EFFECT OF GRAIN MOISTURE AND MACHINE ADJUSTMENTS ON GRAIN SORGHUM THRESHABILITY AND SEED DAMAGE

by

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INTRODUCTION

Due to the fact that grain sorghum is very resistant to drought conditions in comparison with other crops commonly grown for grain, it is an important crop in the areas of moderately low rainfall.

There are more than fifty distinct varieties of grain sorghum now grown in this country. Most of them are grown in much the same way as wheat; namely, the same tillage, planting and harvesting machinery used for wheat is also applicable to the production of grain sorghum. In addition, grain sorghum can also be planted in rows with row crop type planters used for planting corn.

A combine with a grain platform, which cuts the head from the stalks at the time of harvesting and puts only the head into the machine, is an ideal method to harvest sorghum. But, while this method is populary used, the sorghum grower often encounters heavy losses and seed damage during combine harvesting.

According to the experiments carried out by many former workers, the grain loss and seed damage are influenced by grain moisture content at threshing and by the cylinder adjustments. Restricting the harvesting operation to occasions when the grain moisture content is ideal for threshing could be considered as a good way to reduce loss. However, in many areas, due to the climatic condition, a portion of the harvest must take place at other than optimum moisture level. Likewise, the severity of seed damage could be diminished by using lower cylinder speeds or greater cylinder-concave clearance. In accomplishing this however, the machine efficiency was inevitably decreased.

Principally, the cylinder and concave perform two functions-- the removal of grain from ear or stalk, and separation of the grain from the straw. The cylinder adjustments, mainly related to the combination of the cylinder to concave clearance and the cylinder speed, are vital factors in regard to combine performance. Insufficient concave clearance and/or excessive cylinder speed will result in over-threshing, while excessive concave clearance and/or too low a cylinder speed will result in under-threshing.

In addition to the cylinder loss and seed damage, the cylinder adjustment has important influence on the performance of the separating and cleaning units. For example, higher cylinder speeds tend to force more threshed grain through the grate, therefore, reducing the seed load in the walkers, which in turn reduces the walker loss. However, excessive straw breakup makes seed separation more difficult and may increase the shoe loss appreciably.

Many threshing experiments have been done, particularly to those crops such as wheat, barley and corn, but only limited articles are related to grain sorghum.

This report is based on lab experiment results with grain sorghum. Although other parameters, such as feed rate and straw moisture are also influential, investigations are focused on (1) the effect of grain moisture on cylinder loss, (2) the effect of grain moisture on seed damage, and (3) the effect of the cylinder adjustments on the cylinder loss and seed damage.

LITERATURE REVIEW

The main function of a threshing cylinder is to detach the seed from the non-grain parts of the plant. Basically, whenever a force applied on a kernel exceeds the forces which retains it, threshing occurs. There are three general methods for obtaining the threshing force, as Lamp (1960) stated, (a) mechanical methods such as rubbing and stripping; (b) impact or impulsive acceleration, which occurs when a cylinder bar strikes unthreshed grain and (c) non-impulsive acceleration which would result if a head of grain were suddenly accelerated without impact. Threshing is accomplished principally by the use of the first two methods. Using centrifugal force as the threshing force for wheat, Lamp found that a force of 0.30 lb. was sufficient to thresh 98 percent or more of the mature grain independent of the method of holding the head; however, a force of 0.20 lb. was sufficient to thresh 98 percent of grain under typical harvesting conditions. Also if the force were applied in a manner which bent the rachilla, a reduction of up to 50 percent in threshing force would occur. From his work Lamp concluded that threshing and separating processes could be integrated, eliminating the need for special straw separating equipment when using the centrifugal principle.

According to Kepner <u>et</u> <u>al</u>. (1972), several factors affect threshing effectiveness; (a) the peripheral speed of the cylinder, (b) the cylinder-concave clearance, (c) the type of crop, (d) the condition of the crop in terms of moisture content, maturity, etc., and (e) the rate at which material is fed into the machine.

In general, an increase of grain moisture tends to increase cylinder loss, but decrease seed damage. However, according to Arnold (1964), grain damage depends on grain moisture content and efficiency of threshing on straw moisture content, he also indicated that the condition of broken grain and germination of wheat were consistently superior when threshing was carried out in the 'safe zone' between grain moisture levels of approximately 17-22%. Johnson (1959) reported that the highest machine efficiency occurred between 15 and 20 percent grain moisture content. Johnson also suggested that threshing wheat must be limited to grain moisture below 20 percent as far as the resulting condition is concerned. Fairbanks (1976), when harvesting grain sorghum, indicated that harvesting losses were high at grain moisture content between 20 and 30 percent.

Cylinder speed is one of the most important factors affecting threshability; it also affects seed damage. Increased speed reduces the cylinder losses, but may subtantially increase seed damage. This was confirmed by King (1962) and Bainer (1934). Also, a similar result has been obtained by Goss _et al_. (1958) when testing barley.

According to Arnold (1964), the extent of the reduction in losses with increasing cylinder speed was related to the amount of grain remaining in the ear. The more difficult a crop is to thresh, the greater the reduction in losses resulting from a given increase in cylinder speed. Although the occurrence of broken grain depends mainly on the variety and grain moisture, the viability of the grain dropped as the cylinder speed was increased. Kepner _et_. _al_. (1972), based on Arnold's reports, further indicated that the total losses from unthreshed seed plus damaged seed would be minimized at a cylinder speed of about 4500 fpm for the low moisture condition and 5100 fpm for the 20% moisture content.

Delong and Schwantes (1942), testing with barley having 12 to 15 percent moisture, concluded that the speed at which the cylinder operates best at ranges from 5000 to 6000 fpm for all three types of cylinders. More conservative values, 5000 to 5500 fpm, were recommended by Goss (1958) for dry climate areas.

Johnson and Lamp (1962), when harvesting soybeans at 15-20% kernel moisture, reported that cylinder speeds of at least 4500 fpm were required to keep cylinder loss at an acceptable level of less than 1 percent. Crackage was below that which would result in a marketing penalty. Increased cylinder speed depressed germination.

Bainer and Borthwick (1934) in a study on lima beans at 9.1 percent moisture, reported that the cylinder speed and percentage of damage are directly related; the greater the speed, the greater the damage. Total damage varied from

7.6 to 52.5 percent at a threshing speed of 770 to 1560 fpm. Furthermore, a thresher having only one cylinder is not suitable for seed beans because the speed necessary for thoroughness is too high for the production of damage-free seed. Klein (1966), in his study to measure harvesting losses and damage to crimson clover, suggested an optimum peripheral speed and an optimum concave clearance which produces more pure live seed. Accordingly, the optimums are: spike-tooth cylinder, 5070 fpm and 5/32 in.; rubber-covered angle bar, 4110 fpm and 5/32 in., and rubber-covered flat bar, 4830 fpm and 1.32 to 1.8 in. In addition, the rubber-covered flat bar cylinder recovered about 10% more crimson clover seed that either of the other two cylinders. Unthreshed seed loss was reduced to about 5 percent in the process.

Basically, according to Arnold (1964), the concave bars perform two functions: (1) holding or bringing the material into the cylinder bar path for repeated impacts and (2) providing a surface against which the beaters could rub the material. As far as the rasp bar cylinder is concerned, the first function is of prime importance in comparison with the second function.

Although the extent of separating properties of the cylinder can be improved by using a longer concave, increased length of the concave will result in extra broken grain. According to Arnold, approximately 2-3 times as many broken grain occurred with a 20.0 in. as with a 6.7 in. length concave. The tougher the crops being threshed, such as barley, the greater the benefit gained, in terms of extra grain threshed, from increasing the length of the concave.

In order to reduce the seed damage, the threshed grain should be removed as quickly as possible from the path of the beater. Arnold (1964) compared the performance of the open and closed concave and concluded that there were four times as many broken kernels in the sample produced using the closed concave, as in those produced by the open concave; there was no difference in the threshing efficiency of the two types of concave. Goss et al. (1958), reported that a machine with the concave openings covered had more than twice as much free-seed loss over the walkers, as did the open-rate machine. Clark (1976), in studying the distribution pattern of threshed and unthreshed grain along the concave, concluded that the first position along the concave is the key position which correlated best with unthreshed grain. The relationship between the percentage of threshed material obtained in the first position and unthreshed material passed at the back of the concave has potential for practical prediction of combine performance, if the same relation is found for a combine operating under field conditions.

Generally speaking, the influence of concave clearance is not as critical as is the cylinder speed, in regard to threshing efficiency and seed damage. This was proven by several researchers. The setting of concave clearance depends largely on the size of grain and the volume of straw. To encourage the entry of threshing material, the front clearance should be larger than the rear clearance. According to Arnold (1964), the front/rear clearance ratio has little effect on cylinder loss, visible damage, or germination of barley or wheat for any given mean clearance.

As Vas (1969) stated, decreasing concave clearance may have: (1) increased the chance of an ear of grain struck by the cylinder beater bar, and, (2) increased the chance of multiple impacts to the ear before it passed from the threshing zone. When harvesting spring wheat, Vas reported that changing the clearance from 3/4 to 1/4 in. reduced the cylinder loss from 2.1% to 1.2% and increased visible damage from 5.4 to 7.8%.

Feed rate is also associated with threshing effectiveness. An increase in feed rate resulted in a decrease in mechanical damage, although the effect is usually slight. Tests showed that unthreshed seed loss is somewhat proportional to the feed rate. Goss _et_. _al_. (1958), when combining barley, indicated that the total loss increased rapidly when the feed rate exceeded 100 to 125 lb. per min.; walker loss was greater than shoe free seed loss, while unthreshed loss was relatively small. Fairbanks reported that the shoe loss increased rapidly with increased feed rate, when combining grain sorghum, while cylinder loss and walker loss increased at modest rates.

INVESTIGATION

Research Objectives

1. To investigate the effect of grain moisture on cylinder loss.
2. To investigate the effect of grain moisture on seed damage.
3. To investigate the effect of the cylinder adjustments on the cylinder loss and damage.

Threshing Unit

A threshing unit built to measure threshability parameters was used in this study (Fig. 1 & 2). A threshing cylinder was constructed from two 12-in. aluminum discs fitted to a 1-in. central shaft. Four conventional rasp bars 7-$\frac{1}{4}$ inch in length each were mounted on the discs. The shaft was held at either end by a four-bolt flange bearing. To attain complete horizontal and vertical adjustments of the cylinder with respect to the concave, a system including linear ball bushings, pillow block shaft mounts, ball bushing shafts, and a horizontal and vertical adjustment screw was fabricated to support the cylinder bearings. Power was provided by a 3 h.p. capacitor start motor and transmitted via a variable speed V-belt.

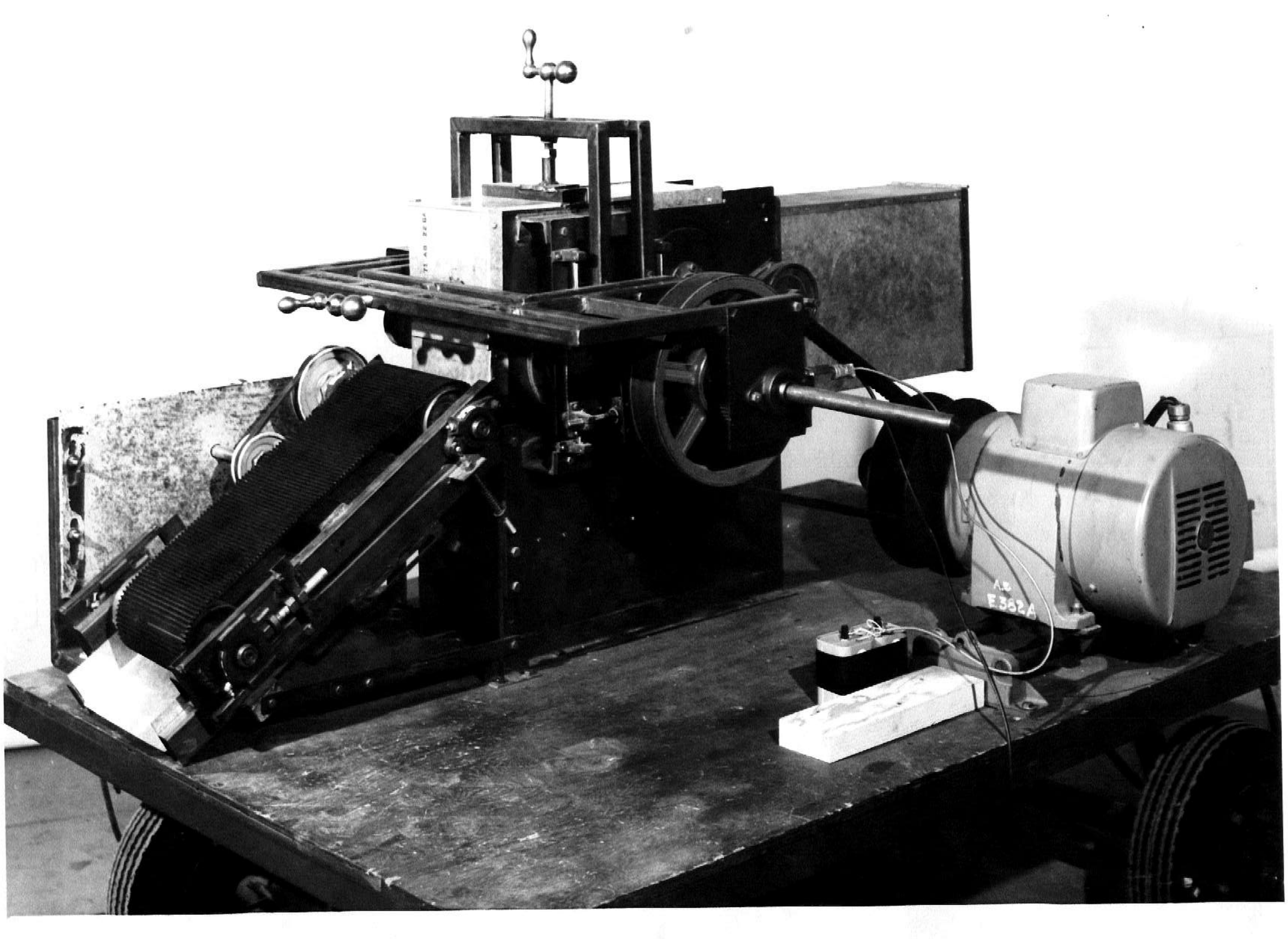

Figure 1. The threshing unit used in this study.

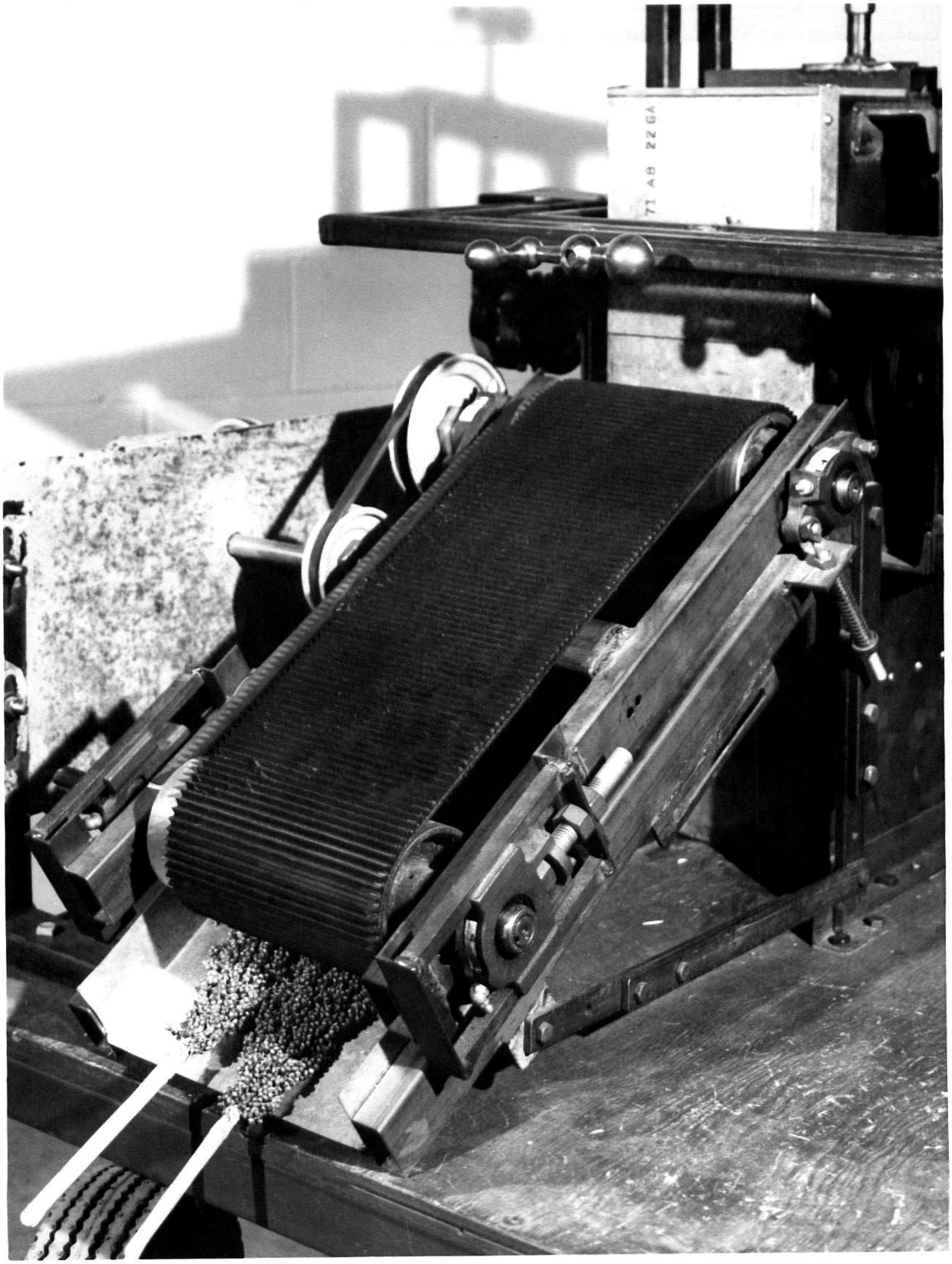

Figure 2. The feeder belt of the threshing unit.

An approximate 130° open-grate concave with a radius 3/16 inch greater than the cylinder was assembled in this unit. For more detailed information on construction, the reader may refer to Zaidis' M.S. thesis.

The cylinder was fed, radially and at angle of about 30° with the horizontal, by a constant-speed (22 ft/min.) belt conveyor. A metal box was placed behind the cylinder to receive the straw as well as the lost grain.

Separating Unit

In this study, the separating unit is composed of three round-hole hand sieves and a shaker (Fig. 3 & 4). The selection of the sieves size is based on a preliminary test. The top sieve has a 12/64 inch round hole opening to allow the good seeds to pass through and at the same time prevents the passage of chaff, straw and stalks with unthreshed grain. An 8/64 inch round hole opening was selected as the middle sieve which holds the good grain and permits the cracked seed to pass through. The cracked seeds and a slight amount of small seeds drop off the bottom sieve which has 2.5/64 inch round hole openings.

The sieves are placed on a shaker in such a way that they have a reciprocating motion. The shaker, made by Burrows Equipment Company, has an oscillating frequency of 34 cycle/min. After the shaker completes 40 strokes (20 cycles), material remaining on each sieve is weighed and the

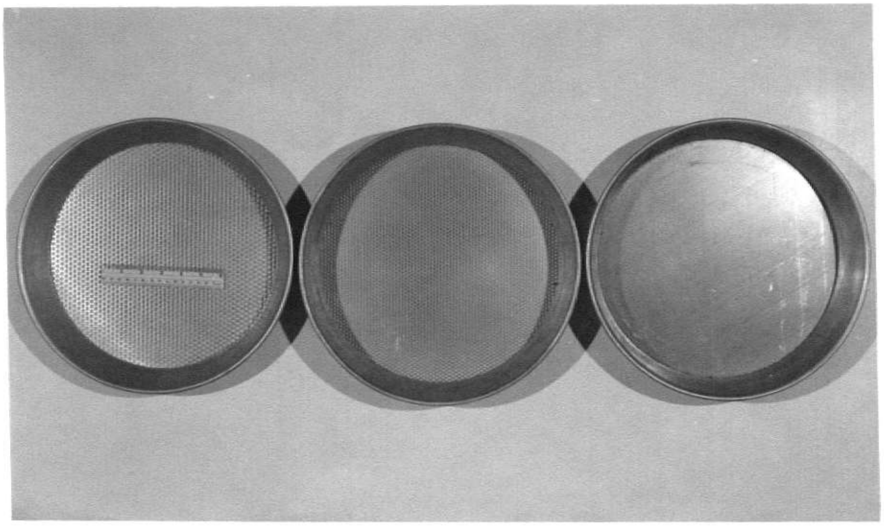

Figure 3. Three hand sieves used in this study.

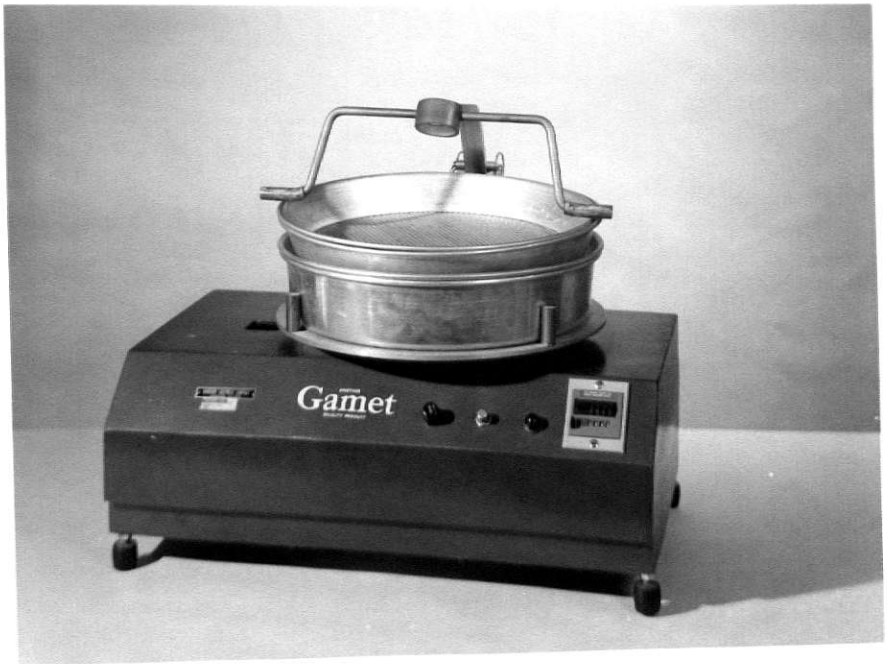

Figure 4. The sieves along with a commercial shaker used in this study.

Figure 5. Grain sorghum samples.

percentage of material on each sieve is calculated. The unthreshed grain along with stalk and chaff remaining on the top sieve are rethreshed by hand before weighing.

Grain Sorghum Varieties

Two grain sorghum varieties, ACCO 1019 and KS 56 were used in this study (Fig. 5). Samples were taken from the Agronomy Research Field, Kansas State University. The average grain-to-straw-ratio was 9.97 based on 13.9% grain moisture content and 59.1% straw moisture content for variety ACCO 1019 and 6.17 for KS 56 based on 13.1% grain moisture content and 53.7% straw moisture content.

The experiment began on September 10, 1976. Sorghum samples were collected every three days and brought into the lab and immediately threshed.

Method and Procedure

Grain moisture content. The grain moisture content is expressed on the wet basis. For each moisture level, three samples each with 100 grams of grain were put in a lab heat oven and subjected to a temperature of 103° C. After a 48 hour heating period, the samples were removed from the oven and weighed quickly.

Cylinder speed. The effect of cylinder diameter can be eliminated by considering peripheral speed rather than rotational speed. Throughout this experiment, the cylinder speed was controlled at 3276, 4082, 4888 feet per minute.

As the cylinder reached the desired speed, which was determined by a stroboscope, two heads of grain sorghum were placed on the feeder belt and were fed into the cylinder at 22 ft/min conveyor speed. Observations were made after each test as to the visible damage, the threshed grain, and also as to the amount of unthreshed grain remaining on the stalk.

Concave clearance. Most combine cylinders are designed in such a way that the front and rear clearance are changed simultaneously but with less change at the rear than at the front. Therefore, in this study, the concave-to-cylinder clearance was determined by taking the mean of the front and rear clearance. It was considered at three levels: 1/4, 7/16, and 10/16 inch.

Kepner et al. based on research results and summary of recommendations found in operator's manuals published by various manufactures, suggested that a range of 4000 to 5000 fpm peripheral speed, and 1/4 to 1/2 inch mean concave clearance would be the most appropriate cylinder adjustments for grain sorghum. In this test, the setting of cylinder speeds and concave clearances were selected as being thought to range from too low to high in terms of cylinder loss as well as grain damage.

The level of each variable under study are provided in Table 1.

Table 1. Variables studied.

Variables	Range
Moisture Content	ACCO 1019 (30.7 - 10.7% KS 56 (29.1 - 10.4%)
Cylinder-Concave Clearance	1/4, 7/16 and 10/16 inch
Cylinder Speed	3276, 4082 and 4888 ft/min.

Two heads of sorghum were used for each run.

The conveyer speed was set at 22 ft/min.

RESULTS AND DISCUSSION

For variety ACCO 1019, the moisture content of the grain dropped from 30.7 percent on September 10 to 10.7 percent on October 11. The average moisture reduction for this period was approximately 0.7 percent per day. For variety KS 56, the grain moisture dropped from 37.7 percent to 10.4 percent. The average moisture content reduction was about 0.9 percent per day. Fig. 6 was provided for

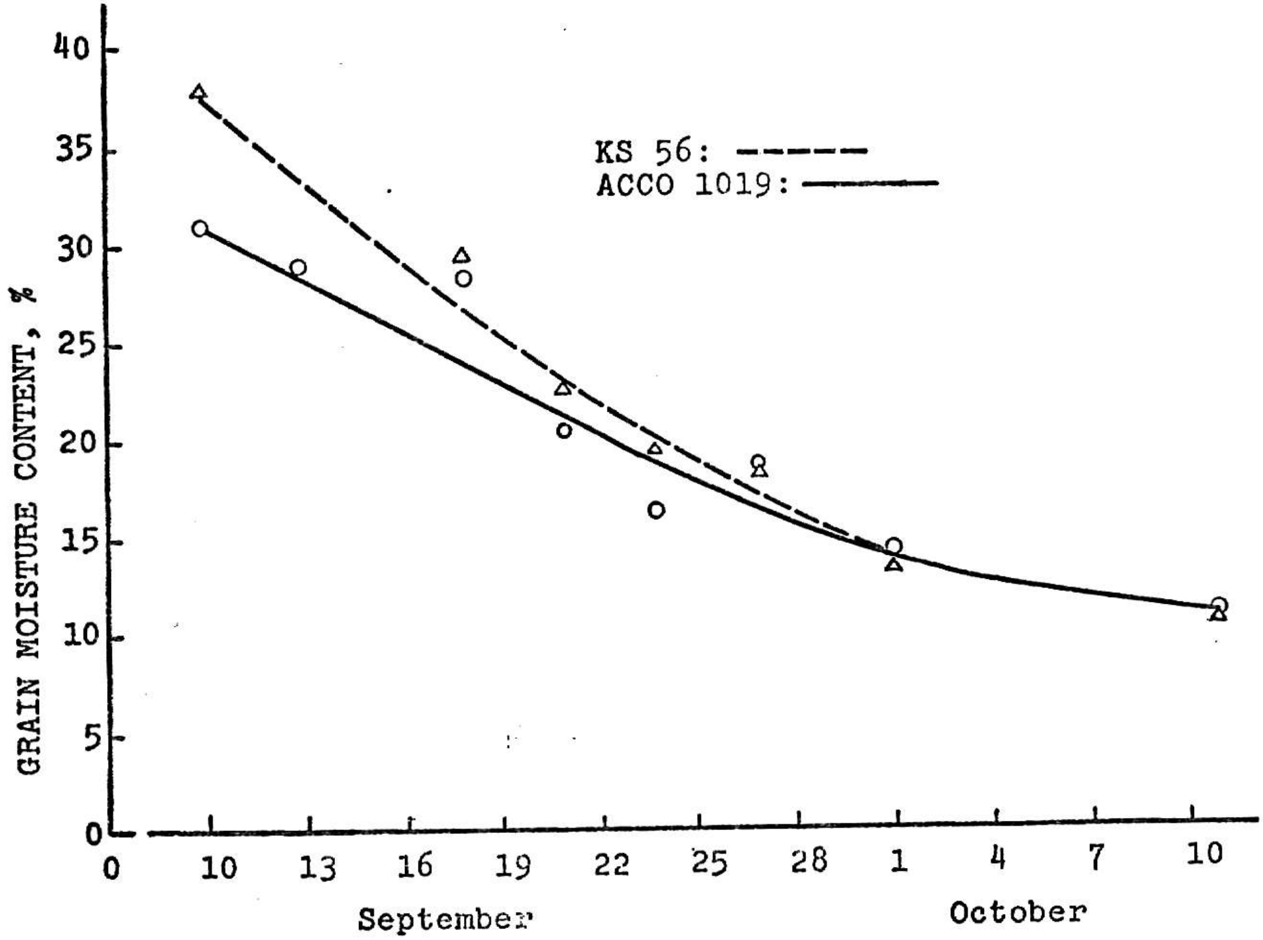

Figure 6. Rate of drying of sorghum grain during the experimental period.

showing the rate of drying for both varieties in the harvesting season. The rainy days of September 15, 25, and 26 may account for the slow drying rate.

Every three days, samples were brought to the laboratory where the experiment was carried out using three cylinder speeds at each of three concave clearances. All three speeds were run at a given clearance and then another clearance was set until runs at all three cylinder-concave clearances were completed. Accordingly, there are two restrictions on randomization. Since the grain moisture is chosen, and the concave clearance is chosen, the speed can be randomized at that particular concave clearance and grain moisture content.

The entire experiment was replicated twice, the grain moisture content and two replications form the whole plots. The concave clearance level may be randomized at each level of grain moisture and in each replication to form a split-plot. At each concave clearance - grain moisture content replication combination, the three cylinder speeds are ramdomly applied forming what is called a split-split-plot design. This design allows few degrees of freedom in the estimate of error of certain important factors, such as moisture content and concave clearance.

To determine the effect of the variable under study, an analysis of variance was performed on the threshed, unthreshed grain and broken grain. Data were processed by means of AARDVARK, a canned statistical program. The model used