical and mechanical characteristics of the tractor and its driving wheels. Little can be done about the soil physical condition except for surface cover and moisture content. Therefore, for efficient traction, the tractor and its wheels must be adopted to the existing soil type.

In many cases, it is observed that in spite of the high tractor brake power, its axle torque and speed could not be converted to useful drawbar power efficiently. This could be due to the improper static weight distribution, wheel ballasting, tire inflation pressure and/or tractor-implement hitch point height, which cause excessive wheel slip and waste of axle power.

Efficiency of tractor operation is closely tied to the wheel slip level. Zoz (18) has shown that for each soil condition there is a range of wheel slip levels where tractive efficiency is the highest. Hauck *et al.* (9) stated that tractors should be weighted to slip between 8-16% for maximum efficiency depending on the soil surface. As soil surface gets softer, maximum drawbar horsepower occurs at higher slip ranges.

Zombori (17) studied the effects of inflation pressure on drawbar pull and tractive efficiency and showed that at constant travel reduction, a decrease in inflation pressure caused an increase in drawbar pull. When drawbar pull was held constant, a decrease in inflation pressure caused a decrease in travel reduction which resulted in a significant increase in tractive efficiency.

Burt *et al.* (4) investigated the effects of dynamic load on tractive efficiency and emphasized that at constant travel reduction, an increase in dynamic load resulted in an increase in tractive efficiency on compacted soil, but caused a decrease in tractive efficiency on uncompacted soil.

Gee-Clough *et al.* (7) stated that for optimizing the output of a wheeled tractor performing a draft operation there has to be a proper matching of tractor power, weight, travel speed and draft force. Reece (12), Zoz (18), Wismer and Luth (16), Brixius and Zoz (3), Domier and Willans (6) and many others tried to develop certain relationship between the above-mentioned parameters for optimum performance.

Lyne *et al.* (11) investigated the effects of tire and engine parameters on efficiency during field operation and showed that tractive efficiency can be optimized by selecting the appropriate dynamic load and inflation pressure.

Several instrumentation systems capable of monitoring and evaluation of the traction performance of tractors in field operations have been developed. These systems vary in complexity and sophistication from measuring one or two parameters by display readings to on-board microcomputer-base monitoring of several operating parameters (1, 8, 13, 14, 15).

In this study, tractional performance of two commonly used tractors in Iran, namely, Massey Ferguson 285 and Universal 650 with 56 and 48.5 kw rated engine powers, respectively, were evaluated and compared. The necessity for conducting this experiment was recognized following claims raised by many farmers that tractional performance of Ferguson 285 was inferior to that of Universal 650 in spite of its higher rated power.

None of the preceding instrumentation systems were available for measurement of the operating parameters affecting tractive efficiency of the tractors. As traction performance of a tractor is related to its fuel consumption, wheel slip and field capacity in tillage operations, mean values of these parameters were used to evaluate and compare the tractive performance of the two tractors.

MATERIALS AND METHODS

The experiment was conducted at the Experimental Station, College of Agriculture, Shiraz University, located in Bajgah valley, 16 km north of Shiraz, Iran. Tractional performance of two commonly used tractors in Iran, namely, Universal 650 and Massey Ferguson 285 were evaluated while pulling primary tillage implements, a 3-bottom mouldboard plow or a 258 cm wide chisel plow at two working depths (150 and 250 mm) on a silty loam soil after wheat harvest. Straw and other plant residues were collected and removed by a baler before tests.

The experiment was conducted in a two-hectare field using split-plots design with three replications. Different combinations of plowing depth and plow type were selected as the main treatments, while the two tractors were considered as sub-treatments. Data were analyzed by analysis of variance procedure and differences between means were subjected to Duncan's multiple range test (DMRT).

Tests were conducted on plots of 150 m length and the data recorded for each test run were time consumption, fuel consumption, tractor advance per 10 wheel revolutions with and without load, depth and width of cut and soil moisture content. The data were used to determine forward speed, field capacity, fuel consumption and wheel slip.

Some relevant specifications of the test tractors are given in Table 1. Rear wheels of the Massey Ferguson tractor were filled with water containing calcium chloride according to manufacturer's recommendations. Also, tire inflation pressures of both tractors were adjusted as recommended by their operating manuals. Tractor fuel tanks were filled-up before tests and no accesories except the fuel measuring devices were mounted on tractors during the experiment.

A 3-bottom mouldboard plow and a chisel plow with effective cutting width of 1.10 and 2.58 m, respectively, were used at two plowing depths of 150 and 250 mm to apply four levels of draft force on tractors.

Table 1. Some technical specifications of the test tractors.

Characteristics	Massey Ferguson 280	Universal 650
Rated engine speed (rpm)	2000	1800
Rated engine power (kw)	56	48.5
Total tractor mass (kg) (without liquid ballasting)	2540	2980
Liquid ballast (kg) (rear wheels)	500	-
Rear axle static mass (kg)	2255	2155
Wheel base (mm)	2286	2430
Rear wheel dia./width (mm)	1500/465	1520/355
Tire inflation pressure rear/front (kpa)	110/207	101/220
Tire size	18.4/15-30	14.00-38
Tire type	Cross-ply	Cross-ply

Fuel Consumption Measurement

For accurate measurement of fuel consumption along each experimental plot, a fuel measuring device consisting of a graduated 500-ml cylindrical reservoir, a six-way two position spool valve and an oil cooler was designed, fabricated and then mounted on each test tractor. The position of fuel measuring device in the tractor fuel system was between the main fuel tank and charging pump.

Two fuel transmission paths could be selected by the directional control (spool) valve as shown in Fig. 1. As the spool valve is shifted to position I, the injection pump receives its fuel from the main fuel tank and the excess fuel from the pump and injectors is returned to the tank. By shifting to position II, fuel is taken from the graduated cylinder and the returned fuel is fed back to it after being routed through a cooling radiator mounted in front of the tractor. Along each test plot the spool valve was shifted to position II by a hand lever and the fuel consumption was measured by recording the fuel level drop in the graduated cylinder.

Engine Speed and Gear Selection

Engine rated speeds of 1800 and 2000 rpm were maintained and gears 2 and 3 were selected on Universal and Massey Ferguson tractors, respectively, during the tests. Selecting higher gears at deeper plowing depth (2500 mm) was not possible due to the higher draft requirements, and at the shallow plowing depth (150 mm) shifting to higher gears could cause unsafe tractor speeds due to the lateral ridges on the field.

The first 30 meters along each test plot was allocated to reach the predetermined tillage depth, and the control lever was set at draft control position to ensure constant draft load.

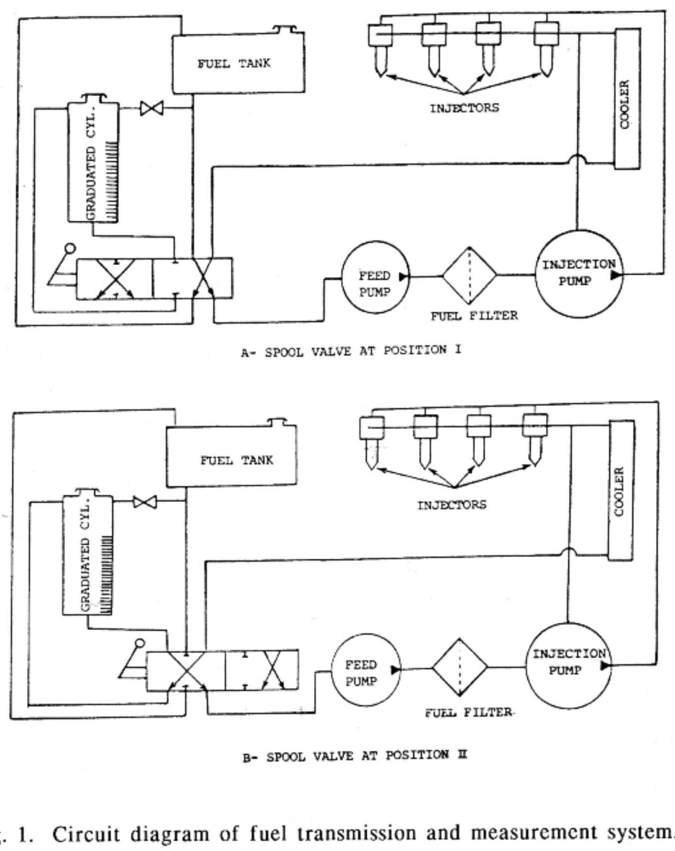

Fig. 1. Circuit diagram of fuel transmission and measurement system.

RESULTS AND DISCUSSION

Analysis of variance for the main effects of plowing depths, plow types and tractor types and their interactions for wheel slip, fuel consumption and field capacity are shown in Table 2.

Table 2. Analysis of variance for the tractor wheel slip, fuel consumption and field capacity.

Source	df	Mean squares		
		Wheel slip	Fuel consumption	Field capacity
Replications	2	0.16	0.01	0.001
Plowing depth, D	1	548.17**	175.25**	0.099**
Plow type, P	1	156.57**	992.40**	2.707**
D × P	1	0.92^{ns}	20.49**	0.014**
Error	6	2.03	0.04	0.00
Main plots	11			
Tractor type, T	1	150.50**	0.26**	0.476**
D × T	1	210.63**	0.79**	0.00^{ns}
P × T	1	6.93*	6.26**	0.046**
D × P × T	1	3.15^{ns}	3.19^{ns}	0.00^{ns}
Error	8	1.09	0.01	0.00
Sub-plots	12			
Total	23			

*, ** Significant at P=0.05 and 0.01, respectively.
ns Nonsignificant

Effect of Plowing Depth

Mean values of the wheel slip, fuel consumption and field capacity at the two plowing depths, D1 D2 are shown in Table 3. Comparison of treatment means using DMRT indicated significantly higher wheel slip and fuel consumption and lower field capacity at higher plowing depth. This is due to the higher draft requirement at deeper plowing.

Table 3. Comparison of mean values of wheel slip, fuel consumption and field capacity with respect to plowing depth.

Plowing depth, D	Wheel slip (%)	Fuel consumption ($1\ ha^{-1}$)	Field capacity ($ha\ hr^{-1}$)
Shallow (D_1)	7.06 b*	9.70 b	0.83 a
Deep (D_2)	16.62 a	15.11 a	0.71 b

* Means followed by the same letter within each column are not significantly different at P=0.01 (DMRT).

Effect of Plow Type

Table 4 shows that using mouldboard plow significantly increased mean values of wheel slip and fuel consumption. This could be attributed to the higher draft requirement of mouldboard plow which displaces, disintegrates and inverts more soil than chisel plow. The results also indicate that higher field capacity was obtained by using chisel plow than mouldboard plow due to its wider width of cut.

Table 4. Comparison of mean values of wheel slip, fuel consumption and field capacity with respect to plow type.

Plow type, P	Wheel slip (%)	Fuel consumption ($l\ ha^{-1}$)	Field capacity ($ha\ hr^{-1}$)
Mouldboard plow (P_1)	14.36 a*	18.83 a	0.43 b
Chisel plow (P_2)	9.28 b	5.97 b	1.11 a

* Means followed by the same letter within each column are not significantly different at P=0.01 (DMRT).

Interaction of Plow Type and Depth

Table 5 shows that the effect of plow type on fuel consumption was significantly higher than that of plowing depth. Using mouldboard plow at shallow depth resulted in higher fuel consumption than chisel plow even at deeper plowing. Higher field capacity of chisel plow at both plowing depths was due to its larger cutting width. Higher draft requirement of mouldboard plow due to its larger degree of soil breaking and inversion caused larger wheel slip and fuel consumption than chisel plow in spite of the chisel larger cutting width.

Table 5. Comparison of mean values of wheel slip, fuel consumption and field capacity with respect to interaction of plow type and plowing depth.

Interactions (DP)	Wheel slip (%)	Fuel consumption ($l\ ha^{-1}$)	Field capacity ($ha\ hr^{-1}$)
$D_1\ P_1$	9.42 c*	15.21 b	0.47 c
$D_1\ P_2$	4.70 d	4.19 d	1.20 a
$D_2\ P_1$	19.36 a	22.46 a	0.39 d
$D_2\ P_2$	13.78 b	7.76 c	1.02 b

* Means followed by the same letter within each column are not significantly different at P=0.01 (DMRT).

Comparing Tractors

Comparison of the mean values of wheel slip, fuel consumption and field capacity of Massey Ferguson 285 and Universal 650 tractors as shown in Table 6 indicated that Massey Ferguson had higher wheel slip and fuel consumption and lower field capacity in tillage operations than Universal. Existence of significancy in comsumption rates in spite of the closeness of their mean values (Table 6) has been due to the fact that fuel consumption is a highly accurate process in diesel engines, making error mean square (EMS) very small (Table 2).

Even though the rear wheels of Massey Ferguson were filled with 500 kg of calcium chloride solution to equalize the static weight on both tractors rear wheels, the test results indicated lower tractive performance of Massey Ferguson. Among the possible factors contributing to the tractive superiority of Universal tractor were longer wheel base, larger drive wheel diameter, lower inflation pressure and greater height of the implement-tractor virtual hitch point. The latest which depends on the geometry and position of the 3-point hitch linkages, determines the amount of the weight transfer on drive wheels. No attempt was made to determine the location of the virtual hitch point on the tractors.

Table 6. Comparison of mean values of wheel slip, fuel consumption and field capacity with respect to tractor type.

Tractor type, T	Wheel slip (%)	Fuel consumption ($l\ ha^{-1}$)	Field capacity ($ha\ hr^{-1}$)
Massey Ferguson (T_1)	14.33 a*	12.5 a	0.63 b
Universal (T_2)	9.33 b	12.3 b	0.91 a

* Means followed by the same letter within each column are not significantly different at P=0.01 (DMRT).

Interaction of Tractor Type and Plowing Depth

Comparison of the mean values considering the interaction of tractor type and plowing depth as shown in Table 7 indicated that Massey Ferguson had larger wheel slip and fuel consumption than Universal at deep plowing and smaller wheel slip and equal fuel consumption at shallow plowing.

As far as field capacity was concerned, Universal had better performance and tractor type had more significant effect than plowing depth.

Table 7. Comparison of mean values of wheel slip, fuel consumption and field capacity with respect to interaction of tractor type and plowing depth.

Interactions (DT)	Wheel slip (%)	Fuel consumption ($l\ ha^{-1}$)	Field capacity ($ha\ hr^{-1}$)
$D_1\ T_1$	6.60 d*	9.66 c	0.69 c
$D_1\ T_2$	7.52 c	9.74 c	0.98 a
$D_2\ T_1$	22.08 a	15.36 a	0.57 d
$D_2\ T_2$	11.15 b	14.90 b	0.85 b

* Means followed by the same letter within each column are not significantly different at P=0.01 (DMRT).

Interaction of Tractor Type and Plow Type

Table 8 shows that Massey Ferguson with chisel plow had the same wheel slip as Universal with mouldboard plow and Massey Ferguson with mouldboard plow had the largest wheel slip. This indicates the superiority of Universal at heavier drafts. This table also shows that Massey Ferguson had the largest and smallest fuel consumptions with mouldboard and chisel plows, respectively. Thus, with increasing the draft load, Massey Ferguson had a higher rate of change in fuel consumption than Universal.

Table 8. Comparison of mean values of wheel slip, fuel consumption and field capacity with respect to interaction of tractor type and plow type.

Interactions (PT)	Wheel slip (%)	Fuel consumption ($l\ ha^{-1}$)	Field capacity ($ha\ hr^{-1}$)
$P_1\ T_1$	17.43 a*	19.34 a	0.34 d
$P_1\ T_2$	11.35 b	18.22 b	0.53 c
$P_2\ T_1$	11.25 b	5.57 d	0.92 b
$P_2\ T_2$	7.32 c	6.38 c	1.30 a

* Means followed by the same letter within each column are not significantly different at P=0.01 (DMRT).

Interaction of Tractor Type, Plow Type and Plowing Depth

Table 9 shows that considering wheel slip and fuel consumption, both tractors acted similarly in shallow plowing but differently in deep plowing. Comparison of mean values also indicated that plow type, tractor type and plowing depth, respectively, had the most influence on field capacity.

Table 9. Comparison of mean values of wheel slip, fuel consumption and field capacity with respect to interaction of tractor type, plow type and plowing depth.

Interactions (DPT)	Wheel slip (%)	Fuel consumption (1 ha^{-1})	Field capacity (ha hr^{-1})
D_1 P_1 T_1	9.13 d*	15.30 c	0.39 f
D_1 P_1 T_2	9.70 d	15.10 c	0.56 e
D_1 P_2 T_1	4.07 e	4.02 f	1.00 c
D_1 P_2 T_2	5.22 e	4.35 f	1.39 a
D_2 P_1 T_1	25.73 a	23.60 a	0.29 g
D_2 P_1 T_2	13.00 c	21.30 b	0.50 e
D_2 P_2 T_1	18.43 b	7.12 e	0.84 d
D_2 P_2 T_2	9.20 d	8.41 d	1.19 b

* Means followed by the same letter within each column are not significantly different at P=0.01 (DMRT).

CONCLUSIONS AND RECOMMENDATIONS

Results of this study indicated that Massey Ferguson 285 had a lower tractive performance than Universal 650 in spite of its higher rated power. This could be attributed to its lower static weight, shorter wheel base, smaller drive wheel diameter and higher tire inflation pressure. The results are in agreement with those of Almasi *et al.* (2).

In order to improve the tractive performance of Massey Ferguson 285 and to prevent its excessive drive wheel slippage and wear, the following recommendations are suggested:

1. Add ballast weight or fill drive wheels with calcium chloride solution when performing high draft tillage operations.
2. Add front mounted weights to provide the possibility of increasing weight transfer to the rear wheels without imparing longitudinal stability of the tractor.
3. Use heavier plows with no gauge wheels in order to transfer larger portion of its weight to the tractor rear wheels.
4. Always select draft control during high draft tillage operations to provide maximum possible traction by increasing drive wheels dynamic load.

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