World Applied Sciences Journal 21 (12): 1789-1794, 2013
ISSN 1818-4952

DOI: 10.5829/idosi.wasj.2013.21.12.2595

Draft Force Inputs for Primary and Secondary Tillage Implements in a Clay Loam Soil

Mohammad Askari and Smail Khalifahamzehghasem

Department of Agricultural Machinery Engineering,
Faculty of Agricultural Technology and Natural Resources, University of Mohaghegh Ardebili, Ardebil, Iran

Abstract: Tillage is the base operation in agriculture and its energy represents a considerable portion of the energy utilized in crop production. To measure the implement force requirements, are used dynamometers that are pull or three-point hitch types. In this research, an 82 kW research tractor equipped with an instrumentation system was used to determine the draft force inputs for four common tillage Implements applied to a clay loam soil in west Azarbaijan, Iran. Implements included moldboard plow plus chisel plow as primary and disk harrow plus field cultivator as secondary implements. Operating depth for the primary and secondary implements was about 250 and 100 mm, respectively. Draft measurements were compared to those predicted by ASABE Standard D497.5 (ASABE Standards, 2006) and were found to vary. It was declared that draft force of moldboard plow and field cultivator was about 2.14 and 1.8 times as much as the chisel plow and disk harrow, respectively. The large difference in implement draft indicates that substantial energy savings can be readily obtained by selecting energy-efficient tillage implements.

Key words: Agricultural dynamometers · Draught requirement · Instrumentation · Plow

INTRODUCTION

Agricultural production in the world will be increased many fold in response to an ever growing demand for food by the domestic and world population. Increasing the production while maintaining or reducing the energy inputs will be needed to provide food in the future years to come when energy resources is limited. Crop production systems currently being utilized must be evaluated for energy efficiency and then alternative systems proposed and evaluated [1]. Tillage is the base operation in agricultural systems and its energy represents a considerable portion of the energy utilized in crop production [2]. The availability of draft requirement data of tillage implements is an important factor in selection of machinery, matching of implements to tractors and estimating fuel consumption for a particular farming situation [3]. In general, measuring the draft requirements of tillage tools is accomplished by the dynamometers which in turn could be grouped into two major categories; drawbar dynamometers and three-point hitch dynamometers [4]. Many research studies have been done on measuring energy inputs for tillage implements. Field measurement methods include three-point hitch dynamometers instrumented with strain gauges [4] and [5], instrumented toolbars for attachment of different tillage tools [6] and drawbar transducers for trailed implements [7], [8] and [9]. Laboratory soil bin studies are usually done with single tillage tools mounted on an instrumented tool carrier [10]. Much of the research has focused on studying parameters that affect tillage implement draft and on developing draft prediction equations and methods [3], [11], [12] and [13]. Many of the results of research on tillage implement draft have been summarized in ASABE Standard D497.5 [14]. This standard uses a simplified draft prediction equation proposed by [11]:

$$D = F_i\,[A + B\times S + C\times S^2]\,W\,T \qquad (1)$$

Where D is the implement draft force; F_i is a dimensionless soil texture adjustment parameter with

Corresponding Author: Mohammad Askari, Department of Agricultural Machinery Engineering, Faculty of Agricultural Technology and Natural Resources, University of Mohaghegh Ardebili, Ardebil, P.O Box: 165, Iran. Tel: +98-9359915284, Fax: +98-4512779558.

different values for fine, medium and coarse textured soils; A, B and C are machine-specific parameters; S is field speed; W is implement width; and T is tillage depth. The objective of the standard is to provide a draft prediction equation that is applicable to a wide range of soil conditions. The standard provides a good estimate of tillage implement draft but indicates that a range in draft of up to ±50% can be expected within the same broad textural soil class [15]. There are many types of tillage systems such as different combinations of moldboard plow or other plows as primary and field cultivator, disk harrow or other harrows as secondary implements. Draft and energy data for many of these systems are sparse or non-existent. Energy input data for a range of conventional primary and secondary tillage implements under local conditions are essential for selecting the most energy-efficient systems. Also, past global researches indicated that the draft requirement of chisel plow was about half of the draft requirement of the moldboard plow in equal width and depth operation. Recently, extensive activities for replacing moldboard plow by chisel plow in dry farming have been done [16].

The Objectives of this Study Were as Follows:

- To measure and present the energy requirements for four conventional tillage implements applied to a clay loam soil.
- To compare the draft requirements of each one of primary implements by the other and secondary implements, too. It means, which of them requires the less draft consequently could be selected the less fuel consumer combination or actually, could be done the less cost.
- To realize be true or not be the consequences of past researches that showed the draft requirement of chisel plow was about half of draft requirement of the moldboard plow in equal width and depth operation.
- To verify the applicability of the ASABE standard equation for predicting the draft force of tillage implements in west Azarbaijan, Iran.

MATERIALS AND METHODS

Field Site: The experiment was conducted at the Urmia University Research Farm, Urmia, Iran. The topography was flat (<1% slope) and the soil type was a clay loam (29% sand, 28% silt and 43% clay), which was poorly drained and poorly aerated. Average organic carbon content was 0.74 weight % and average pH was 7.8.

Pre-tillage Soil Physical Characterization: The properties and parameters of soil that have effect on draft force and energy needed for implements include: soil moisture content, bulk density, cone index and soil structure [17] and [18]. The effects of these parameters are reported by many experts. Soil moisture and other physical properties were measured at 10 points and 2 ranges of soil depth (0-125 and 125-250 mm). Soil samples were weighed, oven dried at 105°C for 24 h and weighed again. Moisture percentages were calculated on a dry basis. Results are detailed in Table 1. Soil cone index was measured at 20 points over the 0-260 mm depth range immediately before tillage using a manually operated cone penetrometer (RIMIK CP20, AGRIDRY, Toowomba, Queensland, Australia). Detailed results of this test are depicted in Figure 1. The soil cone index values were below 2.0 MPa, indicating that soil strength was not sufficient to appreciably impede root growth [15].

Tillage Implements: The implements are representative of the standard primary and secondary tillage implements most commonly used for seed bed preparation in Iran and region. They were owned by the department of agricultural machinery engineering, Urmia University. A general description of each implement is provided in the following paragraphs, Implements structural properties and subjected condition in field tests are detailed in Table 2 and photos of four of the implements are shown in Figures 2 to 5.

Table 1: Obtained data from soil analysis at 10 points and 2 depths consisting of 0 –125 and 125 –250 mm

Mass water content(db)	Porosity	Void Ratio	Particle density g/cm^3	degree of saturation
8.26	0.52	1.08	2.49	0.205

Table 2: Implements structural properties and subjected condition in field study

Implements	tools	Work width (mm)	Work depth (mm)	Forward speed (Km/h)
Moldboard plow	3	1100	250	3.4
Chisel plow	5	2220	250	3.4
Disk harrow	-	2060	100	5.5
Field cultivator	9	2200	100	5.5

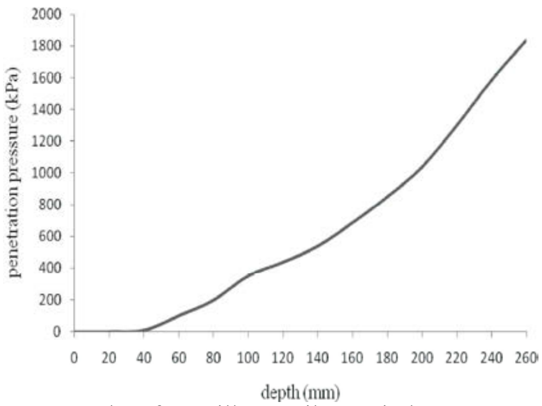

Fig. 1: Results of pre-tillage soil cone index

Fig. 2: The three furrow mounted moldboard plow with 365 mm Furrow width.

Fig. 3: The chisel plow with five shanks mounted on one toolbar. The soil engaging tools were 50 mm wide straight chisels spaced at 445 mm.

Moldboard Plow: The moldboard plow was a three furrow mounted plow. Furrow width was set to 365 mm and plowing depth was set to 250 mm.

Fig. 4: The disk harrow consisted with two gangs of 400 mm dia. Disk spacing on the gangs was 200 mm.

Fig. 5: The field cultivator with nine shanks mounted in a staggered arrangement on two gangs. The soil engaging tools were 100 mm wide twisted chisels spaced at 245 mm.

Fig. 6: Field test of implements (here moldboard plow) by using the instrumentation system and MF399 tractor

Chisel Plow: The chisel plow had five shanks mounted on one toolbar. The soil engaging tools were 50 mm wide straight chisels spaced at 445 mm and were set to operate at 250 mm depth.

Disk Harrow: The disk harrow consisted of two gangs and concave disks angled in opposite directions. Disk spacing on the gangs was 200 mm. There was provision for adding ballast weights to the implement; consequently, the maximum operating depth of the disks was about 100 mm by the weight of the implement, ballast weights and the soil conditions.

Field Cultivator: The cultivator had nine shanks mounted in a staggered arrangement on two gangs. The soil engaging tools were 100 mm wide twisted chisels spaced at 245 mm and were set to operate at 100 mm depth.

Equipment Setup and Field Tests: Field tests consisted of two stages. First, a practice area was used to set and adjust the operational depth of the tillage implement and to determine the gear selection and engine speed that would provide the needed ground speed at a reasonable load matching of the implement and tractor. Stage two consisted of conducting the tillage tests and collecting data (Fig.6). Intended ground speeds were 3.4 km/h for primary and 5.5 km/h for secondary tillage operations (Table 2). Tillage depth and speed were set to be within the ranges normally used for both the implement type and the soil type in the region. Work depth of implements was set by applying stops to limit travel of the hydraulic cylinders on the tractor three-point hitch and the dynamometer arms. The moldboard plow was narrower than the other implements and required almost two times as many passes to cover the same land area. Applied instrumentation system included a novel three-point hitch dynamometer and a data acquisition system. The complete description of the instrumentation system is given by [4]. An FWA tractor, Massey Fergusson model MF-399 (ITM, Tabriz, Iran) with a net engine power of 82 kW (110 hp), was used in all the tests. This tractor is fitted with an onboard data logger to allow measurement and recording of implement draft force as the tractor performs normal field work. The data logger was adjusted to record the dynamometer signals with frequency of 1.3 Hz (78 data in min) for primary implements and 2.1 Hz (126 data in min) for secondary implements (this was for equal number of obtained data about all implements). The tillage implements were set up and adjusted in the plots area. For each implement, tests were repeated four times, so altogether 16 experimental plots, 3 m wide by 30 m long, were obtained. Indeed, tests were performed in a route of 30 m and the data acquisition was accomplished at the distance interval of 10-25 m field plots. Approximately, 10 m was used prior to the beginning of the experimental plots to enable the tractor and implement to reach steady state ground speed and implement depth. Stake lines at either end of the plot provided a visual cue for the data logger operator to start and stop the tractor data logger at either end of the plot. The implements were periodically unhitched from the dynamometer and next implement was hitched. The implements were mounted on the dynamometer three-point hitch via a quick hitch attachment. The quick hitch system facilitated frequent unhitching of the implements. After the experiment and transferring the data into the notebook computer, means were calculated from the 21 individual measurements logged during the interval required to travel 15 m.

RESULTS AND DISCUSSION

Results of measuring the draft requirement of implements in field tests are illustrated in Table 3 and Figure7. It is important to note that the changes in draft resistance (Fig. 7) are caused due to soil failure. The draft force ranged from a minimum of about 1.8 kN for the disk harrow to a maximum of nearly 16.3 kN for the moldboard plow (Table 3). This large variation was due to the difference in forward speed, work depth and width of the tillage implements. These data could be used by local farmers for selecting the best combination of tillage implements, size of tractor and tractor implement match. ASABE Standard D497.5 [14] defines tillage implement draft and this definition will be used for the remainder of this article. The standard provides coefficients for equation 1 to calculate draft for general classes of tillage implements at a given speed and depth for three broad classes of soil texture, fine, medium and coarse. The ASABE data overestimated the moldboard plow, disk harrow and field cultivator by 20%, 26% and 9%, respectively and underestimated the chisel plow by about 11% (Table 3). The ASABE coefficients are for a wide range of soil conditions and consequently cannot be expected to yield accurate estimates for a given situation; the ASABE Standard indicates an expected range of ±25% to ±50% for the various tillage implements [15]. Except for the disk harrow, where the calculations overestimated measured draft by 26%, the measured draft was within the expected range of draft given in the ASABE Standard.

Table 3: Draft (kN) for primary and secondary tillage implements used in the study

Implement	Dynamometer average data	ASABE Estimate
Moldboard plow	16.30	19.55
Chisel plow	15.41	13.67
Disk harrow	1.80	2.28
Field cultivator	3.49	3.82

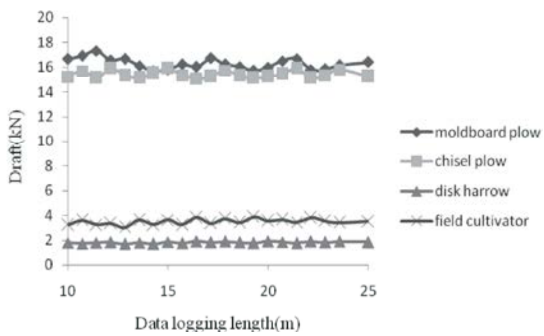

Fig. 7: Draft forces of the implements obtained in field tests.

By considering the obtained draft forces from field tests (Table3) and work width of the all implements, it shows that in the equal work width (1meter), mold board plow draft was 2.14 times as much as the chisel plow draft requirement and field cultivator draft was 1.8 times as much as the disk harrow draft requirement. This result shows that Consequence of past global researches about the relevance between draft requirement of moldboard and chisel plow was indefeasible and would be certified. As the primary purpose of this study was to measure and compare draft for the different implements, we used the implements that were common and available and we did not make any attempt to optimize the tractor operating parameters or tractor implement match. Many factors influence the size of tractors and tillage equipment acquired on farms and mismatched tractor implement combinations are common. Changing cultural practices, the availability of capital, personal preferences and opinions and the availability of used or new equipment from the machinery dealer when the farmer makes a decision to purchase can influence the size of equipment on farms. The range of tractor-implement match for the tillage equipment used in this experiment was considered “typical” of that found on many farms in Iran. As stated earlier by [15], Implement draft, which is dimensionally equivalent to drawbar energy, is independent of the tractor parameters and therefore is an appropriate parameter to use for comparing energy requirements for the different tillage implements.

CONCLUSION

A field experiment was conducted to measure, compare and present the draft and energy inputs for four primary and secondary tillage implements (moldboard plow, chisel plow, disk harrow and field cultivator), in a clay loam soil in west Azarbaijan, Iran. The implements were operated at speeds and depths typically used by commercial farms in the area. Draft measurements were compared to those predicted by ASABE Standard D497.5 [14] and were found to vary. Except for the disk harrow, where the calculations overestimated measured draft by 26%, the measured draft was within the expected range of draft given in the ASABE Standard. Consequently, was verified the applicability of ASABE standard equation for predicting the draft force of tillage implements in west Azarbaijan, Iran. It was declared that draft force of moldboard plow and field cultivator was about 2.14 and 1.8 times as much as the chisel plow and disk harrow, respectively. Consequence of past global researches about the relevance between draft requirement of moldboard and chisel plow was indefeasible and would be certified. The large difference in energy data obtained in this study show that substantial energy savings can be realized by selecting energy-efficient tillage systems. The tillage energy data need to be combined with other agronomic and soils data to select the optimum tillage system for a particular soil and climatic region.

ACKNOWLEDGEMENTS

The authors express their appreciation to the support staff of the Department of Agricultural Machinery Engineering at Urmia University special Nemat Nobakht, Masoome Asgari and Zhila Ghorbani, for their contribution in field operations and data analysis.

REFERENCES

1. Bowers, J.R. and G. Crowell, 1985. Southeastern tillage energy data and recommended reporting. Transactions of the ASAE, 28: 731-737.
2. Larson, D.L. and H.E. Clyma, 1995. Electro-osmosis effectiveness in reducing tillage draft force and energy forces. Transactions of ASAE, 38: 1281-1288.
3. Grisso, R.D., M. Yasin and M.F. Kocher, 1996. Tillage implement forces operating in silty clay loam. ASAE Paper No. 94-1532. St. Joseph, Mich. ASAE.

4. Askari, M., M.H. Komarizade, A.M. Nikbakht, N. Nobakht and R.F. Teimourlou, 2011. A novel three-point hitch dynamometer to measure the draft requirement of mounted implements. Research in Agricultural Engineering, 57: 128-136.
5. Raper, R.L., D.W. Reeves, C.H. Burmester and E.B. Schwab, 2000. Tillage depth, tillage timing and cover crop effects on cotton yield, soil strength and tillage energy requirements. Applied Engineering in Agriculture, 16: 379-385.
6. Palmer, A.L. and N.A. Albert, 1989. Forces on chisel plough tines: A field study. Agricultural Engineering in Australia, 18: 9-16.
7. Godwin, R.J., A.J. Reynolds, M.J. O'Dogherty and A.A. Al-Ghazal, 1993. A triaxial dynamometer for force and management measurement on tillage implements. Journal of Agricultural Engineering Research, 55: 189-205.
8. Kirisci, V., B.S. Blackmore, R.J. Godwin and J. Blake, 1993. Design and calibration of three different three-point linkage dynamometers. ASAE/CSAE Paper No. 93-1009. St. Joseph, ASAE.
9. Chen, Y., N.B. McLaughlin and S. Tessier, 2007. Double extended octagonal ring (DEOR) drawbar dynamometer. Soil and Tillage Research, 93: 462-471.
10. Sahu, R.K. and H. Raheman, 2006. Draft prediction of agricultural implements using reference tillage tools in sandy clay loam soil. Biosystems Engineering, 94: 275-284.
11. Harrigan, T.M. and C.A. Rotz, 1995. Draft relationships for tillage and seeding equipment. Applied Engineering in Agriculture, 11: 773-783.
12. ASAE Standard, 2000. ASAE D497.4, Agricultural Machinery Management Data. ASAE, St. Joseph, MI, USA.
13. Kheiralla, A.F., Y. Azmi, M. Zohadie and W. Ishak, 2004. Modeling of power and energy forces for tillage implements operating in Serdang sandy clay loam, Malaysia. Soil and Tillage Research, 78: 21-34.
14. ASABE Standards, 2006. ASAE D497.5, Agricultural machinery management data. Available at www.asabe.org.
15. McLaughlin, N.B., C.F. Drury, W.D. Reynolds, X.M. Yang, Y.X. Li, T.W. Welacky and G. Stewart, 2008. Energy inputs for conservation and conventional primary tillage implements in a clay loam soil. Transactions of ASABE, 51: 1153-1163.
16. Shafei, A., 1995. Tillage Implements. 5th ed. University of Tehran, Tehran, Iran.
17. Upadhyaya, S.K., T.H. Williams, L.J. Kemble and N.E. Collins, 1984. Energy requirement for chiseling in coastal plain soils. Transactions of ASAE, 36: 1267-1270.
18. Upadhyaya, S.K., T.X. Ma, W.J. Chancellor and Y.M. Zhao, 1987. Dynamics of soil-tool interaction. Soil and Tillage Research, 9: 187-206.