ESTIMATING TILLAGE DRAFT[1]

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Well-conditioned oxen are capable of working draft loads measured as tension (pounds-force, lbf) equal to 10-12% of their body weight throughout the day and greater loads for short periods of time. This bulletin provides a range of normal draft requirements for commonly used tillage implements. This information can help the teamster plan fieldwork, match implements with the power available and establish realistic guidelines for animal performance.

INTRODUCTION

An ability to estimate implement draft is important in working draft animals. A well-matched team and implement allow efficient use of time for fieldwork. In training, young animals can become discouraged if forced to draw too heavy a load. Mature animals may also refuse to pull their best if frequently confronted with a heavy draft load they are unprepared for or cannot move.

A convenient rule-of-thumb for estimating the working ability of oxen when drawing tillage tools is that a well-conditioned team can handle draft loads measured as tension in the draft chain equal to 10-12% of their body weight throughout the day. Tillage draft standards published by the American Society of Agricultural Engineers (ASAE) can be used to predict draft for common ox-drawn tillage tools when adjusted for speed and depth of operation.

A normal moldboard plow draft can range from 320 to 990 pounds-force per foot of plow width.

POWER MEASUREMENT

Draft power is often described in units of horsepower (hp). The horsepower unit was developed by James Watt in England in the late eighteenth century. Watt found that an average horse could lift 366 lb of coal out of a mine at the rate of one foot per second (366 ft-lb/sec). In seeking to rate his steam engines in terms of the rival power source of the day--the horse--but not wanting to overstate the ability of his engines, Watt purposely inflated the power delivered by a horse to 550 ft-lb/sec. The ability to move 550 lb with a velocity of one foot per second has been used ever since as the unit of horsepower.

Power delivery is a measure of work accomplished. It is not

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always a reliable measure of a team's effort. In equation form:

Hp = (force, lb. X distance, ft) / time, sec

Power delivery is increased by increasing force (draft, lbf), or speed (ft/sec). In pulling competitions, victory requires power delivery. But even though a team may struggle mightily to move a heavy load, if the load does not move, no power is delivered. Draft measured as tension in the towing chain is independent of time and distance. For most teamsters, draft alone is more descriptive and meaningful than power delivery in managing and training draft animals.

Our Need to Know . . .

In initiating this series of articles on implement draft, we at ***Tillers International*** are seeking to improve the relationship of people with their working animals. We are committed to easing the burden of animals as they help meet the energy needs of small farms.

If we lack an understanding of what we ask of our animals, we have limited means of knowing why they may act up in particular ways. If a teamster mistakenly thinks a load is light, he or she may become overly demanding. Underestimating a load may lead to a heavy whip and frustrate the animals into becoming nervous and unpredictable. Repeatedly overloading a team will discourage them and reduce their willingness to pull. Our goal is to enhance the teamsters ability to match the ability of the team with the demand of the load.

Calculating a load will take a little practice and attention. But you will be rewarded with a more productive relationship with your animals. They trust us to attend to such details and their trust grows as we demonstrate our trustworthiness to them. Those who have not worked oxen or draft horses may think this overestimates their perceptiveness and memory; nonetheless, experience clearly teaches the perceptive teamster that oxen and horses develop differing levels of trust and respect for variations among drivers. There are real benefits to be gained by understanding the loads you are asking your animals to move. We hope this article will help all teamsters empathize with the tasks they are presenting to their animals.

TILLAGE TOOLS

Draft is the force (pounds-force, lbf) required to move an implement in the direction of travel. Total draft of most tillage implements is primarily resistance to soil and crop residues. Under normal conditions wide variations in draft of tillage tools are common both within and between soil textural groups due to soil moisture, soil strength, residue cover and other physical characteristics. Dry, consolidated soil generally provides greater resistance to tillage tools than the same soil when moist and friable.

The tractive surface in the field can vary from firm and compact to soft or muddy. Loose soil increases rolling resistance of wagon wheels and increases slippage of the animal's hooves. And, draft increases when moving up a slope. These are normal variations in field conditions that can greatly vary the demand on working animals.

In estimating tillage draft, soils can be conveniently categorized as fine, medium or coarse rather than using the traditional but more confusing classifications such as clay, sandy-loam or silty-clay-loam. Fine textured soils can be considered as high in silt and clay, medium textured are loamy soils and coarse textured soils are sandy soils. Implement draft generally increases in going from coarse to fine textured soils.

The draft force required to pull some tillage tools at shallow depths is primarily a function of the width of the implement and the speed at which it is pulled. Typical draft per foot of implement width for a few such implements is provided in Table 1. These values can be adjusted within the range given based upon local experience or when conditions are likely to cause a substantial change from the normal draft requirements.

Table 1. Expected range in draft for shallow tillage tools.

Implement	Draft, lbf/ft Low	Avg	High	Range +/- %
Spike-Tooth Harrow	30	40	50	30
Roller-Packer	20	40	60	50

Source: *ASAE Standards 2000, D497.1, Agricultural machinery management data.* ASAE: St. Joseph MI.

Draft also depends upon the depth of tillage. Expected draft (lbf/ft of implement width or lbf/row) for a range of tillage tools operating in various soils at about two miles per hour is listed in Table 2. Tillage draft generally increases with travel speed so draft at 3 mph will be about 10% greater than at 2 mph.

Table 2. Expected range in draft for common tillage tools in a range of soils.

	Draft, lbf/ft			Range
	Coarse	Medium	Fine	+/- %
Moldboard Plow				
6-inch depth	320	490	740	40
8-inch depth	420	650	990	40
Disk, Tandem				
3- to 4-inch depth	140	160	180	50
Disk, Single Gang				
3- to 4-inch depth	55	65	75	25
Spring-Tooth Harrow				
2-inch depth	90	115	135	30
3-inch depth	130	170	195	30
Grain Drill				
7 -inch spacing	90	90	90	25
	Draft, lbf/row			
Row Crop Planter	110	110	110	25
Row Crop Cultivator				
2.5-inch depth	85	115	135	20
Disk Bedder-Ridger				
3-inch depth	90	100	110	40
5-inch depth	145	165	190	40

Based on: *ASAE Standards 2000, D497.1, Agricultural machinery management data.* ASAE: St. Joseph MI.

Moldboard plowing is a high draft primary tillage operation. When plowing one acre to a depth of six-inches, a plow will cut, lift and turn more than two million pounds of soil. A normal draft for a moldboard plow ranges from 320 to 990 lbf per foot of plow width, but plow draft can vary greatly in the same soil depending upon conditions. Draft will be higher in dry, hard soil than when the soil is moist and friable. Hay and grass sod generally plows harder than ground tilled annually. Disk draft can be variable and difficult to predict. Draft is largely dependent upon depth of tillage, but depth varies with disk weight, disk angle, blade spacing and diameter, soil strength, crop residue cover and many other factors. Light tandem disks typically have a blade spacing of 7.5 to 9 inches, a gang angle of 16 to 20 degrees, and weigh about 200 lb per foot of machine width. A normal draft for a tandem disk varies from about 140 to 180 lbf per foot of width.

Single disk gangs are generally lighter and carry a less aggressive cutting angle than tandem disks. A normal draft ranges from 55 to 75 lbf per foot of cutting width.

HOW MANY ACRES IN A DAY?

How many acres can you expect to till in a day? There is no clear-cut answer when working with horses, mules or oxen. Since the level of conditioning is important in setting the length of the workday, perhaps the best thing to do is first determine how much can be done in one hour, then figure out how many hours the team is likely to work in a day.

A common measure of machine performance is in acres per hour (ac/hr). Acres per hour can be calculated using implement speed, width and an efficiency factor:

$$\textbf{Acres/hour} = (S \times W \times FE) \div 8.25$$

where:

S is forward travel speed in miles per hour
W is implement width in feet
FE is a field operation-specific efficiency factor

Travel speed can be measured on the farm by recording the time needed to travel 100 feet. The relationship between time and distance is shown in Table 3.

Table 3. Time in seconds to travel 100 feet at various speeds.

Seconds	MPH	Seconds	MPH
46	1.5	21	3.3
40	1.7	20	3.5
36	1.9	18	3.8
33	2.1	17	4.0
30	2.3	16	4.3
27	2.5	15	4.6
25	2.7	14	5.0
23	3.0	12	5.5

In our experience, mature oxen will settle in at about 2 or 2½ mph for heavy work such as plowing but will easily step up to 3 mph or so for tasks such as mowing. Horses and mules will be faster, perhaps 3 mph for tillage and 3 to 4 mph for mowing. Of course, some teams are faster than others. Most teams will be more energetic at the beginning of the day than at the end. Many teams that do not work regularly must be held back in the morning but lose a step as the day goes on. In hot weather, horses and mules usually fair better than oxen, but conditioning is a key factor for all teams.

Table 4. Field efficiencies for a range of field operations.

Implement	Field Efficiency	
	Tractor [1]	Draft animals [2]
Moldboard plow	.70-.90	.50-.75
Tandem disk	.70-.90	.50-.70
Spring tooth harrow	.70-.90	.50-.75
Spike tooth harrow	.70-.90	.50-.80
Row cultivator	.70-.90	.50-.75
Row crop planter	.50-.75	.50-.75
Grain drill	.55-.85	.50-.75
Sicklebar mower	.75-.85	.45-.65
Hay rake, side-delivery	.70-.90	.60-.80
Baler	.60-.85	.55-.75
Loose hay loader	.65-.80	.55-.75

[1] Based on: *ASAE Standards 2000, D497.1, Agricultural Machinery Management Data*. St.Joseph MI: ASAE.
[2] The author's estimate for well-conditioned teams.

Row crop cultivator draft can range from 85 to 135 pounds force per row.

Field efficiency can be calculated as a ratio of the time an implement is operating at a normal speed over its full width of action to the total time the implement is committed to the operation. For example, at 100% efficiency (FE=1.0) an 8-foot spring-tooth harrow drawn at 3.1 mph can till 3 acres per hour [(8 ft x 3.1 mph x 1.0) ÷ 8.25 = 3 ac/hr]. Fifteen acres could be tilled in five hours if no time was lost in maneuvering the implement, adjustments, repairs, etc. However, if seven hours were needed to till the field, the field efficiency would be 0.71, not 1.0 (5 hr theoretical time ÷ 7 hr actual time = 0.71). The actual acreage tilled would be 2.1 rather than 3 ac/hr [(8 ft x 3.1 mph x 0.71) ÷ 8.25 = 2.1 ac/hr].

The efficiency factors vary among farms and operations and adjust for time lost in turning on the headlands; loading or unloading planters, drills or wagons; machine maintenance, adjustment and repair; and stopping to rest. It also accounts for capacity lost in overlapping passes of a tillage tool. A one-foot overlap with an eight-foot harrow represents a loss of 12½% of the effective capacity of the harrow. Field efficiency estimates for a range of field operations are listed in Table 4.

Although many factors affect field efficiency, field shape is one of the most important. When fields are square, little time is lost in turning on the headlands. Small, triangular or oddly shaped fields are difficult to navigate and a greater proportion of time is

A normal spring-tooth harrow draft can range from 90 to 195 pounds-force per foot of harrow width.

spent in turning and repositioning equipment. In such fields efficiencies are generally low.

Field efficiencies for tractor-drawn implements are easier to predict than for animal-drawn implements. Tractors need not stop for a rest, and tractors are not hindered by high heat and humidity. When a tractor and implement are well-matched, travel speed is nearly constant and a reserve of power is available for pulling up slopes and overcoming other normal variations in draft.

Field efficiencies for animal-drawn implements are tough to predict. Time lost in resting a team varies with their age and size, their level of training and conditioning, the number of animals in the hitch, temperature, humidity, lay of the land and the tractive surface over which the animals must travel. The effort that a team is willing to give is much more difficult to measure and predict than implement draft.

In Table 4 we have offered a range of likely field efficiencies for draft animals. These estimates are not based on specific field measurements, rather our best guess of what animals are likely to achieve under most conditions. They are lower than for tractors, largely due to the need to rest the animals. But the need for rest will vary considerably. The low end of the range is likely in hot weather, with poorly conditioned animals, when field geometry is unfavorable, and when the implement draft presents a challenging load. The high end of the range may be more representative in cool weather, with well-conditioned teams, and when a multiple hitch shares the burden.

MACHINERY SELECTION AND USE

These tillage draft guidelines can be used to help teamsters plan field work and match implements with the draft power available.

***Example* 1:** Select a moldboard plow suitable for a 3,600 lb team of oxen on a medium soil.

Answer: A normal working draft (10% to 12% of body weight) ranges from 360 to 430 lbf (3,600 lb x .10 = 360 lbf; 3,600 lb x .12 = 430 lbf). Referring to Table 2, a typical draft for a 12-inch moldboard plow at a six-inch depth in a medium soil is 490 lbf. This is near the normal working range for a 3,600 lb team. In hard going you can reduce draft by decreasing depth or width of cut.

Example 2: A teamster will be using a 4-horse hitch and a moldboard plow with two twelve-inch bottoms to plow a 10-acre field. The team travels at about 3 mph when plowing. From past experience the teamster expects a field efficiency of 0.60. Six hours per day are available for plowing. How long will it take to plow the field?

Answer: Acres per hour = [(3 mph x 2 ft x 0.60) ÷ 8.25] = 0.44 acres per hour. Since six hours per day are available for plowing, 6 hrs x 0.44 acres per hour = 2.6 acres per day. Ten acres ÷ 2.6 acres per day = 3.8 days. Therefore, it will take about 4 days to plow the field.

SUMMARY

We at *Tillers International* are committed to easing the burden of animals as they help meet the energy needs of small farms. Our goal is to enhance your ability to match the ability of your team with the demand of the load. An understanding of draft loads can help you match a load with the ability of your team and establish realistic guidelines for animal performance.

Calculating a load will take a little

practice, but you will be rewarded with a more productive relationship with your animals. They trust you attend to such details and their trust grows as you demonstrate your trustworthiness to them. There are real benefits to be gained by understanding the loads you are asking your animals to move.

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