What Size Farm Tractor Do I Need?

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The purchase of a tractor and associated equipment is a substantial investment. The result of improper size can be costly - - a tractor too small can result in long hours in the field, excessive delays and premature replacement.

A tractor too large can result in excessive operating and overhead costs. It is important to know how to determine the size and number of tractors needed for a farm operation. The ideal equipment should get the work completed on time at the lowest possible cost. The size of the largest tractor should be based on getting critical, high-horsepower jobs done within a specified time period.

FOUR WHEEL DRIVE, FRONT WHEEL ASSIST AND TWO WHEEL DRIVE TRACTORS

Tractors can be divided into 3 categories: 2-wheel drive, front-wheel assist or unequal 4-wheel drive, and equal 4-wheel drive tractors. Each one of these tractors has different tire configurations and different ballast requirements.

Two-Wheel Drive Tractors (2WD) are most commonly used in dry or upland farming situations and for transportation. They range in size from 5 HP - 200 HP and need 80% of the weight distributed over the rear axle to maximize traction. The biggest advantages of this type of tractor over other 4-wheel tractors are smaller turning circle, simplicity of design, fewer mechanical parts and lower purchase price. However, a 2WD tractor does not work at all well in wet, hilly and muddy conditions.

Front Wheel Assist (FWA) is commonly known as 4WD or unequal 4-wheel drive. It is the most popular 4-wheel tractor in many parts of the United States and worldwide. These tractors range in size from 5 HP - 240 HP and are capable of delivering between 50-55% of the rated power at the drawbar. Typically, between 75% and 85% of the rated engine HP is delivered to a rear PTO (Power Take-Off) on any diesel tractor.

On a FWA tractor the front drive tires are smaller than the rear tires. These tractors require 40% of the weight distributed over the front axle and 60% over the rear axle. The major advantage in using this type of tractor is that it can deliver 10% more power to the ground at all 4 tires for the same fuel consumption, and thus has much better traction and flotation capabilities than 2-wheel tractors of the same size. FWA tractors normally cost about 15-35% more than the same horsepower two wheel drive tractor.

Equal Four-Wheel Drive (4WD) tractors have all four tires of equal size and range in size from 35 HP - 600 HP. This tractor type has the greatest power to weight ratio and can deliver between 55-60% of power at the drawbar. It is challenging to maneuver and often the size and expense makes these tractors impractical.

DETERMINING HORSEPOWER

Horsepower Defined

Several terms are used by equipment manufacturers to describe the capacity of their tractors. The basic definitions are:

Horsepower (HP) - - A measure of the rate with which work is done. By definition one horsepower is the amount of energy required to move 33,000 pounds a distance of one foot in a time span of one minute or likewise, to move 1 pound 33,000 feet in one minute. It is the measure of a machine's ability to move a load.

Brake Horsepower - - The maximum power the engine can deliver without alterations. This figure is particularly useful in sizing stationary engines.

Power-Take-Off-Horsepower (PTO) - - The power as determined at the power-take-off shaft.

Draft (Drawbar) Horsepower - - The power transmitted by the tractor to the implement. The Nebraska Tractor Tests indicate that maximum drawbar horsepower will average approximately 85 percent of the maximum PTO horsepower for most tractors.

Of the various kinds of horsepower, maximum PTO horsepower is the one most commonly used in designating the size of a tractor. On tractors that do not have a PTO shaft, brake horsepower, or maximum drawbar hp ratings may be used.

Determining Minimum Horsepower Requirements

A suggested procedure for determining the minimum horsepower needed is:

Step 1. Determine the most critical field operation requiring implements with a high draft.

Step 2. From past experiences, estimate how many days are available to complete this critical field operation. If you plan to run a double shift be realistic about maintenance of the machine and the operator's personal time.

Step 3. Calculate the capacity needed in acres per hour in order to get the job done within the time allotted.

Step 4. Determine the size of implement needed.

Step 5. Select a tractor of proper size to pull the implement. To do this:

1. Determine draft of implement (Table 2.),
2. Determine drawbar horsepower needed to pull implement, and
3. Determine PTO horsepower needed.

Obviously the most important decision is to determine the size of the largest tractor. Normally the size of the largest tractor should be based on getting the critical, high-horsepower jobs done within a specified time period. It follows, then, that as much use as possible should be made of the same tractor for other operations.

Keep in mind, also, that large tractors should be matched with large, heavy duty equipment to withstand the heavy loads created by the tillage implement. By the same token, overloading a tractor can lead to serious mechanical failure. This can lead to down time and when a tractor is down, all work associated with that tractor stops.

SELECTION OF TRACTOR SIZE

Using the procedure outlined, let's determine the tractor size needed for a specific tillage operation.

SITUATION: A small farm with 60 acres of sandy soil planted in row crops. During the spring five weeks of calendar time is available to twice disk the land with a tandem disk harrow prior to planting. The owner has 5 days (Saturday's) available to prepare the land. Number of productive hours per work day is assumed to 8.

How large should the tractor and harrow be in order to complete the soil preparation during this five week period?

Determining Tractor Size

Step 1. Determine the critical high draft tillage operation. In this example disking prior to planting is that operation.

Step 2. Determine available time. There are 35 days of calendar time allotted to this job. During this time span, 5 days (40 hours) are estimated to be available for field work.

Step 3. Determine Field Capacity Needed (Acres per Hour).

$$= \frac{Total\ Acres\ to\ Cover}{Number\ of\ Work\ Days\ x\ Average\ Hrs\ per\ Day} = \frac{60\ acres\ x\ disk\ twice}{5\ Days\ x\ 8\ Hrs\ per\ Day} = 3.0\ Acres\ per\ Hr$$

Step 4. Determine Width of Implement Needed

In order to disk 3.0 acres per hour at a speed of 5 mph, a disk of the following minimum width is needed:

$$= \frac{10^{*}\ x\ Acres\ per\ Hr}{Speed\ (mph)} = \frac{10\ x\ 3.0\ Acres\ per\ Hr}{5\ (mph)} = 6\ feet$$

A 6 foot disk would be bought to provide a margin for field capacity.

* The Factor 10, is used to reflect theoretical capacity (1/8.25) of an implement 1-ft wide, 1 mph, and to reflect 18 % field loss for overlap, turning loss, and other inefficiencies of field work.

Step 5. Tractor Selection

1. Determine Draft (Soil Resistance)

= Width of Implement x Draft per Foot per Depth of Operation in Inches

The draft of a tandem disk harrow in sandy soil is 92 pounds per foot width per depth of operation in inches (Table 2). The total load that a 6 feet disk operating 8 inches deep requires of the tractor is:

= 6 *ft. x 92 lbs. draft per foot per inch (from Table 1) x 4 inches deep*
= *2,208 pounds total draft*

2. Determine Drawbar Horsepower Required

$$= \frac{\textit{Total Draft (lbs.) x Speed (mph)}}{375^{**}} = \frac{\textit{2,208 (lbs.) x 5 (mph)}}{375} = \textbf{\textit{29.4 Drawbar Horsepower}}$$

** Conversion Factor

3. Determine Minimum PTO Horsepower:

Table 1. PTO horsepower multiplication factors for different soil conditions.

Soil Condition	Multiply Drawbar HP by
Firm untilled soil	1.5
Previously tilled soil	1.8
Soft or sandy soil	2.1

In this instance, the tractor would be working on sandy soil.

29.4 HP (Drawbar) x 2.1 = 61.8 ESTIMATED PTO HP REQUIRED

This is an approximation of the PTO horsepower needed to pull this implement under the specified conditions. POWER REQUIREMENTS CAN VARY DUE TO TOPOGRAPHY, SOIL AND CROP CONDITIONS, AND INTEGRAL TRACTOR EQUIPMENT SUCH AS HYDRAULIC SYSTEMS, AIR CONDITIONING, ETC. This method is an acceptable estimation under normal conditions and can be used to estimate minimum horsepower requirements when selecting tractors.

SPEED AND TRACTOR SIZE

Speed is a major factor affecting horsepower requirements. Higher working speeds result in more horsepower needed to perform the job.

In the example a working speed of 5 mph was used. Should the speed be reduced to 3.5 mph, the power requirements would be:

Drawbar Horsepower (3.5 mph)

$$= \frac{2{,}208 \text{ (lbs. Total Draft) X } 3.5 \text{ (mph)}}{375}$$

= 20.6 Drawbar Horsepower

PTO Horsepower Required (3.5 mph, Sandy Soil)
= 20.6 hp (Drawbar X 2.1)
= 43.3 hp (PTO)

This is a reduction of 18.5 horsepower (PTO) required to pull a 6 ft. wide tandem disk harrow. Obviously the performance rate (acres per hour) will be reduced by traveling at a lower speed. In instances where timeliness is not a necessity, a small tractor can be used to perform the job provided adequate drawbar pull is available.

SIZING TRACTOR ACCORDING TO ROTATIONAL IMPLEMENT POWER NEEDS

What is a PTO? - A Power Take Off does exactly what its name implies. It takes some of the power that the tractor's engine creates and uses it to run mowers, tillers, and any rotary tools attached to a tractor. On most tractors, the PTO is typically located at the rear of the tractor but tractors can have mid-mount PTOs as with true belly mower tractors. In the case of a combine all the horsepower generated by the engine is used for separating the grain and to propel the machine as PTO horsepower. The PTO horsepower required to operate the device is normally size on the width or the amount of material the implement must process during a given time (tons/hour wet basis). Table 2 and 3 give PTO power requirements for various implements.

References

1. ASAE EP496.3. 2006. Agricultural Machinery Management. 2006 ASABE Standards, St. Josephs, MI.
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3. ASAE. 1971. ASAE Yearbook. St Josephs, MI.
4. Givan, William and Cecil Hammond. 1978. Selection of Farm Tractors. Cooperative Extension Service. University of Georgia College of Agriculture. Athens, GA. Miscellaneous Publication Number 68.

Table 2. Draft and power requirements for tillage and seeding implements.

Implement	unit	*Speed (mph)*	*Draft (pound force/unit/ inch depth)* Clay Soil	*Draft (pound force/unit/ inch depth)* Loamy Soil	*Draft (pound force/unit/ inch depth)* Sandy Soil
MAJOR TILLAGE TOOLS					
Subsoiler/Manure Injector					
narrow point	tools	5	295	206	133
12 inch winged point	tools	5	382	267	172
Moldboard Plow	ft	4.5	223	156	101
Chisel Plow					
2 inch straight point	tools	5	115	98	75
3 inch shovel/14 inch sweep	tools	5.5	139	118	91
4 inch twisted shovel	tools	5.5	160	136	104
Sweep Plow					
primary tillage	ft	5	136	116	89
secondary tillage	ft	5	90	76	58
Disk Harrow, Tandem					
primary tillage	ft	5.5	117	103	92
secondary tillage	ft	5.5	71	62	55
Disk Harrow, Offset					
primary tillage	ft	5	134	117	104
secondary tillage	ft	5	82	72	64
Disk Gang, Single					
primary tillage	ft	5.5	39	34	30
secondary tillage	ft	5.5	27	23	21
Coulters					
smooth or ripple	tools	5	54	48	42
bubble or flute	tools	5	65	57	51
Field Cultivator					
primary tillage	tools	5	50	43	33
secondary tillage	tools	5	35	30	23
Row Crop Cultivator					
S-tine	rows	5	129	109	84
C-shank	rows	5	239	203	155
No-till	rows	5	417	354	271
Rod Weeder	ft	4.5	63	54	41
Disk-Bedder	rows	5	209	180	163
MINOR TILLAGE TOOLS					
Rotary Hoe	ft	7	53	53	53
Coil Tine Harrow	ft	5	20	20	20
Spike Tooth Harrow	ft	5	52	52	52
Spring Tooth Harrow	ft	5	182	182	182
Roller Packer	ft	5	60	60	60
Roller Harrow	ft	5	270	270	270
Land Plane	ft	5	798	798	798
SEEDING IMPLEMENTS					

Table 2. Draft and power requirements for tillage and seeding implements.

Implement	unit	*Speed (mph)*	*Draft (pound force/unit/ inch depth)* Clay Soil	*Draft (pound force/unit/ inch depth)* Loamy Soil	*Draft (pound force/unit/ inch depth)* Sandy Soil
Row Crop Planter, prepared seedbed					
mounted					
seeding only	rows	5	138	138	138
drawn					
seeding only	rows	5	250	250	250
seed, fertilizer, herbicides	rows	5	438	438	438
Row Crop Planter, no-till					
seed, fertilizer, herbicides					
1 fluted coulter/row	rows	5	513	513	513
Row Crop Planter, zone-till					
seed, fertilizer, herbicides					
3 fluted coulters/row	rows	5	1033	1033	1033
Grain Drill w/press wheels					
< 6.5 feet drill width	rows	5	113	113	113
6.5 to 10 feet m drill width	rows	5	84	84	84
> 10 feet drill width	rows	5	31	31	31
Grain Drill, no-till					
1 fluted coulter/row	rows	5	216	216	216
Hoe Drill					
primary tillage	ft	5	630	630	630
secondary tillage	ft	5	300	300	300
Pneumatic Drill	ft	6	375	375	375

Table 3. Rotary power requirements for implements based on material input.

Implement	**HP (PTO)/Feed Rate Wet Basis(tons/hr)**
Baler, small rectangular	3.9
Baler, large round (var. chamber)	6.7
Baler, large round (fix. chamber)	5.6
Combine, small grains	31.2
Combine, corn	48.9
Feed mixer	2.8
Forage blower	1.1
Flail harvester, direct-cut	14.7
Forage harvester, corn silage	12.0
Forage harvester, wilted alfalfa	12.9
Forage harvester, direct-cut	14.9
Forage wagon	0.3
Grinder mixer	4.9
Manure spreader	0.3
Tub grinder, straw	16.9
Tub grinder, alfalfa hay	11.3

Table 4. Rotary power required for various implements based on width.

Implement	Horse Power (PTO)/width (ft)
Cotton picker	3.8
Cotton stripper	0.8
Mower, cutterbar	0.5
Mower, disk	2.0
Mower, flail	4.1
Mower-conditioner, cutterbar	1.8
Mower-conditioner, disk	3.3
Mower, rotary horizontal	10.4
Rake, side delivery	0.2
Rake, rotary	0.8
Tedder	0.6
Windrower/swather, small grain	0.5

SELECTING TRACTOR SIZE WORKSHEET

1. FIELD CAPACITY NEEDED (ACRES PER HOUR)

$$= \frac{Total\ Acres\ to\ Cover}{Number\ of\ Work\ Days\ x\ Average\ Hrs\ per\ Day}$$

$$= \frac{\_\_\_\_\_\ acres}{\_\_\_\_\ Days\ x\ \_\_\_\_\_\ Hrs\ per\ Day} = \_\_\_\_\_\ ^{AC.}/_{Hr.}$$

2. MINIMUM WIDTH OF IMPLEMENT NEEDED (feet)

$$= \frac{10\ x\ Acres\ per\ Hr}{Speed\ (mph)}$$

$$= \frac{10\ x\ \_\_\_\_\_\ Acres\ per\ Hr}{\_\_\_\_\_\ mph} = \_\_\_\_\_\ ft.$$

3. TOTAL DRAFT (SOIL RESISTANCE)(Draft pounds)

= *Width of Implement* x *Depth of Operation x Draft per ft. width per inch depth (from Table 1)*

= _____ *Implement x* _____ *Depth* _____ *Draft per ft. per in.* = _____ Draft lbs

4. DRAWBAR HORSEPOWER REQUIRED (Draft Horsepower)

$$= \frac{Total\ Draft\ (lbs.)\ x\ Speed\ (mph)}{375}$$

$$= \frac{\_\_\_\_\_\ Total\ Draft\ x\ \_\_\_\_\_\ mph}{375} = \_\_\_\_\_\ Draft\ HP$$

5. ESTIMATED MINIMUM PTO HORSEPOWER =

- - On firm, untilled soil, multiply Drawbar HP by 1.5
- - On previously tilled soil - - - - - - - - - - 1.8
- - On soft or sandy soil - - - - - - - - - - - - 2.1

= _____ *Drawbar HP x* 1.5; 1.8 or 2.1*)* = _____ PTO HP

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