

November 24, 1959

To the Graduate Council:

I am submitting herewith a thesis written by Dan Houston Luttrell entitled "Hay Conditioning in Tennessee." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Engineering.

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HAY CONDITIONING IN TENNESSEE

A THESIS

Submitted to
The Graduate Council
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science

by

Dan Houston Luttrell

December 1959

ACKNOWLEDGEMENTS

The author is deeply grateful to Dr. C. W. Bockhop for his guidance in conducting this research and in writing this thesis.

The author wishes to express his appreciation to the International Harvester Company and the New Holland Machine Company for the equipment they furnished to conduct this research work.

The author also wishes to express his appreciation to the University of Tennessee Dairy Department and Mr. Cecil Carmen, Dairy Herdsman, for their cooperation in providing the locations for the experiments.

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CHAPTER I

INTRODUCTION

Importance of Hay in Tennessee

Harvesting high quality hay with minimum losses using field curing methods has long been a problem facing farmers. A ten year average from 1948 through 1957 showed that approximately 1,853,000 tons of hay were produced on 1,584,000 acres annually in Tennessee (1). If this hay has an average value of twenty-five dollars per ton the total crop value is \$46,325,000.00. Unfavorable weather conditions when harvesting hay may cause a loss of 10 to 40 per cent of the dry matter; 60 to 90 per cent of the carotene; and 10 to 25 per cent of the water soluble vitamins (16). These data point out the importance of efficient haymaking machinery and practices in Tennessee.

Characteristics of High-quality Hay

Morrison (14) stated that to be of high quality, hay must have been made from plants cut at a sufficiently early stage of maturity. Next, high-quality hay has been cured and handled so that it is leafy and green in color. The stems are soft and pliable. It is free from mustiness or mold. It has an attractive fragrance that adds to its palatability. It has but little foreign material, such as weeds or stubble.

Such hay is more nutritious and more palatable than that which does not possess these qualities, therefore it has a much higher feeding value per ton (14).

Purpose of the Study

The purpose of this study was to investigate the effects of the conditioning process on the drying time of hay and its importance with respect to the average lengths of curing periods in Tennessee.

It normally takes from two- to three-days to field cure alfalfa hay in Tennessee and four- to five-days to cure soybean hay.

Many farmers cannot employ the use of artificial drying methods because of the high investment required for equipment. When a farmer uses field curing methods, he must try to avoid bad weather in order to get high quality hay. It seems possible, with the use of hay conditioners, that a farmer's chances of getting hay into the barn without rain would be greatly increased if he could reduce the curing time one- to two-days.

Haymaking

The objective of haymaking is to reduce the moisture content of the green plants to a level which will allow the hay to be stored safely and retain as much of its original food value as possible. A generally accepted safe moisture content for hay to be placed in storage is 20 per cent; however, under Tennessee conditions, the moisture content should be lower. Hay stored with too much moisture content will ferment and mold resulting in a great reduction of feeding value and a severe fire hazard.

The reduction of the moisture content of green plants has been accomplished by field curing, barn drying, wagon drying, and dehydration. Field curing has long been and still is most frequently used. This

method utilizes the elements of nature to dry the material in the field before it is placed in storage. The plants are cut and left in a swath for drying. They are next gathered into a windrow by a rake for additional drying and easier handling. The hay is then handled either loose, baled or chopped, depending on the mechanical equipment a farmer has available for handling his hay.

The barn drying method employs the use of a fan with or without heated air to remove the moisture from the hay after it is placed in the barn. Wagon drying is accomplished in a similar manner by passing air through the hay while it remains on the wagons.

In the dehydration method, the green forage is chopped with a forage harvester, and passed through a dryer which subjects the material to a temperature of 600 degrees Fahrenheit or more. This high temperature does not injure the forage because of the cooling effect produced when the water is evaporated.

The artificial drying methods produce less losses resulting in a higher quality hay; however, the initial investment and labor problems involved with these methods have kept farmers from using them extensively in Tennessee.

Losses by Field Curing Hay

There are always some losses in field curing hay, but when weather conditions are favorable, these losses can be reduced if proper management is used.

The losses that occur in haymaking are: (1) losses of leaves and other finer parts of stems by shattering; (2) losses by fermentation and bleaching; and (3) losses of water soluble nutrients by leaching in case of rains (14).

Shattering losses occur when the leaves become too dry. According to Dr. Rodney Briggs, University of Minnesota Agronomist, (7) uniform drying of stems and leaves is highly important. If one has to wait for the stems to be dry enough for safe storage, half or more of the leaves can be lost from shattering. Alfalfa leaves contain 70 per cent of the protein and as much as 90 per cent of the minerals and vitamins of the plant; and they also contain less fiber and more of the easily digestible nutrients than do the stems. Briggs found that losses due to leaf shattering was as much as 700 pounds equivalent of linseed oilmeal plus 250 pounds of corn per acre. This hay still qualified as U. S. No. 2 alfalfa hay. The proportion of leaves was therefore one of the important factors in determining the feeding value of any particular lot of hay.

Losses by fermentation occur both in the field and in the barn after storage. Fermentation in the field causes some of the organic nutrients, especially the sugars and starch, to be oxidized to carbon dioxide and water, thus they are lost. Fermentation also has a very destructive effect on the carotene of hay (14). Fermentation will occur unduly after the hay is placed in the mow if the hay has been under-cured. However, if the hay has been well dried the losses of dry matter will usually not exceed 5 to 7 per cent.

If hay is badly bleached by long exposure to the sun, nearly all

the carotene will be lost. In general, the amount of carotene in hay is in proportion to the greenness in color. Green-colored hay is nearly always rich in carotene, and straw-colored or brown hay very poor in it (14).

If hay that is nearly cured is exposed to heavy and prolonged rain, especially when it is in the swath, severe losses may occur through leaching. At least 20 per cent of the protein, and considerably more of the nitrogen-free extract may thus be lost by leaching (14). Severe leaching results only when the hay has dried out considerably before rain comes, and when the rain is so heavy that the hay is thoroughly soaked and washed. Hard rain soon after the crop is cut does not cause much loss.

The total loss of nutrients in hay during field curing and subsequent storage before feeding will vary according to weather conditions and management of the operations. Under favorable drying conditions and proper methods of handling the total loss of dry matter from the green crop to manger should not exceed 20- to 30-per cent for legume hay and 10- to 15-per cent for grass hay (14).

Weather and Haymaking

The drying rate of green plants in the field is controlled largely by the weather conditions during the time of harvest. The elements of weather which seem to influence field drying are: temperature, humidity, wind, sunshine and precipitation. When evaporation takes place heat is required, therefore temperature plays an important role in the speed of drying any material. Relative humidity is the ratio of the amount of

moisture which is present in the atmosphere to the amount it will hold at a given temperature. It is logical that the lower the relative humidity is the easier it is for moisture to be transferred from plants to the air. Sunshine is a source of heat which is conducive to evaporation; therefore, its presence aids in the evaporation of moisture from hay. The meteorological definition of precipitation is the deposit of water on the earth in various forms. The forms pertinent to haymaking are rain, hail, and dew. When any form of precipitation occurs during the field curing process, the drying time is lengthened.

Farmers cope with the elements every time they attempt to make hay. To avoid losses they try to select a time when drying conditions are good, and when they have a rain-free period long enough to get the hay in storage. Efforts are then made to cut and dry the hay as fast as possible without losing much of its quality.

Weather forecasters can predict weather conditions with a reasonable amount of accuracy one to two days in advance. Forecasts for longer periods are less reliable. Considering the fact that two to five days are required to cure various forage crops in Tennessee under good drying conditions, a farmer's risks are greatly reduced if the drying time is short.

Since nothing can be done about the weather, farmers must work with the conditions they have, and improve their methods of processing and handling hay to get the best quality obtainable.

Introduction of Hay Conditioners

It is well known that leaves dry more rapidly than the stems. Thus, by the time the stems have dried to the proper moisture content, the leaves have been overdried. This excessive drying of the leaves increases shattering in subsequent operations, and also causes a high loss of nutrients due to bleaching. If the stems are crushed so that direct air can pass through (Figure 1), moisture is more readily discharged. Crushed stems dry nearly as fast as the leaves. Thus, weather risks are reduced, and there are less nutrients lost through bleaching, leaching, shattering and fermentation. This concept prompted the design and development of the hay conditioner.

Basically all of the conditioners on the market by 1959 consisted of two or more rollers approximately seventy to eighty inches in length. They pick up a swath of hay and pass it between the rollers, thus crushing the stems. The inner parts of the stem are exposed to the air and they can dry more rapidly.

Types of Hay Conditioners

Many different types of conditioners have been developed. They are put into four general classifications; the corrugated roller, the smooth roller, the combination roller and the flail type.

The corrugated roller machine is commonly referred to as a crimper. It is made with two interlocking rollers which mesh like gear teeth. These rollers are from seventy-two to eighty inches long (8). Some of the rollers are made of malleable cast-iron with tapered flutes. Others are fabricated with steel bars welded axially to form

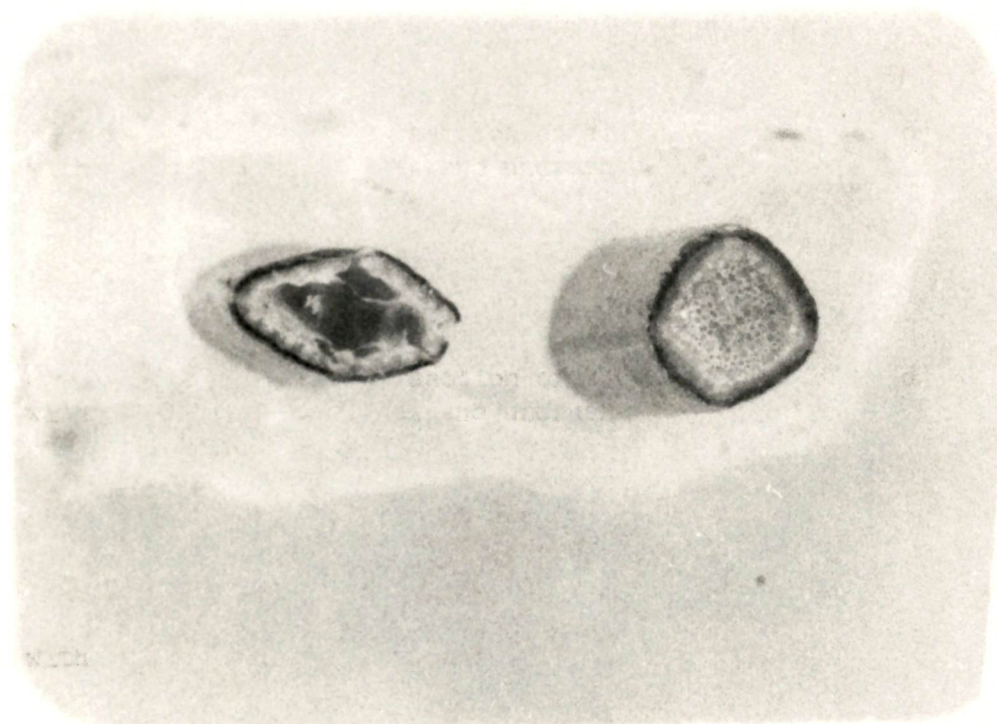


Figure 1. Cross section of alfalfa stems crushed with a conditioner, left, and uncrushed, right.

the teeth of the roller. Springs hold the upper moveable roller against stops limiting the amount of radial overlap to approximately three-eighths inch, depending on the design. The springs also permit spreading of the rolls when a heavy slug of hay is encountered, and produce the pressure necessary for the crimping action. Some crimpers have one powered roller transmitting power to the second roller, and others have both rollers receiving power from either chain or belt drives. These machines are mounted on two rubber tires, and trail behind the tractor. Some crimpers operate behind the tractor in combination with a mower. Both the mower and the crusher are pto driven.

The smooth roll machines are commonly called crushers. They are built with two smooth rollers made either of steel or fiber impregnated rubber. Roller lengths range from seventy to eighty inches (8). The upper roller is spring-loaded at both ends. These springs provide the crushing pressure, and allow for separation of the rolls when heavy amounts of hay are encountered. Some of these machines have a three- to four-inch diameter slotted pick-up cylinder just ahead of the crushing rollers. One machine with fiber impregnated rubber rollers has helical grooves in both rollers which aid in picking up hay from the swath. Both rollers on crushers are driven by either belts or chain drives indirectly powered from the tractor pto. These machines are used in combination with a mower or as a separate machine.

There are several combinations of rollers used on other conditioners. These combinations include grooved rubber rollers operating against

smooth steel rollers; smooth steel against ribbed steel; slotted steel against smooth steel; corrugated rubber against corrugated steel; and grooved rubber rollers against slotted steel rollers (8). Other units pass the hay between two corrugated rollers, and then between two smooth rollers producing a crimping and crushing action.

Roller diameters on conditioners vary between four to twelve inches. Some conditioners have rollers with different diameters, and others have rollers with equal diameters (8).

All of the conditioners have adjustments which can be made to control roll pressure and operating height above the ground. Some manufacturers are equipping their conditioners with windrow shields, and practically all units employ the use of deflecting shields to produce a fluffing effect as the material is discharged onto the ground.

The basic difference in the effects of the different conditioners is the crushing action on the stems. The crimper, because of its corrugated rollers, cracks the stems at intervals varying between one-half to two inches. The smooth rollers crush the stem along its entire length. The combination units' crushing action depends on the type of rollers used.

Roll speeds vary with different machines up to a speed of 1900 rpm.

Some recent interest has been shown in the use of the flail forage harvester as a conditioner. This machine was not built to be used as a conditioner; however, it produces a conditioning action which has been recognized. The flail harvester has the advantage of effectively combining the mowing, conditioning and raking operations into one operation.

The flail harvester machine is designed with knives suspended in evenly spaced rows, from a horizontal shaft to get complete cutting action as the shaft revolves. These knives hang freely from a pin through a bracket welded to the shaft. During operation the knives extend outward due to centrifugal force. The shaft can be adjusted to produce the desired cutting height of the material. The machine trails behind the tractor, and is powered by the pto.

The cutting action of the flail harvester cuts the stems in various lengths depending on the peripheral speed and number of knives in relation to the ground speed. Many of the stems are cracked or lacerated at points between the cut ends. These factors produce a condition on the stems which will allow air to flow through the stems.

At least one manufacturer has made a flail harvester which was fitted with a haymaking attachment to channel the hay into a windrow as it leaves the machine. Two or more windrows can be placed side by side, and picked up together after curing. Other machines have been used by opening a rear baffle permitting the material to fall in a swath on the ground. When this was done it was necessary to rake the material before it was baled or picked up.

Horsepower Requirements of Conditioners

Power studies, at the University of West Virginia on smooth-roll crushers and crimpers, showed the roll crusher required 7- to 10.8-horsepower when using various roller pressures. The crimper required less than four horsepower (18). The tests were run on alfalfa having a yield of 3.65 tons per acre with 74 per cent moisture.

Purdue University tests showed the pto transmits four to seven horsepower to operate a smooth-roll type conditioner (8). Less horsepower is required when less tension is used on the rolls. Tests on the corrugated or "crimper" type roll machines at Purdue usually ran less than four horsepower.

Though the power requirement of the mower-crusher was within the capacity of a two plow tractor, the weight of a three plow tractor was required for easy maneuverability according to both the West Virginia and Purdue University engineers.

Review of Previous Work Done

Development of Conditioners

Early development of the hay conditioner began in the early 1930's with a machine designed by E. B. Cushman in cooperation with the Food Machinery Corporation, San Jose, California (6). The early machine was a self-propelled unit powered by a Ford Model A industrial unit. The unit consisted of a cutter-bar and draper similar to a grain binder platform with a set of crushing rolls bed by the platform draper. Later the machine was redesigned with the crushing rolls parallel to the cutter-bar and of essentially the same length. Corrugated rubber-covered steel rollers were used on the early machine. Rotating brushes were used to keep the rolls clean. The later machine was equipped with one smooth rubber-covered roll and one steel roll. Subsequent experimental work on conditioners was conducted in Illinois, Mississippi, Missouri, and Kansas on machines of various types. Later experimental work was

conducted on commercial and experimental machines in Michigan, Wisconsin and Pennsylvania.

After World War II, hay conditioners were manufactured and sold commercially. Most of these models gave some trouble under field conditions, and were so costly that farmers did not accept them readily.

Several companies began to see the apparent advantage in crushing hay by 1950, and began to develop their own machines. Much progress was made in the development of conditioners after 1950. Five manufacturers had machines on the market in 1956, and by May 1959, fifteen manufacturers were making twenty-three different models (8). Other companies were beginning to plan or had plans ready for production at that time.

Drying Rate

Several colleges and universities have conducted tests on hay conditioners. Similar results of drying rates have been obtained; however, various climatic conditions in the different parts of the country have caused some differences.

The first report of tests on hay conditioners was one made by Roy Bainer (3) working with the California Agricultural Experiment Station during June 1930. The crushed hay required twenty-three hours to reach 15 per cent moisture, whereas the uncrushed hay did not reach this moisture content until forty-nine hours after cutting.

Later Frank J. Zink, Associate Professor of Agricultural Engineering, Kansas State College, (19) ran six tests in 1931 and 1932

which showed conditioned hay dried much faster than unconditioned hay. Alfalfa, cut by Zink, at 10:30 was dried to 25 per cent by 2:30. The uncrushed did not dry to 25 per cent until the next morning.

T. N. Jones and R. F. Dudley (10) made a study in Mississippi during 1947 on Johnsongrass, Sudan, and soybeans using a hay conditioner. They found that, by crushing these large-stemmed hays, the time required for field curing was one-third to one-half of that required for untreated hay.

A study by Allen K. Lawrence (12) at Rutgers University in 1951, indicated that as the roll pressure was increased, so was the drying rate. He investigated the drying rate with different time intervals between cutting and conditioning. These tests revealed that as the time interval was increased, the drying rate was decreased. Hay crushed eighty minutes after cutting, for example, lost half the value obtained by crushing when compared with a twenty-minute interval. However, in every case crushed hay dried faster than uncrushed hay.

H. D. Bruhn (6), Professor of Agricultural Engineering, University of Wisconsin, pointed out in 1955 the relationship of weather conditions to drying rates. Conditioned hay dried faster than the check in both good and average drying conditions. He also ran tests on the effect of multiple passes with the conditioner; the effect of roll pressure and roll speed on the drying rate, and the effect of delayed conditioning. The results showed multiple crushing did increase the drying rate slightly; increasing the roll pressure did speed the drying rate, and there was a trend toward faster drying when the roll speed was increased.

Bruhn's tests on delayed crushing showed that delaying the crushing just meant a drying rate similar to uncrushed material during the delay, and then a drying rate after crushing comparable to crushed material of the same moisture content. Double crushing, with a delay between the first and second crushing, produced a high drying rate with a considerable jump at the time of the second crushing (5).

P. John Zachariah, et al. (18) reported tests in West Virginia showed that, during average drying weather, forage containing 65 to 70 per cent initial moisture, mowed and crushed in the morning, dried to 18 to 25 per cent by late afternoon. However, if the initial moisture content of the crop was more than 75 per cent and if the yield was not more than ten tons (wet basis), the forage had to be left in the field overnight. They also found an increase in crushing pressure tended to increase the drying rate. Increasing the roller pressure affected the drying rate more in red clover and alfalfa than in timothy and brome. Zachariah did some work on the fluffing of hay relative to the drying rate. He found that fluffing promoted uniform drying through the entire thickness of the forage.

Tests run by John Strait, et al. (17) at the University of Minnesota Agricultural Experiment Station comparing smooth roll and crimping roll conditioners showed that there were some variations in the drying rates for different treatments; however, the differences did not favor any one machine. In every test mechanically treated hay dried faster than the untreated check.

California tests showed no great difference in drying rates with four different conditioners according to R. A. Kepner, et al. (11). Two models of crimpers and two models of smooth crushers were compared in these tests.

C. L. Hill, Extension Agricultural Engineer, Purdue University, (8) reported that if the weather is cloudy, humid, cool or still, the drying rate was slowed, and conditioned hay does not dry much faster than ordinary hay.

According to K. K. Barnes, Professor of Agricultural Engineering at Iowa State University, (2) conditioning hay shortened curing time by one day. The proper timing of cutting conditioning was important, however.

Recent work has been conducted at two experiment stations which compared the flail harvester as a conditioner to the roller type conditioner. M. M. Boyd, Instructor at the Agricultural Engineering Department, University of Massachusetts, (4) compared unconditioned, crimped and flail-cut timothy-brome mixture during 1957. He found the flail-cut material had the most rapid drying rate. During the early morning hours the dew evaporated more rapidly from the flail-cut crop than from either the crimped or the unconditioned hay. However, there was a greater overnight moisture pick-up in the unconditioned material. His 1958 test of the same mixture showed the rate of dew evaporation during the early morning hours was about equal for crimped and crushed material. Late in the forenoon, the flail-cut material began to show a drying advantage over the crushed material. By early afternoon the flail-cut material was ready for baling, whereas the crushed crop still

required additional drying for several hours. Boyd concluded that the flail harvester exhibited some advantage in speeding the field curing of forage over more conventional methods of conditioning. The flail harvester cut and conditioned equivalent areas in less time than was possible with other conditioning methods. The problem of losses after flailing should be further investigated.

H. D. Bruhn (4) reported that on the basis of tests at the University of Wisconsin he would not recommend the flail harvester as a forage conditioner until decided improvements in operation characteristics are made.

C. L. Hill (9) felt the flail-type harvester should be considered only on the basis of using the machine for additional jobs such as stalk chopping and silage making. Dividing machine costs a number ways, the flail harvester became an economical hay crusher.

The flail harvester has been used in England as a hay conditioner, but no experimental results were available from that country (13).

The Effect of Conditioners on Losses

The use of a conditioner promotes some field losses by clipping or stripping leaves and stems as the hay passes through the conditioner. The clippings and leaves are so small a rake will not pick them up.

R. A. Kepner, et al. (11) found, through some field tests in California on alfalfa, that when hay was crushed there was a 1.1 per cent of total yield lost compared to the control treatment. When a crimper was used, there was 3.6 per cent of the yield lost due to the conditioning. All differences were highly significant at the

1 per cent level. They also found that increasing the roll pressure on the smooth roller machines increased the total loss. One machine showed an increase in the total loss by 50 to 60 per cent when the roll pressure was raised from nine pounds per inch to thirteen and one-half pounds per inch. Because of the predominance of leaves and stalk tips, the protein content of the material lost in the conditioned treatments averaged several percentage points higher than the protein content of the baled hay.

Boyd (4) studied losses in alfalfa and in a timothy-brome mixture. He found, by checking the amount of material left on the ground for each conditioning method, the crimper caused more loss than the crusher. He included a flail harvester in his tests. The flail harvester caused a somewhat greater loss than the other conditioners. This was attributed to the shorter cutting characteristics; which makes the pick-up by subsequent operations less effective.

Through observations, Bruhn (5) concluded that, because of excessive damage to the crop in the form of stripping of leaves or clipping, an attempt should not be made to obtain a high drying rate by carrying the factors of high roll pressure and high roll speed to extremes. Each factor should be so controlled that the sum of the effect of individual factors should bring about the maximum desired drying rate with only very limited leaf loss.

Quality and Feeding Response of Conditioned Hay

Jones and Dudley (10) found in conditioning large stemmed hays

that the carotene content of crushed hay at baling time was approximately 35 per cent higher than uncrushed at the time of baling. After storage for two months, carotene content was 35 per cent higher in crushed hay.

Work done by other experiment stations (18) showed that the quality of crushed hay was better than uncrushed. Carotene content in crushed hay at the time of baling and after five months storage was reported to be 20 to 50 per cent higher than uncrushed hay which was cured to the same moisture level. Crushing of the thick and woody stems makes the hay more palatable.

California tests on alfalfa by Kepner, et al. (11) indicated crimped hay had a higher crude fiber content than rolled or untreated hay, and the average protein content of the crimped hay at the time of baling was lower. Experiments with the unconditioned hay and the rolled hay showed protein contents at the time of baling were essentially the same as for the standard crop at the time of mowing. There was no appreciable change in protein or crude fiber contents during storage. The carotene content in the conditioned hay averaged 13 per cent of the initial amount, whereas the control averaged 11 per cent. The advantage of conditioned hay in regard to carotene content at the time of baling disappeared during storage.

Feeding trials conducted with sheep in California (11) indicated a statistically significant difference at the 5 per cent level of probability in favor of crushed hay. The absence of a satisfactory explanation in terms of chemical content of the hay raised some doubt as to the validity of any generalization based on the one set of tests

run. Experience indicated that feeding results may vary somewhat in different tests, probably because of biological variations. Furthermore, tests with dairy cows at the Pennsylvania Agricultural Experiment Station showed no difference between crushed and uncrushed hay in regard to milk production or changes in body weight during twenty day periods, although the crushed hay appeared to be more palatable and was eaten more rapidly.

Operation Characteristics of Conditioner

Bruhn (6) reported one very disagreeable feature of a crusher was the clogging of the crushing rolls by large stemmed weeds. The weeds, instead of entering the crushing rolls tip first, would come to the roll crosswise, and prevent additional forage from entering the rolls. Special unclogging devices were of limited help. Bruhn surmised by mathematical analysis, that the diameters of the crushing rolls have a definite bearing on the feeding characteristic of a crusher. Larger rollers in relation to the diameter of the stems produce greater friction factors, therefore for large stemmed weeds the larger rollers feed better.

Another difficulty in feeding reported by Bruhn resulted from bunching of the forage. Bunching may be caused by faulty mower operation, or from poor design in the pick-up and conveying portion of the crusher. Crushers on which the roll pressure is controlled by long springs, fed bunches better than those on which the pressure was controlled by short springs. Short springs caused the roll pressure to increase rapidly as the rolls separated.

Zachariah, et al. (18) reported both crimpers and crushers worked best shortly after mowing. While crushing alfalfa and clover, and occasional build-up on the crusher was observed but it did not create any problem. Wrapping on the crimper roller was observed while crimping timothy and red clover. On most occasions, wrapping occurred at the ends of swaths when the pto speed was reduced before stopping the forward motion of the tractor.

Bruhn (5) encountered no increase in the tendency for crushers and crimpers to wrap or clog due to delays in crushing.

Zachariah (18) pointed out that when mowing was done at a low ground speed, the forage was not laid on the ground uniformly, and some of it was crosswise to the swath. This resulted in bunching of the material when it was conditioned. He has also observed that too much roll pressure caused the leaves to dry faster than the stems.

Observations by researchers at Purdue University as well as their discussions with farmers who have hay conditioners, have produced several pointers for using a conditioner more effectively (8). They are as follows:

1. Conditioning should be done immediately after mowing or within fifteen to thirty minutes.
2. The pick-up should be raised as high as possible to avoid trash, rocks and soil.
3. Pressure on rolls should be adjusted according to type of hay, stage of maturity and yield.
4. Timothy-brome hay requires the least pressure; clover-timothy mixtures take a medium pressure; and alfalfa, red clover or

soybeans need high pressures.

5. Rolls operating at high surface speeds give best results.

6. In critical weather periods, it is well to condition hay twice in order to cut down exposure to rain during drying time.

However, if the weather is cloudy, humid, cool or still, the drying rate is slowed, and conditioned hay does not dry much faster than ordinary hay. In poor drying weather double conditioning is of no value.

7. The operator should see that the crushed hay is laid down in a fluffed condition to obtain fast drying. This requires adjusting a swath deflector on most machines.

Hill (8) pointed out, in the case of the flail type harvester, that a few changes are needed to convert these units for conditioning, such as slowing down the knife drive, adjustment of the shear bar to maximum clearance, and provision of some means to lay the crushed hay down in a swath.

CHAPTER II

MATERIALS AND METHODS

Location of Experiments

The field research for this thesis was conducted in two locations. Most of the experiments were conducted on the University of Tennessee Cherokee Farm, adjacent to Fort Loudon Lake. One experiment on soybeans was conducted on the Joel Anderson farm about one mile south of Cherokee Farm on Fort Loudon Lake.

Hay Studied

The experiments for this thesis were confined to the first, second and third cuttings of Buffalo alfalfa in 1959, and one experiment conducted on soybeans during August in 1958.

The crops used were typical of most Tennessee conditions.

Machines Used for Experiments

There were four different types of machines used in the experiments.

A New Holland crimper was used on the 1959 tests (Figure 2). This conditioner has two fabricated bar-type rollers that have different diameters. The larger roller is on top and slightly in front of the smaller one. Adjustments can be made on the height of operation, deflection of material and spring tension.

A Cunningham crimper was used in the 1958 tests. The description of the New Holland crimper also applies to this crimper since they are very similar in construction.



Figure 2. New Holland Crimper with fabricated crimping rollers.

An International Harvester No. 2 rubber roller crusher was used on some of the experiments (Figure 3). This machine has two smooth fiber impregnated rubber rollers with different diameters. The rolls have spiral grooves in them which make it possible to pick up hay from the swath. The rolls are crowned in the center to assure even crushing pressure throughout the entire length. The crushing roll pressure, deflection shields and height of operation can be adjusted. The machine can be raised by either a hydraulic cylinder or a ratchet cylinder. This machine has a roll speed of 1900 rpm.

New Holland's smooth-roll mower-crusher, Model 440 (Figure 4), was used on one of the 1959 experiments. The crusher is mounted rigidly behind the mower, and rides on two caster wheels. This crusher has two smooth metal rollers having an equal diameter of twelve inches. A fluted roller runs slightly in front of the crushing rolls to aid in picking up the swath of hay. The height of this pick-up roller is adjustable. The roll pressure and deflecting shields can be adjusted to crop conditions.

The John Deere No. 15 flail-type forage harvester was used on two of the 1959 tests (Figure 5). This machine has a five-foot cutting width. Its height of cut can be adjusted. The material is conveyed to a blower by an auger; however, a rear baffle can be opened to allow the material to fall on the ground.

A cross section of all types of conditioners used is shown in Figures 6, 7, 8 and 9.

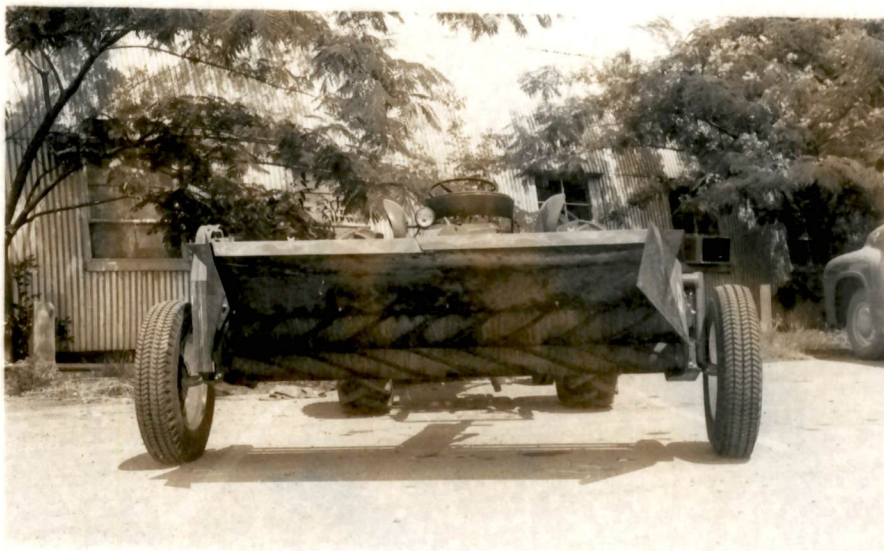


Figure 3. International Harvester No. 2 hay conditioner with rubber rollers.

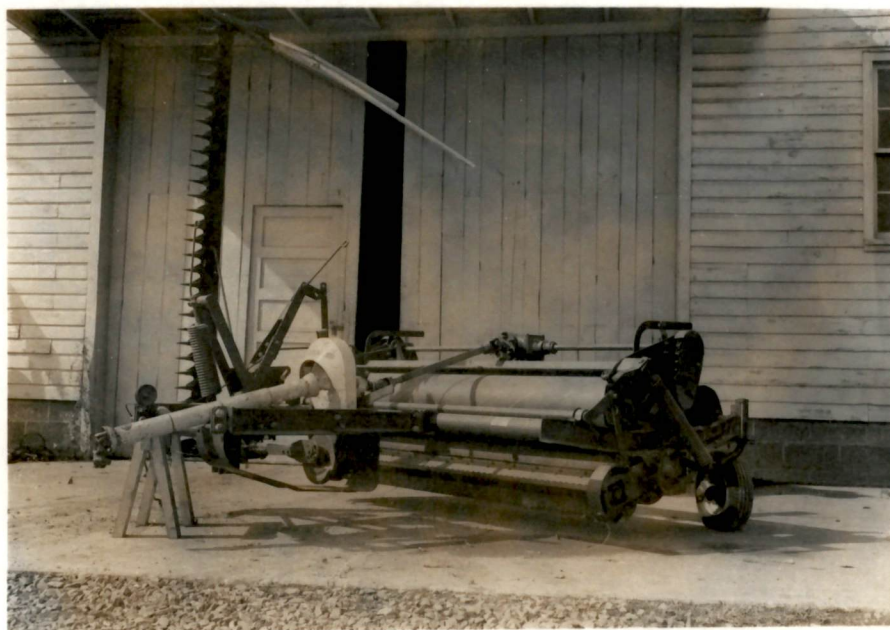


Figure 4. New Holland hay conditioner with smooth steel rollers.



Figure 5. John Deere No. 15 flail-type forage harvester with rear baffle open.

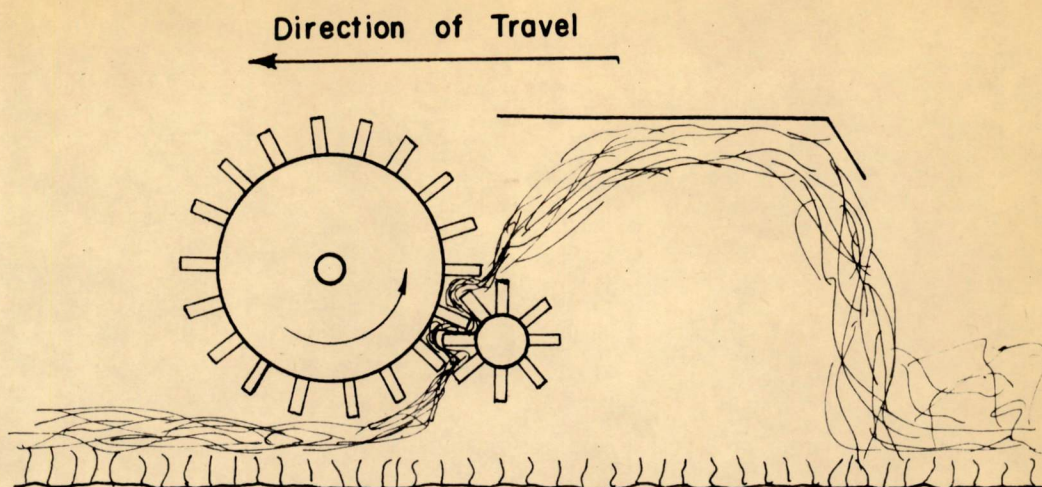


Figure 6. Diagram of the crimper type conditioner

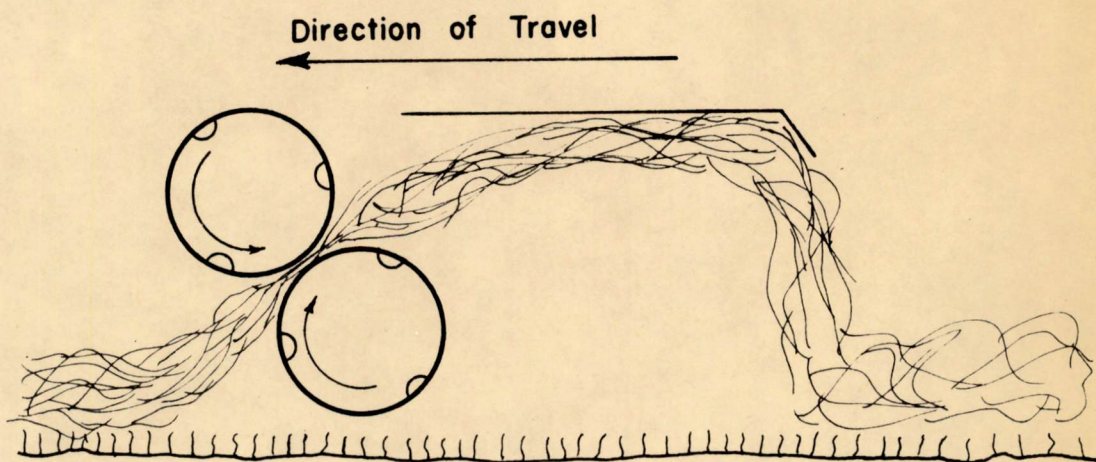


Figure 7. Diagram of the rubber roller conditioner

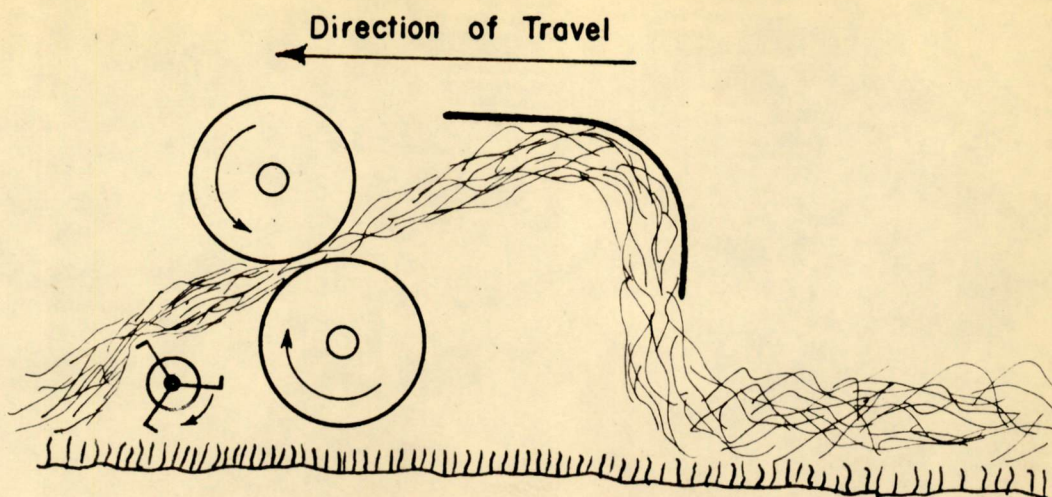


Figure 8. Diagram of the smooth steel roller conditioner.

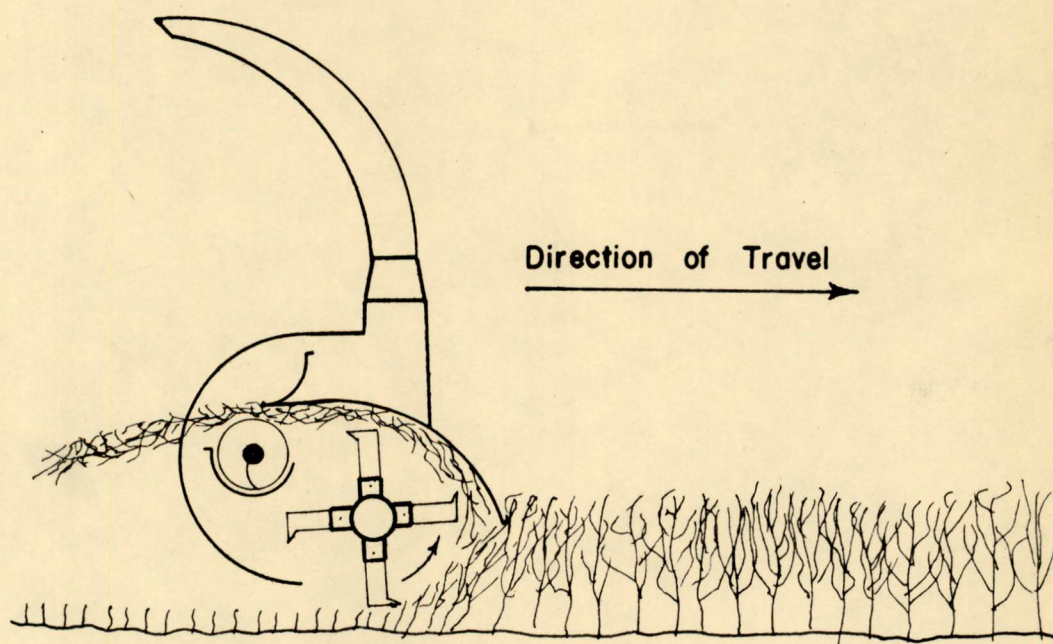


Figure 9. Diagram of the flail harvester.

A conventional side delivery rake and baler were used to rake and bale the hay.

Two-plow tractors or larger were used to power the hay-making equipment.

Instrumentation

The experiments included the determination of the moisture content of the hay, the temperature, relative humidity, wind speed, and cloud cover at a given time of day.

The moisture content was determined by the oven method and oil method. The oven method employed the use of a pair of torsion scales accurate to a tenth of a gram, and a forced air electric oven. The samples of hay taken were weighed as soon as possible, then placed in the oven and dried at 160 degrees Fahrenheit for forty-eight hours. They were again weighed to determine the amount of moisture lost. The moisture content was then determined as follows:

$$\text{Moisture content in per cent} = \frac{\text{wet weight} - \text{dry weight}}{\text{wet weight}} \times 100$$

The oil method used employed the use of the following equipment:

1. Dietetic scales of 1000 gram capacity with a rotating dial.
2. LP gas camp stove.
3. 200 degrees centigrade thermometer
4. One quart can with a piece of screen wire cut to fit inside the can. A hole was cut in the center of the wire for the thermometer to pass through.

5. Pure vegetable oil.

6. Pair of shears.

The hay sample was cut into approximately one-inch lengths with the shears, and placed in a quart can on the scales. One hundred grams of hay was added, and the screen placed on the hay to hold it down. Pure vegetable oil was poured into the can until it covered the hay. The thermometer was inserted into the hole in the screen to about half the depth of the hay. The dial of the scale was rotated to read zero. The material in the can was boiled until it reached a temperature of 145 degrees centigrade. Then the can was weighed and the per cent moisture of the hay was read directly on the scales since the number of grams lost by evaporation is equal to the per cent of moisture lost. This method was used only to determine the moisture content quickly in order to know when to rake and bale.

A sling psychrometer was used to determine the temperature and relative humidity.

A Dwyer wind meter was used to determine the wind velocity.

The cloud cover was estimated since there was no instrumentation available for determining this or the amount of radiation from the sun.

Sampling

Mowing and conditioning of a field of hay was started in a normal way with the conditioner mounted on a separate tractor. The mower was kept one round ahead of the conditioner. When a uniform section of the field was reached, two swaths were left unconditioned

for approximately 200 feet for a check plot. Adjacent to this check plot the conditioned plots were established as the mowing operation proceeded. Two swaths were conditioned by each conditioner.

The two-hundred foot section of treatments was divided into four equal plots for replication of sampling. Approximately one-hundred gram samples were taken from each plot at cutting time to determine the initial moisture content. Samples were then taken of each treatment from each plot every hour with the exception of some experiments which were conducted on a two-hour basis, and at night when no samples were taken. The samples were always taken from a section of the swath which appeared representative of the entire plot.

The cans used for sampling had been previously weighed. The weights of the can and the can number were stamped on the can with a metal stamp. The can number was recorded with the treatment and plot number as the samples were taken.

Can sampling after raking presented a problem of getting a representative sample since such a small amount of hay could be placed in a can. Some three foot square frames were made with hooks on each corner. These frames were covered with one-half inch hardware cloth. A section of the windrow was placed on this frame at raking time and weighed. A can sample of the hay was also taken at the time of raking to determine the moisture content at this time. After calculating the dry weight of the hay on the frames, the per cent moisture was then determined at each weighing.

Each time a group of samples was taken, notations were recorded of the temperature, relative humidity, wind and cloud cover. A sample

data sheet is shown in Appendix A.

Drying Rate

The drying rate was defined as the change in moisture content of a treatment with respect to a unit of time. The drying rate in these experiments was expressed as the loss of moisture content in per cent per hour. The slope of a line tangent to the line representing the moisture contents of a treatment at various hours of the day is equivalent to the drying rate at the point of tangency.

Weather Analysis

Rainfall data for the thirty-eight year period from 1917 to 1954 were obtained from the Hydraulic Data Branch of the T.V.A. in Knoxville (15). These data consisted of the recorded daily rainfall for the years mentioned. The number of one, two, three, four and five day periods with no rainfall between April 15 and September 30 were counted for each year. Practically all hay in Tennessee is harvested between the dates of April 15 and September 30.

The results of this analysis are shown in Figure 10. There was an average of 6.2 rain-free periods which were five days or more in length during the haying months. There was also an average of 9.2 four day periods; 14.4 three day periods; 22.3 two day periods; and 99 one day periods without rain.

If hay can be cured in two days instead of three, a farmer's chances of getting his hay into the barn without rain are increased 55 per cent. The ability to make hay in only one day would greatly

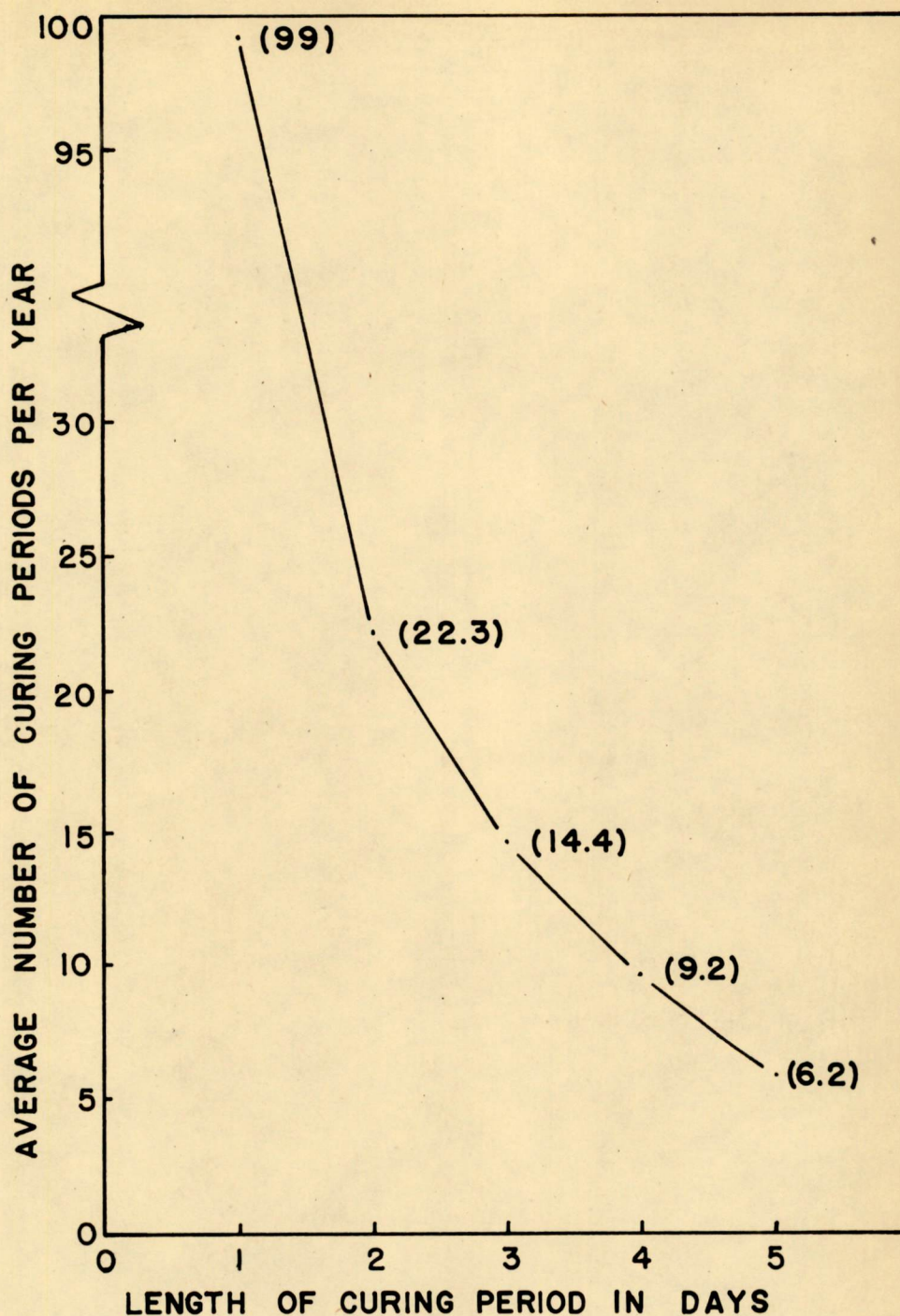


Figure 10. Expecting curing periods with no rain in Knoxville, Tennessee between April 15 and September 30, during any year based on a thirty-eight year average.

reduce the risk in haymaking; however, one must remember that hay does not dry rapidly the day following a wet period or a heavy rain due to ground moisture.

CHAPTER III

RESULTS AND DISCUSSION

First Experiment

The first cutting of alfalfa was used for the first experiment. The area selected for the experiment was along the middle of a seven acre field containing a good stand of Buffalo alfalfa. This field was located on the University of Tennessee Cherokee Farm adjacent to Loudon Lake.

The alfalfa was mowed at 10:30 a.m. on May 11, 1959, and conditioned within five minutes after mowing. The flail forage harvester was not used, however, until 12:15 p.m.

The first two swaths were left unconditioned to serve as a check plot. The next two were conditioned with a rubber roller conditioner. The crimper was used to condition the next two swaths. The flail harvester was used next, but there was a delay caused by hitching time and unexpected adjustments.

The first attempt with the flail harvester was made channeling the material through a pipe into a windrow. The material was chopped so short it was compacted as it fell onto the ground. The next attempt was made with the rear baffle raised, which allowed the material to fall evenly distributed over the ground. The samples in this experiment were taken from the latter material.

The entire area selected was divided into four sections. Samples of all treatments were taken from each plot at intervals of one and one-half to two hours. The samples were carried in air tight

cans directly to the scales and weighed. The oven drying method was used for determining the moisture content on the wet basis.

Table I shows the means of the moisture content of the individual plots with respect to time under all treatments as found in Appendix B. Details of the weather are also shown. This same information can be seen graphically in Figures 11 and 12. Figure 10 shows the relationship of the treatments with respect to actual cutting time. The data is plotted in Figure 11 on the basis of the time elapse after mowing.

The moisture content of the hay conditioned with the rubber roller conditioner ran consistently below all other treatments.

When the conditioned treatments reached the 20 per cent moisture level, there was very little difference between them, but the moisture content of the check plot was approximately 40 per cent. The material in the check plot had to dry some on the third day to reach a safe moisture content, whereas the conditioned plots were ready for baling by noon on the second day.

The drying rates of the conditioned material remained steady for the first three hours after cutting; then they began to drop. The drying rate of the check plot steadily decreased after cutting. On the second day of drying the drying rate of the check plot was below all other treatments during the afternoon. This change is probably due to the fact that the easier expelled moisture had already been discharged from the conditioned plots, but not expelled from the check.

TABLE I

MEAN MOISTURE CONTENT OF THE FIRST CUTTING OF BUFFALO
ALFALFA HAY UNDER DIFFERENT CONDITIONING TREATMENTS
AT KNOXVILLE, TENNESSEE

Experiment 1

Date and Time of Day	Per Cent Moisture* (Wet Basis)				Temperature Of	Relative Humidity Per Cent	Wind Velocity m.p.h.	Cloud Cover Per Cent
	Check	Crimped	Rubber Roller	Flailed				
May 11, 1959								
12:30 p.m.	64.9	62.3	60.6		87.5	40	0-8	25
2:30 p.m.	57.4	52.0	48.6	61.1	88.5	41	0-6	50
4:00 p.m.	53.7	42.7	36.1	48.3	86.0	41	0-6	40
6:00 p.m.	49.4	34.9	30.1	49.8	84.5	54	0-0	20
May 12, 1959								
9:15 a.m.	49.1	34.1	28.9	38.5	81.0	64	0-4	30
10:30 a.m.	43.5	27.1	22.6	32.6	83.2	58	0-6	40
12:00 noon	42.0	17.6	16.0	24.1	83.5	53	6-8	75
2:45 p.m.	**30.0				86.0	50	0-7	90
2:50 p.m.				**20.8	86.0	50	0-7	90
3:15			**11.5		86.0	50	0-7	90
3:30 p.m.		**13.0			86.0	50	0-7	90

Moisture content of uncut hay: 77.0 per cent
 Time of mowing and conditioning: 10:30 a.m., May 11, 1959
 Time of flailing: 12:15 p.m., May 11, 1959

* These data are an average of four plots.

** Moisture content at raking time.

— — — CHECK
 - - - CRIMPED
 + ROLLED
 —△— FLAILED

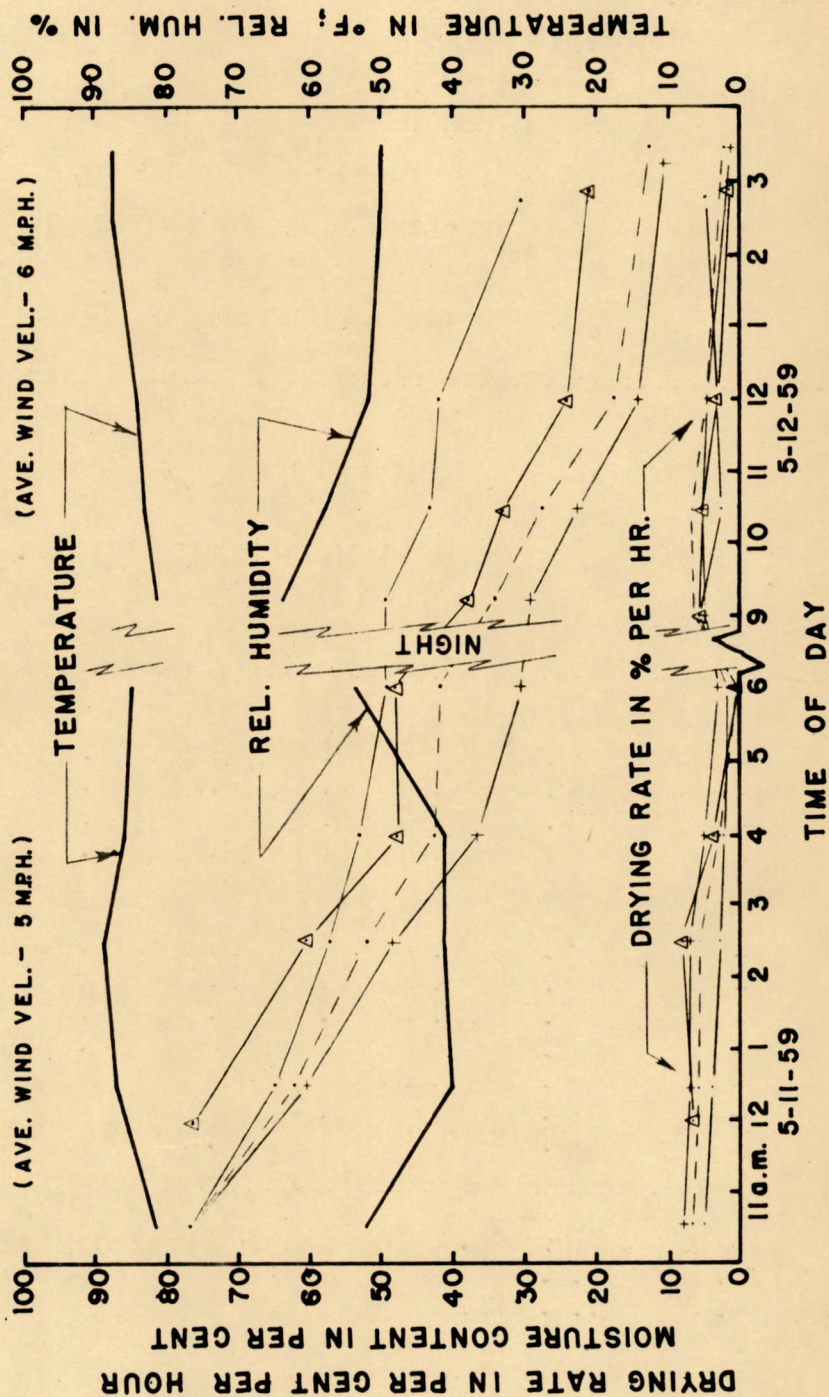


Figure 11. Mean moisture content and drying rate of the first cutting of Buffalo alfalfa under different conditioning treatments at Knoxville, Tennessee.

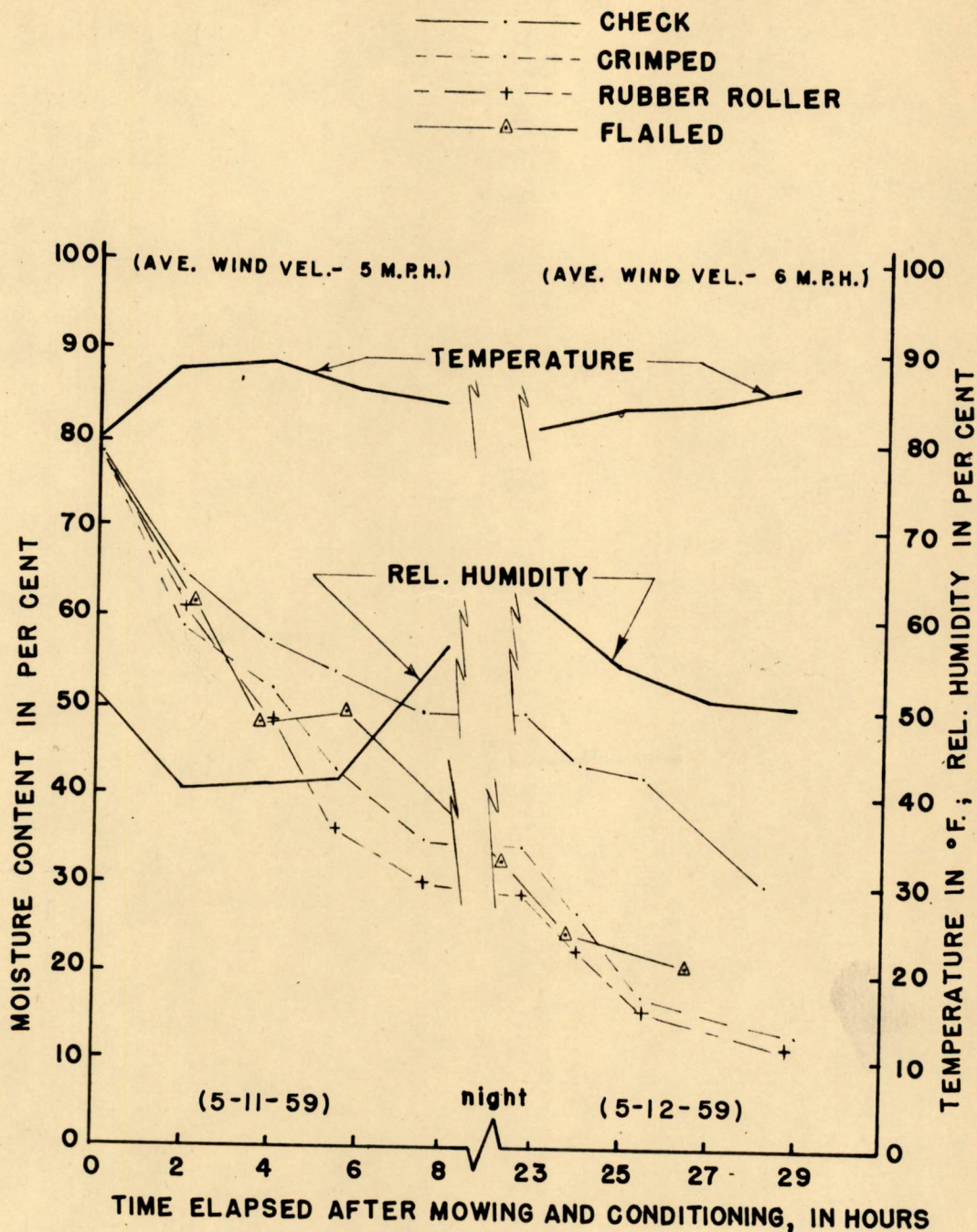


Figure 12. Mean moisture content of the first cutting of Buffalo alfalfa under different conditioning treatments at Knoxville, Tennessee.

The temperature range during the experiment was 81 to 88.5 degrees Fahrenheit. The relative humidity range was 40 to 64 per cent. There were clouds and a consistent breeze on both days of the experiment.

In this experiment the conditioned plots were ready for baling on the day after cutting. The unconditioned material had to dry some on the third day, thus requiring a minimum of a three day period with no rain to make hay.

Second Experiment

The second experiment was conducted on a field of second cutting of Buffalo alfalfa adjacent to the one used in the first experiment. The experiment was set up and conducted in a similar manner using a crimper, a rubber roller conditioner, a smooth steel roller conditioner, and a flail harvester. A plot was left unconditioned for a check.

The hay was cut during the afternoon on June 15, 1959. A time difference in cutting was caused by the delay in mowing around the field.

Table II shows the means of the moisture levels and the weather details throughout the experiment. This information is shown graphically in Figures 13 and 14. The field data are shown in Appendix C.

The moisture content of the check plot ran consistently higher than all other treatments. There were some differences between the moisture contents of the conditioned plots.

TABLE II

MEAN MOISTURE CONTENT OF THE SECOND CUTTING OF BUFFALO
ALFALFA HAY UNDER DIFFERENT CONDITIONING TREATMENTS
AT KNOXVILLE, TENNESSEE

Experiment 2

Date and Time of Day	Check	Per Cent Moisture* (Wet Basis)					Temperature °F	Relative Humidity Per Cent	Wind Velocity m.p.h.	Cloud Cover Per Cent
		Crimped	Smooth Steel Rolled	Rubber Rolled	Flailed					
June 15, 1959										
4:45 p.m.	70.6	62.2	58.8	63.1	67.8	84.0	37.5	0-5	2	
6:00 p.m.	66.5	55.5	54.9	54.8	59.8	82.0	38.5	0-2	0	
June 16, 1959										
9:00 a.m.	65.2	53.7	50.4	50.6	54.4	79.0	70.0	0	1	
10:00 a.m.	50.7	45.8	43.4	41.1	45.3	80.0	42.0	0	1	
11:00 a.m.	52.9	39.4	36.1	34.0	37.1	81.5	38.0	0-3	2	
12:00 noon	46.5	28.3	30.9	25.3	33.4	84.0	29.0	6-8	0	
1:00 p.m.	43.7	24.1	26.1	19.9	26.8	87.0	25.0	5-10	0	
2:00 p.m.	40.6	19.6	21.0	22.4	23.9	87.0	25.0	0	0	

Moisture content of uncut hay:

74.4 per cent

Time of mowing and conditioning with

smooth steel roller crusher:

2:45 p.m., June 15, 1959

crimping roller

3:15 p.m., June 15, 1959

rubber roller crusher

3:45 p.m., June 15, 1959

Time of mowing of check:

4:00 p.m., June 15, 1959

* These data are an average of four different plots.

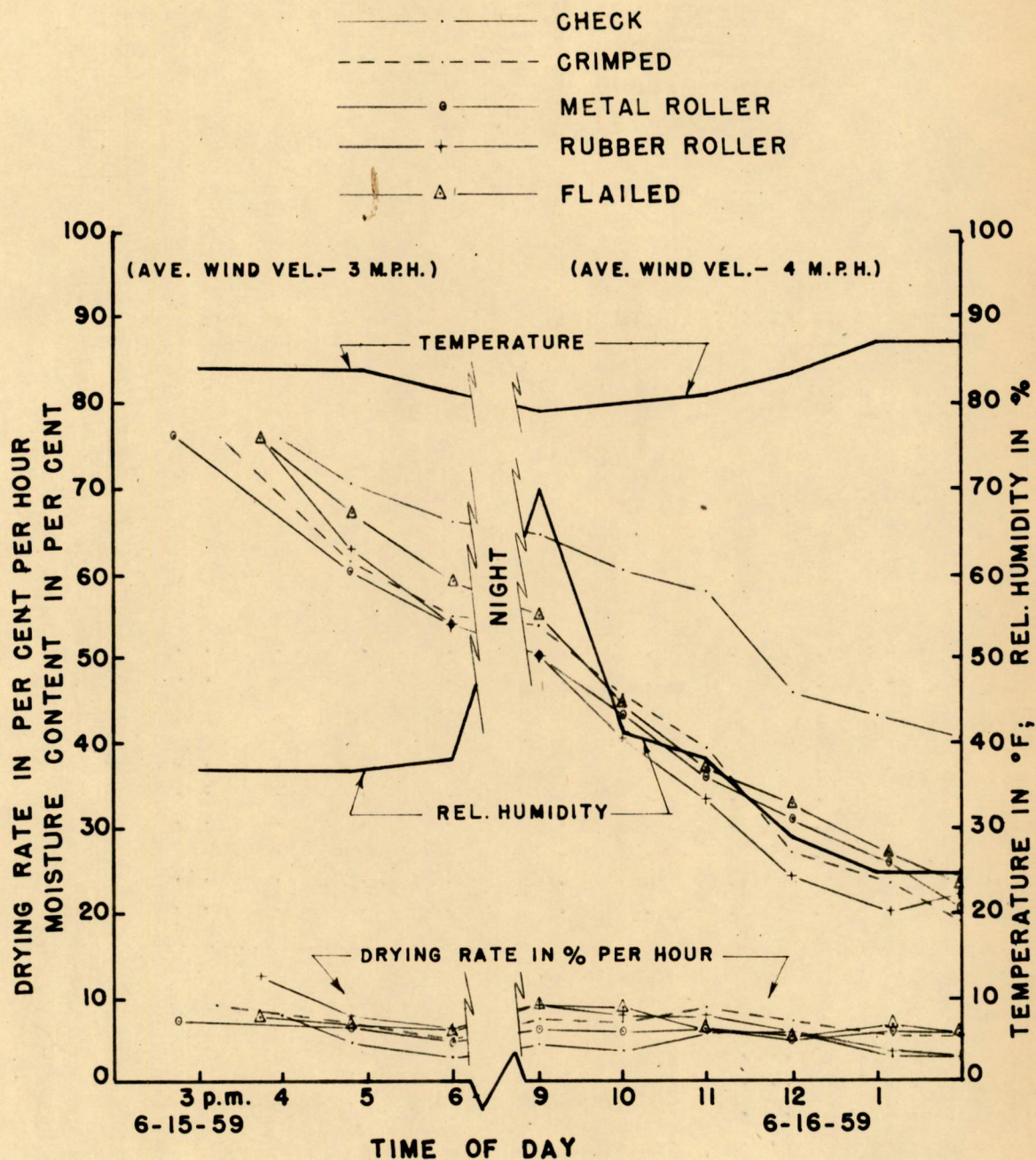


Figure 13. Mean moisture content and drying rate of the second cutting of Buffalo alfalfa under different conditioning treatments at Knoxville, Tennessee.

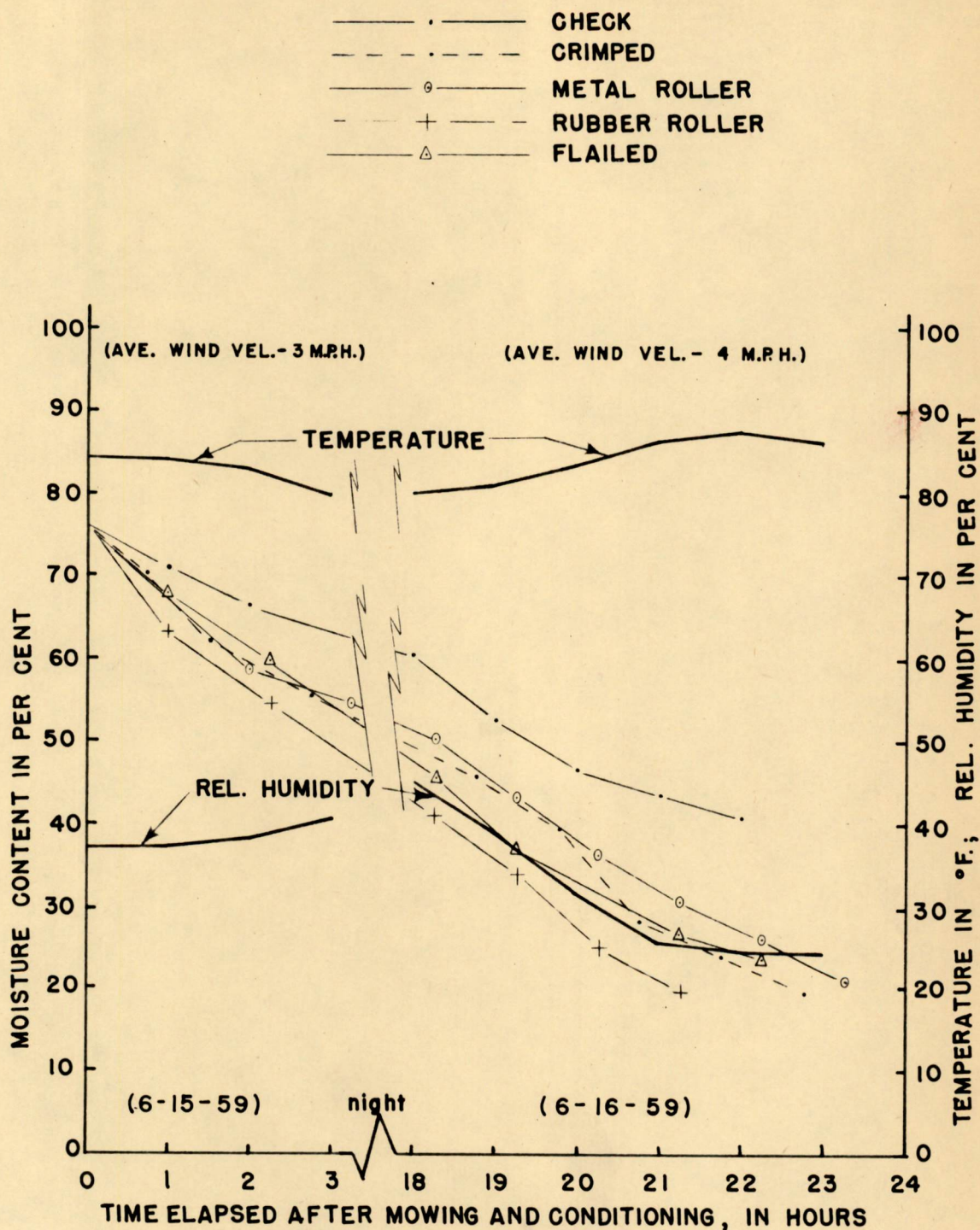


Figure 14. Mean moisture content of the second cutting of Buffalo alfalfa under different conditioning treatments at Knoxville, Tennessee.

The rubber roller conditioner again produced lower moisture contents than the other conditioners. A statistical analysis of the moisture content levels taken at 1:00 p.m. on June 16, 1959 was made using the Duncan's Multiple Range Test. This analysis gave a highly significant difference between the conditioned plots and the check plot. There was no significant difference at the 95 per cent level between any of the conditioners used. The analysis was conducted on the data taken at the time when the moisture content of the rubber rolled material reached 20 per cent. There was a wide range of differences between the moisture contents of the conditioned plots at this time.

The temperature range for this experiment was seventy-nine to eighty-seven degrees Fahrenheit. The relative humidity varied between 25 and 70 per cent during the sampling period, however, it was below 40 per cent except during the early morning hours. The wind velocity on the first day was zero to five miles per hour, whereas on the second day it was as high as ten miles per hour. The higher velocities were recorded during the afternoon of both days. There were only a few cumulus clouds visible throughout the experiment.

The drying rates of all the plots began about the same with the exception of the plot conditioned with the rubber roller conditioner. The drying rate of the rubber rolled material started at 13 per cent per hour, but dropped sharply to a rate nearly the same as the other plots. The drying rates of the conditioned plots ran near the same level on the second day of the experiment. The drying rate of the check plot was lower than that of all conditioned plots except at

cutting time and during the last three hours of sampling. The overnight increase in moisture resulted in an overall increase in drying rates.

All conditioned plots in this experiment were ready for baling on the day after cutting. The unconditioned material contained 40 per cent moisture at 2:00 p.m. on the day after cutting when sampling was stopped. The drying rate at this time was not high enough to reduce the moisture content to 20 per cent by night.

Third Experiment

The third cutting of Buffalo alfalfa was used for this experiment. It was conducted on the same site as the first experiment.

This experiment was conducted on July 27 and 28, 1959. Its purpose was to determine the effect of delayed conditioning on the drying time and drying rate. Only the rubber roller conditioner was used for conditioning the material.

All of the hay was cut at 10:00 a.m. on July 27, 1959. Two swaths were left for a check plot, and two swaths were conditioned adjacent to the check as soon as the hay was mowed. One hour after cutting time, two swaths were conditioned. Two more swaths were conditioned two hours after mowing. All treatments were divided into four equal sections for replication. Samples were taken every hour.

The mean results of this experiment derived from the field data found in Appendix D can be seen in Table III, and are graphically presented in Figure 15.

The moisture content of the treatment with no delay ran consistently lower than all other treatments.

TABLE III

MEAN MOISTURE CONTENT OF THE THIRD CUTTING OF BUFFALO
ALFALFA HAY UNDER DELAYED CONDITIONING TREATMENTS
AT KNOXVILLE, TENNESSEE

Experiment 3

Date and Time of Day	Check	Per Cent Moisture* (Wet Basis)			Temperature °F	Relative Humidity Per Cent	Wind Velocity m.p.h.	Cloud Cover Per Cent
		No Delay	1 hr. Delay	2 hr. Delay				
July 27, 1959								
11:00 a.m.	63.3	64	62.4	65.3	85.5	64	0-6	50
12:15 p.m.	51.1	45.8	52	50.7	85.5	62	0-6	50
1:00 p.m.	45.2	37	43	45.7	90.0	52	5-8	70
2:00 p.m.	33.9	24.8	32.3	33.6	87.0	57	0-6	75
3:00 p.m.	30.0	20.6	26.4	29.3	91.0	47	3-6	60
4:00 p.m.	29.2	15.6	22.9	23.2	89	55	0-5	90
5:00 p.m.	26.9	13.8	20.9	20.0	89	55	4-7	95
6:00 p.m.	24.2	14.1	18.2	19.8	82	65	4-10	100
July 28, 1959								
9:00 a.m.	34.1	29.5	29.7	32.1	78.5	76	0	85
10:00 a.m.	28.3	20.5	22.4	25.3	81.5	72	0-3	90
11:00 a.m.	25.1	18.3	18.0	25.6	85	67	0-6	70
12:00 noon	20.3	14.9	15.2	16.2	90	53	4-8	50
1:00 p.m.	18.0	11.1	12.0	13.9	90	53	4-6	5

Moisture content of uncut hay:	74.8 per cent
Time of mowing of check:	9:55 a.m., July 27, 1959
Time of mowing and conditioning with no delay:	10:00 a.m., July 27, 1959
Time of mowing of one hour delayed conditioning:	9:45 a.m., July 27, 1959
Time of mowing of two hours delayed conditioning:	10:05 a.m., July 27, 1959

* These data are an average of four different plots.

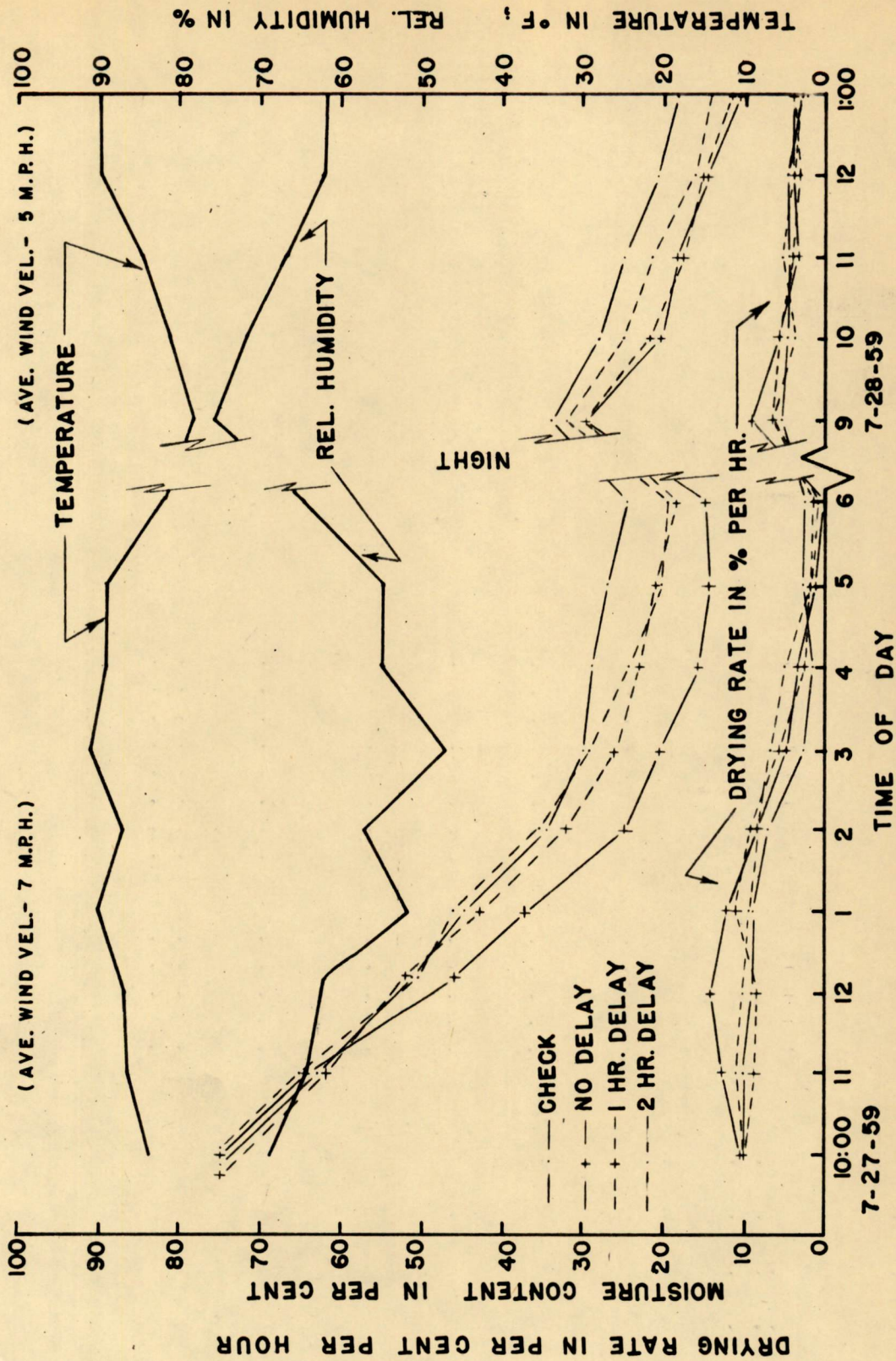


Figure 15. Mean moisture content and drying rate of the third cutting of Buffalo alfalfa under delayed conditioning treatments at Knoxville, Tennessee.

A statistical analysis using the Duncan's Multiple Range Test revealed there was no significant difference at the 95 per cent level of probability between the treatments with one and two hour delays and the check. It did show a significant difference at the 95 per cent level of probability between the treatments with no delay and all other treatments. This analysis was run on the data obtained at 3:00 p.m. on July 27, 1959. These data were selected because one treatment had reached the moisture content of 20 per cent.

There was not as much difference between the moisture content of the conditioned treatments on the second day as there was on the first day. The treatment with no delay and one hour delay ran close together, and they reached a moisture content of 20 per cent two hours before the check. The treatment with a two hour delay reached 20 per cent moisture content one hour before the check.

There was a noticeable difference between the drying rates of the treatment with no delay shortly after cutting and during the early morning hours on the second day. The no delay treatment attained higher drying rates at the points mentioned. All other treatments had fairly steady drying rates until 2:00 p.m. The drying rates began to decrease at this point. The drying rate of the check plot gradually dropped below all other treatments until late afternoon when it ran above all treatments.

The relative humidity was above 50 per cent except for one hour when it briefly dropped to 47 per cent. The temperature was between

eighty and ninety degrees Fahrenheit. The cloud cover ranged from 50 to 100 per cent. Normally these conditions would cause poor drying conditions; however, there was an average wind speed of approximately seven miles per hour throughout the first day. This could account for the fast drying received during this experiment.

Fourth Experiment

The experiment was conducted on August 26 and 27, 1958 with two different types of conditioners on soybeans. It was located on the Joel Anderson farm in Knox County, Tennessee. This experiment cannot be classed as a controlled experiment since there were only two replications of each treatment. However, it does indicate the effect which might be expected when conditioning soybeans.

The soybeans on the area selected had stems averaging three-eighths inch in diameter approximately two inches above the ground. The yield was relatively heavy for most Tennessee conditions.

The experiment was set up and conducted similar to the first and second experiments. Only a crimper and a rubber roller conditioner were used for conditioning the material. The treatments were divided into two equal sections, and samples were taken every two hours.

The moisture content of the conditioned plots ran consistently lower than the check plots. This can be seen in Table IV and Figure 16. The field data are shown in Appendix E.

The crimped material had a consistently lower moisture content than the rolled material. This difference probably is due to the fact that the crimper broke the large stems severely, whereas the roller

TABLE IV

MEAN MOISTURE CONTENT OF SOYBEAN HAY UNDER DIFFERENT
CONDITIONING TREATMENTS IN KNOX COUNTY, TENNESSEE

Experiment 4

Date and Time of Day	Check	Per Cent Moisture* (Wet Basis)		Temperature °F	Relative Humidity Per Cent
		Crimper	Crusher		
August 26, 1958					
4:00 p.m.	73.8	66.6	66.3	84.0	47
6:00 p.m.	67.8	54.5	61.0	78.0	55
August 27, 1958					
10:00 a.m.	60.9	47.0	61.2	75.0	63
12:00 noon	56.4	38.3	48.2	83.5	47
2:00 p.m.	55.8	27.9	36.5	85.0	43
4:00 p.m.	54.2	13.6	25.7	85.0	38
August 28, 1958					
4:00 p.m.	39.9	8.75	10.4	86.5	33

Cutting time: 2:00 p.m. August 26, 1958
 Moisture content at cutting time: 77.6 per cent
 Wind speed: 0-2 mph (every day)
 Cloud cover: scattered cumulus clouds
 (every day)

* These data are an average of two different plots.

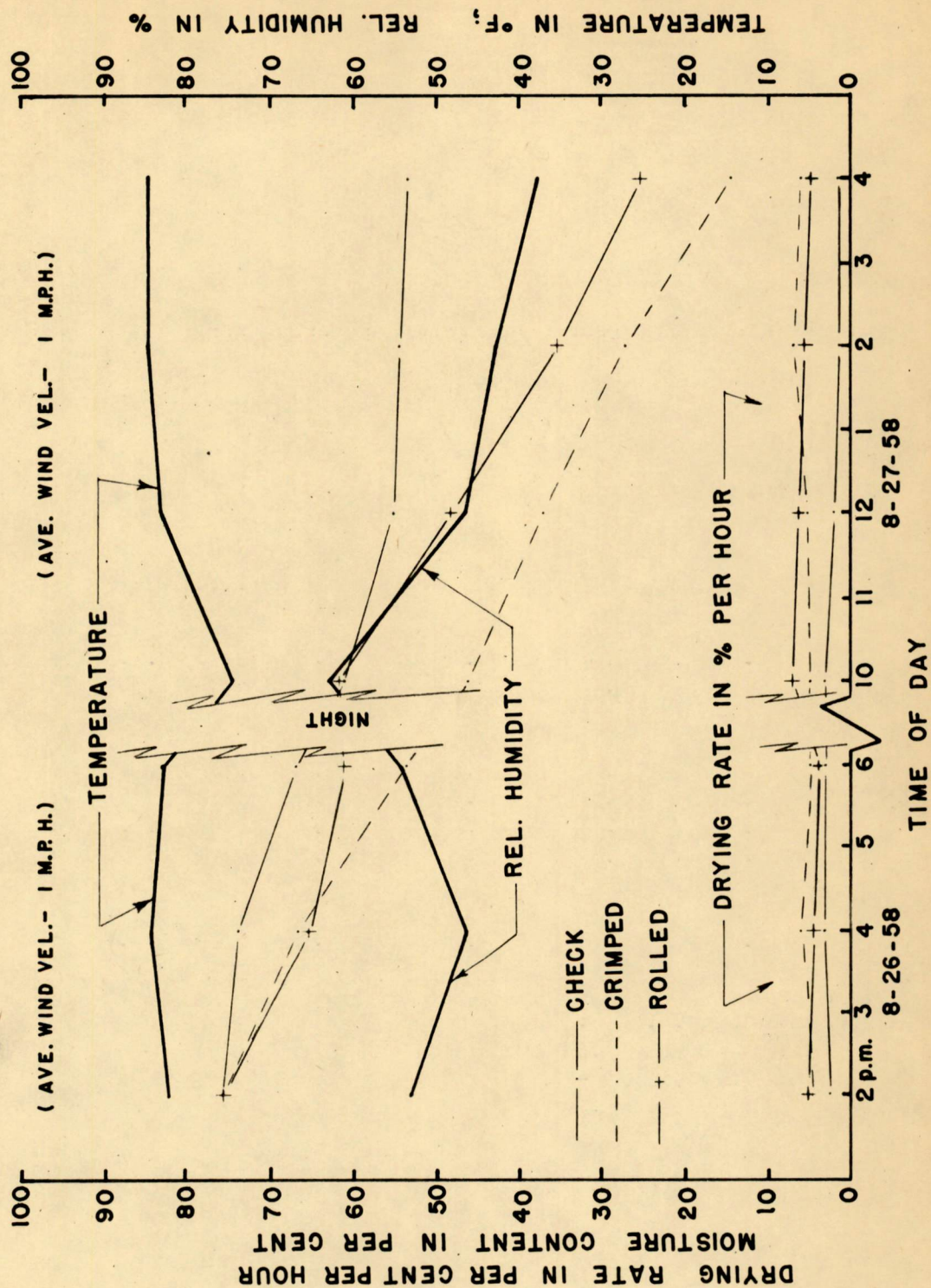


Figure 16. Mean moisture content and drying rate of soybean hay under different conditioning treatments in Knox County, Tennessee.

only crushed the stem. Thus, the crimped material had better air circulation through the stem which perhaps permitted more rapid evaporation of the moisture.

The crimped material dropped to a 20 per cent moisture content by 3:00 p.m. on the day after cutting. The rolled material contained 30 per cent moisture at this time with the check plot remaining about 53 per cent moisture.

Samples were taken only at 4:00 p.m. on the third day. The moisture content of the conditioned material was below 11 per cent, but the check plots contained 39.9 per cent moisture. There was very little difference between the conditioned plots by this time.

The drying rate of the check plot ran lower than the rates of both of the conditioned treatments throughout the entire experiment. The crimped material dried faster than the rolled material on the afternoon of the day of cutting. The rolled material dried faster on the second day until 1:00 p.m. The drying rate of the crimped material varied more directly with the temperature and relative humidity than it did on the other treatments.

The temperature was near eighty degrees Fahrenheit throughout the sampling period. The relative humidity dropped to 47 per cent on the first day and to 38 per cent on the second. The wind speed was near zero. Only a few cumulus clouds were observed during the experiment.

One Day Experiments

Attempts were made on May 5, June 8, and June 15, 1959 to cut

and condition alfalfa hay during the morning and bale it the same day. Fields six to eight acres in size were mowed and conditioned by 10:00 a.m. The oil method for determining moisture content was used to get a quick check on the moisture content of the material in the field.

On June 15, 1959, a sample taken at 4:15 p.m. contained 20 per cent moisture. The baler was not available immediately because the moisture content had dropped faster than expected. Baling was started at 6:00 p.m. One hundred twenty bales were made before the material began to collect moisture.

The hay in the attempts made on May 5 and June 8, appeared to lack from one to two hours of drying time to be ready to bale.

Observations of Hay Under Different Conditioning Treatments

Hay which was conditioned retained more of its green color than that which was not conditioned. There was no noticeable difference in green color between conditioned plots. More leaves seemed to be retained on the conditioned hay than the unconditioned hay and the stems appeared to be more palatable. The flailed material was broken and lacerated much more than the crushed or crimped material, resulting in a more palatable appearance than hay from all other treatments.

Observations of Operating Characteristics of the Hay Conditioners Used

The roller type conditioners gave very little difficulty in operation. The crimper encountered some wrapping on the rollers in soybeans when the pto was operated below 545 r.p.m. Only three stops

due to wrapping were necessary in a nine acre field. There was no trouble with wrapping on either the crimper or the rubber roller conditioners on alfalfa. The smooth steel roller machine wrapped hay on the pick-up cylinder when the conditioner was permitted to creep into an adjacent swath, but there was no wrapping on the crushing rollers.

None of the roller type conditioners would pick up all of the alfalfa when it was short and thin. The machines would pick up hay best in heavy yielding areas.

Large weeds in soybeans gave considerable trouble in feeding through the rubber roller machine. When the weeds were lying parallel to the rollers after being picked up, they would not pass between the rollers and would prevent other material from flowing through. The crimper passed these weeds between its rollers easily.

The flail harvester was used only on alfalfa. Attempts were made to windrow the material by passing it through the blower and through a tube shown in Figure 5. When the blower knives were used, the material flowed freely through the machine, but the stems were chopped so short the swath was too compact for fast drying. The blower knives were then removed, but this caused clogging of the blower outlet with material which was too long. The rear baffle was then raised to allow the flailed material to fall evenly on the ground by-passing the blower (Figure 9). No other trouble was encountered with the flail harvester, but the baler packed more of the flailed material on one side of the bale, causing the bales to buckle badly.

There were some noticeable losses encountered as a result of conditioning. The crimper clipped some small ends of stems and leaves. These clippings were not large enough to be picked up by a rake or baler. The rubber roller conditioner snapped off leaves and short stems as the material was passed between the rollers. This was caused by the high roller speed. The smooth steel roller conditioner did not seem to cause much clippage. The roll speed of this machine was much less than the rubber roller. When a high roll speed was used, the layer of material was thinner as it passed between the rollers than when a slower roll speed was used. Crushing a thinner layer appeared to produce a more uniformly crushed hay.

The flail harvester produced losses by cutting much of the hay too short for subsequent operations. Short pieces were left on the ground after raking and baling.

Future Research Needed

There is a need for future research on the following related phases of this study:

1. Research needs to be planned and conducted to determine the proper moisture content hay should contain for safe storage under Tennessee conditions.
2. Further research should be conducted to develop the flail harvester for use as a hay conditioner.
3. The effect of the elements of weather on the field drying rate of hay should be investigated.
4. Studies need to be made to determine if daily weather predictions can be made on the basis of past weather data.

5. Research should be made to see if it is possible to increase the drying rate of hay by adding heat or breaking the cell walls through the use of electronics and ultra high frequency sound waves.

6. The proper management of equipment and labor for making hay with various kinds of operations needs to be studied.



CHAPTER IV

SUMMARY AND CONCLUSIONS

The purpose of this study was to investigate the effect of the conditioning process on the drying time of hay, and its importance with respect to the average lengths of curing periods found in Tennessee.

Normally two to three days are required to field cure alfalfa hay in Tennessee. Four to five days are required for curing soybeans. A farmer's risks possibly can be greatly reduced by shortening the curing time of hay one to two days with the use of hay conditioners.

Experiments were conducted on the first, second, and third cuttings of alfalfa, plus one cutting of soybeans. An analysis of the expected curing periods of various lengths was conducted on weather data kept for a thirty-eight year period in Knoxville, Tennessee. Four different types of hay conditioners were used in the experiments, and the results of using them were compared with untreated plots. All treatments were replicated. Efforts were made to collect representative samples, and gather accurate weather data.

There was a reduction of at least one day in the curing time of alfalfa when conditioners were used. Conditioners can reduce the curing time of soybeans one to two days. The crimper type conditioner seemed to be more effective in soybeans than the rubber roller type.

There was no significant difference at the 95 per cent level

between the types of conditioners used on alfalfa when the moisture content had dropped to 20 per cent. However, the moisture content of material crushed with the rubber roll conditioner ran consistently lower than that which was crushed with other conditioners. There was a highly significant difference between conditioned and unconditioned hay.

Alfalfa hay conditioned as soon as possible after cutting required the least drying time.

The analysis of weather data disclosed that there were 6.2 five day, 9.2 four day, 14.4 three day, 22.3 two day and 99 one day periods with no rain which can be expected during the hay making months in Tennessee.

The conclusion from the experiments was that the curing time of hay in Tennessee can be reduced by one day using a conditioner. This reduction of curing time increases the farmers chances of curing hay without rain by 55 per cent.

In order to get the maximum benefits from a conditioner, good management must be used in the hay making operation. Hay cutting should be timed with both the proper stage of maturity and weather conditions. The conditioner should be used within thirty minutes after cutting. Then, the material should be raked at a moisture content which will prevent unnecessary leaf loss and allow drying to continue. The hay should be placed in storage as soon as it is ready. If good management of labor and machines is not used, the benefits of the conditioning operation can be lost by over exposure to the elements of the weather.

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CRANESHOLM CREST

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APPENDIX A

Date: _____

Crop: _____

Location: _____

Cutting: _____

[illegible]

APPENDIX B

TABLE V

MOISTURE CONTENT OF THE FIRST CUTTING OF BUFFALO ALFALFA
HAY UNDER DIFFERENT CONDITIONING TREATMENTS
AT KNOXVILLE, TENNESSEE.

Plot 1

Date and Time of Day	Check	Per Cent Moisture (Wet Basis)			Temperature °F	Relative Humidity Per Cent	Wind Velocity m.p.h.	Cloud Cover Per Cent
		Crimped	Rubber Rolled	Flailed				
May 11, 1959								
12:30 p.m.	61.1	55.8	57.1		87.5	40	0-8	25
2:30 p.m.	50.7	49.5	43.7	62.4	88.5	41	0-6	50
4:00 p.m.	57.3	40.0	28.8	47.5	86.0	41	0-6	40
6:00 p.m.	48.3	31.7	31.8	48.2	84.5	54	0-0	20
May 12, 1959								
9:15 a.m.	45.1	35.5	25.8	34.4	81.0	64	0-4	30
10:30 a.m.	38.2	27.0	18.3	28.9	83.0	58	0-6	40
12:00 noon	45.7	18.3	15.4	20.8	83.5	53	6-8	75
2:45 p.m.	*27.7				86.0	50	0-7	90
2:50 p.m.				*78.5	86.0	50	0-7	90
3:15 p.m.			*13.0		86.0	50	0-7	90
3:30 p.m.		*11.5			86.0	50	0-7	90

Moisture content of uncut hay:

77.0 per cent

Time of mowing and conditioning:

10:30 a.m., May 11, 1959

Time of flailing:

12:15 p.m., May 11, 1959

* Moisture content at raking time.

TABLE VI

MOISTURE CONTENT OF THE FIRST CUTTING OF BUFFALO ALFALFA
HAY UNDER DIFFERENT CONDITIONING TREATMENTS
AT KNOXVILLE, TENNESSEE.

Plot 2

Date and Time of Day	Check	Per Cent Moisture (Wet Basis)				Temperature of	Relative Humidity Per Cent	Wind Velocity m.p.h.	Cloud Cover Per Cent
		Crimped	Rubber Rolled	Flailed					
May 11, 1959									
12:30 p.m.	67.0	67.8	63.2		87.5	40	0-8	25	
2:30 p.m.	58.0	54.3	49.7	59.9	88.5	41	0-6	50	
4:00 p.m.	48.7	44.0	27.0	49.8	86.0	41	0-6	40	
6:00 p.m.	47.6	37.4	28.8	46.0	84.5	54	0-0	20	
May 12, 1959									
9:15 a.m.	46.5	27.1	25.7	41.0	81.0	64	0-4	30	
10:30 a.m.	48.6	26.3	28.9	24.9	83.0	58	0-6	40	
12:00 noon	38.0	12.2	10.2	22.4	83.5	53	6-8	75	
2:45 p.m.	*31.9				86.0	50	0-7	90	
2:50 p.m.				*24.3	86.0	50	0-7	90	
3:15 p.m.			*11.2		86.0	50	0-7	90	
3:30 p.m.		*13.7			86.0	50	0-7	90	

Moisture content of uncut hay:

77.0 per cent

Time of mowing and conditioning:

10:30 a.m., May 11, 1959

Time of flailing:

12:15 p.m., May 11, 1959

* Moisture content at raking time.

TABLE VII

MOISTURE CONTENT OF THE FIRST CUTTING OF BUFFALO ALFALFA
HAY UNDER DIFFERENT CONDITIONING TREATMENTS
AT KNOXVILLE, TENNESSEE.

Plot 3

Date and Time of Day	Check	Per Cent Moisture (Wet Basis)				Temperature °F	Relative Humidity Per Cent	Wind Velocity m.p.h.	Cloud Cover Per Cent
		Crimped	Rubber Rolled	Flailed					
May 11, 1959									
12:30 p.m.	64.9	62.4	61.0		87.5	40	0-8	25	
2:30 p.m.	62.9	47.5	51.5	67.5	88.5	41	0-6	50	
4:00 p.m.	57.0	42.5	43.6	42.8	86.0	41	0-6	40	
6:00 p.m.	50.8	37.8	25.2	56.2	84.5	54	0-0	20	
May 12, 1959									
9:15 a.m.	52.1	35.7	31.0	39.9	81.0	64	0-4	30	
10:30 a.m.	40.3	25.3	23.0	41.3	83.0	58	0-6	40	
12:00 noon	36.9	22.5	14.6	22.0	83.5	53	0-8	75	
2:45 p.m.	*27.5				86.0	50	0-7	90	
2:50 p.m.				*18.9	86.0	50	0-7	90	
3:15 p.m.			*11.0		86.0	50	0-7	90	
3:30 p.m.		*12.2			86.0	50	0-7	90	

Moisture content of uncut hay:

77.0 per cent

Time of mowing and conditioning:

10:30 a.m., May 11, 1959

Time of flailing:

12:15 p.m., May 11, 1959

* Moisture content at raking time.

TABLE VIII

MOISTURE CONTENT OF THE FIRST CUTTING OF BUFFALO ALFALFA
HAY UNDER DIFFERENT CONDITIONING TREATMENTS
AT KNOXVILLE, TENNESSEE.

Plot 4

Date and Time of Day	Check	Per Cent Moisture (Wet Basis)				Temperature °F	Relative Humidity Per Cent	Wind Velocity m.p.h.	Cloud Cover Per Cent
		Crimped	Rubber Rolled	Flailed					
May 11, 1959									
12:30 p.m.	66.8	63.1	61.4		87.5	40	0-8	25	
2:30 p.m.	57.5	56.5	47.7	54.5	88.5	41	0-6	50	
4:00 p.m.	51.8	44.2	34.4	48.7	84.5	41	0-6	40	
6:00 p.m.	50.7	32.8	34.4	48.7	84.5	54	0-0	20	
May 12, 1959									
9:15 a.m.	52.6	38.2	32.9	38.7	81.0	64	0-4	30	
10:30 a.m.	47.0	29.4	20.0	30.2	83.0	58	0-6	40	
12:00 noon	47.4	17.4	23.7	31.0	83.5	53	6-8	75	
2:45 p.m.	*33.0				86.0	50	0-7	90	
2:50 p.m.				*21.6	86.0	50	0-7	90	

Moisture content of uncut hay:

77.0 per cent

Time of mowing and conditioning:

10:30 a.m., May 11, 1959

Time of flailing:

12:15 p.m., May 11, 1959

* Moisture content at raking time.

APPENDIX C



TABLE IX

MOISTURE CONTENT OF THE SECOND CUTTING OF BUFFALO ALFALFA
HAY UNDER DIFFERENT CONDITIONING TREATMENTS
AT KNOXVILLE, TENNESSEE.

Plot 1

Date and Time of Day	Check	Crimped	Per Cent Moisture (Wet Basis)			Temperature °F	Relative Humidity Per Cent	Wind Velocity m.p.h.	Cloud Cover Per Cent
			Smooth Steel Rolled	Rubber Rolled	Flailed				
June 15, 1959									
4:45 p.m.	70.6	67.5	58.6	65.8	68.3	84.0	37.5	0-5	2
6:00 p.m.	69.8	54.4	59.5	59.1	54.7	82.0	38.5	0-2	0
June 16, 1959									
9:00 a.m.	66.6	57.0	47.0	50.3	57.0	79.0	70.0	0	1
10:00 a.m.	56.9	45.2	42.7	38.3	45.2	80.0	42.0	0	1
11:00 a.m.	55.7	38.1	31.6	33.2	39.2	81.5	38.0	0-3	2
12:00 noon	48.3	34.8	27.5	26.0	35.0	84.0	29	6-8	0
1:00 p.m.	44.5	29.8	25.0	18.9	31.9	87.0	25	5-10	0
2:00 p.m.	40.6	16.7	19.6	21.7	21.7	87.0	25	0	0

Moisture content in uncut hay:	76.4 per cent
Time of mowing and conditioning with smooth steel roller crushers:	2:45 p.m., June 15, 1959
crimping roller:	3:15 p.m., June 15, 1959
rubber roller crusher:	3:45 p.m., June 15, 1959
flail harvester:	3:45 p.m., June 15, 1959
Time of mowing of check:	4:00 p.m., June 15, 1959

TABLE X

MOISTURE CONTENT OF THE SECOND CUTTING OF BUFFALO ALFALFA
HAY UNDER DIFFERENT CONDITIONING TREATMENTS
AT KNOXVILLE, TENNESSEE.

Plot 2

Date and Time of Day	Check	Per Cent Moisture (Wet Basis)					Temperature Of	Relative Humidity Per Cent	Wind Velocity m.p.h.	Cloud Cover Per Cent
		Crimped	Smooth Steel Rolled	Rubber Rolled	Flailed					
June 15, 1959										
4:45 p.m.	71.5	57.0	58.7	67.3	66.8	84.0	37.5	0-5	2	
6:00 p.m.	62.1	56.1	52.8	50.3	58.5	82.0	38.5	0-2	0	
June 16, 1959										
9:00 a.m.	63.4	53.5	48.0	51.7	56.0	79.0	70.0	0	1	
10:00 a.m.	62.5	47.2	39.5	40.4	45.7	80.0	42.0	0	1	
11:00 a.m.	49.7	42.3	38.4	37.7	34.1	81.5	38	0-3	2	
12:00 noon	38.4	21.3	36.8	24.5	36.8	84.0	29	6-8	0	
1:00 p.m.	48.0	18.9	22.4	23.4	29.0	87.0	25	5-10	0	
2:00 p.m.	36.9	21.5	18.1	20.4	22.9	87.0	25	0	0	

Moisture content in uncut hay:

76.4 per cent

Time of mowing and conditioning with
smooth steel roller crushers:
crimping roller
rubber roller crusher
flail harvester

2:45 p.m., June 15, 1959

3:15 p.m., June 15, 1959

3:45 p.m., June 15, 1959

3:45 p.m., June 15, 1959

Time of mowing of check:

4:00 p.m., June 15, 1959

TABLE XI

MOISTURE CONTENT OF THE SECOND CUTTING OF BUFFALO ALFALFA
HAY UNDER DIFFERENT CONDITIONING TREATMENTS
AT KNOXVILLE, TENNESSEE.

Plot 3

Date and Time of Day	Check	Crimped	Per Cent Moisture (Wet Basis)		Flailed	Temperature Of	Relative Humidity Per Cent	Wind Velocity m.p.h.	Cloud Cover Per Cent
			Smooth Steel Rolled	Rubber Rolled					
June 15, 1959									
4:45 p.m.	69.7	62.1	54.3	58.5	66.6	84.0	37.5	0-5	2
6:00 p.m.	66.0	52.8	49.9	53.8	61.8	82.0	38.5	0-2	0
June 16, 1959									
9:00 a.m.	67.3	49.3	53.1	49.3	55.5	79.0	70.0	0	1
10:00 a.m.	63.8	40.5	43.5	45.5	40.6	80.0	42.0	0	1
11:00 a.m.	52.8	34.7	36.6	32.7	37.4	81.5	38.0	0-3	2
12:00 noon	49.3	30.3	28.5	28.5	29.8	84.0	29.0	6-8	0
1:00 p.m.	44.8	22.3	32.0	13.8	23.7	87.0	25.0	5-10	0
2:00 p.m.	43.3	24.5	22.9	22.2	28.9	87.0	25.0	0	0

Moisture content in uncut hay:	76.4 per cent
Time of mowing and conditioning with	
smooth steel roller crushers:	2:45 p.m., June 15, 1959
crimping roller:	3:15 p.m., June 15, 1959
rubber roller crusher:	3:45 p.m., June 15, 1959
flail harvester:	3:45 p.m., June 15, 1959
Time of mowing of check:	4:00 p.m., June 15, 1959

TABLE XII

MOISTURE CONTENT OF THE SECOND CUTTING OF BUFFALO ALFALFA
HAY UNDER DIFFERENT CONDITIONING TREATMENTS
AT KNOXVILLE, TENNESSEE.

Plot 4

Date and Time of Day	Check	Per Cent Moisture (Wet Basis)				Flailed	Temperature ° F	Relative Humidity Per Cent	Wind Velocity m.p.h.	Cloud Cover Per Cent
		Crimped	Smooth Steel Rolled	Rubber Rolled						
June 15, 1959										
4:45 p.m.	70.0	62.1	63.4	60.6	69.4	84.0	37.5	0-5	2	
6:00 p.m.	68.0	58.6	57.5	56.0	64.0	82.0	38.5	0-2	0	
June 16, 1959										
9:00 a.m.	63.6	54.9	53.6	51.1	49.0	79.0	70.0	0	1	
10:00 a.m.	59.6	50.3	47.8	40.3	49.6	80.0	42.0	0	1	
11:00 a.m.	53.3	42.5	37.8	32.5	37.6	81.5	38.0	0-3	2	
12:00 noon	50.0	26.9	30.9	22.2	32.1	84.0	29.0	6-8	0	
1:00 p.m.	37.4	25.2	25.0	23.6	22.5	87.0	25.0	5-10	0	
2:00 p.m.	41.7	15.8	23.5	25.3	22.2	87.0	25.0	0	0	

Moisture content in uncut hay:

76.4 per cent

Time of mowing and conditioning with

smooth steel roller crusher:

2:45 p.m., June 15, 1959

crimping roller:

3:15 p.m., June 15, 1959

rubber roller crusher:

3:45 p.m., June 15, 1959

flail harvester:

3:45 p.m., June 15, 1959

Time of mowing of check:

4:00 p.m., June 15, 1959

APPENDIX D



TABLE XIII

MOISTURE CONTENT OF THE THIRD CUTTING OF BUFFALO ALFALFA
HAY UNDER DELAYED CONDITIONING TREATMENTS
AT KNOXVILLE, TENNESSEE

Plot 1

Date and Time of Day	Check	Per Cent Moisture (Wet Basis)			Temperature °F	Relative Humidity Per Cent	Wind Velocity m.p.h.	Cloud Cover Per Cent
		No Delay	1 hr. Delay	2 hr. Delay				
July 27, 1959								
11:00 a.m.	62.5	62.4	61.4	66.4	85.5	64	0-6	50
12:15 p.m.	50.5	45.0	53.3	52.2	85.5	62	0-6	50
1:00 p.m.	47.0	43.8	42.0	48.2	90.0	52	5-8	70
2:00 p.m.	38.7	23.4	30.4	33.7	87	57	0-6	75
3:00 p.m.	25.6	20.0	31.0	26.5	91	47	3-6	60
4:00 p.m.	28.8	14.8	18.8	23.8	89	55	0-5	90
5:00 p.m.	29.7	12.4	19.1	16.1	89	55	4-7	95
6:00 p.m.	25.6	16.8	17.5	16.8	82		4-10	100
July 28, 1959								
9:00 a.m.	33.7	28.2	29.0	31.7	78.5	76	0	85
10:00 a.m.	26.5	20.5	21.4	25.8	81.5		0-3	90
11:00 a.m.	26.3	19.4	17.9	25.7	85		0-6	70
12:00 noon	18.8	14.3	13.9		90		4-8	50
1:00 p.m.	21.2	12.4	11.7	12.6	90		4-6	5

Moisture content of uncut hay:	74.8 per cent
Time of mowing of check:	9:55 a.m., July 27, 1959
Time of mowing and conditioning with no delay:	10:00 a.m., July 27, 1959
Time of mowing of 1 hr. delayed conditioning:	9:45 a.m., July 27, 1959
Time of mowing of 2 hr. delayed conditioning:	10:05 a.m., July 27, 1959

TABLE XIV

MOISTURE CONTENT OF THE THIRD CUTTING OF BUFFALO ALFALFA
HAY UNDER DELAYED CONDITIONING TREATMENTS
AT KNOXVILLE, TENNESSEE.

Plot 2

Date and Time of Day	Check	Per Cent Moisture (Wet Basis)			Temperature ° F	Relative Humidity Per Cent	Wind Velocity m.p.h.	Cloud Cover Per Cent
		No Delay	1 hr. Delay	2 hr. Delay				
July 27, 1959								
11:00 a.m.	64.8	66	63.3	64.8	85.5	65	0-6	50
12:15 p.m.	53.4	44.8	52.0	49.5	85.5	62	0-6	50
1:00 p.m.	44.5	33.2	43.2	42.6	90.0	52	5-8	70
2:00 p.m.	33.8	26.1	32.7	34.4	87	57	0-6	75
3:00 p.m.	32.2	23.8	27.2	30.9	91	47	3-6	60
4:00 p.m.	34.0	15.9	26.2	23.0	89	55	0-5	90
5:00 p.m.	26.3	12.8	19.1	25.5	89	55	4-7	95
6:00 p.m.	20.7	13.9		20.0	82		4-10	100
July 28, 1959								
9:00 a.m.	32.4		29.7	30.8	78.5	76	0	85
10:00 a.m.	30.1	21.8	24.5	26.4	81.5		0-3	90
11:00 a.m.	24.4	17.4	17.8	17.8	85		0-6	70
12:00 noon	19.5	12.9	16.9	16.9	90		4-8	50
1:00 p.m.	17.8	9.7	11.5	14.3	90		4-6	5

Moisture content of uncut hay:	74.8 per cent
Time of mowing of check:	9:55 a.m., July 27, 1959
Time of mowing and conditioning with no delay:	10:00 a.m., July 27, 1959
Time of mowing of 1 hr. delayed conditioning:	9:45 a.m., July 27, 1959
Time of mowing of 2 hr. delayed conditioning:	10:05 a.m., July 27, 1959

TABLE XV

MOISTURE CONTENT OF THE THIRD CUTTING OF BUFFALO ALFALFA
HAY UNDER DELAYED CONDITIONING TREATMENTS
AT KNOXVILLE, TENNESSEE.

Plot 3

Date and Time of Day	Check	Per Cent Moisture (Wet Basis)			Temperature °F	Relative Humidity Per Cent	Wind Velocity m.p.h.	Cloud Cover Per Cent
		No Delay	1 hr. Delay	2 hr. Delay				
July 27, 1959								
11:00 a.m.	64.1	63.8	64.0	66.0	85.5	65	0-6	50
12:15 p.m.	53.0	48.7	49.5	50.0	85.5	62	0-6	50
1:00 p.m.	40.8	35.5	45.0	45.5	90.0	52	5-8	70
2:00 p.m.	33.0	23.7	35.0	31.0	87	57	0-6	75
3:00 p.m.	35.7	17.0	25.0	29.6	91	47	3-6	60
4:00 p.m.	30.6		21.4	22.7	89	55	0-5	90
5:00 p.m.	23.5	16.1	20.8	18.4	89	55	4-7	95
6:00 p.m.	24.3	13.6	16.8	21.0	82		4-10	100
July 28, 1959								
9:00 a.m.	35.3	31.8	28.7	35.2	78.5	76	0	85
10:00 a.m.	28.6	17.4	23.0	22.5	81.5		0-3	90
11:00 a.m.	25.2	16.7	17.9	22.0	85		0-6	70
12:00 noon	24.7	12.3	15.0	15.3	90		4-8	50
1:00 p.m.	17.1	10.3	13.3	15.1	90		4-6	5

Moisture content of uncut hay:	74.8 per cent
Time of mowing of check:	9:55 a.m., July 27, 1959
Time of mowing and conditioning with no delay:	10:00 a.m., July 27, 1959
Time of mowing of 1 hr. delayed conditioning:	9:45 a.m., July 27, 1959
Time of mowing of 2 hr. delayed conditioning:	10:05 a.m., July 27, 1959

TABLE XVI

MOISTURE CONTENT OF THE THIRD CUTTING OF BUFFALO ALFALFA
HAY UNDER DELAYED CONDITIONING TREATMENTS
AT KNOXVILLE, TENNESSEE.

Plot 4

Date and Time of Day	Check	Per Cent Moisture (Wet Basis)			Temperature °F	Relative Humidity Per Cent	Wind Velocity m.p.h.	Cloud Cover Per Cent
		No Delay	1 hr. Delay	2 hr. Delay				
July 27, 1957								
11:00 a.m.	61.8	63.8	61.2	64.2	85.5	64	0-6	50
12:15 p.m.	47.5	45.0	53.5	51.2	85.5	62	0-6	50
1:00 p.m.	48.7	35.8	41.0	46.7	90.0	52	5-8	70
2:00 p.m.	30.3	26.2	31.4	35.4	87	57	0-6	75
3:00 p.m.	26.8	21.8	22.7	30.4	91	47	3-6	60
4:00 p.m.	28.3	16.1	25.4	23.5	89	55	0-5	90
5:00 p.m.	28.4	14.0	24.9	20.3	89	55	4-7	95
6:00 p.m.	26.2	12.1	20.4	21.4	82		4-10	100
July 28, 1959								
9:00 a.m.	35.0	28.6	31.4	30.7	78.5	76	0	85
10:00 a.m.	28.0	22.4	20.9	26.7	81.5		0-3	90
11:00 a.m.	24.7	19.8	18.6		85		0-6	70
12:00 noon	18.3	20.4	15.0	16.4	90		4-8	50
1:00 p.m.	16.0	12.2	11.8	13.7	90		4-6	5

Moisture content of uncut hay:	74.8 per cent
Time of mowing of check:	9:55 a.m., July 27, 1959
Time of mowing and conditioning with no delay:	10:00 a.m., July 27, 1959
Time of mowing of 1 hr. delayed conditioning:	9:45 a.m., July 27, 1959
Time of mowing of 2 hr. delayed conditioning:	10:05 a.m., July 27, 1959

APPENDIX E



TABLE XVII

MOISTURE CONTENT OF SOYBEAN HAY UNDER DIFFERENT
CONDITIONING TREATMENTS IN KNOX COUNTY,
TENNESSEE.

Plot 1

Date and Time of Day	Check	Per Cent Moisture (Wet Basis)		Temperature °F	Relative Humidity Per Cent
		Crimped	Crushed		
August 26, 1958					
4:00 p.m.	73.8	66.6	66.3	84.0	47
6:00 p.m.	67.8	54.5	61.0	78.0	55
August 27, 1958					
10:00 a.m.	62.1	45.8	65.7	75.0	63
12:00 noon	55.8	39.0	48.2	83.5	47
2:00 p.m.	56.7	29.7	41.1	85.0	43
4:00 p.m.	58.4	14.4	24.3	85.0	38
August 28, 1958					
4:00 p.m.	35.7	8.7	11.4	86.5	33

Cutting time:	2:00 p.m., August 26, 1958
Moisture content at cutting time:	77.6 per cent
Wind speed:	0-2 mph every day
Cloud cover:	scattered cumulus clouds every day

TABLE XVIII

MOISTURE CONTENT OF SOYBEAN HAY UNDER DIFFERENT
CONDITIONING TREATMENTS IN KNOX COUNTY,
TENNESSEE.

Plot 2

Date and Time of Day	Per Cent Moisture (Wet Basis)			Temperature Of	Relative Humidity Per Cent
	Check	Crimped	Crushed		
August 26, 1958					
4:00 p.m.	73.8	66.6	66.3	84.0	47
6:00 p.m.	67.8	54.5	61.0	78.0	55
August 27, 1958					
10:00 a.m.	59.7	49.0	56.8	75.0	63
12:00 noon	57.0	37.7	60.2	83.5	47
2:00 p.m.	55.0	43.7	32.0	85.0	43
4:00 p.m.	50.0	12.8	27.1	85.0	38
August 28, 1958					
4:00 p.m.	44.2	8.8	9.4	86.5	33

Cutting time:

Moisture content at cutting time:

Wind speed:

Cloud cover:

2:00 p.m., August 26, 1958

77.6 per cent

0-2 mph every day

scattered cumulus clouds
every day