E diesel On-Farm

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Project Title: Evaluation of E diesel as an alternative fuel in agricultural machinery

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In the second half of 2000, the on-farm evaluation of E diesel was extended to include two combines and the 9400 tractors on Shafer Farms were again monitored during chisel plowing operations. This report covers details and preliminary results from both activities. The objectives of this research are the following:

(a) Determine the economic impact of E diesel to the profitability of the individual farmer, in particular, and to the broader agricultural sector, in general.

(b) Demonstrate E diesel as an alternative fuel for use in tractors and combines.

(c) Compare machine performance and durability with E diesel to that with standard diesel fuel.

(d) Determine if E diesel is suitable for on-farm use without engine modification.

(e) Develop a meaningful and practical way to evaluate on-farm machine durability.

Negotiations and discussions took place in August with Bloomingdale Farms near Bloomington, IL, Shafer Farms near Wyoming, IL, Deere & Company, Illinois Corn Growers Association, Illinois Department of Commerce and Community Affairs, Growmark, Inc. and University of Illinois. Two new John Deere 9650 combines (see table 1 for engine specifications) were identified for evaluation of E diesel on Bloomingdale Farms, in a similar approach as adopted for the two John Deere 9400 4WD tractors at Shafer Farms. The maximum power output for the engines fitted to these combines were obtained from Deere & Company and the engine developing 2% more power was selected to run on E diesel in order to minimize the fuel energy content differential, with the other combine engine running on standard #2 diesel. Both combines were fitted with Greenstar yield mapping systems and John Deere data logging systems for recording torque, engine speed, fuel consumption rate, ground speed, unloading status, coolant, fuel and manifold air temperatures. Towards the end of the harvesting period, Deere & Company added GPS information to the recorded data. A daily log of overall fuel usage was also kept. Oil samples were collected at the beginning and at 100-hour intervals from both combines as an assessment of engine condition.

This report contains the results from both the combines and the tractors during the Fall.

1. Combine Results

1.1 Daily Fuel Usage

A daily log of fuel consumption and engine hours was recorded for each combine and is presented in Table 2. The overall results showed a 4.8 to 5.6% increase in consumption by volume for the combine operating on E diesel. This percentage was close to the estimated decrease in heating value of E diesel of 3.9% by volume. The fact that it was higher than the decrease in heating value can be attributed to different operating conditions rather than different combustion efficiencies as discussed later.

1.2 In-Field Combine Performance

The data captured while the combines were working in the field included torque, engine speed, fuel consumption, ground speed and crop yield. The sampling rate was 1s. Tables 3 to 7 show summaries of results from five different fields, three of which were cornfields. The data were grouped according to five ground speed ranges so that approximately 20% of the data was represented within each range. The average values within each range were calculated, as well as an overall average. The tables have results for both the diesel (D) and the E diesel (E) combines and the bottom segment of the tables provides the ratios of E diesel to diesel (E/D). For the first field (Leary) both combines operated on #2 diesel to establish a baseline from which to compare the two combines. The effect of E diesel on combine performance is discussed in the following sections.

1.2.1 Power

The power values shown in Tables 3 to 7 were computed from torque and speed using the rated torque calculated from the respective power values given in Table 1 for each combine, which were supplied by Deere & Company. A comparison of combine performance indicated that the E diesel combine operating in corn required 22% more power than the diesel combine. The E diesel combine was also traveling 12% faster in the field, which would account for a higher power requirement. Higher speeds result in higher frictional losses in the overall combine system in addition to the higher work rate achieved. A small increase in power was evident in soybeans for the E diesel combine, however, the ground speeds were approximately the same.

1.2.2 Fuel consumption

In line with the increased power demand for the E diesel combine in corn, the fuel consumption increased by 19%. Much smaller increases occurred with E diesel in soybeans.

1.2.3 Engine Efficiency

Both specific fuel consumption (SFC) and brake thermal efficiency (Ebt) were calculated as measures of engine efficiency. SFC is the ratio of fuel consumption to power and does not take into account differences in energy content of the fuel. Brake thermal efficiency is the ratio of power output to power input with the latter being determined from the energy content of the fuel and the fuel consumption rate. The energy content of #2 diesel was assumed to be 45,500 kJ/kg and the energy content of E diesel was computed by assuming that the petroleum-based additive had the same energy content as #2 diesel.

Table 3 shows that the engine of the E diesel combine started out with 3.5% higher efficiency than the engine of the diesel combine, with both engines running on #2 diesel. Subsequently, Tables 4-7 show that the E diesel ran at a higher efficiency ranging from 4.3 to 6% or a net efficiency gain of approximately 1 to 2.5%. This efficiency gain can be attributed primarily to slightly improved combustion efficiency. Extra oxygen is made available for combustion via the ethanol present, thus helping to minimize any incomplete combustion in the combustion chamber. If the cetane rating of E diesel is lower than that of diesel, this would cause a longer ignition delay, more premixed combustion

and greater efficiency. The cetane rating would be heavily dependent on the amount of cetane improver present in the additive.

1.3 Oil Analysis

Results from three oil samples were available for analysis. One oil sample was collected from the E diesel combine prior to the switch over to E diesel fuel and the other two samples were collected on the same day from each combine after approximately 100 hours of operation. The laboratory reporting the analyses indicated that the condition of the oil was normal. A study of the metal contaminants for the E diesel combine after 100 hours on E diesel showed no abrupt increases and all the values were similar in magnitude to the contaminant levels in the oil from the diesel combine. Hence from these initial samples it can be concluded that the operation of the one combine on E diesel has caused no detrimental effects on the engine with special reference to components lubricated by the engine oil. Two further samples have been taken and their analysis results will provide a more substantial conclusion as to the effect of E diesel on the engine.

2. Tractor Results

2.1 Daily fuel usage

At the time of preparing this report, the only data available from the tractor tests during the Fall operations was for the diesel tractor as shown in Table 8. Apart from one very high consumption value, the average was similar to the consumption levels for cultivation in the Spring. Further data for the E diesel tractor is to be obtained shortly.

2.2 In-Field Tractor Performance

Data were collected using the data-logging units on Oct 13, 14, 17 and 18 for the E diesel tractor and on Oct 20, 24, 26 and 27 for the diesel tractor. One set of data was selected for each tractor for preliminary analysis to compare levels of loading for the chisel plowing operation. Figures 1 to 4 show histograms of fuel consumption and engine speed for the two tractors. It can be seen that the E diesel tractor tended to work at a slightly lower speed than the rated engine speed, which also meant that it was operating at a slightly higher load and fuel consumption level as compared to the diesel tractor in Figures 3 and 4. The increased fuel consumption is partly due to the reduced energy content of E diesel. It is also possible that the E diesel tractor was operated under different conditions and at a higher ground speed and this can be established through further analysis of the data. It can be concluded that the E diesel tractor was being used at sufficiently high loads to provide an adequate test of the effect of E diesel on the tractor.

3. Economic analysis

A preliminary economic evaluation is presented in a separate document entitled “Economic evaluation of oxydiesel as an alternative fuel in agricultural machinery”.

4. Conclusions

(a) The fuel usage recorded for both combines showed that the combine operating on E diesel for 190 hours consumed an average of 9.7 gal/h as compared to 9.2 gal/h for the combine run on diesel, representing a 5% increase. This is a little more than the estimated 3.9% decrease in energy content by volume of E diesel. It also compares very closely to the 4.8% increase recorded for the tractors during the Spring 2000 operations.
(b) In-field data collected from the combines showed some variation with the crop being harvested with the E diesel combine tending to use more power when harvesting corn. This was attributed to machine operation rather than a difference caused by the fuels.
(c) Engine efficiencies calculated when the two combines were initially run on diesel and then on their respective fuels indicated that there was a 1-2.5% increase in engine efficiency with E diesel. Part of this increase may have been due to a higher loading of the E diesel engine, however, the results from the Bane field show an increase in efficiency with all the other parameters being approximately the same for both combines.
(d) Oil analysis from 100 hours of engine operation on E diesel showed no abnormal wear and contaminant levels were comparable with the engine operating on #2 diesel.
(e) The one tractor continued to operate satisfactorily on E diesel. Further analysis of the data collected during the chisel plowing operations in the Fall 2000 is required.
(f) The overall conclusion is that E diesel continues to yield largely positive results when run in standard diesel engines.

5. Future Work

(a) The present tractor and combine will continue to operate on E diesel in 2001 and will be monitored in a similar way with data loggers, along with the control vehicles running on #2 diesel. Oil samples should be taken at regular intervals so that oil analyses can be used as a measure of engine wear.
(b) More flexible data logging software for the tractors would facilitate data capture and processing. A system similar to that used on the combines would be ideal. Such software/hardware needs to be investigated with the assistance of Deere & Company.
(c) The use of portable emissions equipment to measure actual emissions in the field would be a logical and valuable extension to the present project and would provide direct evidence of the benefits of E diesel over diesel. The availability and cost of the necessary equipment would have to be investigated.

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BetzDearBorn

Table 1 Summary of specifications for John Deere 9650 combines

Specification	**Diesel Combine**	**E Diesel Combine**
Combine Serial No.	H09650W685689	H09650W685698
Engine Serial No.	RG6081H093946	RG6081H093634
Rated horsepower (Factory)	273.55 hp (204 kW)	279 hp (208 kW)
Horsepower with power boost	308 hp (223 kW)	
Rated speed	2200 rev/min	
Type of engine	In-line, 6-cylinder	
Aspiration	Turbocharged and aftercooled	
Displacement	496 cu. in (8.1 L)	
Fuel tank capacity (maximum usable)	150 U.S. gal. (565 L.)	

Table 2 Summary of fuel usage on Bloomingdale during combine operations in Fall 2000

Date	9650 Combine run on E-Diesel						9650 Combine run on Diesel							
	Fuel Gal. Used	Eng. Hours	Sep. Hours	Eng. gph	Sep. gph	Oil qts.	Fuel Gal. Used	Eng. Hours	Sep. Hours	Eng. gph	Sep. gph	Oil qts.	Eng. gph Ratio E/D	Sep. gph Ratio E/D
Mon 9/25	79.8	204	138				77	194	128					
Wed 9/27	102	218	147	7.29	11.33		117	209	137	7.80	13.00		0.9341	0.8718
Thu 9/28	138	231	157	10.62	13.80		126	223	148	9.00	11.45		1.1795	1.2048
Sat 9/30	96	242	166	8.73	10.67		100	235	157	8.33	11.11		1.0473	0.9600
Mon 10/2	119	254	175	9.92	13.22		114.5	247	166	9.54	12.72		1.0393	1.0393
Mon 10/9	141	269	187	9.40	11.75		125	261	178	8.93	10.42		1.0528	1.1280
Tue 10/10	93.1	278	195	10.34	11.64		92.2	271	186	9.22	11.53		1.1220	1.0098
Wed 1011	108	289	204	9.82	12.00	3	105.4	282	195	9.58	11.71	5	1.0247	1.0247
Thu 10/12	91.4	297	212	11.43	11.43		88.5	291	202	9.83	12.64		1.1619	0.9037
Fri 10/13	179	314	225	10.53	13.77		160	307	215	10.00	12.31		1.0529	1.1188
Sat 10/14	132	327	237	10.15	11.00		138	321	227	9.86	11.50		1.0301	0.9565
Thu 10/19	105	342	248	7.00	9.55	2.5	90	336	238	6.00	8.18	4	1.1667	1.1667
Fri 10/20	120	354	256	10.00	15.00		106	347	247	9.64	11.78		1.0377	1.2736
Sat 10/21	89	362	263	11.13	12.71		86	355	254	10.75	12.29		1.0349	1.0349
Tue 10/10							52.5	361	258	8.75	13.13			
Wed 10/25	50	374	271											
Thu 10/26	95	377	274				91	371	266	9.10	11.38			
Fri 10/27	187	394	289	10.38	12.77		192.4	388	281	10.50	12.32		0.9884	1.0363
Total	1845.5	190	151	9.71	12.22		1784.5	194	153	9.20	11.66		1.0560	1.0479

Table 3 Summary of combine data for field: Leary

Field: **Leary 55.7** **Date:** **9-8-00**

CanLog D Corn

GROUP	Torque(%)	Speed(rpm)	Fuel(kg/h)	mph	ac/h	gpa	CYLD_ADJ	Power(kW)	SFC (kg/kWh)	Ebt
Mph: 0 - 3	58	2330	25.4	2.45	5.94	1.57	171	125	0.202	0.39
Mph: 3 - 3.37	65	2316	29.6	3.24	7.85	1.39	174	140	0.212	0.37
Mph: 3.37 - 3.56	67	2313	30.2	3.49	8.46	1.31	174	144	0.210	0.38
Mph: 3.56 - 3.7	68	2311	29.8	3.64	8.82	1.24	172	146	0.204	0.39
Mph: 3.7 - 4.97	69	2309	30.6	3.83	9.28	1.21	171	148	0.207	0.38
Entire field	66	2314	29.6	3.44	8.34	1.30	172	142	0.209	0.38

CanLog E Corn Note: Combine was run on diesel

GROUP	Torque(%)	Speed(rpm)	Fuel(kg/h)	mph	ac/h	gpa	CYLD_ADJ	Power(kW)	SFC (kg/kWh)	Ebt
Mph: 0 - 3	60	2324	25.9	2.61	6.33	1.50	171	132	0.196	0.40
Mph: 3 - 3.37	65	2313	28.6	3.21	7.78	1.35	169	142	0.201	0.39
Mph: 3.37 - 3.56	67	2309	29.9	3.46	8.39	1.31	159	146	0.204	0.39
Mph: 3.56 - 3.7	65	2314	29.9	3.62	8.78	1.25	172	142	0.210	0.38
Mph: 3.7 - 4.97	70	2298	32.0	3.94	9.55	1.23	141	152	0.210	0.38
Entire field	64	2314	28.3	3.13	7.59	1.37	167	140	0.202	0.39

CanLog E/D Corn

GROUP	Torque(%)	Speed(rpm)	Fuel(kg/h)	mph	ac/h	gpa	CYLD_ADJ	Power(kW)	SFC (kg/kWh)	Ebt
Mph: 0 - 3	103%	100%	102%	107%	107%	96%	100%	105%	103%	103%
Mph: 3 - 3.37	100%	100%	97%	99%	99%	98%	97%	102%	105%	105%
Mph: 3.37 - 3.56	100%	100%	99%	99%	99%	100%	91%	102%	103%	103%
Mph: 3.56 - 3.7	96%	100%	100%	99%	99%	101%	100%	98%	97%	97%
Mph: 3.7 - 4.97	101%	100%	104%	103%	103%	101%	82%	103%	99%	99%
Entire field	97%	100%	96%	91%	91%	105%	97%	99%	103%	103.5%

Table 4 Summary of combine data for field: Hawes

Field: **Hawes 40** **Date:** **9-16-00**

CanLog D Corn

GROUP	Torque(%)	Speed(rpm)	Fuel(kg/h)	mph	ac/h	gpa	CYLD_ADJ	Power(kW)	SFC (kg/kWh)	Ebt
Mph: 0 - 2.67	60	2327	26.4	2.40	5.83	1.69	174	129	0.204	0.39
Mph: 2.67 - 2.98	64	2318	28.7	2.84	6.88	1.53	178	138	0.208	0.38
Mph: 2.98 - 3.17	65	2318	28.3	3.07	7.45	1.39	173	140	0.202	0.39
Mph: 3.17 - 3.29	69	2307	30.8	3.26	7.92	1.43	177	148	0.209	0.38
Mph: 3.29 - 7.33	68	2311	31.3	3.41	8.27	1.39	162	146	0.214	0.37
Entire field	62	2322	27.7	2.67	6.48	1.59	175	133	0.208	0.38

CanLog E Corn

GROUP	Torque(%)	Speed(rpm)	Fuel(kg/h)	mph	ac/h	gpa	CYLD_ADJ	Power(kW)	SFC (kg/kWh)	Ebt
Mph: 0 - 2.67	70	2301	30.8	2.40	5.82	1.97	176	152	0.202	0.40
Mph: 2.67 - 2.98	74	2292	32.7	2.87	6.97	1.73	176	160	0.204	0.40
Mph: 2.98 - 3.17	77	2286	33.9	3.11	7.54	1.65	178	166	0.204	0.40
Mph: 3.17 - 3.29	77	2287	34.3	3.25	7.88	1.60	175	166	0.206	0.40
Mph: 3.29 - 7.33	77	2285	34.3	3.73	9.03	1.45	164	166	0.206	0.40
Entire field	75	2291	33.1	2.98	7.23	1.71	175	162	0.204	0.40

CanLog E/D Corn

GROUP	Torque(%)	Speed(rpm)	Fuel(kg/h)	mph	ac/h	gpa	CYLD_ADJ	Power(kW)	SFC (kg/kWh)	Ebt
Mph: 0 - 2.67	117%	99%	117%	100%	100%	117%	101%	118%	101%	104%
Mph: 2.67 - 2.98	116%	99%	114%	101%	101%	113%	99%	117%	102%	106%
Mph: 2.98 - 3.17	118%	99%	120%	101%	101%	119%	103%	119%	99%	103%
Mph: 3.17 - 3.29	112%	99%	111%	100%	99%	112%	98%	113%	101%	105%
Mph: 3.29 - 7.33	113%	99%	110%	109%	109%	104%	101%	114%	104%	107%
Entire field	121%	99%	119%	112%	112%	108%	100%	122%	102%	105.4%

Table 5 Summary of combine data for field: Alexander

Field: **Alexander** **Date:** **9-21-00**

CanLog D Corn

GROUP	Torque(%)	Speed(rpm)	Fuel(kg/h)	mph	ac/h	gpa	CYLD_ADJ	Power(kW)	SFC (kg/kWh)	Ebt
Mph: 0 - 4.16	73	2299	32.7	3.96	9.6	1.26	185	156	0.210	0.38
Mph: 4.16 - 4.35	75	2295	33.7	4.28	10.4	1.19	182	160	0.211	0.37
Mph: 4.35 - 4.47	77	2292	34.1	4.44	10.8	1.16	183	164	0.209	0.38
Mph: 4.47 - 4.6	77	2291	33.4	4.57	11.1	1.11	182	164	0.204	0.39
Mph: 4.6 - 6.03	79	2288	34.2	4.76	11.5	1.09	176	168	0.204	0.39
Entire field	76	2293	33.5	4.34	10.5	1.18	182	162	0.207	0.38

CanLog E Corn

GROUP	Torque(%)	Speed(rpm)	Fuel(kg/h)	mph	ac/h	gpa	CYLD_ADJ	Power(kW)	SFC (kg/kWh)	Ebt
Mph: 0 - 4.16	80	2279	35.9	3.88	9.4	1.43	187	172	0.208	0.39
Mph: 4.16 - 4.35	84	2270	36.7	4.30	10.4	1.29	183	180	0.204	0.40
Mph: 4.35 - 4.47	85	2269	37.3	4.44	10.8	1.27	181	182	0.205	0.40
Mph: 4.47 - 4.6	86	2267	37.9	4.57	11.1	1.26	177	184	0.206	0.40
Mph: 4.6 - 6.03	86	2267	37.5	4.77	11.6	1.19	171	184	0.203	0.40
Entire field	83	2273	36.6	4.22	10.2	1.33	182	178	0.205	0.40

CanLog E/D Corn

GROUP	Torque(%)	Speed(rpm)	Fuel(kg/h)	mph	ac/h	gpa	CYLD_ADJ	Power(kW)	SFC (kg/kWh)	Ebt
Mph: 0 - 2.67	110%	99%	110%	98%	98%	113%	101%	111%	101%	104%
Mph: 2.67 - 2.98	112%	99%	109%	100%	100%	108%	101%	113%	104%	107%
Mph: 2.98 - 3.17	110%	99%	109%	100%	100%	109%	99%	111%	102%	105%
Mph: 3.17 - 3.29	112%	99%	113%	100%	100%	114%	97%	113%	99%	103%
Mph: 3.29 - 7.33	109%	99%	110%	100%	100%	109%	97%	110%	100%	104%
Entire field	109%	99%	109%	97%	97%	113%	100%	110%	101%	104.3%

Table 6 Summary of combine data for field: Bane

Field: **Bane 80** **Date:** **10-24-00**

CanLog D Soybeans

GROUP	Torque(%)	Speed(rpm)	Fuel(kg/h)	mph	ac/h	gpa	CYLD_ADJ	Power(kW)	SFC (kg/kWh)	Ebt
Mph: 0 - 4.16	69	2273	30.0	3.42	8.29	1.52	43.6	145	0.207	0.38
Mph: 4.16 - 4.72	84	2274	36.6	4.50	10.90	1.23	51.0	177	0.207	0.38
Mph: 4.72 - 5.1	87	2267	37.9	4.97	12.04	1.16	53.7	183	0.207	0.38
Mph: 5.1 - 5.34	88	2263	38.2	5.25	12.73	1.10	55.8	185	0.207	0.38
Mph: 5.34 - 7.39	91	2255	39.4	5.59	13.54	1.07	57.0	190	0.207	0.38
Entire field	84	2263	36.6	4.79	11.61	1.20	52.9	176	0.208	0.38

CanLog E Soybeans

GROUP	Torque(%)	Speed(rpm)	Fuel(kg/h)	mph	ac/h	gpa	CYLD_ADJ	Power(kW)	SFC (kg/kWh)	Ebt
Mph: 0 - 4.16	75	2283	32.6	3.64	8.83	1.42	51.0	162	0.201	0.41
Mph: 4.16 - 4.72	85	2267	36.7	4.49	10.90	1.24	56.4	182	0.202	0.41
Mph: 4.72 - 5.1	87	2263	37.4	4.99	12.08	1.14	57.7	186	0.201	0.41
Mph: 5.1 - 5.34	87	2263	37.9	5.24	12.71	1.09	56.7	186	0.203	0.40
Mph: 5.34 - 7.39	88	2259	38.3	5.63	13.65	1.03	55.4	188	0.204	0.40
Entire field	84	2263	36.4	4.74	11.50	1.19	55.5	180	0.203	0.40

CanLog E/D Soybeans

GROUP	Torque(%)	Speed(rpm)	Fuel(kg/h)	mph	ac/h	gpa	CYLD_ADJ	Power(kW)	SFC (kg/kWh)	Ebt
Mph: 0.23 - 5.57	109%	100%	108%	106%	107%	93%	117%	111%	103%	106%
Mph: 5.57 - 6.08	101%	100%	100%	100%	100%	101%	111%	103%	102%	106%
Mph: 6.08 - 6.42	100%	100%	99%	100%	100%	98%	107%	102%	103%	107%
Mph: 6.42 - 6.76	99%	100%	99%	100%	100%	99%	102%	101%	102%	105%
Mph: 6.76 - 7.56	97%	100%	97%	101%	101%	96%	97%	99%	101%	105%
Entire field	100%	100%	99%	99%	99%	99%	105%	102%	103%	106.0%

Table 7 Summary of combine data for field: Arrow

Field: **Arrow N. 200** **Date:** **10-27-00**

CanLog D Soybeans

GROUP	Torque(%)	Speed(rpm)	Fuel(kg/h)	mph	ac/h	gpa	CYLD_ADJ	Power(kW)	SFC (kg/kWh)	Ebt
Mph: 0.23 - 5.57	77	2286	33.6	4.80	11.6	1.10	43.1	163	0.206	0.38
Mph: 5.57 - 6.08	88	2263	38.6	5.82	14.1	1.02	47.0	185	0.209	0.38
Mph: 6.08 - 6.42	92	2240	40.6	6.25	15.2	1.00	50.2	191	0.212	0.37
Mph: 6.42 - 6.76	97	2211	41.9	6.59	16.0	0.98	51.6	199	0.211	0.38
Mph: 6.76 - 7.56	94	2252	40.5	6.88	16.7	0.91	49.9	196	0.206	0.38
Entire field	88	2253	38.5	5.92	14.4	1.02	48.0	184	0.209	0.38

CanLog E Soybeans

GROUP	Torque(%)	Speed(rpm)	Fuel(kg/h)	mph	ac/h	gpa	CYLD_ADJ	Power(kW)	SFC (kg/kWh)	Ebt
Mph: 0.23 - 5.57	82	2267	35.9	4.88	11.8	1.16	46.5	176	0.204	0.40
Mph: 5.57 - 6.08	92	2244	40.2	5.84	14.2	1.06	51.1	195	0.206	0.40
Mph: 6.08 - 6.42	94	2235	40.9	6.23	15.1	1.01	51.5	199	0.206	0.40
Mph: 6.42 - 6.76	95	2225	41.1	6.57	15.9	0.96	49.9	200	0.206	0.40
Mph: 6.76 - 7.56	94	2245	40.2	6.86	16.6	0.90	48.6	200	0.201	0.41
Entire field	91	2244	39.6	5.90	14.3	1.05	49.7	193	0.205	0.40

CanLog E/D Soybeans

GROUP	Torque(%)	Speed(rpm)	Fuel(kg/h)	mph	ac/h	gpa	CYLD_ADJ	Power(kW)	SFC (kg/kWh)	Ebt
Mph: 0.23 - 5.57	106%	99%	107%	102%	102%	105%	108%	108%	101%	104%
Mph: 5.57 - 6.08	105%	99%	104%	100%	100%	104%	109%	106%	101%	105%
Mph: 6.08 - 6.42	102%	100%	101%	100%	100%	101%	103%	104%	103%	107%
Mph: 6.42 - 6.76	98%	101%	98%	100%	100%	98%	97%	100%	102%	106%
Mph: 6.76 - 7.56	100%	100%	99%	100%	100%	99%	97%	102%	102%	106%
Entire field	103%	100%	103%	100%	100%	103%	104%	105%	102%	105.6%

Table 8 Summary of diesel fuel usage on Shafer Farms during chisel plowing in Fall 2000

Date	Fuel Used (gal)	Tractor Hours	Consumption (gal/h)	L/h	kg/h
10/24/00	Full	567.6			
10/25/00	86.7	573.9	13.8	52.1	43.4
10/25/00	91.1	582.3	10.8	41.0	34.2
10/27/00	206	593.2	18.9	71.8	59.9
Total/Ave	383.8	25.6	15.0	57.0	47.5

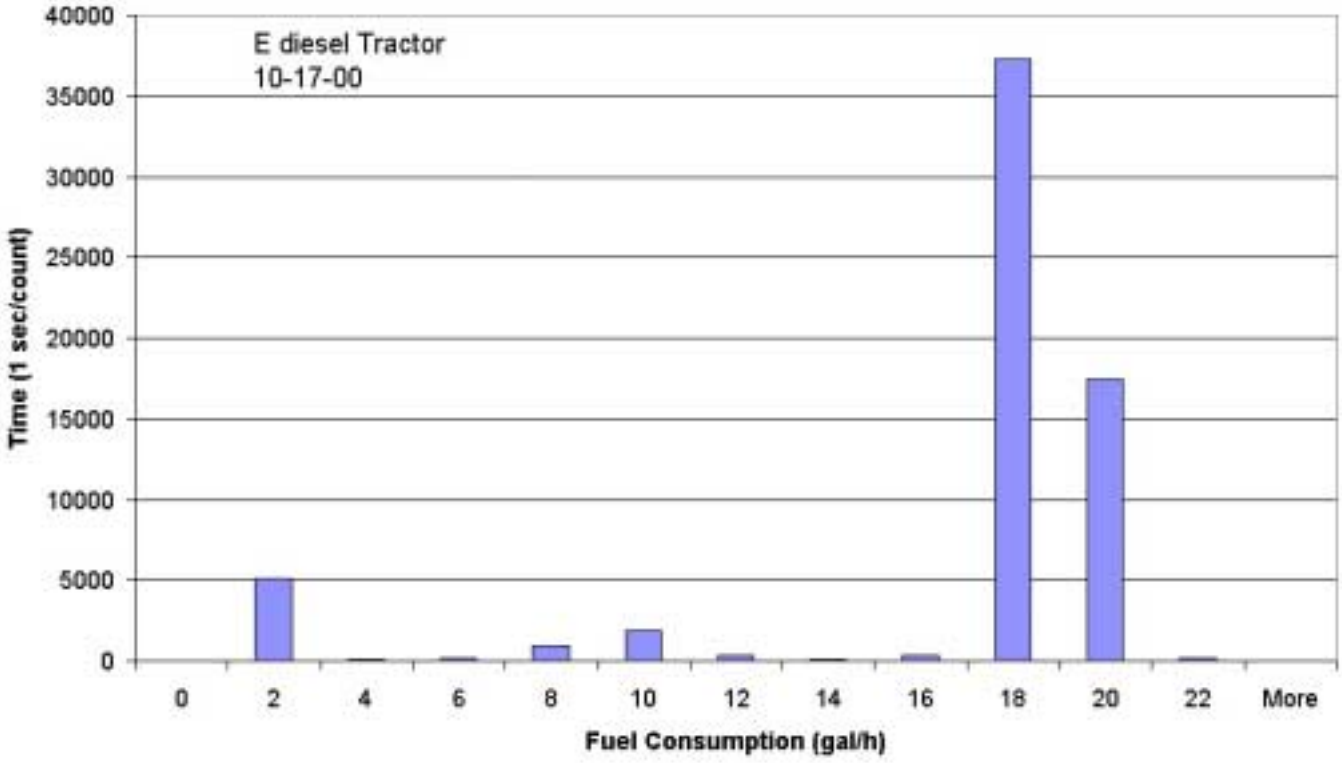

Figure 1 Histogram of fuel consumption for the E diesel tractor during chisel plowing

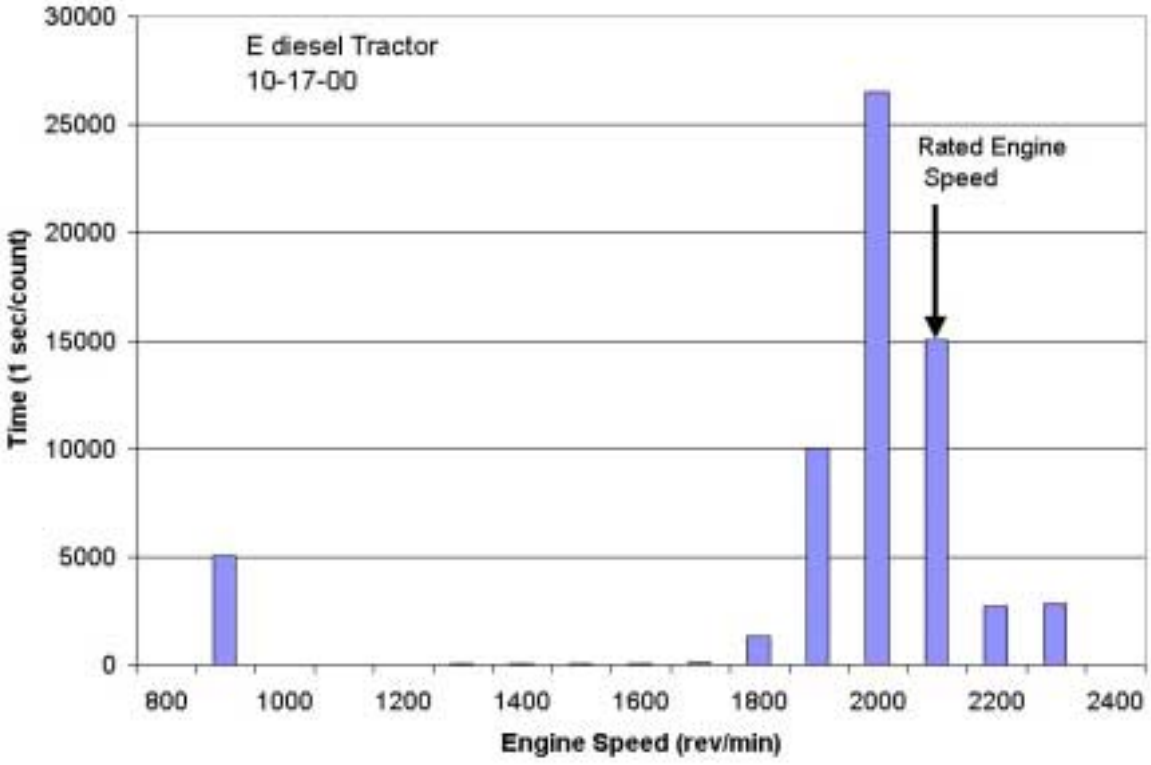

Figure 2 Histogram of engine speed for the E diesel tractor during chisel plowing

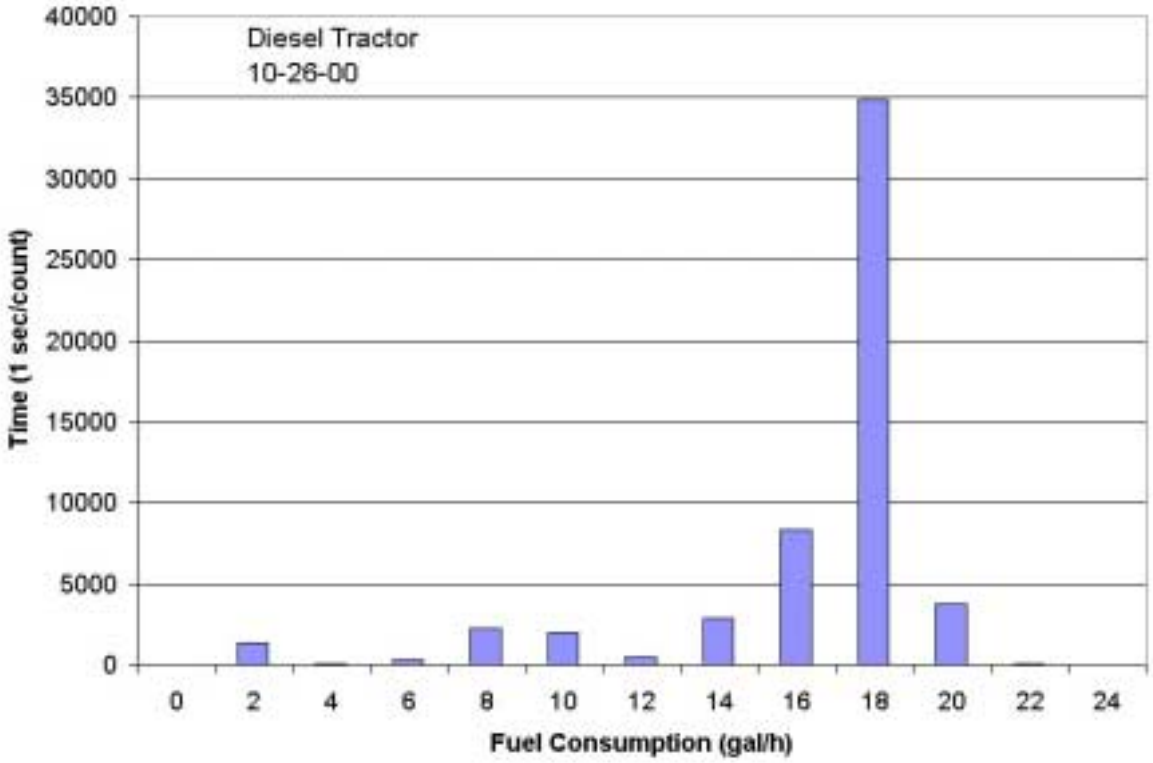

Figure 3 Histogram of fuel consumption for the diesel tractor during chisel plowing

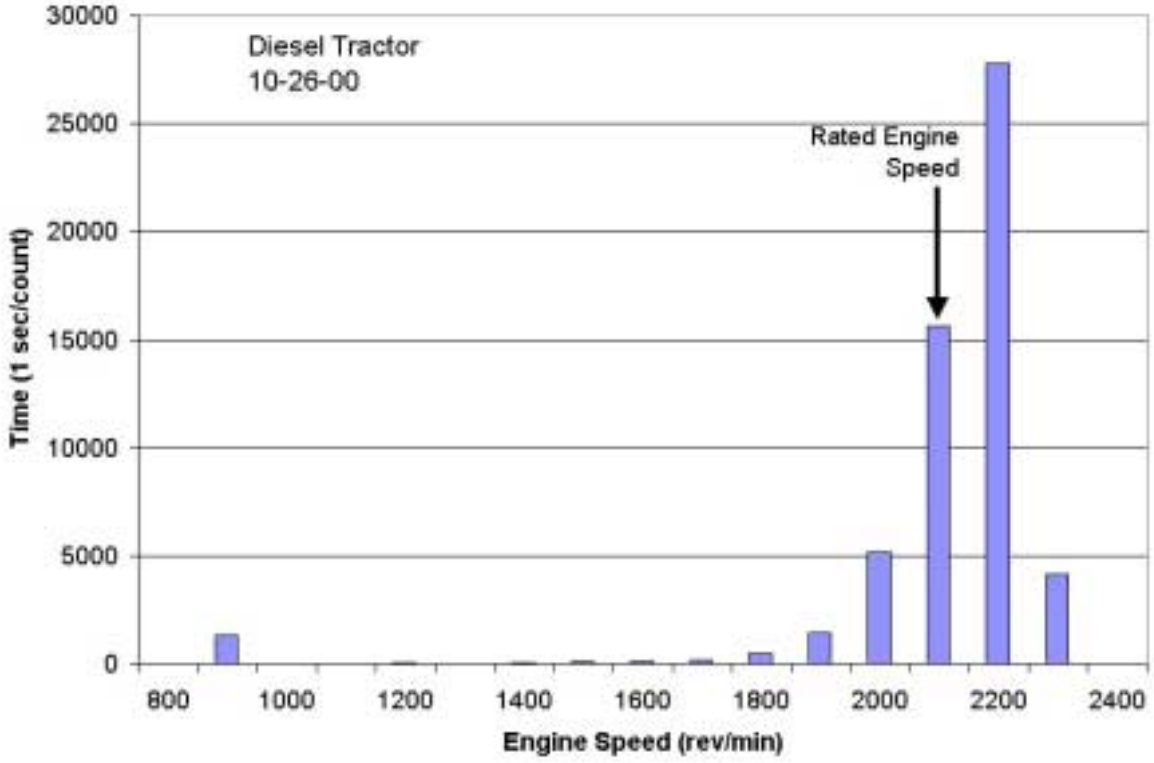

Figure 4 Histogram of fuel consumption for the diesel tractor during chisel plowing