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Energy-Related Data for Selected Implements

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Energy-related data for agricultural implements are needed so that managers can evaluate energy conservation potential of machines that can perform the same field operation.

Tractor instrumentation can now measure draft, fuel consumption, and wheel speeds while the tractor is pulling an implement. Draft and fuel consumption data can be used directly. Wheel speeds are used to determine field speed and drive wheel slippage.

Implements Tested

Testing was done with a 75 power takeoff horsepower tractor and suitably sized implements. The implements are listed in Table 1. The width of each implement and the soil depth at which the implement was operated are listed. Gauge wheels were used to maintain the desired depth. However, maintaining a uniform depth is difficult with tools like the chisel plow and field cultivator. The implements were not modified but were properly adjusted.

TABLE 1. IMPLEMENTS TESTED

Implement	Width (feet)	Depth (inches)
Moldboard Plow	3.50	8.00
Chisel Plow	10.00	12.00
Field Cultivator	12.00	8.00
Tandem Disc	12.92	4.00
Row-crop Planter	12.67	2.00
Grain Drill	7.58	2.00
Row-crop Cultivator	6.33	3.00
Seed-bed Hipper	3.17	16.00

Soil Types in Tests

Three soil types available at the Delta Research Center, Portageville, Missouri, were selected to represent a medium energy-demand soil and an extreme soil at each end of the energy-demand scale. All testing was done at a soil moisture content which gave good implement performance.

Sharkey clay is a gumbo soil with a very low rate of water and air infiltration. It dries slowly and has a narrow moisture content range in which tillage can be done successfully. The mechanical analysis is 3.3 percent sand, 29.2 percent silt, and 67.5 percent clay.

Dubbs silt loam dries quickly and has a wider moisture content range for tillage work. In appearance, it seems to be almost ideal for crop production. The mechanical analysis is 30.9 percent sand, 59.6 percent silt, and 9.5 percent clay.

Clack sand occurs in sand boils resulting from past earthquake activity. It has excellent drainage and infiltration characteristics but has very poor water storage capacity. The tendency of some implements to push the soil causes draft to be higher than expected. The mechanical analysis is 97.5 percent sand and 2.5 percent silt and clay.

Test Results

Table 2 lists information for each implement operated in each of the three soils. Each entry in the table is the average of at least six, and in most cases 10, individual operations.

Fuel consumption was measured in gallons per hour. However, some managers are more interested in how many gallons are required per acre. To convert gallons per hour to gallons per acre, the field capacity (the number of acres processed in one hour) must be known. If the field efficiency is known or can be estimated, the field capacity can be calculated as follows:

$$\text{Field Capacity, A/hr.} = \frac{\overset{(\text{mph})}{\text{field speed}} \times \overset{(\text{feet})}{\text{implement width}} \times \overset{(\%)}{\text{field efficiency}}}{825}$$

Estimated values for the field efficiency of the tested implements are given in Table 3.

TABLE 3. ESTIMATED FIELD EFFICIENCY FOR TESTED IMPLEMENTS

Implement	Field Efficiency (%)
Moldboard plow	80
Chisel plow	80
Field cultivator	80
Tandem disc	80
Planter, row crop	65
Grain drill	70
Cultivator, row crop	80
Seed-bed hipper	80

TABLE 2. DATA FOR IMPLEMENTS OPERATING IN CLAY, LOAM, AND SAND SOILS.

Implement	Field Speed	Drive Wheel Slippage	Unit Draft	Fuel Consumption
	mi/hr	%	lb/ft	gal/hr
Moldboard Plow	(1)	(2)	(3)	(4)
Clay	3.12	13.6	1,185	5.52
Loam	3.70	11.3	1,038	5.40
Sand	4.13	19.4	986	5.31
Chisel Plow				
Clay	4.05	25.6	410	6.26
Loam	3.90	19.5	410	6.20
Sand	4.08	20.7	240	5.42
Field Cultivator				
Clay	4.35	25.9	232	5.65
Loam	4.80	22.9	296	6.40
Sand	3.85	36.8	315	6.53
Tandem Disc after Chisel Plow				
Clay	4.34	14.6	200	5.83
Loam	3.80	23.6	204	5.50
Sand	3.28	40.2	182	5.70
Tandem Disc after Moldboard Plow				
Clay	4.05	14.9	200	6.16
Loam	3.30	38.6	187	6.10
Sand	Omitted because of excessive slippage.			
Planter, Row Crop, No Tillage				
Clay	2.71	14.9	52	2.35
Loam	2.70	2.8	49	2.10
Sand	2.83	19.3	42	2.05
Planter, Row Crop, after Moldboard Plow				
Clay	2.29	12.4	78	2.44
Loam	2.50	8.2	64	2.40
Sand	2.17	26.3	65	2.52
Planter, Row Crop, after Moldboard Plow & Disc				
Clay	2.57	9.6	64	2.34
Loam	2.50	6.9	57	2.20
Sand	Omitted since disc after moldboard plow was not completed.			
Planter, Row Crop, after Chisel Plow				
Clay	2.64	12.0	60	2.40
Loam	2.60	6.1	58	2.20
Sand	2.35	34.8	60	2.32
Planter, Row Crop, after Chisel Plow & Disc				
Clay	2.65	11.5	62	2.32
Loam	2.60	5.5	64	2.20
Sand	2.40	25.4	61	2.33
Planter, Row Crop, after Field Cultivator				
Clay	2.60	11.4	59	2.31
Loam	2.60	5.2	58	2.30
Sand	2.48	27.5	58	2.27
Grain Drill				
Clay	2.60	4.9	118	2.45
Loam	2.90	6.7	114	2.60
Sand	2.64	10.8	116	2.52
Cultivator, Row Crop				
Clay	2.61	5.0	82	2.97
Loam	2.60	4.7	86	2.90
Sand	2.74	5.2	69	2.54
Seed-bed Hipper				
Clay	4.15	16.3	1,033	4.82
Loam	4.00	16.6	418	4.70
Sand	4.25	19.0	601	4.73

Example: Compare the estimated fuel consumption in gallons per acre for the moldboard plow and chisel plow operating in sharkey clay.

Moldboard Plow (3-bottom plow, 14 inch bottoms):

Field Efficiency = 80%

$$\text{Field Capacity} = \frac{(3.12 \text{ mph})\ (3.5 \text{ ft})\ (80\%)}{825} = 1.05 \text{ A/hr}$$

Divide gallons per hour by the field capacity to get gallons per acre.

$$\text{Estimated Fuel Consumption} = \frac{5.52 \text{ gal/hr}}{1.05 \text{ A/hr}} = 5.25 \text{ gal/A}$$

Chisel Plow (10-foot width):

Field Efficiency = 80%

$$\text{Field Capacity} = \frac{(4.05 \text{ mph})\ (10 \text{ ft})\ (80\%)}{825} = 3.92 \text{ A/hr}$$

$$\text{Estimated Fuel Consumption} = \frac{6.26 \text{ gal/hr}}{3.92 \text{ A/hr}} = 1.59 \text{ gal/A}$$

With fuel consumption expressed as gallons per hour, it appears that the chisel plow requires the most fuel. However, the chisel plow is much wider than the moldboard plow and is travelling almost one mile per hour faster. Therefore, the chisel plow can process more acres in an hour than the moldboard plow. In terms of area, the chisel plow required much less fuel than the moldboard plow during the test.

In Table 2, Column 3, the unit draft for each implement is listed. The total draft of any implement may be calculated by multiplying the unit draft by the implement width. For example, the total draft in pounds for a moldboard plow with three, 14-inch bottoms operated in clay can be computed by multiplying unit draft (lb/ft by width (ft).

$$1{,}185 \text{ lb/ft} \times 3.5 \text{ ft} = 4147.5 \text{ lb}$$

The total draft can be used to size the tractor required for power.

$$\text{Drawbar Horsepower} = \frac{\text{Speed (mph) x Draft (lb)}}{375}$$

For the moldboard plow in the previous example,

$$\text{Drawbar Horsepower} = \frac{3.12 \text{ mph x } 4147.5 \text{ lb}}{375} = 34.5 \text{ hp}$$

The tractor should be oversized by 25 percent to allow for occasional overloading (or lugging). Therefore, the drawbar horsepower required to guarantee adequate power would be 34.5 x 1.25 = 43.1 hp. Tractors are rated by power takeoff (pto) horsepower, which is greater than drawbar power. Typically, maximum drawbar power of a two-wheel drive tractor is about 86 percent of rated pto power. In this case, the rated pto power required would be:

$$\text{Rated Pto Hp} = \frac{\text{Drawbar hp}}{0.86} = \frac{43.1}{0.86} = 50.1 \text{ hp}$$

This technique can be used to select the tractor required to adequately power any of the implements listed.

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