Improving Tractor Performance and Fuel Efficiency

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Setting up a tractor for optimum performance takes time and effort but produces significant returns by reducing fuel consumption, field time, drive train or tire wear and soil compaction. It's estimated that poor tractor performance wastes nearly 150 million gallons of fuel each year in the U.S. This fact sheet covers the key steps to setting up and operating tractors for peak performance.

Agricultural engineers at the Agricultural Technology Centre (formerly the Alberta Farm Machinery Research Centre) identified three key areas where tractor performance and fuel efficiency can often be improved. They found that many tractors were not ballasted for optimum performance and in most cases they were carrying too much weight. The second area they identified was that tires were not inflated correctly. A survey conducted in Oklahoma also showed that only 45% of the tractor tires were inflated properly. The last area identified focused on operation rather than setup. They found that many farmers were not operating their tractors in the most efficient engine load range.

Tractor ballast -- the essential first step

The overall weight of the tractor and the way that the weight is distributed between the axles has a huge impact on tractor performance. Over ballasting a tractor wastes fuel due to increased rolling resistance and increases drive train wear and soil compaction. Under ballasting a tractor wastes fuel from excessive tire slip and causes premature tire wear. The steps to correctly ballasting a tractor are listed below:

- **Determine the optimum weight for the tractor.** The operator's manual and input from your dealer are a good starting point. Manufacturers commonly recommend optimum tractor weights ranging from 90 to 140 lbs. per PTO horsepower (hp). As travel speed increases, the required weight is reduced for two reasons: the mechanical properties of soil only allow so much deformation (slip) to occur in a given period of time, and faster speeds are associated with implements having lower draft requirements. Table 1 lists the optimum tractor weights for various types of tractors and travel speeds.

Table 1. Optimum tractor weights

Tractor Type	4.5 mph	5 mph	5.5 mph
2 WD & MFWD (lbs. per PTO hp)	130	120	110
4 WD (lbs. per PTO hp)	110	100	90

Source: Saving Fuel in Field Operations, Mark Hanna

- **Determine how to distribute the weight between the axles.** Again, the operator's manual and the dealer are a good place to start. The weight split is determined by the type of tractor and the way that the implements are hitched or mounted to the tractor. Table 2 shows the recommended front to rear axle weight allocations for two wheel drive (2WD), mechanical front wheel drive (MFWD) and four wheel drive (4WD) tractors. Determine the optimum weight per axle by multiplying the optimum weight for the tractor by the appropriate front and rear axle weight distribution percentages for the tractor type and hitching method.

Table 2. Optimum front and rear axle weight distributions

Tractor Type	Towed Front/Rear (%)	Semi-mounted Front/Rear (%)	Fully-mounted Front/Rear (%)
2WD	25 / 75	30 / 70	35 / 65
MFWD	35 / 65	35 / 65	40 / 60
4WD	55 / 45	55 / 45	60 / 40

Source: Saving Fuel in Field Operations, Mark Hanna

- **Determine the existing front and rear axle weights.** The most accurate method is to weigh each axle separately with the fuel tank full and the operator in the cab. If your tractor is less than 10 years old, you can obtain unballasted axle weights on line at the Nebraska Tractor Test Laboratory web site (http://tractortestlab.unl.edu/).

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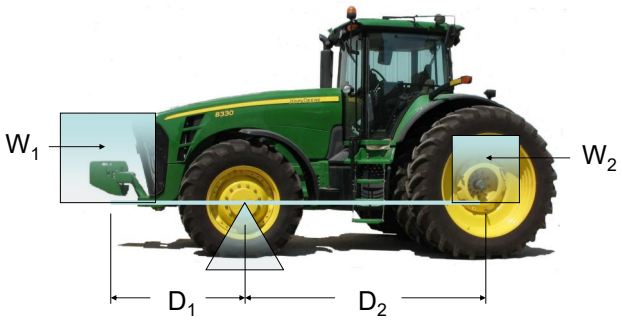
- **Decide how to add weight to the axles.** There are two ways to add ballast to a tractor: attaching cast weights and filling the tires with fluid. Cast weights are more expensive however they make it easier to adjust ballast for changing conditions. Adding fluid to the front tires on a MFWD tractor is an efficient method for adding ballast to the front axle when needed and controlling power hop without exceeding the optimum inflation pressure. If you add fluid to tires on the rear axle, don't exceed 40% fill. Always fill all tires on an axle to the same fluid level. The added weight from adding duals should be considered as ballast on the rear axle.

- **Understand and compensate for the transfer effects that occur to the front and rear axle weights when suitcase weights are added to the front of the tractor.** When you add weight to the front of your tractor, the front axle weight is increased to a greater amount than the actual weight you added and the rear axle weight is decreased. This is because the tractor's frame acts like a lever with the front axle serving as the fulcrum. Tractor manufacturers can provide tables showing how adding suitcase weights changes the front and rear axle weights. You can also easily calculate the transfer effects using the procedure illustrated in figure 1. You will need to measure the distance from the center of the suitcase weights to the center of the front axle and the distance between the center of the front axle and the center of the rear axle for this calculation.

Figure1. Calculating the transfer effect on the front and rear axles when suitcase weights are added



$W_1 \times D_1 = W_2 \times D_2$

For example, how will the axle weights change if 600 lbs. in suitcase weights (W_1) are added, the distance between the center of the suitcase weights and the center of the front axle is 5.3 feet (D_1) and the distance between the front and rear axles is 9.75 feet (D_2)? Insert these values into the formula in figure 1.

$W_1 \times D_1 = W_2 \times D_2$

$600 \times 5.3 = W_2 \times 9.75$

$3{,}180 = 9.75W_2$

326 lbs. $= W_2$

In this example, the front axle weight will be increased by 926 lbs. (600 + 326) and the rear axle weight will be reduced by 326 lbs.

Tractor ballasting example:
We want to ballast a MFWD tractor for optimum performance. The tractor is rated at 200 PTO hp and pulls towed tillage tools at 4.5 mph.

From table 1, calculate the optimum tractor weight.
200 PTO hp x 130 lbs./ PTO hp = **26,000 lbs.**

Using table 2, calculate how to distribute the weight between the axles.
Front axle weight = 0.35 x 26,000 = **9,100 lbs.**
Rear axle weight = 0.65 x 26,000 = **16,900 lbs.**

According to data from the Nebraska Tractor Tests, the unballasted axle weights are:
Front axle weight = **8,930 lbs.**
Rear axle weight = **12,570 lbs.**

Calculate the difference between the optimum axle weights and the unballasted axle weights.
Front 9,100 - 8,930 = **170 lbs.**
Rear 16,900 -12,570 = **4,330 lbs.**

In this example, the front axle requires an additional 170 lbs. of ballast and the rear axle requires an additional 4,330 lbs. of ballast for peak performance.

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Tire selection, configuration and inflation.
Proper tire selection, configuration and inflation all affect the ability of your tractor to transfer power to the soil. Consider the following information:

- **Tire selection.** When selecting tires for improved performance, select radial tires over bias ply tires as they produce a bigger footprint on the soil, reducing wheel slip and compaction. Radial tires require more careful management than bias tires as they typically have significantly lower inflation pressures. Choose the largest tires you can afford for 4WD and the rear axle of MFWD tractors as this allows you to decrease the inflation pressure and increase the footprint of the tire. Try to select tires that will carry the static axle loads at inflation pressures between 6 and 14 pounds per square inch (psi). This will improve performance and ride and reduce power hop and soil compaction. When changing the size of the tires on the rear of a MFWD tractor, you will need to change the size of the front tires also. Work with your local tire or equipment dealer.

- **Tire configuration.** Duals are often required on 2WD and 4WD tractors to improve flotation traction and load carrying capacity. However, duals should not be added to the rear axle on MFWD tractors when not required for load carrying capacity. Numerous research trials have shown that a properly ballasted MFWD tractor with single tires on the rear will perform better than a properly ballasted MFWD tractor equipped with duals on the rear axle. The principle advantage of MFWD tractors is that the rear tires ride over soil that was firmed by the front tires. When duals are added to the rear, the outside tire lifts the inner tire off this firmed soil and the benefit is lost.

- **Tire inflation.** To maximize tractor performance, inflate radial tires to the lowest recommended pressure for the load they carry. North Dakota researchers found that correctly inflated radial tires improve performance by 6%. Figure 2 was taken during a field demonstration at Ag Expo where identical tractors were hitched with a cable and pulley system to a third tractor pulling a high-draft tillage tool. The front tractor with properly inflated tires consistently performed better than the trailing tractor with slightly over inflated tires.

Figure 2. Tire inflation demonstration at MSU's Ag Expo

Source: Tim Harrigan, Michigan State University

Tire Inflation Recommendations:

- Weigh each axle *after* the tractor has been properly ballasted. If fully mounted equipment will be transported, weigh the rear axle with the equipment in the raised position. If liquid manure tanks or grain carts will be towed, add the loaded tongue weight of the equipment to the rear axle weight. Manufacturers can provide this information. Determine the weight carried per tire by dividing the axle weight by the number of tires.

- Use load and inflation tables available from the tire manufacturer and inflate tires to the lowest recommended pressure for the weight carried per tire. Adjust inflation pressures whenever axle loads change.

- Use a high quality tire gauge that is easy to read, accurate, consistent and graduated in at least 1 psi increments. Gauges designed for use on ATV tires are recommended. Digital, pencil and dial gauges will all work. However, dial gauges tend to be the most easily damaged when dropped.

- Check the inflation pressure often and when the tires are cold, preferably in the morning. Gauge readings can be 1 to 3 psi higher when the tires are warm.

- For optimum performance, set all tires on an axle to the same pressure.

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Monitor wheel slip. The best way to determine if a tractor is ballasted properly is to monitor the amount of wheel slip that occurs when performing field operations with properly inflated tires. Wheel slip can be measured two ways: with a performance monitor or by comparing wheel revolutions over a given distance with and without draft. For optimum performance, wheel slip should be between 10% and 15% for 2WD tractors and between 8% and 12% for MFWD and 4WD tractors. The lower end of the range pertains to firm soils and the higher end is appropriate for soft or sandy soils.

Operate tractors efficiently. Engines operated at or near maximum load produce the most work for the fuel consumed. Since many field operations don't require the tractor's maximum rated horsepower, fuel can be saved by shifting to a higher gear and reducing the engine's rpm to maintain your field speed. This practice is commonly referred to as Gear Up, Throttle Down (GUTD) and has been shown to increase fuel efficiency by 13% to 20%. Many newer tractors have infinitely or continuously variable transmissions that achieve greater fuel efficiency without manual adjustments. Consider the following when using GUTD:

- Use GUTD during light load operations requiring less than 70% of the rated engine power.
- Stay within the recommended rpm working range listed in the operator's manual. Engine speed can typically be reduced by 20% to 30% below the rated engine speed.
- Don't overload or lug the engine. Checking for excessive black smoke from the exhaust is one way to monitor engine overloading. Another method is to quickly increase the throttle setting. If the engine responds, you are not overloading the engine. If the engine does not pick up speed quickly, shift to the next lower gear and increase the throttle to maintain the desired speed.
- PTO driven equipment may not function properly and should not be operated at lower throttle settings.

Shut tractors off when not in use. Modern diesel engines should be shut down when not used for 5 to 10 minutes. Idling wastes fuel and can lead to carbon buildup in the injector spray holes and valves.

Stay on a regular maintenance schedule. Dynamometer testing from a University of Missouri case study showed that replacing air and fuel filters lowered fuel consumption by 4%. Be careful to avoid introducing dirt into the system when inspecting and changing air filters.

Additional fuel saving tips. The following practices have also been shown to reduce fuel consumption:

- Reduce or eliminate tillage passes whenever possible as they consume more fuel than other field operations. Avoid creating soil conditions that require tillage such as compaction and deep tire ruts.
- Operate tillage tools no deeper than necessary and keep the ground working parts sharp.
- Use some type of guidance system. Researchers at Purdue University estimated that using lightbar technology reduced annual field time by 11% on a model 1,800 acre corn and soybean farm. They also predicted that using a differential corrected global positioning system (DGPS) or a real time kinematic (RTK) auto guidance system reduced field time by another 6%.

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