Modification of a Self-Propelled Rotary Mower for Wheat Forage Harvest

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ABSTRACT

Many field experiments require the collection of forage yields in addition to grain yield (small grains). In small plot research, mechanized grain harvest is common. However, forage harvest is often accomplished by hand which is time consuming and labor intensive. Sample heterogeneity increases when forage harvest is obtained by hand. The objectives of this study were to construct a mechanized forage harvester that would simplify the harvesting process while providing a homogenous sample and to determine forage yield reduction associated with using the harvester compared to hand clipping at the soil surface. A John Deere GT262 self propelled rotary mower was modified to be used for small plot wheat forage harvesting. Field trials were established at two locations to determine the yield reduction associated with using the forage harvester versus hand clipping at the soil surface. Significant differences in yield were found at both locations. The mean dry matter yield averaged over two years and two locations obtained using the harvester was 63.1% of that obtained by hand clipping at the soil surface during growth stages Feekes 6 and Feekes 10. Total N in wheat forage collected was significantly different using the harvester versus hand clipping. This is partially explained by decreased N in the lower stems at later stages of reproductive growth. The design of the harvester makes it possible to harvest several plots in a short amount of time while also allowing a larger area to be harvested which increases experimental accuracy and sample homogeneity. When the efficiency of the forage harvester (0.631) is used as a correction factor, the difference between the estimated and actual amounts of forage present is ≤ 4% of the total forage present (Feekes 6 through Feekes 10).

INTRODUCTION

Winter wheat (*Triticum aestivum* L.) is one of the main agronomic crops produced in the southern Great Plains. Since fall-spring grazing of wheat forage by beef cattle can be a significant source of income for producers, wheat is often produced as a dual-purpose crop being grown for both forage and grain. Considering the low value of grain in recent years, producers are becoming more interested in wheat forage production, and larger percentages of the acreage planted to wheat are being grazed prior to harvesting the grain. This creates a demand for researchers to conduct winter wheat experiments which evaluate both forage and grain yield. In small plot wheat research, mechanized grain harvest is common, however, forage harvest is often done by hand clipping which is time consuming and labor intensive. Usually, forage harvests are conducted by clipping a small area at the soil surface. Following sub-sampling, only a few of these plants are included for chemical analysis, thus failing to minimize the variation within the harvested area. The objectives of this study were to construct a mechanized forage harvester that would simplify the harvesting process while providing a homogenous whole plot sample that could be reliably sub-sampled and to determine forage yield reduction associated with using the harvester compared with hand clipping at the soil surface.

MATERIALS AND METHODS

Forage Harvester Construction

A John Deere GT262 self-propelled rotary mower was used as the primary element in constructing the forage harvester. Specifications for the mower are listed in Table 1. The mower was initially equipped with a John Deere Power Flow collection system. This system was composed of a side mounted fan which conveyed the forage clippings through a plastic chute into a plastic hood onto which a collection bag was fastened. The first modification was to replace the collection bag with aluminum baskets. Two frames measuring 92.71 cm x 45.72 cm x 50.80 cm were constructed using 2.54 cm aluminum angle iron. The walls of the baskets were 0.32 cm^2 mesh screen. The baskets were attached to the plastic hood via 2.54 cm angle iron secured to the ends of the hood. This design provided a lightweight yet durable receptacle which could be easily removed

Table 1. Specifications for the John Deere GT262 self propelled rotary mower.

Engine:	Single-cylinder, 4-cycle, John Deere K
Horsepower:	17
Transmission:	6-speed
Forward speed:	1.13-10.62 km/h
Dimensions:	
Width, min/max:	0.74-1.05 m
Height:	1.09 m
Length:	1.75 m
Mower deck:	0.96 m
Wheel base:	1.19 m

Table 2. Specifications for the Power-Pak engine.

Manufacturer:	Kawasaki
Model:	FA210D
Horsepower:	6
Cylinders:	1
Engine Speeds:	
Slow:	1800 rpm
Fast:	4500 rpm

when full of forage and replaced with an empty basket, minimizing time spent between plots. After the forage harvester was used, it was determined that the plastic hood would not support the weight of a large sample. A new hood measuring 93.98 cm x 43.18 cm x 27.94 cm was constructed using 2.54 cm angle iron and Plexiglas. The hood was mounted to a 67.31 cm piece of 10.16 cm channel iron which attached to the mower using a spring loaded pin, making the hood removable. The final modification was replacing the fan on the Power Flow. The speed of the belt driven fan was only 3400 rpm. This was not fast enough to prevent forage from plugging the conveyor chute. An FA210D Power-Pak engine was chosen as the replacement blowing system. Specifications for this unit are listed in Table 2. The blower was secured to a 30.48 cm2 plate of sheet metal mounted on a two wheel 1.07 m x 12.7 cm channel iron chassis which was attached to the harvester by a 30.48 cm x 10.16 cm channel iron extension. The plastic conveyor chute was replaced by 17.78 cm flexible duct hose. Materials used in constructing the forage harvester and their associated costs are listed in Table 3.

Table 3. Parts list and cost of materials used in constructing the forage harvester.

Parts	Cost
John Deere GT262	$5551.00
Power-Pak engine	848.00
Aluminum	85.00
Sq. mesh screen	42.00
Steel: sheet metal, angle iron channel iron	110.00
Plexiglas	45.00
Flexible duct hose	45.00
Misc: bolts, nuts, screws, silicone seal, tires, hose clamps, pins	150.00
Labor 40 hours @ $7.00/hr	280.00
Total	$7156.00

Field Experiments

Harvesting forage at the soil surface using the harvester resulted in a large quantity of soil being included in the sample due to the vacuum created by the deck and blower. To eliminate this potential contamination problem, the mower deck must be kept 7.62 cm above the soil surface. However, this results in a percentage of the total forage production being left in the field. Therefore, field trials were necessary to determine the yield reduction associated with using the forage harvester. Two locations were selected as experimental sites. One experiment was conducted at the Oklahoma State University Agricultural Experiment Station in Stillwater, Oklahoma. The second experiment was conducted at the Agronomy Research Station north of Perkins, Oklahoma. A randomized complete block experimental design was employed with the use of paired plots for specific treatment comparisons. The trials consisted of two treatments replicated four times in established wheat fields. Treatments compared were forage yield obtained by harvesting a 9.64 m^2 area using the forage harvester and forage yield obtained by harvesting the same size area using hand clippers. Forage harvests were taken at both locations in 1995 and 1996 when the plants were between growth stages Feekes 5 and Feekes 10. Forage yields were determined on a dry weight basis (0% moisture). Total N in the forage was determined for each sample using a 'Carlo-Erba 1500' dry combustion analyzer.

RESULTS AND DISCUSSION

The major advantages of using the forage harvester are reduced labor and increased whole plot sample homogeneity. The design of the harvester makes it possible to harvest several plots in a short amount of time. It also allows a larger area to be harvested which increases experimental accuracy. The overall length of the machine is only 2.16 m, making the forage harvester extremely maneuverable and easy to transport. Forage collected was determined to be representative of the amount present in the field due to the fact that no plant material was observed to be lost during any phase of sampling when using the forage harvester. Estimates of wheat forage dry matter yields were reduced when using the forage harvester as compared to hand clipping (Table 4). This is largely due to the increased height (approximately 5.0 cm) using the forage harvester compared to hand clipping which can be accomplished at < 2.54 cm. Forage collected using the harvester during growth stages Feekes 6 through Feekes 10 averaged 63.1% of that obtained by hand clipping. Forage harvester use efficiency decreased to 42.4% when the wheat was at growth stage Feekes 5. This decrease is due to substantially less plant material existing above the 7.62 cm cutting height during early growth stages. Estimates of total N from forage harvested sub-samples (Feekes 6 through Feekes 10) were significantly different from those observed for hand clipped sub-samples (Table 4). The chopping and mixing of the forage which occurred with the forage harvester resulted in a more representative sample than the hand clipped sample which consisted of a only a few plants. Lower N concentrations in basal plant stems which would have been included in the hand clipped samples may also aid in explaining these results. At the early growth stages, N is more evenly distributed within the plant, explaining why no difference was observed in total N for the samples collected at Feekes 5. When the efficiency of the forage harvester (0.631) is used as a correction factor, the

Table 4. Mean wheat forage yields and total N from Stillwater and Perkins.

	Stillwater Feekes 5	Perkins Feekes 6	Stillwater Feekes 10	Perkins Feekes 10
		Yield		
		kg ha^{-1}		
Forage Harvester	349.6 A	1295.5 A	772.1 A	1358.5 A
Hand Clipping	824.8 B	2124.9 B	1171.1 B	2132.5 B
	Total N			
		g kg^{-1}		
Forage Harvester	16.2 A	13.9 A	9.9 A	9.7 A
Hand Clipping	15.2 A	16.3 B	8.8 B	7.4 B

Means followed by the same letter are not significantly different.

difference between the estimated and actual amounts of forage present is ≤ 4% of the total forage present (Feekes 6 through Feekes 10). When the same correction factor is used to estimate total forage present at Feekes 5, the error is 32.8%. The difference in the size of the errors indicates that while an accurate estimate of total forage can be made using 0.631 as a correction factor for samples harvested after Feekes 6, additional work may be necessary to establish a correction factor for samples collected during earlier growth stages.

It is important to note that in addition to wheat forage, the harvester has been used on alfalfa, bermudagrass, and bluestem, and no technical limitations have been observed for any crop harvested.

Development of an Automated Grinding Unit for Finely Ground Soil and Plant Tissue Samples

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Abstract

An automated grinder capable of grinding a large number of plant, grain, and soil samples was designed. One of the main reasons for developing the device was to increase the number of samples being processed at one time for dry combustion analysis of total N and organic C that required a high level of fineness. The original prototype was developed at the University of Nebraska (J.S. Schepers) and was modified to increase the number of samples and overall structural security. The device consists of sequentially aligned horizontal rollers spaced 6.67cm apart that are driven simultaneously. French squares bottles (118.3ml)are then placed in the center of the horizontal rollers and by including round steel rods within the bottles (including grain, plant, and soil samples) grinding is accomplished via internal hammering. Before this device was engineered, samples were ground one by one utilizing mortar and pestle techniques that are costly, time consuming and prone to errors. This apparatus will grind approximately 140 samples overnight, at >100 mesh fineness. Using this procedure, samples are contained in sealed bottles where no cross-contamination can take place.

Introduction

Grinding procedures for dry combustion analysis require sample fineness (100 mesh) that generally employ manual use of mortar and pestle techniques. This work was initiated to construct an automated grinding unit that could process > 140 samples simultaneously. Previous work at the University of Nebraska has employed a similar piece of equipment utilizing metal bar hammering within glass containers. The equipment developed at the University of Nebraska was extremely useful in terms of obtaining homogenous samples of high fineness from larger sample sizes (>30g). Errors associated with the use of mortar and pestle techniques can be 20% larger than with other automated units. Larger errors are due to sample fineness which is variable depending on the individual and the time/pressure employed. Sample contamination is also a problem using mortar and pestle techniques, since acid washing and drying is required before processing each individual sample. Because of the problems associated with mortar and pestle techniques, the grinding process becomes extremely time consuming, costly, and can increase experimental

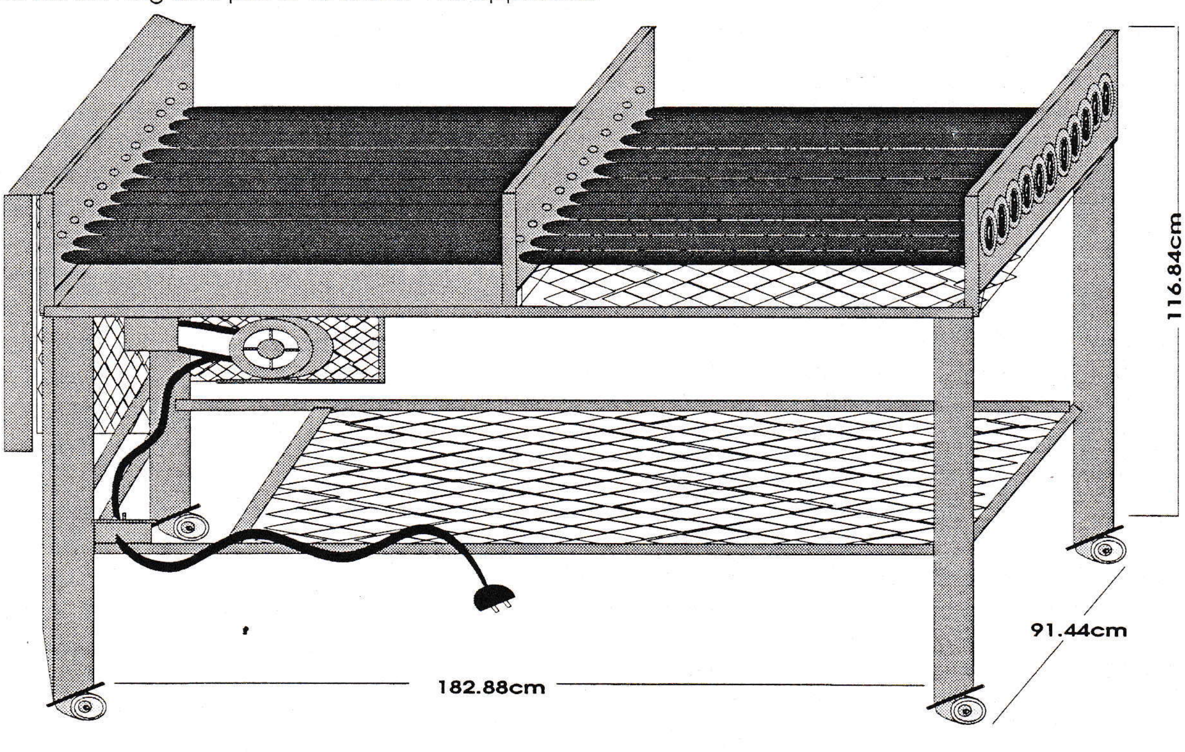

Figure 1. Side view of the automated grinding unit

errors. Smith and Um (1990) found that by gluing two metal bars opposite each other and placing these on the inside of a glass jar jointly with a straw samples, outside rotation induced an internal hammering action which effectively ground the sample material.

The objective of this work was to develop a reliable grinding unit using external horizontal rolling for internal bar hammering within french square glass jars.

Materials and Methods

The frame of the grinder was 182.88 x 91.44 x 116.84 cm in length, width, and height, respectively, consisting of 5.08 cm square tubing, 5.08 cm angle iron and 30.48 cm flat strap. Figure 1 shows a side view of the frame. The device will continuously roll 140 bottles that contain plant, grain or soil material. The unit utilizes 2 oz. french square bottles which are 2.54 x 2.54 x 7.62 cm in length, width, and height, respectively. The bottles rest on eleven steel shafts (1.905 cm in diameter) covered with rubber hose. The shafts are turned by a 0.75 horsepower electric motor that turns a gear reducer. The electric motor and gear reducer were bolted to the under side of the grinder. (Figure 2.) The shafts 0.75 traverse three

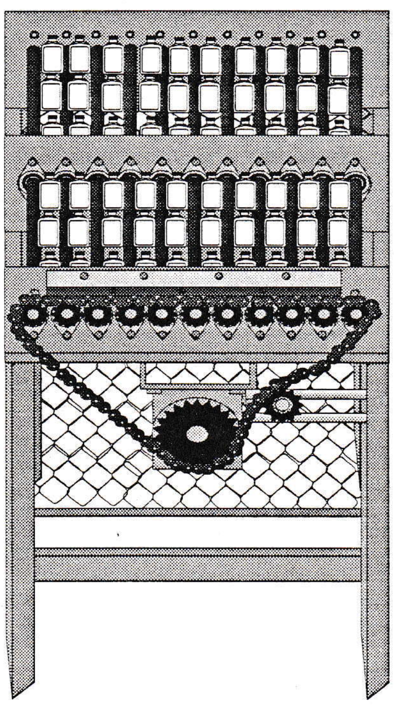

Figure 2. Frontal view of the automated grinding unit illustrating sample placement.

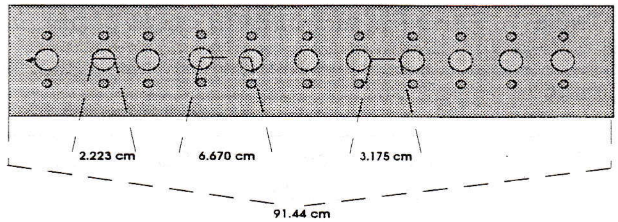

Figure 3. Shaft hole spacing and bearing fasteners distance employed.

pieces of 30.48 cm flat strap that weremachined with eleven 2.223 cm holes. The three pieces of strap were located at the ends and the middle of the device. Bearings were fastened to the three pieces of flat strap which allowed the shafts to turn freely. A twelve tooth sprocket was located on each shaft in the front of the device. The 0.75 horsepower electric motor turns the gear reducer 1850 rpm. The gear reducer decreases the rpm to 385. A twenty-two tooth sprocket was attached to the output shaft of the gear reducer which then turns the twelve tooth sprockets by utilizing a #40 chain. The twelve tooth sprocket was needed to reduce rpm from 385 to 125. Figure 3. gives specific details on hole spacing for shafts and bearing fasteners. All chains and belts were covered with safety shields to prevent accidents.

The grinding unit can be loaded with 140 of the 59.15 ml. bottles that contain plant, grain or soil material. Four stainless steel rods (.61cm diameter, 5.08cm length for soil, .32cm diameter, 5.08cm length for grain, plant and straw) are placed inside the bottles which produces a hammering action comparable to that of the pestle. Bottles are capped to prevent material leakage and cross-contamination. Bottles are left rolling on the grinder overnight to reach the desired fineness (100 mesh).

Results and Discussion

The grinding unit was completed in approximately two weeks. Table 1 gives a list of components and current costs associated with the materials used. Once the unit was complete, a trial run showed that the 59.15 ml, bottles were not large enough. Also, the bottles were sticking to the rubber hose after the unit had run for a while. To correct this, 118.30 ml bottles were utilized instead of 59.15 ml. To prevent the bottles from sticking, a silicone spray was applied to the rubber hose. It was also observed that the chain was rising off the sprockets, causing the shafts to intermittently skip. A 2.54 cm x 76.2 cm piece of angle iron was fastened to a 12.7 cm x 76.2 cm oak

Table 1. Parts list and current costs of purchased materials for the automated grinder.

Parts	Cost
Peerless-Winsmith gear box(Model 3CB;Peerless-Winsmith, Inc., Springville, NY)	$408
3/4 horsepower electric motor	206
Sprockets	91
Pulleys, chain, belts	62
Stainless steel rods (.61cm diameter)	292
Steel: flat strap, channel iron, angle iron, expanded metal, tubing	350
Bearings	413
Bottles & caps(118.30 ml. French square glass)	187
Miscellaneous: bolts, nuts, screws, castors rubber hose, electrical switch	75
Labor	
80 hours @ $7.00/hrs	560
TOTAL	$2644

board which acts as a chain guide to prevent the chain from rising off the sprockets. Once all the problems were eliminated the unit was left on overnight to observe sample fineness. Samples (grain, soil, and plant) were ground fine enough to pass through a 200 mesh screen. Future work will focus on the time required for sample fineness, alternative size and shape of internal hammering bars and type of sample employed.

References

Smith, J.L., and Myung Ho Um. 1990. Rapid procedures for preparing soil and KCl extracts for ^{15}N analysis. Commun. Soil Sci. Plant Anal. 21:2173-2179.