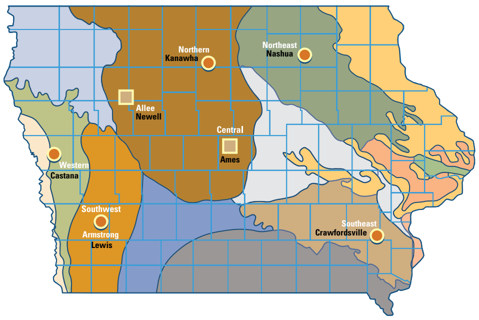

Techniques to improve tractor energy efficiency and fuel savings

Across Iowa's farmland, the purchase of diesel fuel for field operations is the greatest single expense for direct energy consumption. Much of the fuel is consumed during tractor operations for tillage, planting, application of fertilizer and pesticide, and hauling products to and from the field. In some instances, such as reduced tillage, fuel is saved by avoiding a tractor operation. In many other cases when a tractor is required, helpful strategies are available to manage and reduce fuel consumption.

Strategies for saving tractor fuel include shifting up to a higher gear and throttling back for drawbar loads that require less than 100 percent of tractor power, reducing tillage depth, reducing travel speed, and using correct tire inflation pressure. In addition, the use of dual- rather than single-tires and mechanical front wheel assisted drive on a tractor can also affect fuel consumption.

Techniques for saving tractor fuel were measured at seven Iowa State University research and demonstration farms. A small on-board, auxiliary fuel tank was added to a tractor at each site. A load cell underneath the tank measured fuel weight before and after each field trial. Although the research plots were smaller than average fields, replicated measurements of fuel consumption on smaller areas allowed researchers to compare different management strategies. Overall, 43 of the 48 different comparisons of fuel management techniques showed a reduction in fuel consumption during the field trials.

Shift up, throttle back

Shifting up to a higher gear and reducing engine speed while maintaining identical travel speed was used in 19 different field comparisons. Individual treatment comparisons included the following field operations: subsoiling/ripping, field cultivation, planting, disking, using a grain drill to seed cover crops, chisel and moldboard plowing, and stalk chopping. In 18 of the 19 comparisons, fuel was saved when using the higher gear. When the tractor was left in the lower gear/higher engine speed combination, fuel use increased by as much as 51 percent and showed an average increase of 26 percent across all treatment comparisons.

Selected treatment comparisons are shown in Tables 1, 2, and 3.

Table 1. Fuel use at the Northeast Iowa Research Farm, spring 2013.

Operation	No. of replications	Treatment	Gal/acre
		Gear/engine rpm	
Field cultivation, 5 mi/h	3	C1/2080	0.80
	3	C2/1710	0.66
LSD $_{\alpha=0.05}$[a]			0.05

[a] Least significant difference between treatments at a 95% confidence level.

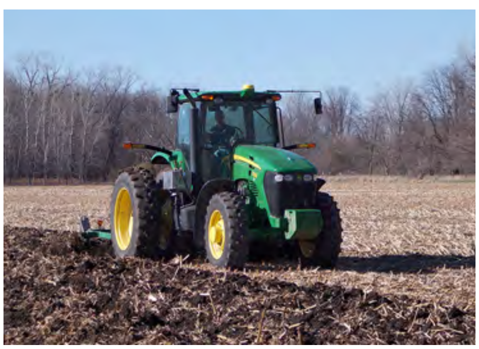

Table 2. Fuel use at the Western Iowa Research Farm, spring 2014.

Operation	No. of replications	Treatment	Gal/acre
		Gear/engine rpm	
Planting, 5.2 mi/h	8	B4/2150	0.57
	8	C2/1900	0.50
LSD $_{\alpha=0.05}$[a]			0.03

[a] Least significant difference between treatments at a 95% confidence level.

Table 3. Fuel use at the Northeast Iowa Research Farm, fall 2013.

Operation	No. of replications	Treatment	Gal/acre
		Gear/engine rpm	
Strip till, 5.2 mi/h	3	C1/2170	2.10
	3	C2/1710	1.39
LSD $_{\alpha=0.05}$[a]			NS[b]

[a] Least significant difference between treatments at a 95% confidence level.
[b] No significant difference at the 95% confidence level.

Tillage depth

Fuel consumption for most tillage operations is directly related to tillage depth. Consider the goal of the tillage operation when setting depth rather than simply pulling the implement as deeply as the tractor power will allow. Fuel consumption and depth were compared in three disking operations and two field cultivation operations. Fuel savings with a shallow tillage depth ranged from 7–41 percent. Two of the comparisons are shown in Tables 4 and 5.

Table 4. Fuel use at the Allee Research Farm, spring 2015.

Operation	No. of replications	Treatment	Gal/acre
		Depth, in.	
Field cultivation, 4.8 mi/h	6	4.5	0.63
	6	3	0.50
LSD $_{\alpha=0.05}$[a]			0.13

[a] Least significant difference between treatments at a 95% confidence level.

Table 5. Fuel use at the Southwest Iowa Research Farm with varying tillage depth, spring 2014.

Operation	No. of replications	Tillage depth, in	Gal/acre
Disking, 4.7 mi/h	4	6	0.32
	4	4	0.23
LSD $_{\alpha=0.05}$[a]			NS[b]

[a] Least significant difference between treatments at a 95% confidence level.
[b] No significant difference at the 95% confidence level.

Travel speed

Travel speed affects the time required to do the job and impacts productivity. In most cases, farmers choose to accomplish work as quickly as possible so reducing field speed is not an appealing option.

Fortunately, although the tractor's speed of operation impacts energy use, in some cases fuel consumption may only be marginally impacted, such as when reduced engine and a higher gear is used for faster travel speed. Fuel consumption may occasionally decrease with faster tillage speed if small changes in drawbar load are balanced by operating the tractor engine at a more fuel efficient combination of greater torque and lower engine speed.

Travel speed was compared 11 times during operations that included chisel plowing, disking, field cultivating, moldboard plowing, mowing hay, and hauling corn. An increase in travel speed increased fuel consumption in 9 of 11 comparisons, although the effect was mixed in two (e.g., Table 7). Fuel savings averaged 15 percent, ranging up to 59 percent. Two of the comparisons are shown in Tables 6 and 7.

Table 6. Fuel use at the Southeast Iowa Research Farm, fall 2013.

Operation	No. of replications	Treatment	Gal/acre
		Travel speed, mi/h	
Chisel plowing	3	3.8	1.12
	3	4.5	1.39
LSD $_{\alpha=0.05}$[a]			NS[b]

[a] Least significant difference between treatments at a 95% confidence level.

[b] No significant difference at the 95% confidence level.

Table 7. Fuel use at the Northern Iowa Research Farm, fall 2013.

Operation	No. of replications	Treatment	Gal/acre
		Travel speed, mi/h	
Chisel plowing	3	4.6	0.91
	3	5.1	0.69
	3	5.5	1.10
LSD $_{\alpha=0.05}$[a]			NS[b]

[a] Least significant difference between treatments at a 95% confidence level.

[b] No significant difference at the 95% confidence level.

Tire inflation

Tires should be inflated to the correct pressure, keeping in mind the operating conditions such as roadway travel or severe field slopes. Over-inflation can reduce contact of tire lugs in soft or adverse soil conditions. Past research has frequently shown excess fuel consumption if tires are over-inflated.

Front- and rear-axle weight was measured on each tractor being tested. Correct inflation was determined by weight and tire size used, according to the tire manufacturer's website and the tractor's operating manual. Allowance for extra inflation was made for over-the-road travel of mounted equipment which added weight to the rear axle or if steep side slopes (as defined by the tire manufacturer) were present. In each case, correct tire pressure was compared to an over-inflated pressure.

Consistently demonstrating fuel savings with this technique was difficult. Less fuel was used in three of the five comparisons using correct inflation, but fuel savings were just 1–2 percent in these cases. Two tests with negative savings were conducted with a single tractor at one farm location. These tests may have been affected by good traction conditions where soil contact by additional tire lugs was not a factor in fuel consumption. Examples of the two tests are shown in tables 8 and 9.

Table 8. Fuel use at the Northern Iowa Research Farm with varying rear tire inflation, fall 2014.

Operation	No. of replications	Rear tire pressure	Gal/acre
Chisel plowing, 3.6 mi/h	3	14	1.09
	3	20	1.12
LSD $_{\alpha=0.05}$[a]			NS[b]

[a] Least significant difference between treatments at a 95% confidence level.

[b] No significant difference at the 95% confidence level.

Table 9. Fuel use at the Southwest Iowa Research Farm with varying rear tire inflation, fall 2014.

Operation	No. of replications	Tire pressure	Gal/acre
Chisel plowing, 3.6 mi/h	3	10	1.21
	3	20	1.16
LSD $_{\alpha=0.05}$[a]			NS[b]

[a] Least significant difference between treatments at a 95% confidence level.

[b] No significant difference at the 95% confidence level.

Dual vs. single tires

Dual tires are typically used when a second wheel is required to support axle weight, or to improve floatation or stability. A second tire may also decrease rolling resistance or improve traction if soil conditions are wet or marginal. Fuel consumption increased 4 percent during planting and 12 percent during field cultivation when dual tires were removed in two different tests, as shown in Table 10.

Table 10. Fuel use at the Allee Research Farm, spring 2014.

Operation	No. of replications	Treatment			Gal/acre
		Depth, in.	Wheels	Travel speed, mi/h	
Field cultivation	5	5	single	5.1	0.74
	5	5	dual	5.1	0.66
LSD $_{\alpha=0.05}$[a]					NS[b]
Planting	4	2	single	5.0	0.25
	5	2	dual	5.0	0.24
LSD $_{\alpha=0.05}$[a]					NS[b]

[a] Least significant difference between treatments at a 95% confidence level.

[b] No significant difference at the 95% confidence level.

Mechanical front-wheel drive

Unpowered front wheels on a two-wheel drive tractor are necessary for steering control, but do not help tractive propulsion unless they are powered. Some two-wheel drive models offer optional front-wheel drive assist to power the front wheels so that they help by pulling the load rather than simply creating rolling resistance when being passively pushed through the soil. To create traction, peripheral speed of lugs on the front wheels are slightly faster than those on rear tires. To prevent extra wear on the drive transmission, manufacturers sometimes recommend disengaging front-wheel drive during road travel when added traction may not be as beneficial.

Fuel consumption was compared with and without mechanical front-wheel drive engaged during row crop planting, seeding cover crops with a grain drill, rotary mowing, and hauling large round bales. Engaging front-wheel drive resulted in fuel savings in all six comparisons. Not powering the front axle resulted in an average of 13 percent more fuel use (ranging from 5–31 percent fuel increase). Example tests are shown in tables 11 and 12.

Table 11. Fuel used at the Western Iowa Research Farm, spring 2014.

Operation	No. of replications	Treatment	Gal/acre
		MFD[a]	
Planting, 5.2 mi/h	8	no	0.55
	8	yes	0.52
LSD $_{\alpha=0.05}$[b]			0.03

[a] Mechanical front-wheel drive engaged (yes) or disengaged (no).

[b] Least significant difference between treatments at a 95% confidence level.



Table 12. Fuel used at the Western Iowa Research Farm, summer 2014.

Operation	No. of replications	Treatment	Gal/acre
		MFD[a]	
Rotary mowing, 4.3 mi/h	4	no	0.78
	4	yes	0.59
$LSD_{\alpha=0.05}$[b]			0.15

[a] Mechanical front-wheel drive engaged (yes) or disengaged (no).
[b] Least significant difference between treatments at a 95% confidence level.

Statistical significance

Overall, the fuel saving trends were generally as expected. The number of times fuel consumption could be observed was frequently limited due to smaller field or plot sizes and time pressures to complete spring or fall field-work during a small window dictated by the weather. Farm staff attempted to collect three or more replicated (observed) measurements of each treatment method when possible. However, the limited number of replicated measurements did not allow ISU researchers to declare statistical significance (e.g. 95% confidence, in some instances).

Summary

Six different strategies to save tractor diesel fuel were compared in replicated tests on ISU research and demonstration farms. In 43 of 48 field trials, average fuel consumption was greater when a fuel saving strategy was not used, although values were not always statistically different due to limited replications and inherent measurement variability.

The following techniques showed a reduction in fuel consumption: shift up, throttle back, shallower tillage depth, and use of front-wheel drive and dual (vs. single) tires when conditions were appropriate. Reduced travel speed also tended to reduce fuel consumption, although field productivity was affected. Demonstrating fuel savings with correct tire inflation was mixed, but may have been affected by tractor operating conditions on one farm.

Table 13. Observed effect of tractor fuel saving treatment strategies.

Strategy	Trials with positive trends	% Excess fuel use, average
Shift up, throttle back	18 of 19	25
Tillage depth	5 of 5	28
Travel speed	9 of 11	17
Tire inflation	3 of 5	-1[a]
Dual vs. single tires	2 of 2	8
Mechanical front-wheel drive	6 of 6	13

[a] Average of +1% savings for three trials with positive savings.

Additional resources:

More specific information for improving tractor fuel efficiency can be found in these publications from ISU Extension and Outreach.

- Shift up and throttle back to save tractor fuel
- Tractor maintenance to conserve energy
- Ballasting tractors for fuel efficiency
- Fuel efficiency factors for tractor selection
- Limiting field operations

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