Comparison of conventional tractors performance during primary tillage in Iran

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Abstract: Primary tillage parameters and their effects on tractor efficiency, fuel consumption management and cost reduction are very important in mechanization. The main goal of this study was to determine some performance parameters in three conventional tractors Massey Ferguson 285(MF 285), Universal 650 (U650) and John Deer 3140 (JD3140) to primary tillage practices in some area of Iran. These parameters are important for selecting tractors to set up mechanization program in a large scale. The sampling method was random in 10 regions with seven replications. After data gathering, results were analyzed using SPSS software. Results indicated that average drawbar power for plowing without considering of area and tractor type was 15 kW. The maximum and minimum drawbar powers were 19.20 kW and 11.10 kW for Esfahan and Fars areas respectively at 1% level significance. There were significant differences between values of rolling resistance of JD3140 tractor with other tractors at 1% level of significance. Besides, no significant differences were observed between tractors of U650 and MF285. Slippage percentage was similar for most areas. The maximum and minimum slippage was recorded for MF285 tractor in Moghan area and JD3140 tractor in Esfahan area respectively. The optimum soil moisture was 15% for slippage reduction. Average Power Delivery Efficiency (PDE) was 25.5%. It was low in comparison with world standards and requires improvement. Tractor of JD3140 had maximum fuel consumption (0.012 $m^3 h^{-1}$) as compared to other types of tractor. Use of the U650 tractor was recommended to farmer and other data can be used for mechanization programs.

Keywords: drawbar power, primary tillage, slippage, primary tillage parameters, rolling resistance

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1 Introduction

Mechanization indices are important factors so that determination of these indices plays important roles for agricultural sector managers to make correct decisions. Primary tillage parameters such as draft force, slippage, drawbar power, fuel consumption, rolling resistance, and power delivery efficiency affect on tractor efficiency, reduction of energy consumption and decrease of mechanization expenditures. One of the problems in agricultural mechanization was lack of information about mechanization parameters. After obtaining these parameters, calculation of mechanization in big scale will be reliable. The objective of this research was to determine these parameters for development of mechanization program.

Draft and power requirements are important parameters for measuring and evaluating performance of tillage implements. Taniguchi *et al.* (1999) studied the effects of forward speed and optional plow attachments on draft of moldboard plow using an open-air soil bin. The results indicated that draft increased with increase in travel speed but that the rate of changes differed with speed levels and increases in speed and the use of a cover board and a plow extension resulted in more pulverization. Draw bar power has a direct relationship with soil moisture and plot type. The draw bar power has maximum value in soil with 8.65% moisture content

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using three-bottom plow and has minimum value in soil with 16%-18% moisture content using chisel plow (Rozbeh *et al.,* 2001). The effects of tillage depth and forward speed on draft of moldboard, disk and chisel plows on sandy loam soil were evaluated. The results showed that draft increased with increases of forward speed and tillage depth for all the implements and the moldboard and chisel plow had highest and lowest specific draft, respectively (Al-Suhaibani *et al.,* 2010). Traction and drawbar power were increased with enhancement of forward speed. Reshadsedghi *et al.,* (2000) concluded that, 16%-18% (dry base) of soil moisture content and 5-7 km h^{-1} for forward speed were best for tillage. MF 285, U650 and ITM tractors had maximum, minimum and median slippages (15.6%, 6.7% and 13.3%) respectively (Khosravani *et al.,* 1998).

The primary purpose of agricultural tractors is to provide drawbar work since drawbar is the most commonly used power outlet of a tractor, the ability to provide draft to pull various types of implements is a primary measure of the effectiveness of a tractor. Drawbar work is achieved through the drive wheel to move the tractor and its implements through the soil (Kathirvel *et al.*, 2001). Drawbar work can be expressed as the product of pull and travel speed. Therefore, the ideal tractor converts all the energy from the fuel into useful work at the drawbar. In practice, most of the potential energy is lost in the conversion of chemical energy to mechanical energy, along with losses from the engine through the drive train and finally through the tractive device (Zoz and Grisso, 2003). Reports from literature indicate that about 20% to 55% of the available tractor energy is wasted wears at the tractive device-soil interface. This energy wears the tires and compacts the soil to a degree that may cause detrimental crop production (Burr *et al.*, 1982; Baloch *et al.*, 1991; Zoz and Grisso, 2003).

A John Deere 8295R IVT tractor with a continuously variable transmission (CVT) and a John Deere 8295R Power Shift (PST) tractor with a standard geared transmission (GT) were tested for fuel consumption at three different travel speeds with six different load levels applied per speed. The JD 8295R PST tractor was tested both at full throttle (FT) and shifted up two gears and throttled back (SUTB) to achieve the same travel speed as at full throttle. For each travel speed with each transmission mode, fuel consumption was determined to be linearly related to drawbar power. Linear regression analyses were performed, and the results showed that the tractor with the CVT was more fuel efficient than the tractor with the GT at FT when the power was below 76% to 81% of maximum drawbar power depending on the travel speed (Howard *et al.*, 2013). The tillage implement and the plowing speed affected on the energy required for plowing a unit area (SEA) and the energy required for plowing a unit volume (SEV) by increasing the plowing speed from 0.89 to 1.92, from 0.89 to 1.62 and from 1.11 to 2.06 m s^{-1} (Khaffaf *et al.*, 2008).

The speed of operation, width of cut, depth of cut, type of soil, and skill of operator affects fuel consumption (Bukhari and Baloch, 1982). The normal range for the overall energy efficiency (OEE) is 10% to 20% and this can be used as a quick check of the validity of fuel consumption measurements, where energy is the specific implement energy and fuel is the fuel consumption under load (Bowers, 1985). The field tests showed significant enhance in the draft with increases in the depth and speed. A general regression equation to predict draft of the implements was developed. Average annual use of tractors was between 200-250 h and fuel consumption was 0.010-0.015 m^3 h^{-1} for 50 kW tractors (Saruth *et al.*, 1998). Fuel specific consumption depended on drawbar power (Smith, 1989). Results indicate that Mahindra tractor Model 605 DI performed better than the other two models during both ploughing and harrowing operations with respect to the parameters evaluated. The 605DI model was therefore recommended among the three tractors from the standpoint of operational efficiency and economy (Suhaibani *et al.*, 2010).

The objective of this study was to survey performance of conventional tractors during primary tillage, besides, to find problems and to modify them in order to direct farmers in selecting suitable tractor-implement combination and to develop programs of agricultural mechanization in Iran.

2 Materials and method

This research was carried out in ten areas of Iran for two years. At first, in each region, soil moisture content and soil texture were determined as Table 1. Primary tillage parameters investigated using three conventional tractors in Iran as Massey Ferguson 285(MF 285), Universal 650 (U650) and John Deer 3140 (JD3140). Specifications of these tractors presented in Table 2.

Table 1 Soil moisture content (%) and soil texture in different areas

Area		Tehran	Fras	Esfahan	Khoozestan	Markazi	Hamedan	Semnan	Khorasan	Charmahal	Moghan
Soil texture		Sandy loam	loam	Sandy loam	Clay	loam	sandyloam	Clay loam	Clay loam	Sandy loam	Clay and clay loam
Soil moisture content	m *	14.02	16.3	4	16.9	9.32	14.5	17.97	12.5	13.9	21.7
	SD**	3.26	5.35	2	1.31	3.39	3.89	4.87	1.84	3.07	3.29

Note: *m= mean; **SD = Standard Deviation.

Table 2 Specification of three type tractors

Specification	Model of tractor		
	U650	MF285	JD3140
Effective output (hp)	65	75	110
Type of fuel	Diesel	Diesel	Diesel
Type of steering system	Mechanical	Mechanical- hydraulic	Hydraulic
Transmission	Gears	Gears	Synchronized gears
Type of injector pump	In line	Rotary	Rotary
Firing order	1342	1342	153624
Fuel tank capacity (L)	125	90	125.9
Lifting capacity (kg)	1100	2227	4020
Rated engine speed (rpm)	1800	2000	2400
Type of cooling system	Liquid-cooled	Liquid-cooled	Liquid-cooled
Country of manufacture	Romania - Iran	England - Iran	Germany - USA
Front tires size (inch)	6.5-20	7.5-15	10.0-16
Rear tires size (inch)	14-38	18.4-30	18.4-34
Weight (kg)	2980	2540	3855
Operating width of mold board (cm)	90	90	110

Forward speed, work width and depth of plowing were measured during plowing by moldboard plow. Then draft force of implements, drawbar power, slippage percentage, fuel consumption and power delivery efficiency and traction efficiency was determined. Relationships between draft force with depth and forward speed showed graphically.

2.1 Forward speed

Outside the long boundary of the test plot, two poles of 20 m apart were placed approximately in the middle of the test run. Two poles in the similar position 20 m apart were placed in opposite side of initial poles position, so that all four poles form corners of a rectangle, parallel to one long side of the test plot. The speed was calculated as the ratio of the distance (20 m) to the time required by the machine to travel the distance.

2.2 Draft force of implements

Draft was measured using a digital dynamometer attached to the front of the tractor on which the implement was mounted. Another auxiliary tractor was used to pull the implement-mounted tractor through the dynamometer. The auxiliary tractor pulled the implement-mounted tractor with the latter in neutral gear but with the implement in the operating position. Draft was recorded in the measured distance (20 m) as well as the time required to traverse the distance. On the same field, the implement was lifted out of the ground and the draft recorded. The difference between the two readings is the draft of the implement. This procedure was repeated for each of the tractors evaluated.

2.3 Drawbar power

Drawbar power was evaluated using the relation between draft and speed as follows. (Srivastava et al., 1993)

$$P_{db} = (\frac{D \times S}{3.6}) \quad (1)$$

where, *n* this equation P_{db} is drawbar power required for the implement, kW; *D* is implement draft, kN; *S* is travel speed, km h^{-1}.

2.4 Slippage percentage

The distance tractor moves forward in a given number of revolutions of the drive wheel decreases when wheel slip. The amount of wheel slip was measured using a mark on the tractor drive wheel with colored tapes and the distance the tractor moved forward was measured, 10 revolutions under no load (L_1) and on the same surface with the same number of revolutions with load (L_2). Percentage of wheel slip (*S*) was calculated using following Equation 2.

$$S = (\frac{L_1 - L_2}{L_1}) \times 100 \quad (2)$$

2.5 Fuel consumption

The fuel required for each tillage operation was determined by filling the tank to full capacity before and after the test. Amount of refueling after each test is the fuel consumption for the test.

2.6 Specific fuel consumption (SFCv)

The fuel consumption characteristics of an engine are generally expressed in terms of specific fuel consumption in Liter per hour of fuel per kilowatt or (Lit (kW h)$^{-1}$) with considering traction efficiency (%) and fuel consumption (Lit h^{-1}), maximum power (*Q*) was determined by the following formula (Srivastava et al., 1993):

$$Q = SFC_v \times P_{pto} \quad (3)$$

where, P_{pto}= Power take of equivalent.

2.7 Traction efficiency

It is defined as the ratio of output power to the input power for a traction device. It is the measure of efficiency with which the traction device transforms the torque acting on the axle into linear drawbar pull. The traction efficiency of tractors was calculated using Equation (4) (Srivastava et al., 1993; Barger et al., 1967).

$$T.E = \frac{P}{P+R}(1-S) \quad (4)$$

where, *T.E* = tractive efficiency, %; *P* = pull, N; *P*+*R*= gross thrust force acting on the wheel.

2.8 Power delivery efficiency

Power Delivery Efficiency (PDE) is defined as the ratio of the delivered drawbar power of a tractor to the vehicle input power of the tractor. It represents the percentage of power produced by the engine of a tractor that is available as tractive power delivered through the drawbar. If engine power cannot be measured on a tractor but the tractor has a Power Take-Off (PTO) shaft, equivalent PTO power can be used for the PDE calculation (5). In this research equivalent PTO power was used (Srivastava et al., 1993).

$$PDE = \frac{Drawbar\ power}{Equvalent\ PTO\ power} \quad (5)$$

2.9 Rolling resistance

Rolling resistance of a tractor was measured by a dummy tractor towing the test tractor through load cell connected in between with a digital load indicator. Rear tractor was kept in neutral position while the front tractor pulled the rear one. The reading of load indicator was noted from digital indicator at fixed interval of time. An average of four readings was considered in computing the force required to pull a tractor.

For each tractor the number of samples was 7 in area (7 replications) that for one year total of samples was 210 and for two year was 420 (10 samples were misleading). The total number of samples was 410 during two years. Cluster sampling method was used for statistical analysis. Some data was gathered from farmers and others measured in the field. Three types of conventional tractor in Iran (MF285, U650 and John Deer 3140) were evaluated in eleven areas. After recording all observations and information data were analyzed using the ANOVA and the mean comparisons were determined using Duncan’s multiple range tests (SPSS-15 software) and results reported.

3 Results and discussion

3.1 Draft force and power requirement

Draft force without considering of the tractor type was different between areas. Relationships between draft and speed showed that with increasing forward speed, draft increased (Figure 1). The maximum draft was 17 kN with 5.4 km h^{-1} speed. Average power requirement for tillage by moldboard plow was 15 kW without considering area and tractor type (Reshadsedghi *et al*., 1997). Interaction effects between treatments for Tractor-area were significant at 5% level. On the other hand, not only there was a significant difference between areas, but also tractors were different in terms of tillage power consumption. Power requirement was different for tillage in different areas. Therefore, the tractors must be selected according to power requirements. Maximum power requirement for Esfahan area was 19.20 kW and minimum power requirement for tillage practices obtained 11.10 and 11.32 kW in Fars and Markazi areas respectively. These areas had a significant difference to each other at 1% level. Thus, it is recommended that higher power tractors be used for Esfahan and lower power tractors for Fars and Markazi areas.

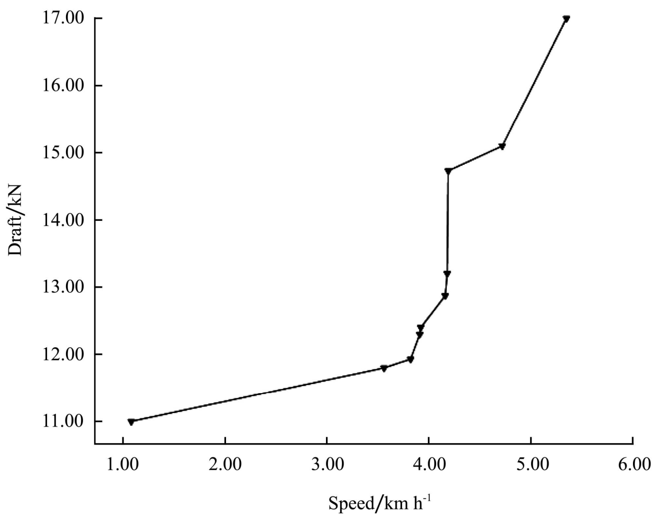

Figure 1 Relationships between draft and forward speed

The different soil texture, moisture content, previous crops, different ages of implements and using methods of tractors were main reasons for different power requirements. There was a significant difference between JD 3140 tractors with average 17.43 kW and other types from aspect of power requirements, but there was no significant difference between U650 and MF285 tractors at 1% level. The John Deer Tractor (JD 3140) had maximum power requirement in Esfahan area and U650 tractor had minimum power requirement in Fars area. One of the reasons for higher power requirement was performance of tillage practices with more depth in JD 3140 tractor (Table 3).

Table 3 Comparison of power requirement in the different areas

Area	Power/kW	Gabriel test	
		5%	1%
Chaharmahal	15.60	c	bc
Hamedan	14.34	de	cd
Markazi	11.32	g	e
Moghan	16.54	ab	ab
Esfahan	19.20	a	a
Tehran	14.85	cd	cd
Khoozestan	13.31	f	de
Khorasan	15.37	cd	cd
Semnan	13.45	ef	de
Fars	11.11	g	e

3.2 Slippage

Non-linear correlation was found between soil moisture content and slippage in three types of tractors. As observed in Figure 2, Slippage percent decreased with 15% soil moisture content (Figure 2). This figure indicates slippage is high in low soil moisture content and also in soil with high moisture content, it was minimum in 10%-20% of soil moisture content and had a significant difference in different areas. The maximum slippage was belonging to MF285 tractor in Moghan area (27.1%) and minimum was belonging to JD 3140 tractor in Esfahan area (11.6%).

There was no any significant difference between U650 and JD3140 tractors for slippage percent. The lowest and highest slippage percent (without considering of areas) were obtained by MF285 and U650 tractors respectively (Table 4).

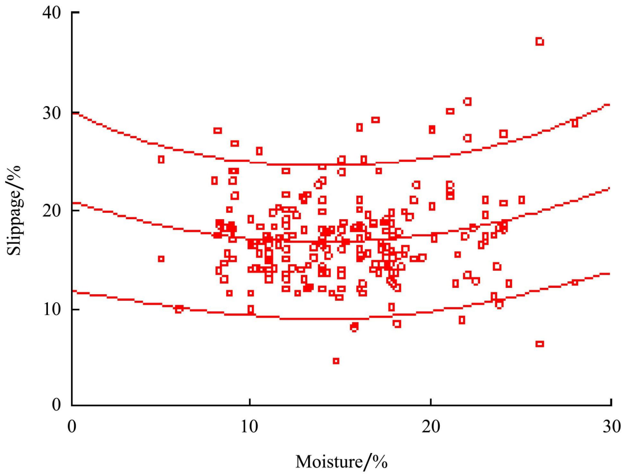

Figure 2 Correlation between tractors slippage percentage and soil moisture contents

Table 4 Comparison of tractor wheels slippage

Tractor	Slippage/%	Gabriel test	
		5%	1%
JD3140	15.5	b	b
MF285	18.2	a	a
U650	14.6	c	b

3.3 Rolling resistance

This parameter was different in the experimental areas with considering tractors weight, soil conditions. This factor resists against moving of tractor. Rolling resistance factor was different between tractors at 1% level of significance. Rolling resistance of JD3140 tractor was different in comparison with other types of tractors. However, there was not any significant difference between U650 and MF285 tractors (Table 5). The higher rolling resistance in JD 3140 tractor was due to higher weight and more tillage depth in this tractor in comparison with U650 and MF285 tractors.

Table 5 Comparison of tractors wheel rolling resistance

Tractor	Rolling resistance /kN	Gabriel test	
		5%	1%
JD3140	3.3	a	a
MF285	2.6	b	b
U650	2.6	b	b

3.4 Traction efficiency and power delivery efficiency

Results of traction efficiency and power delivery efficiency for the tractors are indicated in Table 6. Observation showed that the highest and lowest draft force were obtained by JD 3140 and U650 respectively. Values of traction efficiency were almost the same for JD 3140 and U 650. However, MF285 tractor had the lowest traction efficiency among three types of tractors.

Table 6 Traction and power delivery efficiencies

Parameters	JD 3140	U650	MF285
Speed/km h^{-1}	4	4.6	3.9
Draft force/kN	15.9	10.8	12.4
Slippage/%	15.5	14.6	18.2
Rolling resistance/kN	3.3	2.6	2.6
Traction Efficiency/%	70	69	67
Power delivery efficiency/%	24.1	28.2	24.2

3.5 Fuel consumption

Fuel consumption differed between each tractors (Table 7). The highest and lowest fuel consumption was obtained by JD 3140 tractor (12.4 L h^{-1}) and MF 285 tractor (9 L h^{-1}) respectively. This parameter was 11 L h^{-1} for U 650 tractor.

Table 7 Fuel consumption of tractors

Tractor	Fuel consumption/L h^{-1}	Gabriel test	
		5%	1%
JD3140	12.4	a	a
MF285	9	c	c
U650	11	b	b

Relationships between operating depth and fuel consumption without considering of tractor type showed that with increasing of depth, fuel consumption increased in ten areas (Figure 3).

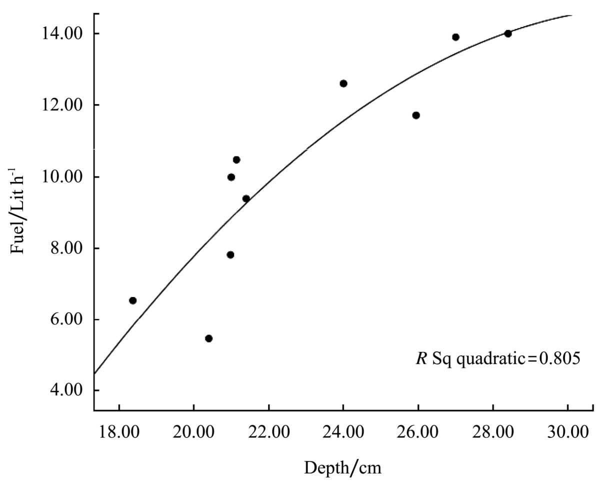

Figure 3 Relationships between operating depth (cm) and fuel consumption (Lit h^{-1})

Using traction efficiency (Table 5), fuel consumption (Table 6) and P_{Pto} equivalent Power, Specific Fuel Consumption (SFC_v) was presented in Table 8. In this table tractor U 650 had maximum SFC_v significantly.

Table 8 Specific fuel consumption of tractors

Tractor	SFC_v (L kwh)	Gabriel test	
		5%	1%
JD3140	0.22	c	c
MF285	0.24	b	b
U650	0.33	a	a

4 Conclusion

Power Delivery Efficiencies (PDE) for JD3140, U650 and MF285 tractors were determined 24.1%, 28.7%, and 24.2% respectively. These results indicated, PDE is low in different tractors and about 75% of nominal power is lost from engine to draw bar. The main loss was due to power transmission from wheel axle to draw bar. The average of PDE was 25.7% and less than world average (40% to 45%). This parameter increases with adding of tractor weight, changing of soil moisture content, and reducing of rolling resistance. The optimum soil moisture content during performance of tillage practices for minimum slippage of tractor wheels was 15%. Using ballast weights is recommended for MF285 tractors in comparison with rest of tractors (JD3140 and U650). There was non-linear correlation between slippage of tractors wheel and soil moisture content. The maximum slippage was measured in zero and thirty percent of soil moisture contents and minimum slippage was obtained in 15% soil moisture content.

5 Recommendation

U650 tractor indicated low power requirement, low slippage, and high PDE. Besides, this type of tractor has simple technology and adjustments in comparison with MF285 and JD3140 tractors. Thus, most of Iranian farmers are interested in using U650 tractors to perform agricultural practices. However, fuel consumption of U650 tractor was higher than MF285 tractor. It is due to aging of U650 tractors as compared with MF285 tractors. To solve this problem it could be suggested that new universal tractors be substituted with old universal tractors. However the fuel price in Iran is cheaper than most countries in the world and the high fuel consumption is not serious problem for this type of tractors.

References

Al-Suhaibani, S. A., and A. A. Al-Janobi. 1997. Draught requirements of tillage implements operating on sandy loam soil. *Journal of Agricultural Engineering Researches*, 66: 177-182.

Baloch, M. J., B. A. Mirani, and S. Bukhari. 1991. Prediction of field performance of wheel tractors. *AMA*, 22(4): 21-24.

Barger, E. L., J. B. Liljedahl, and E. C. McKibben. 1967. Tractors and their power units. New Delhi, India: Wiley Eastern.

Bowers, J. C. G. 1985. Southeastern tillage energy data and recommended reporting. *Transaction of the ASAE,* 28(3): 731-737.

Bukhari, Sh. B., and J. M. Baloch. 1982. Fuel consumption of tillage implements. *AMA,* Vol. (13): 20-22.

Burr, E. C., P. W. L. Lyne, P. Metring, and J. F. Keen. 1982. Ballast and inflation pressure effects on tractive efficiency. ASAE paper No. 82 – 1567. St. Joseph, MI: ASAE.

Howard, C. N., M. F. Kocher, R. M. Hoy, and E. E. Blankenship. 2013. Testing the fuel efficiency of tractors with continuously variable and standard. *Transactions of the ASABE*, 56(3): 869-879.

Kathirvel, K., Manian R., and M. Balasubramanian. 2001. Tractive performance of power tiller tyres. *Agricultural Mechanization in Asia, African and Latin America*, 32(2): 32-36.

Khaffaf, A., and A. Khadr. 2008. Effect of some primary tillage implement on soil pulverization and specific energy. Misr J. Ag. Eng., 25(3): 731-745.

Khosravani, A., M. Loghvi, and A. Solhjoo. 1998. Evaluation and comparison of traction performance of middle power tractors in Iran (in Farsi). In *Proc.* 1st National Congress of Agricultural Machinery Engineering and Mechanization, 34-41, Karaj, Iran.

Reshadsedghi, A., Loghavi M., and A. Solhjoo. 2000. First Agricultural Mechanization Conference, 2000: Evaluation of traction resistance and soil pulverization in different speed and soil moisture by offset disk (in Farsi). Karaj, Iran, p: 124-132.

Roozbeh, M., M. Almasi, and A. Hemmat. 2001. Evaluation and comparison of requirement energy for corn tillage (in Farsi). *Journal of Natural Resources and Agricultural Sciences of Gorgan*, 16 (1): 117-128.

Saruth, C., and D. Gee-Clough. 1998. Agriculture mechanization in Cambodia: A case study in Takeo province. *Journal of Agricultural Mechanization in Asia, Africa and Latin America,* 29 (2): 561-570.

Srivastava, A. K., C. E. Goering, and R. P. Rohrbach. 1993. Engineering principles of agricultural machines. American Society of Agricultural Engineers. St. Joseph, MI, USA.

Smith, L. A. 1989. Power requirement for implements used in cotton and soybean production system. *Transaction of the ASAE,* 32 (1): 17-24.

Suhaibani, S. A. Al., A. A. Al-Janobi and Y. N. Al-Majhadi. 2010. Development and evaluation of tractors and tillage implements instrumentation system. *American Journal of Engineering and Applied Sciences,* 3 (2): 363-371.

Taniguchi, T., J. T. Makanga, and K. Kishimoto. 1999. Draft and manipulation by a moldboard plow under different forward speed and body attachments. *Transactions of the ASAE*, 42(6): 1517-1521.

Zoz, F. M., and R. D. Grisso. 2003. Agricultural Equipment Technology Conference, February 9 – 11, 2003: Traction and tractor performance. Louisville, Kentucky, USA.