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Forage Harvester Evaluation

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Brian Marsh, Farm Advisor – Kern County

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*) was slightly past physiological maturity when it was cut for silage. Prior to the test, cut length was adjusted to 13 mm (0.5") and each processor was set at 2 mm (0.08"). Each machine had a 25 foot head except for the Claas which had a 20 foot head. The machines made three rounds cutting 60 rows per replication for a total of 180 rows. The Claas machine cut three rounds the first replication and four rounds the other replications for a total of 176 rows. The Krone machine was operating at about 650 hp instead of the rated 826 hp. Other machine specifications are listed in Table 1. The machines were driven by different operators who had substantial experience operating 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.

The harvested area for each machine per replication was about four acres. Each plot consisted of six passes, harvesting 10-30" rows by 1175 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. Five semi 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. Two truckloads 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 back and forth five times on a flat surface, rotated 90°, shaken five times, rotated 90°, and repeated so it was shaken 40 times. Material from each box was weighed, dried and re-weighed. Ten randomly selected segments from the middle box were measured for length before drying. 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

Yield per acre and percent moisture of the harvested corn silage were not significantly different for each machine (Table 2). Direct comparison between the machines is more problematic because the Krone and Claas machines had significantly different configurations. The Claas machine with the eight row head spent had lower percent chopping time than the other machines with 10 row heads. The Class machine chopped more per hour but used more fuel per ton chopped. The Krone machine with less horsepower with the same size head had higher run time and chop time than the others however it chopped less material per hour as would be expected from a lower horsepower machine.

The measured cut length was significantly different which makes direct comparisons less appropriate (Table 3). The John Deere and New Holland machines chopped equivalent tonnage but the John Deere used less fuel and chopped more per gallon, although not significant, and had a shorter cut length. Cut length from the New Holland and Class machines were closest to the target 13 mm cut length. Average cut length from individual plots ranged from 11.2 to 13.2 in 2011. Data from the 2010 and 2011 tests are included in Figures 2 and 3. A description of and results from that test can be found at http://cekern.ucdavis.edu/files/98859.pdf. Cut length in the 2010 test ranged from 14.8 to 16.8 mm with the target length of 17 mm. Cut length had a significant impact on throughput and fuel consumption. The relationship of cut length versus throughput as tons harvested (fresh weight) per hour chop time, for data from 2011 and combined data from 2010 and 2011 are shown in Figures 1 and 2, respectively. A very good relationship (R^2=0.85***) was observed for tons of fresh material harvested per hour of run time versus cut length (Figure 3). Shortening cut length from 17 to 11 mm increases fuel consumption 53 percent measured as tons of silage harvested per gallon of fuel used and a 42 percent decrease in capacity as tons of fresh material per hour run time.

The following formula can be used to determine potential harvest capacity at different cut lengths:

$$Y1 = 15.6X - 29.5$$

where

Y = tons of fresh corn silage harvested per hour of run time

X = cut length in mm

The following can be used to determine potential fuel consumption at different cut lengths:

$$Y = 0.41X + 0.34$$

where

Y = tons of fresh corn silage harvested per gallon of fuel

X = cut length in mm

Quality of cut was determined through particle size analysis. There was no significant difference in the amount in the upper sieve (> 0.75”) between the machines. The John Deere and Class machines had five to seven percent less in the middle sieve and the John Deere had four percent more in the lower sieve (<0.31”). While these differences were statistically significant, they would have little influence on feed quality.

Quality of processing was measured using the Corn Silage Processing Score (CSPS). Although each processor was set at 2 mm, there were differences in size separation between machines. There was significant difference was observed between the machines for material in the upper screen (> 4.75 mm). The John Deere harvester had the significantly less in the upper sieve and more in the middle and lower screens. The New Holland and Claas had the least amount in the middle screen. Percent moisture was lower than optimal which may have had an impact on processing. These differences did not have an impact of CSPS. Total starch percentage on unshaken samples, percent starch passing through the 4.75 mm screen, total neutral detergent fiber (NDF) and Physically Effective NDF were equivalent. 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 when above 70% and acceptable above 50%. Anything below 50% would indicate inadequate processing. The low harvest moisture appears to have had an impact on kernel processing.

A comparison of cut length on processing score was also made. Each machine was operated with cut length settings of 13 and 17 mm. Samples were collected and analyzed for CSPS. Cut length did have a small but statistically significant difference in size analysis. There was more in the upper screen, less in the middle screen and no difference in the lower (data not shown). There were no differences in total starch percentage and total neutral detergent fiber (NDF) on unshaken samples nor percent starch, and Physically Effective NDF passing through the 4.75 mm screen. Cut length at this moisture did not have an effect on processing score.

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 850	FR 9090
Rated Horsepower	800	860	826	824
Header	770	Orbis 635	Ezy Collect 753	
Engine Hours	210	2181	16	19
Cutter Hours	142	411	4	5
# of Knives	40	24	20	24
Processer	9.45” chrome	9.8” standard	10” chrome roll	10” standard
KP Differential	32%	30%	30%	22%
Blower gap	1 mm	4.85 mm	3 mm	2 mm

Table 2. Machine throughput and time data.

	Forage Harvested				
	Fresh Weight	Moisture	Chopping Time	Run Time	Chopping Time
	-- Tons --	-- % --	---- minutes ----		-- % --
Krone	73.4	58.9	24.9 a	33.4 a	74.9 a
New Holland	75.0	58.1	19.8 b	26.2 b	75.6 a
John Deere	75.4	57.6	20.6 b	27.2 b	75.8 a
Claas	73.1	54.4	16.3 c	24.1 b	67.2 b
$LSD_{0.05}$[‡]	ns[††]	ns	2.9	5.22	6.3
C.V. %[‡‡]	8.1	3.0	7.2	9.4	3.4

[†]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		Cut Length	Total Used	Chop Time	Run Time
	Tons/hr	Tons/gal	mm	Gal	------- Gal/hr ------	
Krone	177.2 c	5.2 b	11.8 b	14.2 ab	34.2 c	25.6 c
New Holland	226.9 b	4.8 b	12.6 a	15.6 a	47.1 a	35.6 a
John Deere	219.6 b	5.4 ab	11.6 b	14.0 ab	40.7 b	30.8 b
Claas	269.5 a	6.1 a	13.0 a	12.1 b	44.9 ab	30.1 b
$LSD_{0.05}$	13.6	0.77	0.58	2.5	4.36	3.04
C.V. %	3.0	7.2	2.4	9.0	5.2	5.0

Table 4. Particle Size Analysis

	Upper > 0.75"	Middle	Lower < 0.31"	Cut Length
	--------------- %	---------------		mm
Krone	12.0	70.3 a	17.6 b	11.8 b
New Holland	12.2	69.6 a	18.2 b	12.6 a
John Deere	13.7	64.0 b	22.3 a	11.6 b
Claas	20.5	62.4 b	17.1 b	13.0 a
$LSD_{0.05}$	ns	4.9	3.0	0.58
C.V. %	25.0	3.7	8.0	2.4

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
	-- %	--					
Krone	58.7 b	33.3 b	8.0 b	33.9	46.7	44.6	41.4
New Holland	64.7 a	28.3 c	7.0 b	32.6	42.7	45.6	44.0
John Deere	49.0 c	40.7 a	10.3 a	34.9	44.7	45.2	41.4
Claas	62.7 ab	29.3 c	7.7 b	35.3	49.3	43.2	40.4
$LSD_{0.05}$	5.16	3.5	2.0	ns	ns	ns	ns
C.V. %	4.4	5.3	12.0	7.04	15.8	6.9	6.1

†Physically Effective Neutral Detergent Fiber

Table 6. Conversion Table†

------Inches	------	mm	mm	-------Inches	-------
0.31	≈ 5/16	≈ 8	2	0.08	≈ 3/32
0.75	3/4	≈ 19	13	0.51	≈ 1/2
			17	0.67	≈ 11/16
			4.75	0.19	≈ 3/16
			1.18	0.05	≈ 1/16

† Numbers used in this paper use the same units as in the original papers or settings.

Figure 1. Cut Length versus Tons of Fresh Material per Hour Chop Time (2011).

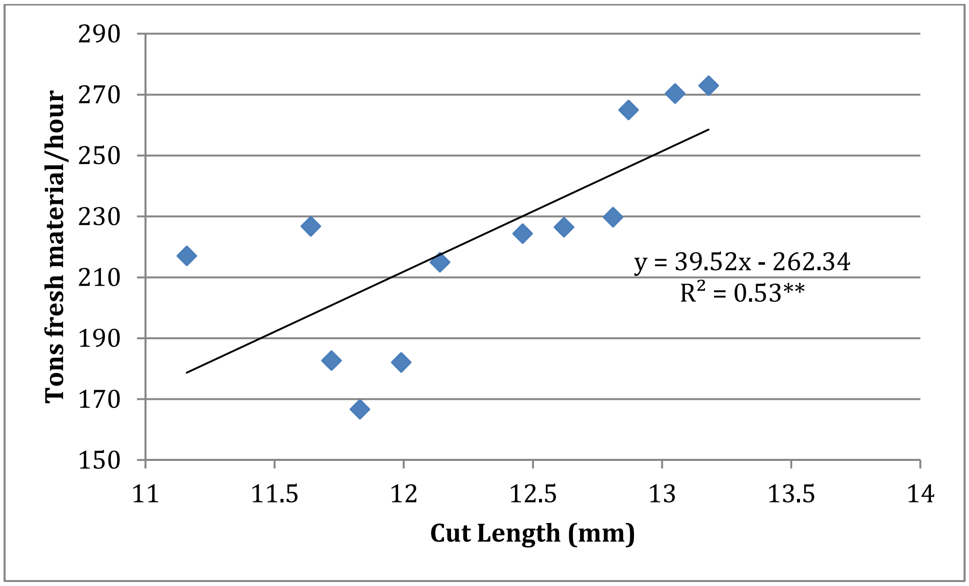

Figure 2. Cut Length versus Tons Fresh Weight per Hour Chop Time (2010-11).

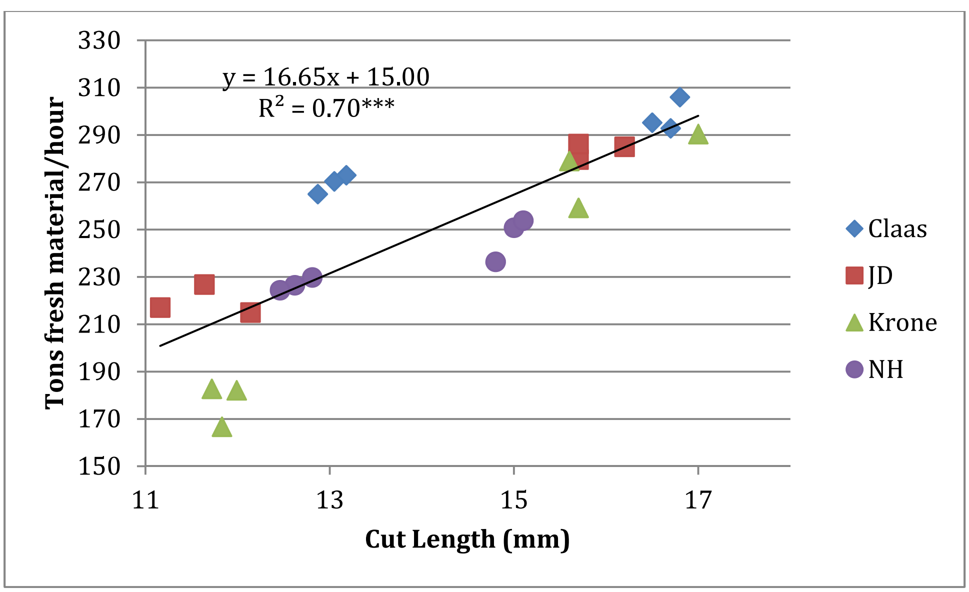

Figure 3. Cut Length versus Tons Fresh Weight per Hour Run Time (2010-11).

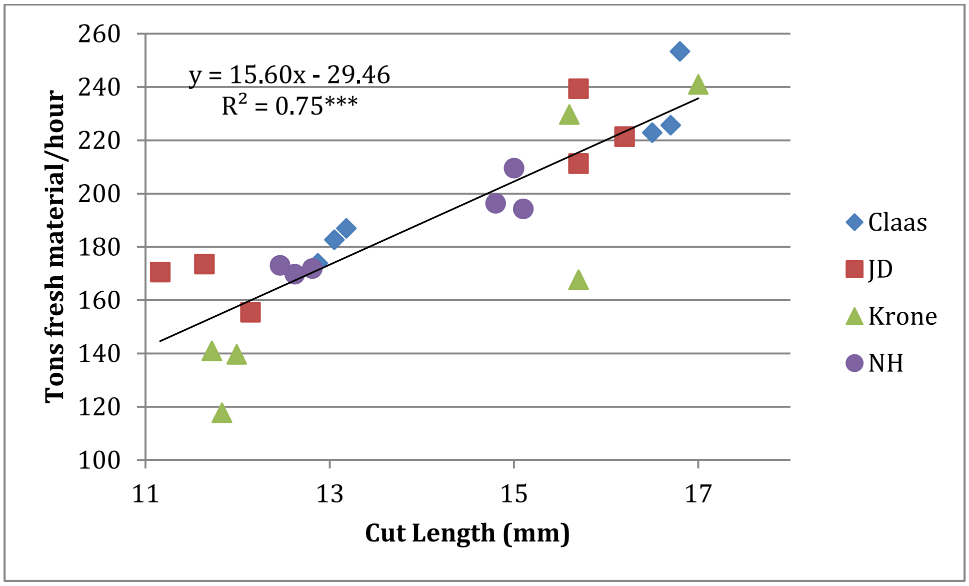

Figure 4. Cut Length versus Tons Fresh Weight per Gallon of Fuel (2010-11).