Forage Harvester Evaluation

Forage harvester efficiency is one of the factors to be considered in obtaining a unit. Harvester capacity needs to be matched with capacity of vehicles needed for transporting the material. Other considerations are cost, reliability, maintenance and repair costs, dealer support and ease of operation. Four self-propelled forage harvesters were tested for throughput, fuel consumption and quality of processing.

Materials and Methods

A randomized complete block design with three replications was used for the test. Corn (*Zea mays*) variety Seedtec 7634RR was near physiological maturity when it was cut for silage. Prior to the test, cut length was adjusted to 17 mm (0.75”) and each processor was set at 2 mm (0.08”). Each machine had a 25 foot head. Other machine specifications are listed in Table 1. The machines were driven by different operators. Each operator had more than 1000 hours experience driving that make and model.

Each machine was warmed up, ready to harvest and parked at a specified location where the fuel tank was topped off. Time was recorded for harvest time and for travel time to and from the field and turning on the field ends. After each plot the machine was returned to the same specified location and refueled. Fuel consumption was measured as the amount to refill the fuel tank. Fuel temperature was measured at each fill. Accuracy and repeatability of the fuel meter was verified in the 0.5 to 2.0 gallon range.

The harvested area for each machine per replication was 5.8 acres. Each plot consisted of four passes, harvesting 10-30” rows by 2545 feet. Approximately 50 feet on each end of the field was previously harvested to provide adequate turn around space. Sufficient trucks were available for continuous harvest. Eight or nine trucks were required for each plot. Trucks were weighed full and empty for each load. Samples for moisture analysis were collected from each load from at least 10 spots as the trucks unloaded. Three truck loads per plot were also sampled for particle size following the Penn State Particle Size Separator methodology (Heinrichs, 1996). Approximately three pints of corn silage were placed in the upper sieve. The sieve consisted of three boxes. The upper box had 17 mm (3/4”) holes. The middle box had 8 mm (5/16”) holes. The sieve was shaken five times on a flat surface, rotated 90°, shaken five times, rotated 90°, and repeated for a total of 40 shakes. Material from each box was weighed, dried and re-weighed. Ten randomly selected segments from the middle box were measured for length. Samples from each truck were composited for Corn Silage Processing Score (Mertens and Ferreira, 2001). This test was completed by Dairyland Laboratories, Inc. This test measures starch and neutral detergent fiber (NDF) before and after separation on screens sized 4.75 mm and 1.18 mm.

Results and Discussion

Driving time and percent chopping time were not significantly different between machines therefore all calculations used chopping time (Table 2). Corn silage yield per acre (dry matter) and percent moisture were not significantly different for each machine but they were significantly different by replication (data not shown). There were areas of the field that had higher yields. There were small differences in corn silage yield (fresh weight) where randomization placed each machine but not in dry weight. There was a significant difference in chopping time between machines. The Claas machine moved through the plots at a higher speed and harvested more corn silage (fresh weight) per hour than the other machines (Table 3). The John Deere and Krone machines were comparable and the New Holland was the slowest and harvested the least per hour.

The machines were comparable in fuel consumption per hour of operation (Table 3). Fuel consumption data from the ISO-Bus was retrieved only from the John Deere (Figure 1) and is shown for demonstration only. The Claas machine had the highest throughput, tons of fresh material per gallon of fuel. The John Deere and Krone were comparable and the New Holland had the lowest values. The measured cut length was significantly different. It was the shortest for the New Holland, equivalent for the John Deere and Krone machines, and the longest for the Claas machine. Cut length had a significant impact on throughput and fuel consumption. Figures 2, 3 and 4 show the relationship of cut length versus throughput and fuel consumption as tons harvested (fresh weight) per gallon of fuel, acres harvested per gallon of fuel and tons harvested per hour, respectively. Increasing cut length from 15 to 17 mm increases fuel efficiency 22 percent measured as tons of silage harvested per gallon of fuel used and a 19 percent increase in capacity, tons per hour.

Quality of cut was determined through particle size analysis. No significant difference was observed between the machines for fresh or dry weight in the upper sieve. Although it was not significantly different, there was a trend that the New Holland harvester had the least amount in the upper sieve and that amount was below the recommended threshold. The other machines had equivalent values which were within the recommended guideline. Averaged across all machines, less material was in the bottom sieve than would have been expected and no differences were observed between machines. A lower percentage in the bottom sieve is beneficial when corn silage makes up a greater proportion of the ration. There was a significant difference between machines for the amount of fresh material in the middle sieve. New Holland had the most, John Deere and Krone were equivalent and Claas had the least. The amount in the middle sieve was directly correlated with cut length (R^2= 0.82). That relationship can be described as:

$$\% \text{ fresh weight in middle screen} = -5.9613(\text{cut length})^2 + 180.77(\text{cut length}) - 1296.6$$

Quality of processing was measured using the Corn Silage Processing Score (CSPS). Although each processor was set at 2 mm, there were differences between machines. There was no relationship between cut length and any of the CSPS measurements. The John Deere and Krone machines had significantly higher amounts that did not pass through the 4.75 mm screen. The Claas and New Holland were equivalent and less than the other two. Those results are mirrored for the other size fractions. A higher percentage of material was in the medium and fine fractions for the Claas and New Holland harvesters, which were equivalent. The Krone harvester had the least amount in the medium and fine fractions. It also had more hours on its processor than the other machines. Starch in large particles (>4.75mm) is considered to have less nutritional value. The percent of total starch passing through the 4.75 mm screen is optimum above 70% and acceptable above 50%. Anything below 50% would indicate inadequate processing. Total starch percentage on unshaken samples was equivalent. The percentage of starch that passed through the 4.75 mm sieve was higher for the Claas and New Holland machines, which was the same pattern as size fraction percentage.

References:

Heinrichs, Jud. 1996. Evaluating particle size of forages and TMRs using the Penn State Particle Size Separator. DAS 96-20.

Lammers, B., D. Buckmaster and A. Heinrichs. 1996. A Simple Method for the Analysis of Particle Sizes of Forage and Total Mixed Rations. Journal of Dairy Science 79:922-928.

Mertens, D. and G. Ferreira. 2001. Partitioning in vitro digestibility of corn silages of different particle sizes. Abstract #826, ADSA Meetings, Indianapolis, IN.

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Table 1. Machine specifications.

Make	John Deere	Claas	Krone	New Holland
Model	7950 Prodrive	Jaguar 980	Big X 800	FR 9090
Year	2010	2009	2008	2010
Rated Horsepower	800	860	826	824
Header	770	Orbis 750	Ezy Collect 7500	480 FI
Engine Hours	20	1469	890	10
Cutter Hours	3.4	1400	662	2.5
# of Knives	40	24	28	24
Processer	9.45” chrome standard	Scherer 10” chrome	10” chrome roll	10” standard
KP Differential	21%	30%	20%	22%
Processer Hours	3.4	≈50	≈500	2.5
Blower gap	1.5 mm	5.3 mm	3.3 mm	2 mm

Table 2. Machine throughput and time data.

	Forage Harvested						
	Fresh Weight	Moisture	Dry Weight	Chopping Time	Driving Time	Chopping Time	Yield
	Tons	%	Tons	sec.	sec.	%	Tons/ac @ 70 % moisture
John Deere	159.8 a†	64.8	103.5	2027 b	540	79.0	25.3
Claas	152.3 ab	66.0	100.5	1838 c	506	78.5	24.6
Krone	150.3 b	65.7	98.9	1957 b	625	75.8	24.2
New Holland	158.5 a	65.7	104.4	2307 a	545	81.0	25.5
$LSD_{0.05}$‡	7.95	ns††	ns	117.6	ns	ns	ns
C.V. %‡‡	2.6	3.3	3.5	2.9	8.8	7.8	3.5

†Numbers followed by the same letter are not significantly different.

‡Least Significant Difference.

††Not Significantly Different.

‡‡Coefficient of Variation.

Table 3. Machine throughput and fuel consumption.

	Forage Harvested			Fuel		
	Fresh Weight		Dry Cut Length	Total Used	Chop Time	Total Time
	Tons/hr	Tons/gal	mm	Gal	------- Gal/hr ------	
John Deere	283 b	6.86 b	15.88 b	23.3 b	41.3	32.6
Claas	298 a	7.43 a	16.68 a	20.5 c	40.3	31.5
Krone	276 b	6.81 b	16.10 b	22.1 b	40.6	31.1
New Holland	247 c	6.08 c	14.96 c	26.1 a	40.8	33.1
$LSD_{0.05}$	11.5	0.49	0.41	1.55	ns	ns
C.V. %	2.0	3.6	8.8	3.2	3.1	9.0

Table 4. Particle Size Analysis

	Fresh Weight			Dry Weight			
	Upper > 0.75”	Middle	Lower < 0.31”	Upper > 0.75”	Middle	Lower < 0.31”	Cut Length
	------------------------------------- % ------------------------------------						mm
John Deere	13.7	69.2 b	17.1	12.6	62.0 a	25.4 bc	15.88 b
Claas	14.8	64.4 c	20.8	14.0	57.3 b	28.9 a	16.68 a
Krone	16.0	70.9 ab	13.1	15.2	63.2 a	21.5 c	16.10 b
New Holland	9.1	73.7 a	17.2	10.0	62.7 a	27.3 ab	14.96 c
$LSD_{0.05}$	ns	3.9	ns	ns	2.29	3.1	0.41
C.V. %	29.5	2.8	16.0	15.5	1.9	6.1	8.8

Table 5. Corn Silage Processing Score

	Particle Fractions			Starch		NDF	
	Coarse >4.75mm	Medium	Fine <1.18 mm	Total	% passing thru 4.75 mm screen	Total	†PE NDF
	-- % --						
John Deere	58.3 a	34.0 bc	7.7 b	23.6	35 b	49.2	46.4
Claas	51.3 b	39.3 ab	9.3 a	24.8	58 a	47.3	43.8
Krone	63.0 a	31.0 c	6.3 c	23.2	36 b	49.1	46.6
New Holland	51.0 b	40.3 a	8.7 ab	22.0	52 a	51.1	47.4
$LSD_{0.05}$	6.3	5.4	1.2	ns	14.6	ns	ns
C.V. %	5.6	7.5	7.5	10.0	16.2	3.9	4.5

†Physically Effective Neutral Detergent Fiber

Figure 1. ISO-BUS fuel consumption versus time for John Deere 7960.

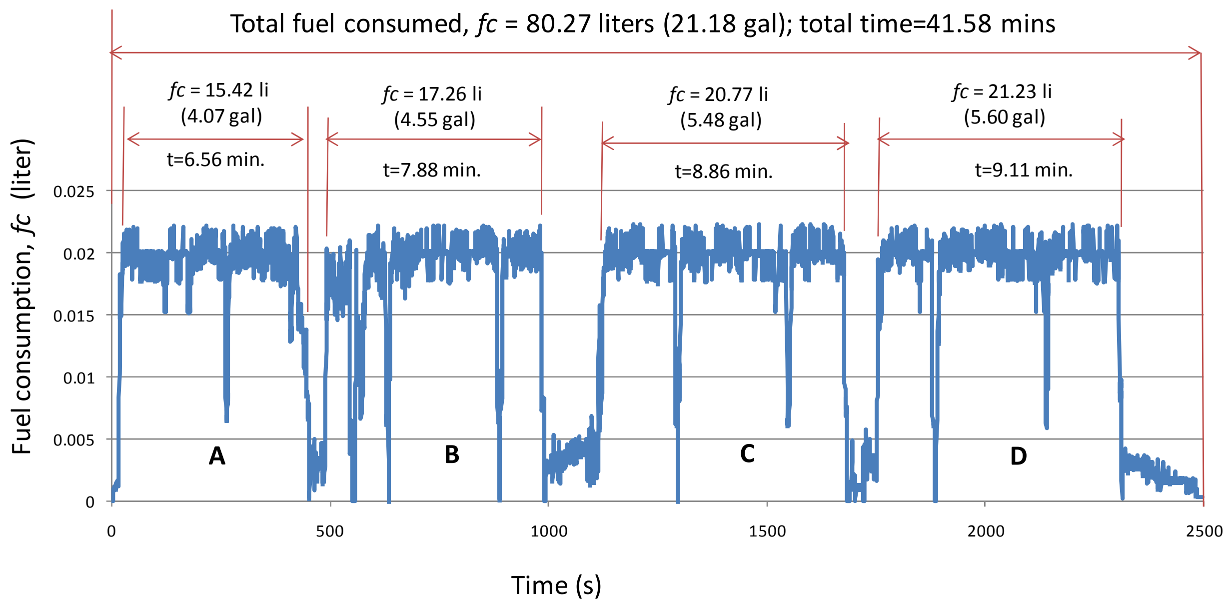

Figure 2. Cut Length versus tons of fresh material per gallon of fuel.

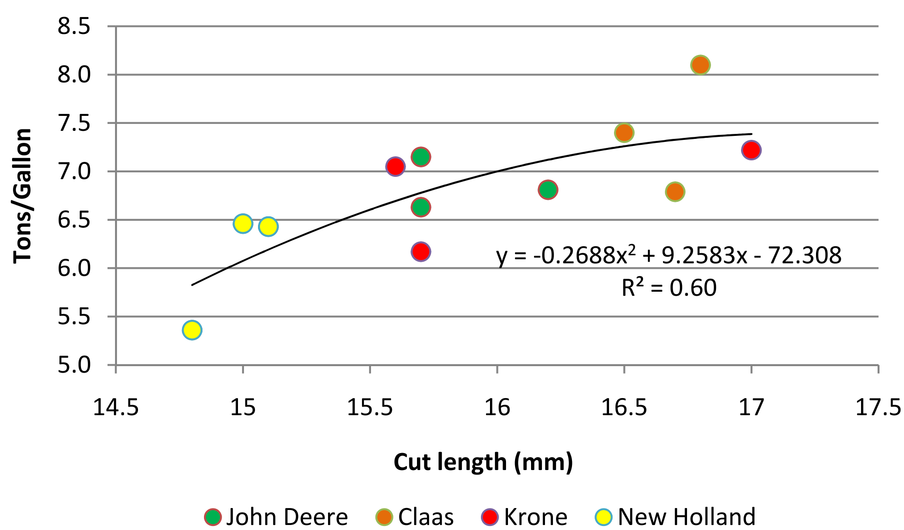

Figure 3. Cut Length versus Gallons/Acre

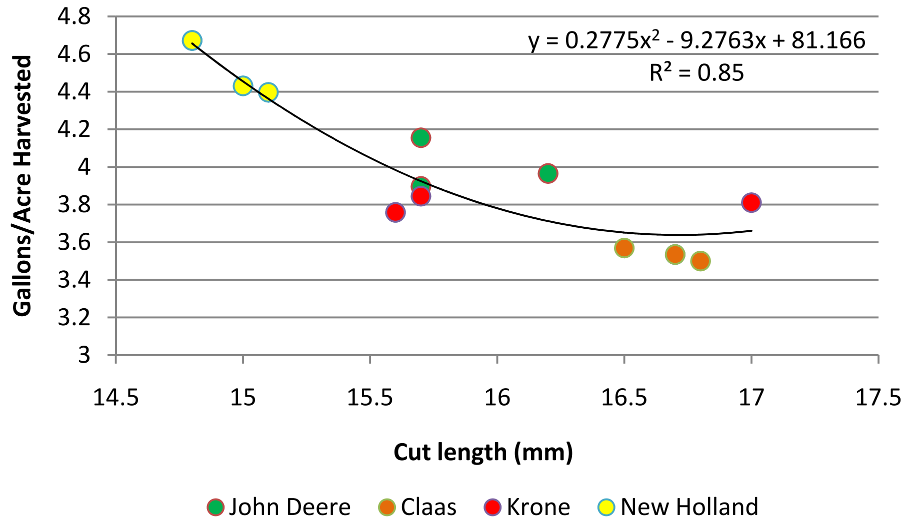

Figure 4. Cut Length versus Tons (fresh weight)/Hour