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Forage Harvester Evaluation

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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. Five self-propelled forage harvesters were tested for throughput, fuel consumption and quality of processing.

Materials and Methods

Corn (*Zea mays*) was cut for silage in a randomized complete block design with three replications for the test. Theoretical length of cut (TLC) for each machine was set at 16 mm (0.5") and each processor was set at 2 mm (0.08"). Each machine had a 25 foot head (8 rows/pass) except for the NH 9060 which had a 20 foot head (6 rows/pass). The machines made three rounds cutting 8 rows per pass for a total of 144 rows. 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 eight 38" rows by 1226 feet. The New Holland 9060 had a smaller head which harvested six rows. 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. 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. Twenty 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 was rated at more than 1000 horsepower. The John Deere, Claas and New Holland 9090 machines were rated at about 800 horsepower and the New Holland 9060 was rated at 580 horsepower. The smaller NH 9060 did harvest less material, as expected. Although not significantly different, there was a trend for a higher percentage of chopping time. The Class and Krone machines had significantly lower chopping times than the other machines.

The measured cut length was significantly different which makes direct comparisons less appropriate (Table 3). The Class machine chopped more per gallon of fuel. However, it also had the longest cut length, almost 2 mm longer than the TLC setting. The Krone machine with more horsepower with the same size head had a lower run time and chop time than the others. It also chopped more material per hour than the other machines with similar cut length as would be expected from a higher horsepower machine.

The John Deere and New Holland 9090 machines chopped equivalent tonnage, equivalent tons per hour, and tons per gallon. The John Deere, although not significant, had a shorter cut length. Measured cut length from the New Holland 9090 was at the target 16 mm cut length. Results from 2012 are shown in Figures 1 and 2. Data from the 2010, 2011 and 2012 tests are included in Figures 3 and 4. A description of and results from the other tests can be found at http://cekern.ucanr.edu. Cut length ranged from 14.8 to 16.8 mm with TLC at 17 mm and 11.6 to 13.0 with TLC at 12.0 mm in the 2010 and 2011 tests, respectively. Cut length had a significant impact on throughput and fuel consumption. A very good relationship (R^2=0.78***) was observed for tons of fresh material harvested per hour of chop 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:

$$Y = 18.5X – 9.3$$

where

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

X = cut length in mm

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

$$Y = 0.50X – 0.79$$

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. The Claas, and New Holland machines, with the longest cut, had the most material in the upper sieve and less in the middle sieve. There was no difference in the lower sieve. 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, again influenced by the length of cut (Table 4). There was significant difference was observed between the machines for material in the upper screen (> 4.75 mm). Total starch percentage on unshaken samples was equivalent. There was a significant difference in CSPS. The NH 9060 had the lowest and the Krone 1100 was the highest. 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. These samples were collected at harvest. Length of time in the silage pile does have an impact on CSPS which generally increases with increase time in the pile.

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	Claas	John Deere	Krone	New Holland	New Holland
Model	Jaguar 980	7950 Prodrive	Big X 1100	FR 9090	FR 9060
Rated Horsepower	860	800	1031	824	544
Header	Orbis 750	770	EzyCollect 753	480 FI	450 FI
Engine Hours	349	1401	16	40	78
Cutter Hours	309	902	4	20	46
# of Knives	24	40	20	24	24
Processer	new 9.8" standard	9.5' w/ Horning Spiral cut rolls	10" chrome roll 123 teeth/roll	heavy duty 99/126 tooth	heavy duty 99/126 tooth
KP Differential	30%	32%	30%	22%	22%

Table 2. Machine throughput and time data.

	Forage Harvested				
	Fresh Weight	Moisture	Chopping Time	Run Time	Chopping Time
	-- Tons --	-- % --	---- minutes ----		-- % --
Claas	107.2 a	65.5	18.8 b	30.4	63.8
John Deere	108.4 a	67.6	24.3 a	37.1	69.6
Krone 1100	109.8 a	66.3	18.4 b	26.0	71.7
NH FR 9090	104.9 a	64.9	23.1 a	30.5	75.7
NH FR 9060	84.0 b	64.7	24.2 a	30.5	79.2
$LSD_{0.05}$‡	6.9	ns††	2.0	ns	ns
C.V. %‡‡	3.8	4.2	5.2	15.2	9.6

†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 ------	
Claas	342.2 a	8.6 a	17.8 a	12.40 bc	39.7 b	25.5 c
John Deere	268.5 b	6.9 c	15.2 c	16.04 a	39.3 b	27.2 bc
Krone 1100	354.9 a	7.8 b	15.1 c	14.11 ab	45.7 a	32.8 a
NH FR 9090	274.4 b	6.8 c	16.0 bc	15.55 a	40.6 b	30.7 ab
NH FR 9060	207.9 c	7.2 bc	16.9 ab	11.58 c	28.9 c	22.9 c
$LSD_{0.05}$	21.4	0.79	1.3	2.5	4.36	5.0
C.V. %	4.2	6.1	4.3	9.0	5.2	9.5

Table 4. Particle Size Analysis

	Upper > 0.75”	Middle	Lower < 0.31”	Cut Length
	--------------- % ---------------			mm
Claas	55.0 ab	33.0 bc	11.7	17.8 a
John Deere	40.7 c	44.0 a	15.3	15.2 c
Krone 1100	47.3 bc	39.7 ab	13.3	15.1 c
NH FR 9090	57.0 ab	29.3 c	13.7	16.0 bc
NH FR 9060	53.3 ab	35.3 bc	11.3	16.9 ab
$LSD_{0.05}$	8.05	8.9	ns	1.3
C.V. %	8.4	13.1	17.8	4.3

Table 5. Corn Silage Processing Score

	Particle Fractions			Starch		NDF	
	Coarse >4.75mm	Medium	Fine <1.18mm	Total	% passing thru 4.75 mm screen	Total	†PE NDF
	-- % --						
Claas	55.7 abc	36.3 abc	8.0	30.9	48.0 ab	47.4 bc	44.5 bc
John Deere	54.3 bc	37.3 bc	8.3	25.0	41.0 bc	51.2 a	48.2 a
Krone 1100	51.3 c	40.3 a	8.3	30.6	53.3 a	44.8 c	42.8 c
NH FR 9090	60.0 ab	33.0 bc	7.0	26.4	48.0 ab	49.8 ab	47.2 ab
NH FR 9060	61.0 a	32.0 c	6.7	26.8	35.3 c	50.4 ab	47.8 a
$LSD_{0.05}$	5.7	5.0	ns	ns	10.4	ns	3.1
C.V. %	7.1	9.6	11.2	10.5	13.2	6.9	3.8

†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.

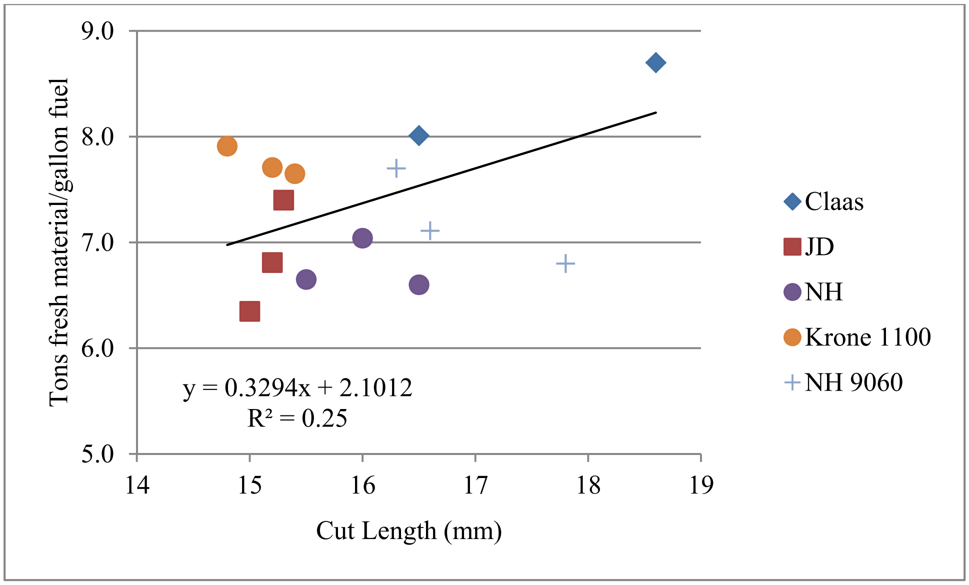

Figure 1. Tons of Fresh Material per Gallon of Fuel versus Cut Length (2012).

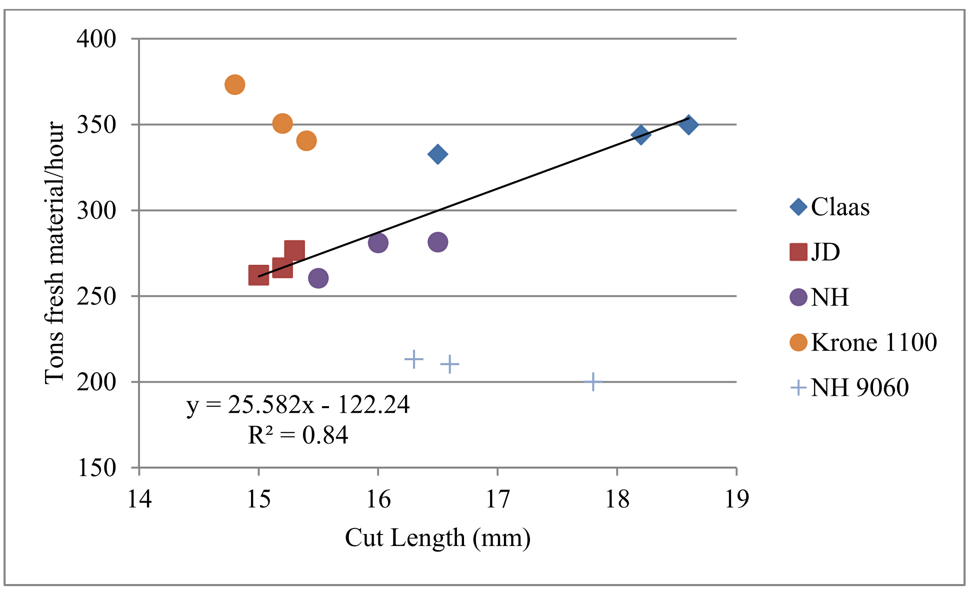

Figure 2. Tons Fresh Weight per Hour Chop Time Cut versus Length (2012).

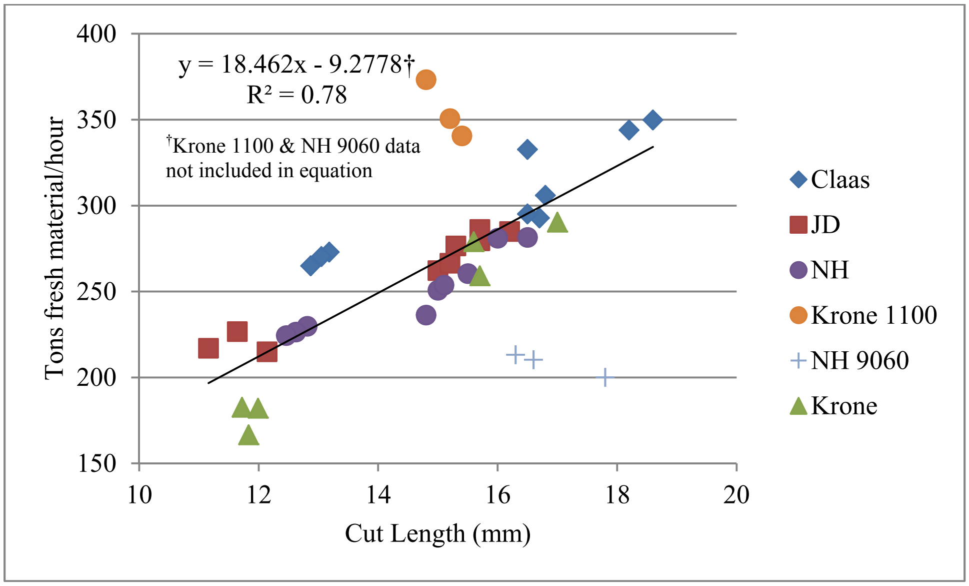

Figure 3. Tons Fresh Weight per Hour Chop Time versus Cut Length (2010-12).

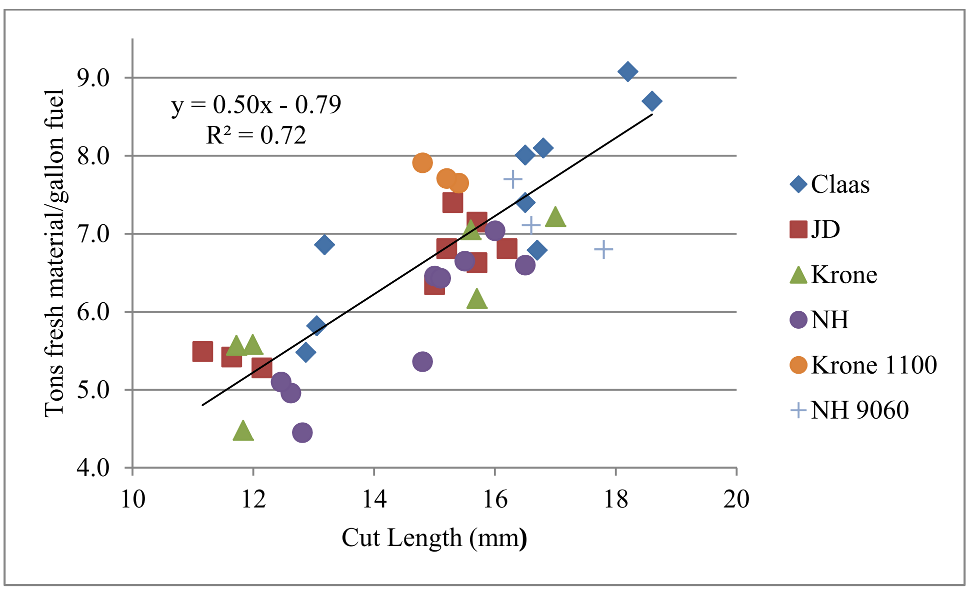

Figure 4. Tons Fresh Weight per Gallon of Fuel versus Cut Length (2010-12).