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Methods of field curing hay

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Summary and Conclusions

1. The practice of windrowing alfalfa hay aids a continuation of the natural physiological process of transpiration, resulting in a greater moisture loss for a day's period.

2. Double windrowing two to three hours after cut furnishes hay with a better color, larger percentages of leaves, and a lower moisture content at the end of the day.

3. Data indicate that the leaf of alfalfa plants aids greatly in lowering the moisture content of the entire plant.

4. Photomicrographs showed a reopening of the stomata following windrowing two hours after cut.

5. Hay if left in the field overnight should be left in such position as to expose smallest amount of hay surface.

6. The process of crushing large-stemmed hays such as Johnson grass and soybeans will permit a needed change in methods and time required in curing.

7. Leaves contain 60 to 90% of the proteins and vitamins of hay.

8. Crushed hay can be stored having a higher carotene content than mowed hay.

9. Crushed hay is as rich as mowed hay in proteins, sugars and dextrin, ether extract and ash.

10. Light, temperature, oxidative enzymes, copper, pH, relative humidity and the rate of drying were found to affect the manner carotene is lost from hays or hay plants.

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METHODS OF FIELD CURING HAY

By T. N. JONES, O. A. LEONARD, and I. E. HAMBLIN

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Hay making is an important phase of farming almost everywhere in the world and especially in the United States.

In the south, where chief attention has been directed toward cotton production, the hay crop has been of smaller importance than in any other general agricultural section of the country. During recent years, however, there has been a marked trend in Mississippi and other cotton states toward a more diversified system of agriculture. Pastures have been enlarged and improved, livestock numbers have been increased, and about a million acres of cropland has been taken out of cotton production and put into production of food and feed crops.

The greater portion of this acreage released from cotton production is now devoted to the production of hay, and there has resulted a significant increase in the quantity of hay produced on the farms. Statistics published by the United States Department of Agriculture indicate that during the ten-year period ended in 1937 the average production of all hay in the state was 699,000 tons annually. In 1939, the total production of hay on Mississippi farms was 1,242,000 tons, an increase of nearly 100 percent.

Soybeans were more widely and extensively used than any other hay crop, yielding 370,000 tons. There were 192,000 tons of lespedeza hay produced in 1939, 172,000 tons of cowpea hay, 150,000 tons of alfalfa hay, 65,000 tons of sweet sorghum hay, and 102,000 tons of wild hay. The classification lists miscellaneous tame hay totaling 221,000 tons, which probably includes the production of Johnson grass hay.

Most hay produced in Mississippi is consumed on the farm where grown; and, while relatively small surplus quantities are marketed throughout this state, two sections of Mississippi have expanded rapidly in commercial hay production during recent years. The Yazoo-Mississippi delta produces large quantities of alfalfa hay and increasing quantities of soybean hay, and the "Black Belt", or prairie area, produces large quantities of Johnson grass hay and less important quantities of alfalfa hay.

Statistics relating the volume of hay marketed through commercial channels are incomplete. For about ten years the Federal-State hay inspection service has been available to growers and shippers in Mississippi, and it is thought that the inspections have been made of practically all carlot shipments of hay. Statistics made available by the State Department of Agriculture, Jackson, Miss., show that carlot shipments of inspected hay have increased from 125 carloads in 1938 to 440 carloads during 1940.

The 1939 total production of hay is equivalent to approximately four tons per farm. The production is not evenly distributed, however, and on a very large number of farms in the state there is always a distinct shortage of hay needed to feed farm animals. Nevertheless, at normal market evaluation, the hay crop is of considerable economic importance, its value being exceeded only by lint cotton, cotton seed, and corn.

Perhaps less research has been done throughout the country on hay than on any other field crop of equal importance. Coupled with this continuing need of information on hay making, is the fact that in Mississippi many thousands of farmers are making hay for the first time in a more than incidental sense. It is hoped that this report may be of value not only to virtual beginners in the business of hay production, but also to large scale commercial producers.

Problems in Haymaking

While much work has been done on the curing of hay, both artificially and by improved field methods, knowledge of the relationship between the fundamental factors governing water movement and removal in hay plants is limited. Curing hay in good weather does not present such a problem; in bad weather the difficulties may be insuperable. Persistent wet weather is the greatest handicap to the hay-maker, and in the humid climate of the southern states, the hazard of frequent rains is always great. A study of weather records at State College shows that during the hay season (April to October, inclusive), rain may be expected on an average of every four and one-half days with an average of .51 inches per rain.

During rainy weather there is considerable loss in weight, aside from any loss of quality that may result. In many instances the deterioration in value of the hay is so great as to make it useless for livestock, in which case many tons of hay have been burned in the field as the easiest means of disposal.

FIGURE 1—Dump rake, such as found on numerous Mississippi farms, may be used for windrowing by dumping before the mass of hay within the fingers becomes compacted.

The proper stage for cutting most hay crops is just prior to maturity. At this time they have just passed through the period of most rapid growth and are very succulent; the newly formed cells and tissues have not yet hardened, with the consequent decrease in moisture content to form the reenforcing structure for fruit support. There is in the living plant at this time a continous stream or mesh of water, the molecules of which are within and between cells from the deepest root tip to the edge of the uppermost leaf or shoot, and from the pith to the corky bark or surface of the stem. This water enters the plant through the root hairs and is drawn upward, mainly through woody xylem tissues, finally passing out through the leaves in the form of vapor into the surrounding atmosphere. This process of moisture loss by plants is known as transpiration, and under favorable conditions causes a movement of the water stream upward through the plant of at least two inches per minute. Thus, within a very few minutes, an hour at most, the water entering the root hair will be escaping from a stomatal pore of an uppermost leaf.

If plants cut for hay could be so handled as to preserve or promote this natural flow of plant moisture, the process of natural dehydration would defeat for all times the hazards presented by the time element. Thus, haymaking is usually a race against time, and hay of the highest quality and food value is quickly dried, quickly baled, and fed within a year.

The two main sources of loss in field cured hays are:

(1) Loss of leaves, the more valuable part of the hay. The better hays consist of 40% to 60% in weight of leaves; in turn, the leaves usually contain 70% to 80% of the feeding value of hay in protein, minerals and vitamins. The leaves are lost by cutting too late and by improper methods of curing and handling the hay.

(2) Loss by weathering. Since the stems dry slower than the leaves, it is essential that the hay crop be left in the field until the stems are dry enough for storage, which usually means that the

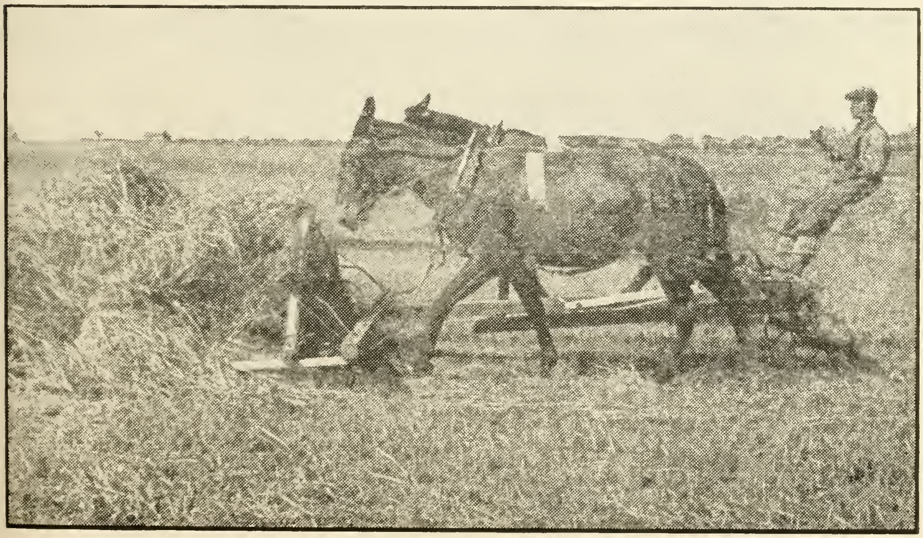


FIGURE 2—Push rake, an economical method of moving hay a short distance.

hay is left exposed to dew or rain for at least one night. When partially cured hay is exposed to dew or rain followed by hot sunshine, the proteins are greatly reduced plus shattering of leaves and discoloring of the hay plant.

Research in Haymaking

The Agriculture Engineering Departmen of the Mississippi Station has been conducting research in haymaking since 1931. These studies have sought to establish the fundamental explanation for the characteristic behavior of certain curing plants, to the end that methods of field handling may be formulated to hasten the natural process of drying.

The procedure followed in our experimental work consisted essentially of curing hay in the field by different methods in common use, measuring the factors involved in curing, and determining the interrelationships between these factors and the grade or feeding value of the hay produced.

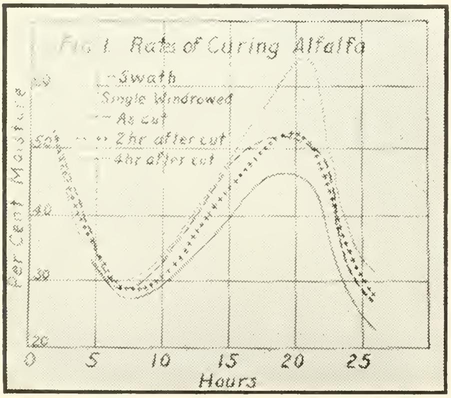
Among the principal methods studied in field handling of hay were:

1. In the swath.
2. In single and double windrows raked at 3 separate intervals.
   (a.) At time of cutting
   (b.) Two hours after cutting
   (c.) Four hours after cutting
3. Crushed and uncrushed

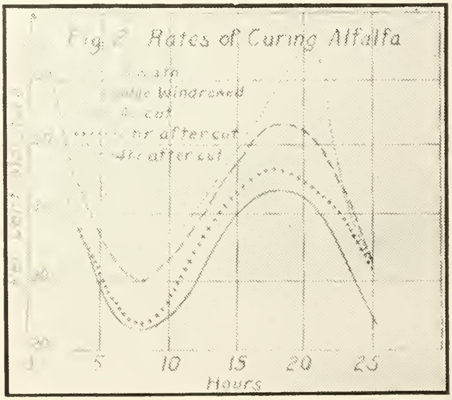
From these different positions. representative samples were taken in duplicate at one hour intervals from time of cutting, placed in 25-pound paper bags, and weighed immediately. On several occasions these samples were taken on through the night and the following day to determine the physiological and natural changes of the plant during that period. These samples with the wet weight recorded were brought to the laboratory, where they were oven-dried and the percentage of moisture determined. At the time each sample was taken, the temperature, relative humidity, time of day, wind velocity, and moisture content of soil were recorded and used in the construction of curves by multiple correlation. These curves as shown in graphs 1 and 2 show the rates of curing alfalfa in seven field methods.

Mower-Crusher Constructed

The principle of crushing plants to hasten the curing process was new and relatively untried at the beginning of



GRAPH 1—Rates of curing alfalfa in the swath as compared to single windrowed as cut, and single windrowed two and four hours after cut; and the amount of moisture absorbed overnight.



GRAPH 2—Rates of curing alfalfa in the swath as compared to double windrowed as cut, and double windrowed two and four hours after cut; and the amount of moisture absorbed overnight.

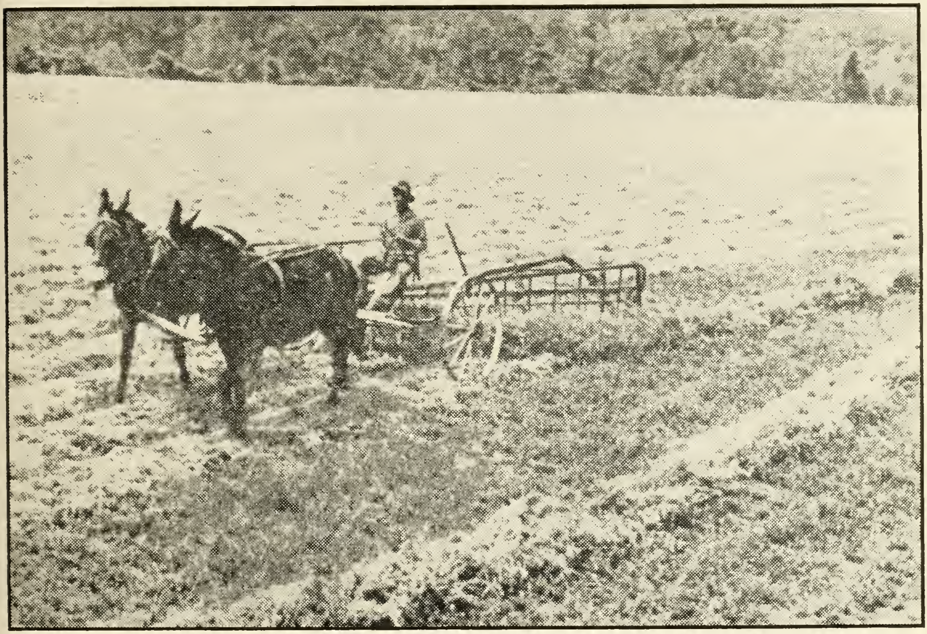


FIGURE 3—Side delivery rake doing a good job of raking.

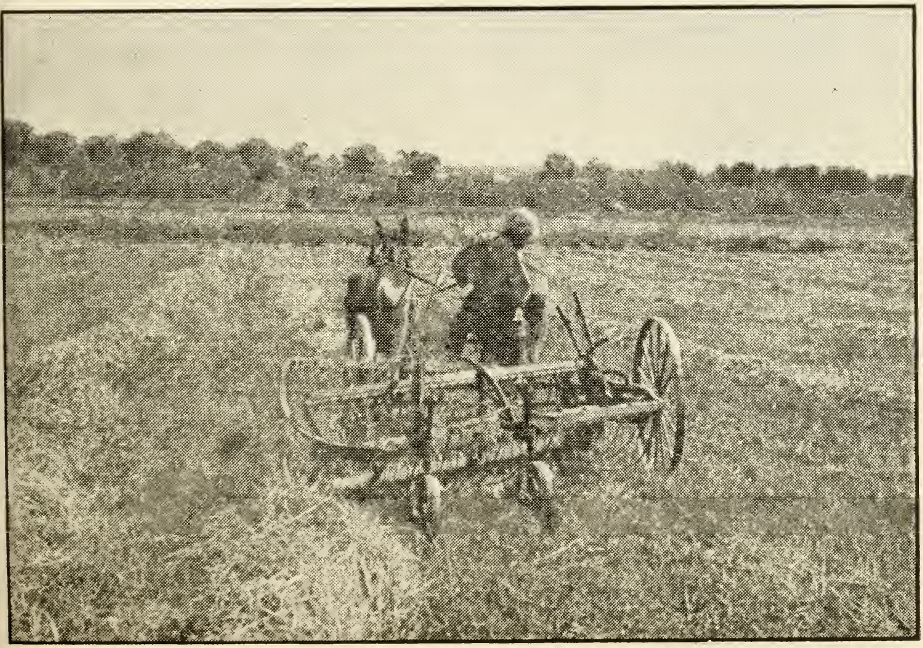


FIGURE 3-A—Another view of the side delivery rake in operation

these experiments and is only now ready to emerge from the experimental stage. No machine was available through commercial channels for crushing the mown plants at the beginning of the work, and a pioneer crusher was designed and constructed by our department. Its early use revealed major defects and a second and improved mower-crusher was similarly designed and constructed in 1933. Further basic improvements are incorporated in the machine designed and constructed in 1940.

A comprehesive report of these ten years work in hay making is soon to be published in technical bulletin numbere 27, entitled "Methods of Field Curing Hay." From the viewpoint of the average good farmer, the essential features of the technical paper are included in the present bulletin. It may be observed that three principal phases of the subject are herein discussed:

(1) An analysis of field practices which may be adopted by farmers everywhere, whether utilizing small unit equipment or whether using specialized large-scale equipment.

(2) A study of crushing the hay plants at the time of cutting, a process especially advantageous to large scale producers.

(3) A practical discussion of hay making practices which yield the maximum food value in hay.

I. CURING HAY BY MEANS OF COMMONLY USED EQUIPMENT

Common practices in haymaking may be summed up as follows:

(1) The hay is mowed.

(2) The mowed plants lie in the swath as they fall from the mower blade until partially or completely cured.

(3) After partial or complete curing, the hay is raked into windrows, either for convenience in handling, or to complete the curing process.

(4) The cured hay is stacked, or stored loose, or baled.

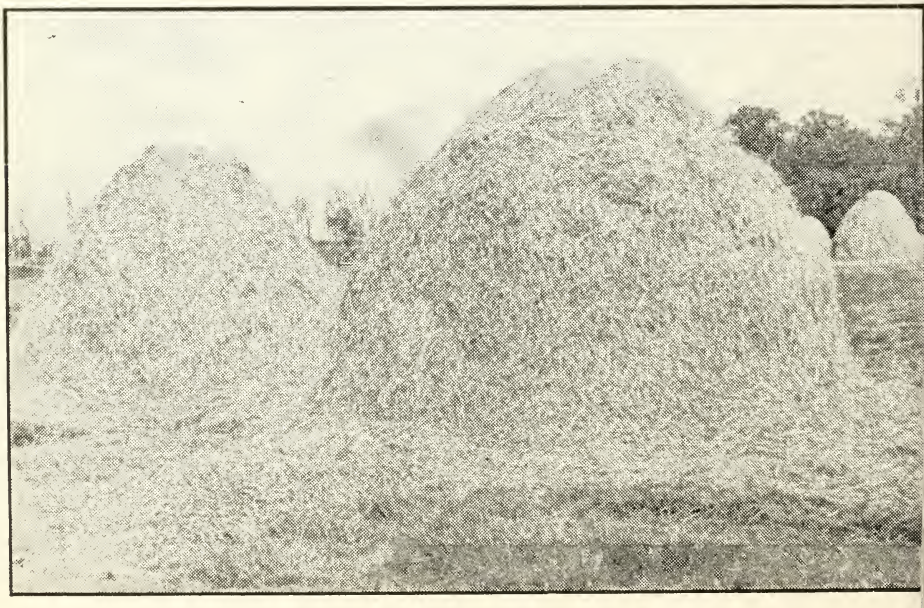


FIGURE 4—Hay stacks—a wasteful method of keeping hay.

In commercial hay producing areas of the state it is reported that hay is commonly windrowed while only partially cured, thus following good haymaking practices. In non-commercial areas it is reported that hay is commonly left in the swath until the cure is thought to be complete, thus resulting in excessive loss of leaves and other damage.

Thus it would appear that somewhere in the execution of these four simple haymaking practices is the difference between marketable hay and unmarketable hay, between good hay and poor hay.

Our first experiment was, in reality, a measure of results of varying the execution of these common practices. Alfalfa, at the proper stage of growth, was mowed in the morning from 8 to 9 o'clock. A portion of it was left in the swath to cure. The remainder was windrowed. Separate plots were single windrowed (1) as cut, (2) two hours after cutting, and (3) four hours after cutting. Other separate plots were double windrowed as (1) cut, (2) two hours after cutting, and (3) four hours after cutting. The percent of moisture was determined on all plots as cut, two hours after cutting, four hours after cutting, eight hours after cutting, twenty hours after cutting and twenty-five hours after cutting. The percentage of moisture in hay varies considerably, but 20% moisture is generally thought low enough for safety in baling, ricking, or storage.

Double Windrowing Recommended

Results of studies on the rates of curing by the different field methods show that double windrowing two or three hours after cutting furnished a cured hay with a more desirable color, a larger percentage of leaves remaining on the stems, and a lower moisture content at the end of the day due to the continuous activity of stomata.

The windrows, as raked with the side-delivery rake, were rolls of an average diameter of 1½ and 3 feet respectively, for single and double; and the samples taken consisted of a full cross section of the roll so that it would be representative of all the hay within the windrow.

Alfalfa hay double windrowed two hours after cutting, it will be observed by reference to table 1, contained 17 percent moisture after twenty-five hours, and was therefore ready for baling the day after cutting. All the plots wind-

TABLE 1—RATE OF NATURAL DRYING ALFALFA HAY CUT FROM 8 TO 9 A. M.

Method of Handling	Per Cent Moisture					
	As Cut	2 Hrs. After Cutting	4 Hrs. After Cutting	8 Hrs. After Cutting	20 Hrs. After Cutting	25 Hrs. After Cutting
Swath	70	60	44	26	46	25
Single Windrowed As Cut	70	62	38	21	38	22
Double Windrowed As Cut	70	64	34	26	38	27
Single Windrowed 2 Hrs. After Cut	70	60	40	22	37	22
Double Windrowed 2 Hrs. After Cut	70	60	32	18.5	30	17
Single Windrowed 4 Hrs. After Cut	70	60	44	21	25	21
Double Windrowed 4 Hrs. After Cut	70	60	44	20	30	20.5

rowed two hours or four hours after cutting were dry enough for baling at the end of the day after cutting. Hay which remained in the swath without windrowing was but little dryer after twenty-five hours than after eight hours, and required an additional day to cure.

As will be pointed out in the next section, more rapid drying of all hays should occur in the double windrow than in the swath, at least in hot weather and under low relative humidity conditions.

Even without the advantage of more rapid drying, double windrowing two to three hours after mowing should be practiced. The advantages of having a hay better in color, higher in carotene and fats, and with more leaves, are considerable. Sunlight has decided destructive effect upon carotene and the fatty materials (ether extract); hence, double windrowing will protect most of the hay from the intense and destructive rays of the sun, as will be pointed out later. Hay windrowed within two to four hours after cutting will not shatter the leaves as readily as hay left longer in the swath. Since the leaves represent the most valuable part of the plant from a nutritional point of view, saving the leaves is of utmost advantage.

Influence of Leaves

There is a rather prevalent opinion, and one that has frequently found expression in agricultural literature, that forage crops cure more quickly if handled in such a way as to maintain the leaves in as fresh condition as possible until enough time has elapsed to permit the stems to lose much or most of their moisture. An understanding of this principle is of high importance to hay producers.

If attached leaves remove and transpire water from stems, these leaves should dry more slowly than if they had

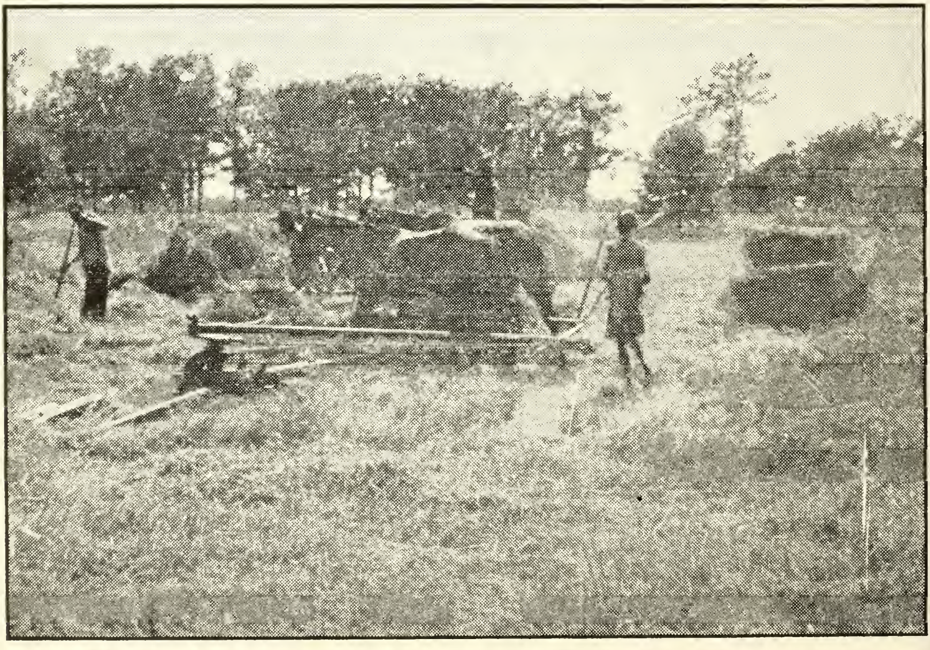


FIGURE 5—A horse power baler.

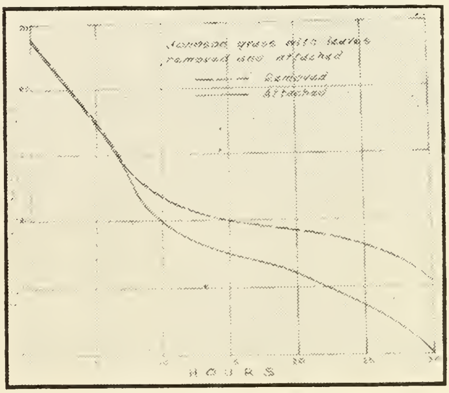
been detached. In one test on sweet clover, leaves attached to a plant contained 58 percent moisture after drying 30 hours in the laboratory, while detached leaves contained but 15 percent moisture. In field tests, significant differences also have been observed.

In a test to determine the value of leaves in removing water from stems, leaves were removed from a number of cut sweetclover plants. The upper six inches of one-half the plants was removed by clipping, and a separate study made. All cut ends were paraffined. After drying in the laboratory 70 hours (table 2), the entire stem, which had the leaves attached, had lost 71% of the water initially present in the stem; and of this water loss, at least 84% had been lost through the leaves and 16 percent from the stem. The small-stemmed upper 6 inches had lost 66 percent of the water in the stem, of which at least 40 percent had been lost through the leaves and 60 percent or less through the stems. The larger stem for the entire plant lost more of its water through the leaves than did the smaller stem on the upper part of the plant.

Alfalfa and Johnson grass with the leaves removed (graph 3) dried more slowly than plants with leaves attached. These data demonstrate again that leaves may have considerable influence on removing water from stems. Experiments of this type were conducted by Kiesselbach and Anderson (1926) on alfalfa, with smaller differences than we obtained.

Leaves on a stem sometimes dry rather uniformly, while at other times there is a marked difference in the rates of drying of individual leaves. After drying 72 hours, leaves on a branch of sweetclover from base to tip had the following moisture contents: 13.3 percent, 25.4 percent, 52.7 percent, 58.6 percent, and 61 percent respectively. (Initial moisture was about the same.)

Similar differences were observed for Johnson grass, if studied before the panicle had appeared. A movement of moisture will take place from base to tip in stems of sweetclover and Johnson grass. All except the uppermost leaves were removed from sweetclover plants, and then the tops of one-half these plants were removed and all cut ends paraffined. The plants with the lower leafless portion of the stem at-



GRAPH 3—Difference in rates of drying Johnson grass with leaves removed and with leaves attached.

TABLE 2—LOSS OF MOISTURE FROM SWEET CLOVER STEMS AS INFLUENCED BY LEAVES

	Whole stem; % Moisture	% of Initial Water in Stems Lost	Upper 6 in. of stem; % Moisture	% of Initial Water in Stems Lost
Initial Moisture	70.4	----	85.1	----
Dry 18 Hours				
Leaves on Stem	63.0	29	79.0	34
Leaves off Stem	71.6	0	84.9	2
Dry 70 Hours				
Leaves on Stem	41.0	71	61.0	66
Leaves off Stem	68.0	11	78.0	38

tached had leaves containing 70 percent moisture and stems containing 82 percent moisture 44 hours after the experiment was started. Those plants with the lower leafless portion of the stem removed had leaves and stems containing 34% and 57% moisture respectively, after the same period.

A rough test in determining whether Johnson grass has cured sufficiently is to take a handful of hay and twist the upper portion to see if there is any free moisture. One reason for the moisture content of the upper portion of the stem (before emergence of panicle) remaining higher than in other parts is because of moisture movement from the base to the apex; therefore, the top is the last to dry.

II. CRUSHING HAY TO HASTEN THE CURING PROCESS

In an effort to further hasten the process of curing hay, an experimental machine for crushing the stems of the hay plants was developed by the Agricultural Engineering Department of the Mississippi Station.

The first factor to determine in the crushing process was the proper time to crush the hay; in other words, should the hay be crushed at time of cutting, or one, two, three or four hours after cutting. Therefore, the first machine designed and built by the Experiment Station was one with a pick-up attachment so that the hay could be picked up from the ground after mowing.

From tests in 1932 it was well established that the proper time to crush hay was at the time of cutting. With this in mind the first mower-crusher developed by this department was built and proved in 1933, (figure 9). This machine has been improved and tested during the years since. This crusher was power

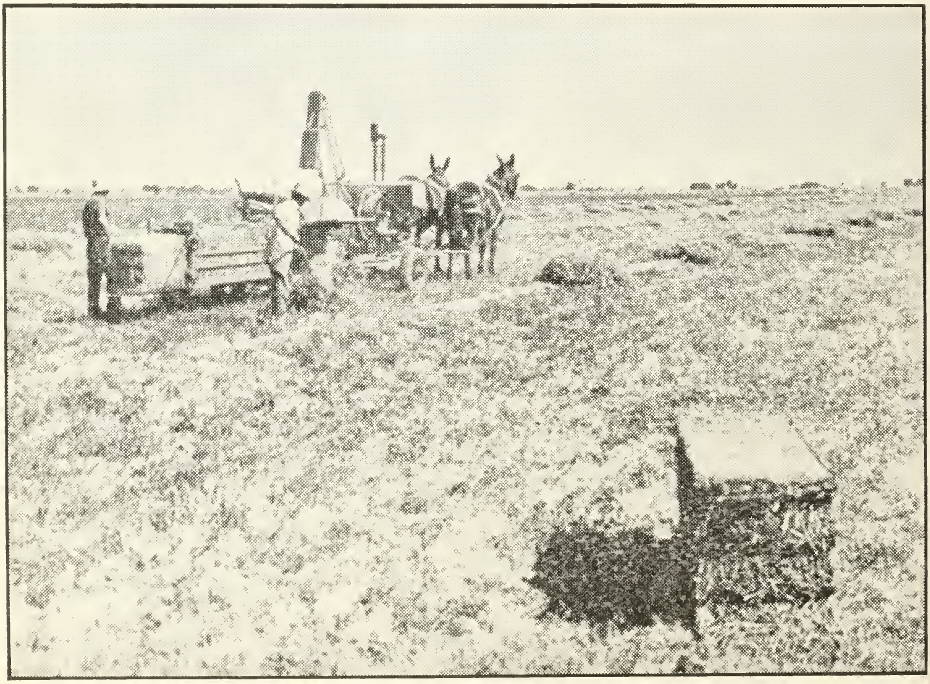


FIGURE 6—Gasoline engine power baler.

take-off driven, and required approximately 10% to 15% more power than the tractor mower alone. The crusher rolls were six inches in diameter and the pressure was controlled by compression springs. The springs should be at least 18 inches long, soft and flexible, so that hard objects such as stalks may be permitted to pass through the rolls. The rolls were made of six inch steel pipe, and were machined round.

During the year 1940 another crushing machine was constructed, which was power take-off driven but used as an attachment to the regular tractor mower. The frame of this machine was supported from the axle of the row-crop type tractor and two castor wheels which permit mowing and crushing in one operation. One man operated the tractor and mower-crusher, and the mowing process is not materially slowed down by the crushing mechanism. See figure 10.

This machine gave marked results in reducing the curing time of large stem hays during the 1940 season.

We have already shown that the leaf will lose water considerably faster than the stem if the two are separated. A leaf which is attached to the stem will not become dry as rapidly as one which is loose, since it has the extra burden of removing some of the water from the stem. Crushing machines have been developed to hasten the rate of drying of the slower drying stems. Since moisture in leaf and stem is roughly interdependent, a more rapidly dried stem also means a more rapidly dried leaf, a fact which we have always observed in the field, and a fact which determines the manner carotene is lost in crushed and uncrushed hays, as will be pointed out later.

Crushing Johnson Grass

Johnson grass that was cut at 10:00 a. m. contained only 25 percent moisture at 5:00 p. m., a period of only seven

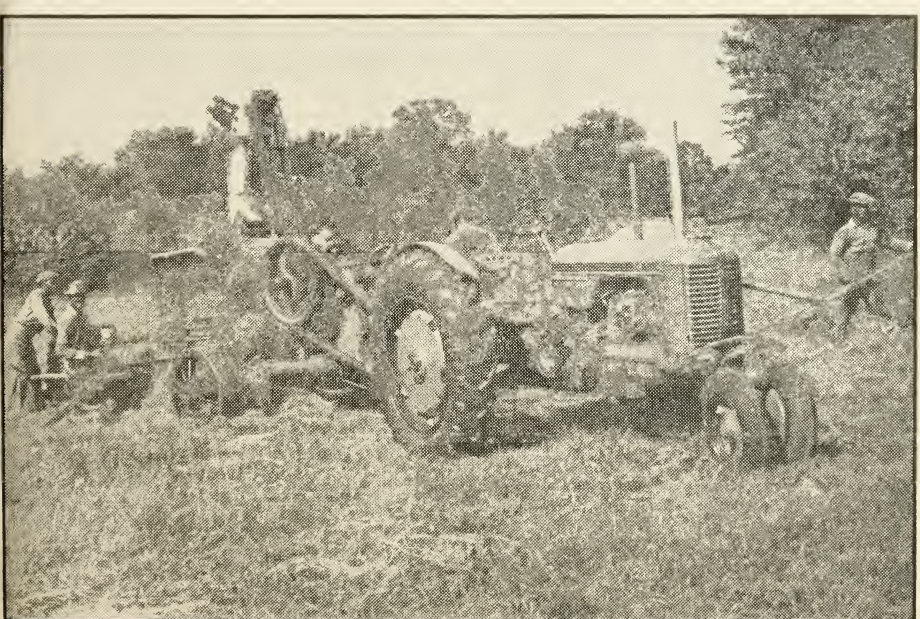


FIGURE 7—The direct hitch tractor power, take-off driven baler.

hours; whereas the uncrushed Johnson grass containel 37 percent moisture at the same time seven hours after cutting. In similar tests where the hay was cut earlier, the moisture content was brought below 20 percent by 5:00 p. m. Hay with a moisture content of 25 percent or less may be stored loose or put in small cocks or stacks, thus eliminating the greater portion of the hay being exposed to dew. Naturally, when hay is cured in this manner, it will have better color, better grade, retain more proteins, and be more palatable.

Experiments revealed that medium and heavy crushing brought about practically the same rate of drying.

The above evidence indicates that in crushing hay the pressure should be adjusted for the particlar hay in such a way that most of the stems are crushed, but that further pressure, unless greatly increased, will not appreciably affect the rate of drying of the hay.

No Loss in Food Constituents

The question arises as to what loss, if any, occurs in the food constituents by crushing. It will later be pointed out that in crushed stems of Johnson grass a weight loss of 1% usually was observed, and this loss was mainly accountable through evaporation of the water squeezed out of the stems and covering the surfaces. Analyses of alfalfa and Johnson grass show that there was no material loss due to crushing in the content of crude (total) protein, soluble protein, soluble carbohydrates (sugars and dextrin), ether extract, and ash.

Chemical analyses in other tests also revealed that there was no loss in the chemical constituents due to crushing. However, there was an increase in soluble proteins (soluble nitrogen compounds) due to curing (drying), and a

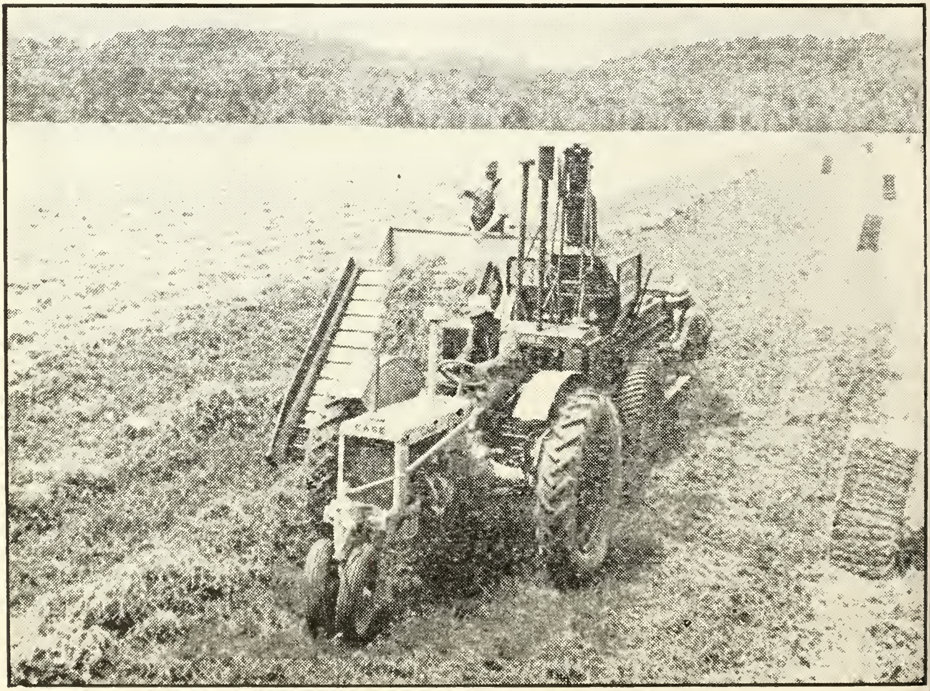


FIGURE 8—The modern pick-up baler with auxiliary engine.

slight decrease in soluble carbohydrates due to respiration. These results were expected and are also well known.

Studies were conducted to determine whether crushed stems were poorer in carotene than uncrushed stems. The data revealed that crushed stems were as rich in carotene as mowed stems by the time the mowed plants were dry.

The leaves behaved in a similar manner. The reason carotene is lost in this manner will be explained in the technical bulletin under the heading "Carotene As Affected by Rate of Drying".

Most of the experiments on crushing Johnson grass were conducted at the West Point Forage Crops Field. In the course of the last several years a variety of such tests have been made, using different kinds of experimental crushing machines.

Drying Process Hastened

Johnson grass has been crushed under various weather conditions and also under various conditions of plant growth. The influence of some of these variable factors on the rates of curing will be considered.

Other studies show the effect of mowing and crushing Johnson grass. The hay was crushed with a commercal crusher, and by 2:20 P. M. (only 3 hours and 20 minutes) it was ready for baling, whereas, the mowed hay was not as dry the following afternoon at the same time. The snort period of time required for curing of the crushed hay was due to the low initial moisture content of the grass, the thinness of the stand, and the good drying conditions made possible by the hot, sunshiny day and moderate relative humidity. Carotene was more

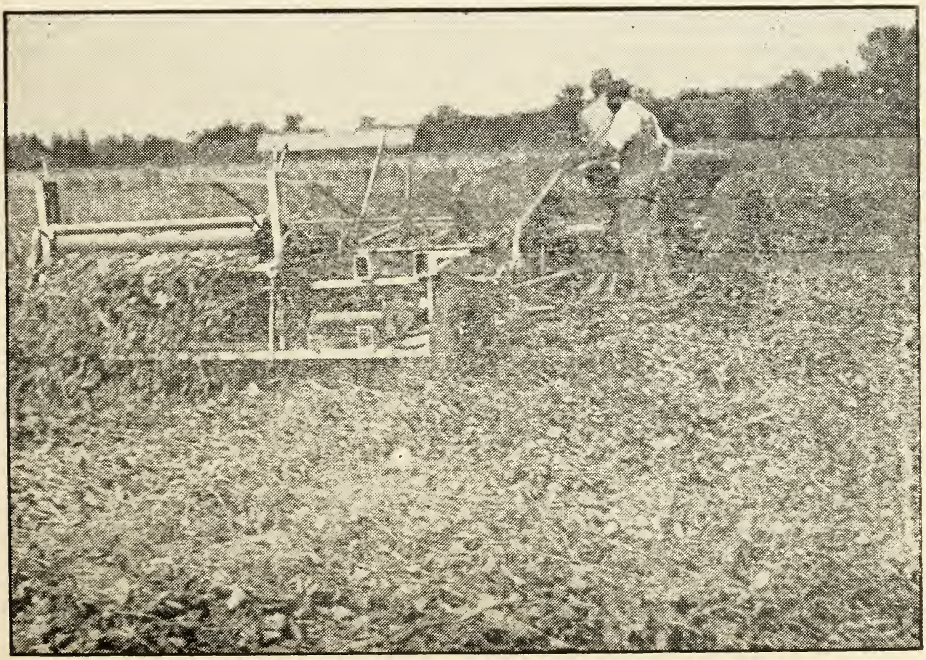


FIGURE 9—The mower-crusher designed and constructed by the Agricultural Engineering Department in 1933, operating on soybeans.

abundant in the mowed than in the crushed hay at the end of the first day's drying, but about the same the following afternoon. It is interesting to note that the contents of moisture and carotene of the hay are correlated.

The stands of Johnson grass reported thus far were thin and stems rather small. Table No. 4 shows an experiment conducted with large-stemmed Johnson grass which was very succulent and had about one-third the panicle showing. Approximately two-fifths of the fresh weight was leaves and three-fifths stems. The weather and other conditions were ideal for curing hay: relative humidity was low, temperature high, and the ground dry. The mowed hay still contained 52% moisture after drying in the swath seven hours, while the crushed hay contained 27% moisture. The relative humidity under the hay, which was piled deep on the ground, was 10% higher than the relative humidity of the air. Even this humidity favored rapid transpiration. By 1:00 P. M. the

TABLE 3—EFFECT OF MOWING AND CRUSHING JOHNSON GRASS ON ITS CHEMICAL COMPOSITION

	Crude Protein % Dry Wt.	Soluble Protein % Dry Wt.	Soluble Carbohydrates % Dry Wt.	Ether Extract % Dry Wt.	Ash % Dry Wt.
Johnson Grass					
Fresh	5.25	0.37	4.98	......	6.4
Mowed	5.31	0.82	4.65	1.90	6.3
Crushed	5.37	0.69	3.91	1.83	6.4
Alfalfa					
Fresh	22.93	3.24	5.91	......	13.0
Mowed	22.93	6.81	4.18	4.60	10.0
Crushed	22.56	4.75	4.70	5.96	13.0

TABLE 4—COMPARISON OF DRYING RATES ON CRUSHED AND MOWED JOHNSON GRASS

					Mower		Commercial Crusher	
Time	Temp. C.	Relative Humidity	Light In Ft. Candles	Wind	Moisture, %	Carotene p.p.m. Dry Wt.	Moisture %	Carotene p.p.m. Dry Wt.
First Day								
10:00 A. M.	29.0	42	11,859	Still	66.8	125	66.8	125
11:00 A. M.	29.4	42	12,283	Still	62.9	......	56.4	......
12 Noon	30.0	38	12,283	Still	61.2	......	55.4	......
1:00 P. M.	33.4	32	12,390	Light Breeze	59.6	......	46.0	......
2:00 P. M.	32 8	34	11,151	Still	56.5	......	37.9	......
3:00 P. M.	29.4	34	9,800	Still	54.0	......	35.0	......
4:00 P. M.	27.2	37	6,500	Still	52.9	......	28.3	......
5:00 P. M.	27.0	42	4,200	Still	52.0	......	27.0	......
Second Day								
10:00 A. M.	30.6	44	11,682	Still	50 5	......	25.7	......
11:00 A. M.	31.2	38	11,682	Still	51.8	......	20.9	......
12 Noon	32.8	34	12,036	Still	43.7	......	20.0	68
1:00 P. M.	37.4	28	11,859	Still	39.5	......	13.4	......
2:00 P. M.	35.2	27	11,328	Still	40.4	......	12.0	......
3:00 P. M.	34.0	29	9,200	Still	44.5	......	11.2	......
4:00 P. M.	32.6	32	2,600	Still	35.8	......	20.0	......
5:00 P. M.	29.5	35	1,600	Very				
Rain				Windy	39.4	53	15.4	42
Sixth Day								
3:00 P. M.	......	......	......	......	18.0	18	......	......

next day the crushed hay was ready for baling, containing 13.4% moisture, while the mowed hay still contained 40% moisture. Because of a light shower, dew and cloudy weather, the mowed hay was not ready for handling until five days after cutting. The crushed hay could have been baled at a time when its carotene was 68 p. p. m. (parts per million) while the mowed hay could not have been thus handled before its carotene content was 18 p. p. m. on a dry weight basis.

At cutting, when the moisture content was high, the carotene content was high, and as moisture was reduced, the carotene content decreased. However, when the mowed hay was ready for baling six days after cutting, the carotene content was only 18 p. p. m. The crushed hay was ready for baling at noon the day after cutting, and then contained 68 p. p. m. carotene, nearly four times as much as the mown hay.

It was found in frequent tests that hay could have been baled the day it was cut and crushed, if dried in the swath and if the stems were small; however, if the stems were medium size or large, two days might be required for curing under favorable weather conditions.

Crushing Alfalfa

Several crushing tests have been made on alfalfa with the data showing that the curing time may be reduced about one-third, depending, of course, upon the size of stems and weather conditions. By crushing alfalfa one may expect with good weather conditions to cock the hay the first day, thereby preventing much damage from dew and lowering greatly the chances of the damage by rain.

Crushing Soybeans

Soybeans crushed with the first crusher reached a moisture content of 27

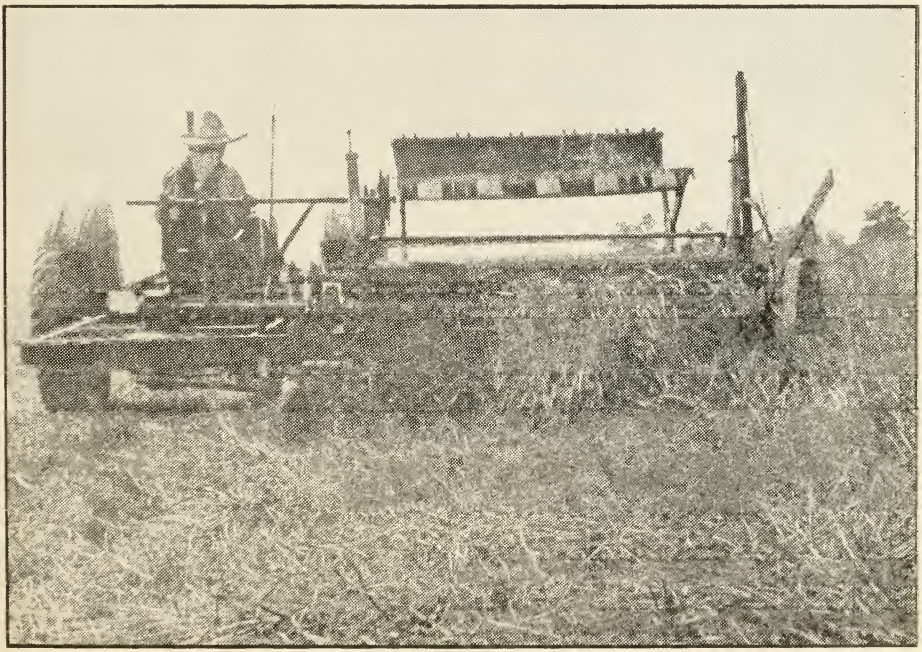


FIGURE 10—The 1940 improved mower-crusher, also designed and built by the Agricultural Engineering Department, operating on Johnson grass.

percent at the end of six hours after cutting and crushing, while the uncrushed hay still contained 42 percent moisture at the end of the same period. These tests were made in October after the days had shortened considerably and the temperature was below the summer average.

It has already been pointed out that large-stemmed Johnson grass (table 4) dried more slowly than that with smaller stems, and that crushing had a more decided influence on reducing the curing time on these large-stemmed plants than on the smaller ones. The same relationship is true for small and large-stemmed soybeans, both at the same relative stage of growth, but the one more vigorous than the other.

Crushing tests were made on small-stemmed soybeans, using the commercial crusher. The crushed small-stemmed plants had decreased from 70 percent moisture to 19% moisture in seven hours curing, and thus were ready for baling the first day. The mowed plants had 40% moisture after seven hours drying. The following afternoon at 5:00 p. m. the mowed soybean plants contained 18% moisture and were ready for baling. Crushing thus reduced the curing period by 50%. The crushed hay could have been baled when its carotene content was 100 p.p.m., and the mowed hay when its carotene content was 52 p.p.m. Carotene in the fresh soybeans was 167 p.p m., dry weight basis.

Large-stemmed soybeans are influenced more by crushing than small-stemmed soybeans, although a longer curing period is required. By 1:50 p. m. of the second day after cutting, the crushed soybeans were ready to bale (table 5) while the mowed soybeans were not ready to handle until five curing days after being cut. The curing period was reduced about 70%. It is interesting to observe that crushed large-stemmed soybeans dried more rapidly than uncrushed small-stemmed plants. The crushed large-stemmed soybeans at baling time had lost a larger percentage of their carotene than had the

TABLE 5—COMPARISON OF DRYING RATES OF CRUSHED AND MOWED SOYBEANS, PLANTS LARGE

Time	Temp. C.	Relative Humidity	Light In Ft. Candles	Wind	Mower Moisture, %	Mower Carotene p.p.m. Dry Wt.	Commercial Crusher Moisture %	Commercial Crusher Carotene p.p.m. Dry Wt.
First Day								
10:30 A. M.	21.5	33	10,600	Mod.	67 5	125	67.5	125
11:30 A. M.	22.8	34	11,000	Mod.	64.9	----	61.2	----
1:30 P. M.	24.0	31	11,000	Mod.	60.7	----	38.4	----
2:30 P. M.	24.0	30	11,000	Mod.	55.2	----	38.2	----
3:30 P. M.	23.4	32	11,000	Breeze	55.1	----	40.0	----
4:30 P. M.	22.2	34	8,100	Low Breeze	55 3	----	32.7	----
5:30 P. M.	19.6	36	1,700	Low Breeze	47.5	----	35.8	----
Second Day								
10:50 A. M.	26.0	36	11,000	Light Breeze	42.8	----	24.2	----
12:50 A. M.	27.6	29	11,000	Still	42.1	----	21.6	----
1:50 P. M.	27 6	31	11,000	Still	44.9	----	17.8	----
2:50 P. M.	26.2	31	11,000	Still	38.8	----	8.8	----
4:50 P. M.	19.5	43	4,500	Still	37.0	60	11.3	58
Third Day								
10:30 A. M.	26.0	40	10,000	Still	36.5	----	14.1	----
Fifth Day								
5:00 P. M.	----	--	----	----	18.5	38	----	----

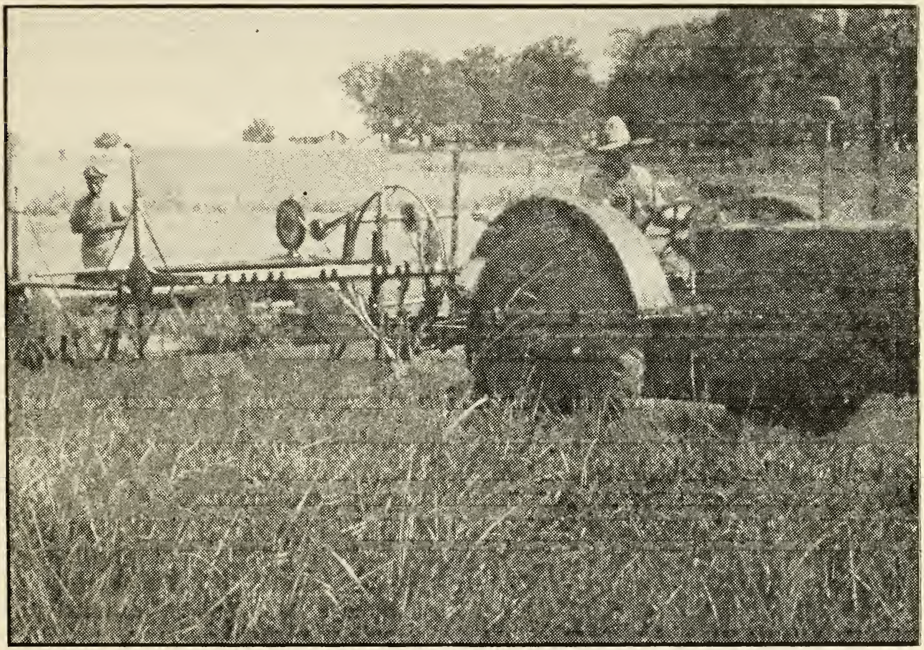


FIGURE 10-A—Another view of the direct hitch, power take-off driven crusher using regular tractor mower.

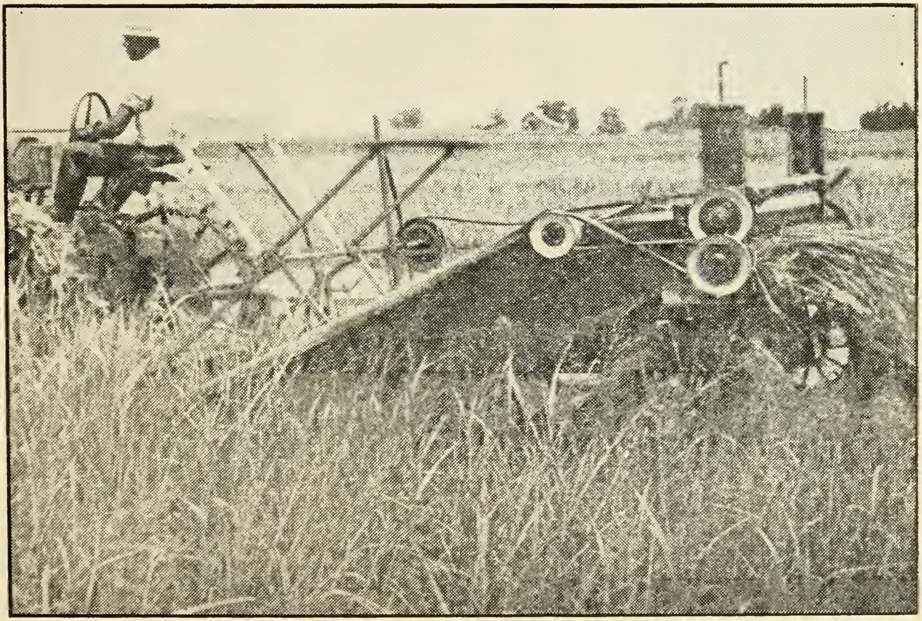


FIGURE 10-B—Close-up, showing crushed hay passing through the mower-crusher

small-stemmed plants.

Figure 13 shows cross section views of hay from crushed and uncrushed Johnson grass

Crushing Kudzu

Kudzu is a promising perennial legume which may be increasingly used as a hay plant. It is a soil conserving plant and Kudzu hay is rather rich in protein. When compared with other hay plants Kudzu may be disadvantaged because it yields only one or two cuttings per year; on the other hand, an advantage of kudzu is that it may be cut any time desired from mid-June until frost occurs. Limited experimental data indicates that kudzu grows well on the well-drained sandy soil areas where alfalfa and Johnson grass are difficult to produce and where the need is great for an efficient hay plant.

Kudzu was crushed with the commercial crusher. This was the only cutting made on this ground during the year, hence, some of the vines were woody but there were some younger stems and leaves. Table 6 gives the drying rates of crushed and mowed kudzu. Cut at 9:20 a. m., by 2:20 p. m. the crushed kudzu was ready to bale, while the mowed kudzu was not ready until about 11:00 a. m. the next morning. Crushing produced favorable results on kudzu. Possibly younger kudzu would respond even more favorably to crushing.

Crushing Sweetpotato Vines

Crushing hastens the rate moisture is lost from sweetpotato vines, as with other plants tested. However, even with crushing, curing is slow because the vines are high in moisture and cannot be harvested until the roots are ready to be dug in the fall, when the days are cool and short. In a crushing test at Laurel, Miss., on October 22, 1940, crushed vines decreased about 20% in moisture during six hours drying in the field, while the mowed vines decreased about 10%. These figures are only approximate, since there was considerable variability in the samples. The following forenoon was cloudy and cool, hence, there was little additional drying in either the mowed or crushed samples.

Protein was 7.78 percent and carotene was 253 p.p.m. (both on dry weight basis) in the fresh vines. The crushed vines had lost two-thirds and the mowed vines had lost one-half their carotene by noon of the second day. The moisture content of the crushed vines was 55 to 58 per-

TABLE 6—COMPARISON OF DRYING RATES OF CRUSHED AND MOWED KUDZU

					Mower		Commercial Crusher	
Time	Temp. C.	Relative Humidity	Light In Ft. Candles	Wind	Moisture, %	Carotene p.p.m. Dry Wt.	Moisture %	Carotene p.p.m. Dry Wt.
First Day								
9:20 A. M.	22.0	42	11,000	Light Breeze	56.6	151	56.6	151
10:20 A. M.	25.8	37	11,000	Light Breeze	55.6	----	53.0	----
11:20 A. M.	27.4	34	11,000	Light Breeze	50.3	----	46.0	----
1:20 P. M.	27.6	29	11,000	Still	41.3	----	29.5	----
2:20 P. M.	27.6	31	11,000	Still	34.9	----	20.4	----
3:20 P. M.	26.2	32	11,000	Still	34.4	----	19.3	----
4:20 P. M.	24.2	32	9,500	Still	35.7	----	13.0	----
5:20 P. M.	19.0	47	1,400	Still	28.5	117	10.2	112
Second Day								
9:15 A. M.	24.0	45	11,000	Light Breeze	29.2	----	18.7	----
10:45 A. M.	26.0	40	11,000	Still	21.6	82	14.4	79

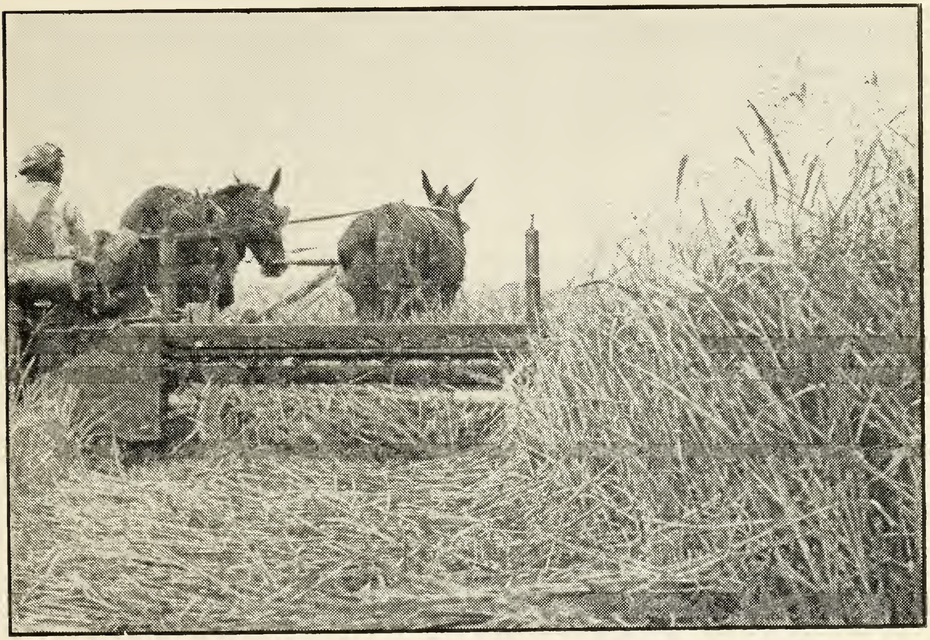


FIGURE 11—The John Bean Quick Hay Maker in operation in Johnson grass.

FIGURE 12—The John Bean Quick Hay Maker in operation in Kudzu.

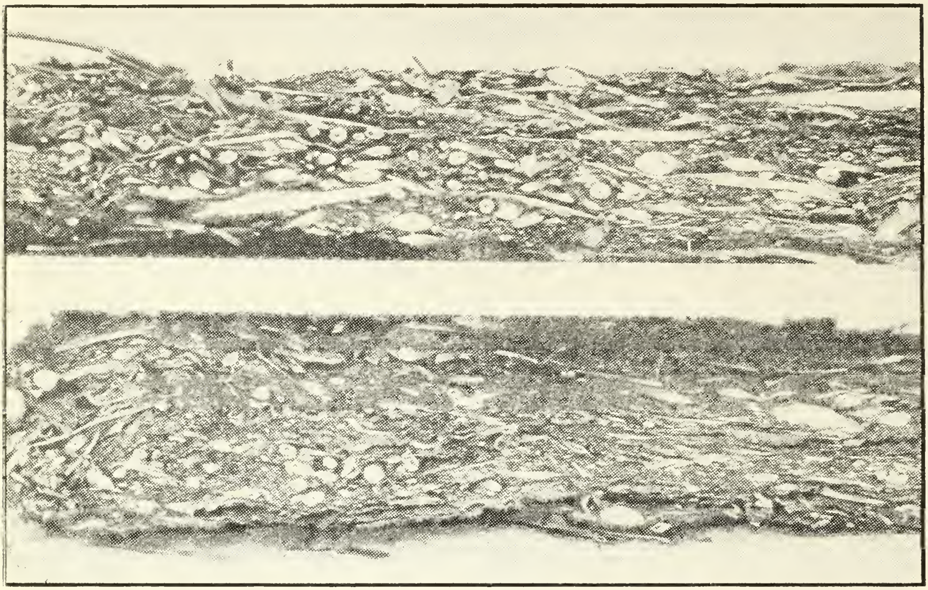


FIGURE 13A—Cross section view of crushed and uncrushed soybean hay.

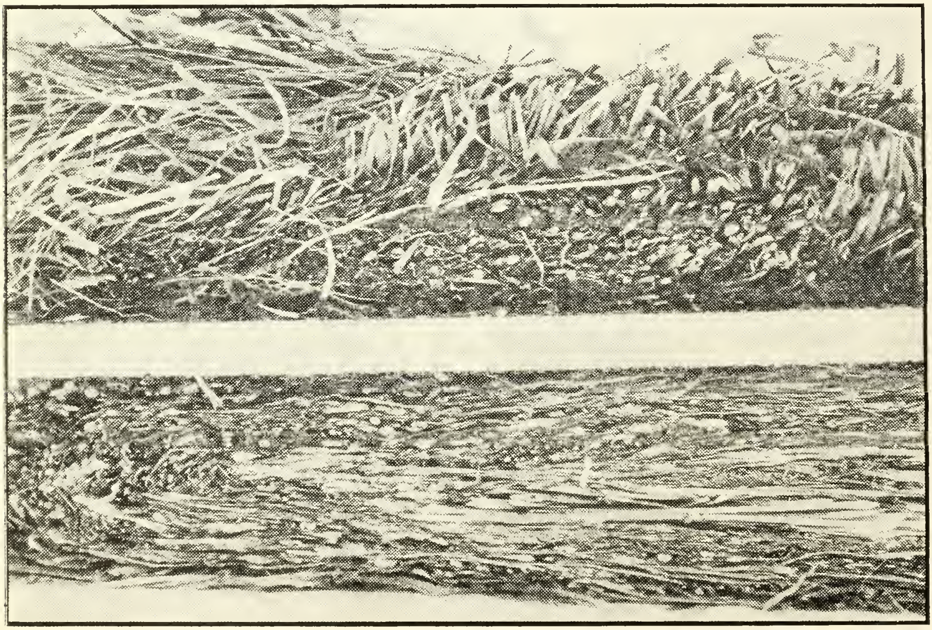


FIGURE 13-B—Cross section view of crushed and uncrushed Johnson grass hay.

cent and of the mowed vines 68 to 70 percent at this time.

Table 7 shows the moisture, protein, and carotene, in the fresh sweet potato vine. About two-fifths the dry weight of the tops consists of leaf-blades, the most valuable part of the vine. By raising the cutter bar 1½ inches above the bed, D. M. Warriner, president of the Warriner Starch Company, found that one could harvest 86.4% of the leaf-blades, 53% of the petioles and 6.9% of the stems (vines), which was equal to 1,311 pounds of leaf-blades, 460 pounds of petioles, and 112 pounds of stems (vines) per acre, dried to a moisture content of 10%.

It was found by using vine lifters on the mower, as shown in figure 15, which were made to fit the bed and thus lift the vines so that the cutter bar of the mower would get under them, that 85 per cent of the vines were cut. However, in crushing these vines much difficulty was encountered because the potatoes were planted on beds, allowing many of the vines, when cut, to fall into the middle. Since the pick-up attachment of the crusher will not pick the vines up out of the middle, many of the vines were not crushed.

This material would represent a feed of considerable value if it could be properly handled. The vines cause trouble when sweetpotatoes are harvested, and their removal for hay would facilitate harvesting the roots, would not reduce the yield of roots, and may one day prove a valuable by-product to the sweetpotato producer.

III. PRESERVING MAXIMUM FEED VALUE IN HAY

Leaves are richer than stems in many important constituents. Protein, ether extract, calcium and phosphorous are generally two or more times as abundant in leaves as in stems. The value of protein for animals is well known. The main part of the animal body is built of protein. The ether extract consists of fatty

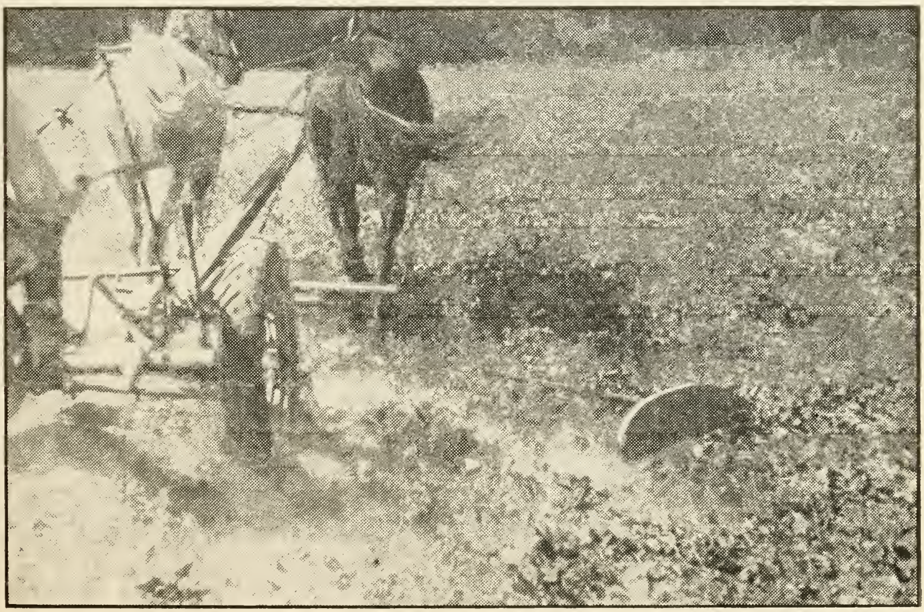


FIGURE 14—Mowing machine cutting sweetpotato vines for hay.

materials, which have numerous functions in the body. Calcium and phosphorous are necessary in making bone, teeth, as well as having other functions.

The following are some protein values for leaves (leaf-blades) and stems (rest) of some hay plants:

PROTEIN VALUES IN LEAVES AND STEMS

	Protein in leaves percent	Protein in stems percent
Johnson Grass	9.62	3.93
Soybeans	20.12	5.93
Kudzu	16 62	5.93
Sweetpotato vines	16.75	6.03

It will be noted that Johnson grass is poor in protein in both leaves and stems, when compared with the legumes. It is a wise practice to feed legume hay as it furnishes a supply of cheap protein.

Carotene (precursor of Vitamin A), Vitamin C, Vitamin D and Vitamin G are known to be more abundant in leaves than in stems. Carotene (beta carotene, mainly) is a yellow ether soluble pigment which is changed into Vitamin A in the bodies of animals. Without sufficient Vitamin A animals will be weak, sterile, may not grow well, and may die. Cattle seem to make enough Vitamin C for their needs under most conditions, although

TABLE 7—PROTEIN, CAROTENE AND MOISTURE IN DIFFERENT PARTS OF THE SWEETPOTATO VINE (TOP)

Plant Part	Percent Moisture	Per Cent of the Total Dry Weight of the Vine	Protein % Dry Wt.	Carotene p.p.m. Dry Wt.
Leaf-Blade	80.0	39.6	16.75	423
Petiole	90.3	27.1	4 56	48
Stem (Vine)	82.3	33.3	7.18	29
Entire Vine (Top)	85.1	100.0	10.37	180

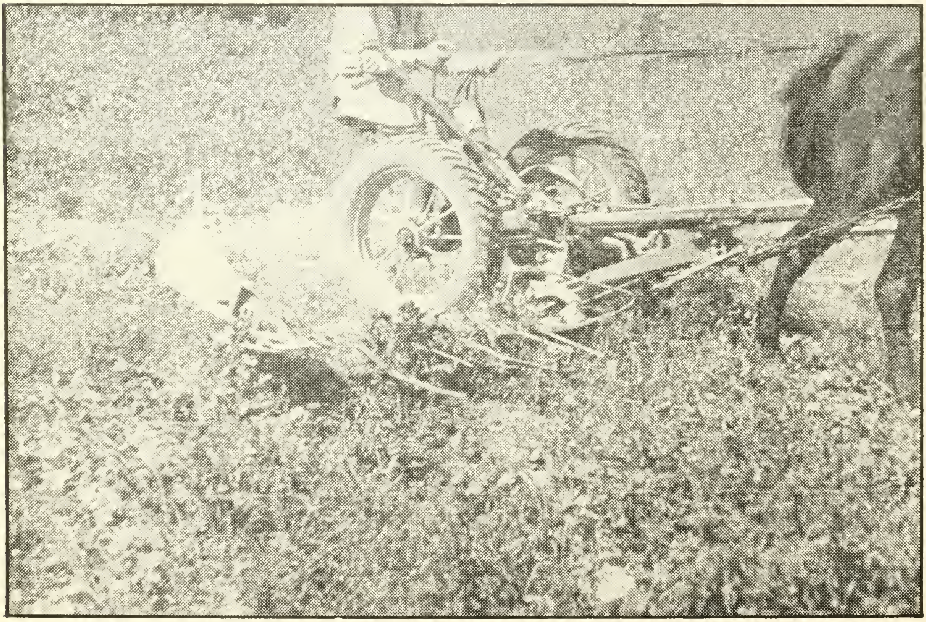


FIGURE 15—Experimental vine lifters found necessary in cutting sweetpotato vines.

there may be exceptions. Lack of Vitamin C results in scurvy in humans. Vitamin D is necessary for the proper formation of bones. Vitamin G aids in growth. Workers elsewhere have found Vitamin D to be six or seven times as abundant in leaves as in stems of alfalfa and Vitamin G to be four or five times as abundant in leaves as in stems.

Preserve Leaves

The distribution of carotene and Vitamin C was determined on Johnson grass, alfalfa, soybeans, sweet clover, kudzu and sweetpotato plants. Examples of the distribution of carotene and protein (table 7) and carotene and Vitamin C (table 8) are shown for sweetpotatoes and soybeans respectively. The leaves of the soybeans were ten times higher in carotene and four times higher in Vitamin C than any of the other parts of the plants tested The upper, greener portion of the stem was considerably richer in these vitamins than the lower, woody part. For the most part, 80 percent to 95 percent of the carotene in hay plants tested was present in the leaves, in the fresh state.

It is now pertinent to inquire how this proportion of carotene is affected in the curing of hay. Table 9 gives the values of carotene in leaves and stems of the Johnson grass, soybeans and kudzu. It is evident that although great losses occurred in the curing process, these losses were about the same for the leaves and stems. While still fresh 78 percent, 89 percent, 88 percent, and 92.4 percent of the carotene was present in the Johnson grass, large soybeans, small soybeans and kudzu leaves, respectively. The hays were mowed and cured in the swath until dry. Crushing affected the absolute values of carotene in leaf and stem but not the proportion of carotene lost.

The composition of plants varies with age This fact is true not only because young leaves and stems are richer in carotene than the same organs when mature, but also because the proportion of leaf to stem is greatest in young plants. Table 10, on carotene, is an illustration of the above statement. Protein, ether extract, minerals and vitamins decrease as the hay plants become mature.

The composition of a plant is affected by the conditions under which it is grown. In general, the more favorable the conditions for growth, the greater will be the carotene and other vitamins, protein and mineral values. Thus weather, fertility of the soil, and the disease markedly affect the composition of hay plants.

Preserve Carotene

Carotene is affected remarkably by various factors, and considerable destruction occurs in the curing process. Leaves

TABLE 8—CAROTENE AND VITAMIN C IN DIFFERENT PARTS OF THE SOYBEAN

Plant Part	Carotene p.p.m. Dry Wt.	Vitamin C % Dry Wt.
Leaf-Blade	908	0.73
Petiole	80	0.17
Upper Stem (Succulent)	90	0.18
Lower Stem (Woody)	18	0.06
Root	0	0.01

Plants were 2 feet tall and growing vigorously.

TABLE 9—CAROTENE IN LEAF-BLADES AND STEMS OF FRESH AND DRIED MOWED JOHNSON GRASS, SOYBEANS AND KUDZU. VALUE AS P.P.M. DRY WEIGHT

	Johnson Grass		Soybean—Small		Soybeans—Large		Kudzu	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Leaf-Blades	400	61	400	123	408	115	254	140
Stems and Rest	38	6	32	10	20	5	24	10

left exposed to the sun lose their carotene more rapidly than those left in the shade. The mere process of drying the plants results in a considerable loss of carotene, especially if the drying is slow. The degree of destruction in the sun depends upon a number of factors, such as the light intensity, temperature, humidity, and the number of leaves which overlap. Plants grown under different conditions will lose a different proportion of their carotene upon drying, the more succulent seeming to lose carotene faster than the less succulent plants. Hay that has been wet by dew or rain is reduced thereby in carotene.

In a test, Johnson grass was raked five hours after being cut and compared with unraked hay after standing two days in the field. The shocked hay (interior of shock) had 65 p.p.m. carotene, and the surface of the shock had 25 p.p.m. and the hay in the swath contained 16 p.p.m. One can conclude from this test that the sun will lower the carotene content of hay wherever it is struck, but that shading, even by the outer layers of hay, reduces the destruction. Double windrowing alfalfa two hours after being cut would result in a product higher than if drying were allowed to proceed for a while longer in the swath. Thus, the hay would not only dry faster, as was pointed out earlier in this bulletin, but would also have a higher content of carotene.

Hasten Haymaking Process

Since light destroys carotene, the sooner hay can be removed from the field, the better. Crushed hay can be stored sooner than mowed hay, and, because of this, will always have more carotene. If crushed hay is left in the field as long as the mowed hay, there is little difference in the carotene values. Some of the factors which affect the destruction of carotene, such as light, temperature, and rain, also affect the quantity of ether extract and Vitamin C in hay.

In storage, carotene is still lost rather rapidly, the rate of loss depending on the temperature and other factors. Since carotene is lost from hay in storage, it is wise not to keep hay for more than a year.

The composition of plants varies with age. This fact is true not only because young leaves and stems are richer in carotene than the same organs when mature, but also because the proportion of leaf to stem is greatest in young plants. Table 10, on carotene, is an illustration of the above statement. Protein, ether extract, minerals and vitamins decrease as the hay plants become mature.

The composition of a plant is affected by the conditions under which it is grown. In general, the more favorable the conditions for growth, the greater will be the carotene and other vitamins, protein and mineral values. Thus weather, fertility of the soil, and disease markedly affect the composition of hay plants.

TABLE 10—CAROTENE AND RELATIVE WEIGHTS OF LEAF TO STEM IN SOYBEANS AT DIFFERENT STAGES OF GROWTH

	% Dry Wt. of Plant as Blade	P.P.M. Carotene In Plant (Dry Wt.)	P.P.M. Carotene Stem	P.P.M. Carotene Blades	% Total Carotene In Blades
Seedling (6" Stage)	82	541	156	625	94.8
14" Stage	64	453	85	660	93.2
Mature	27	125	20	408	89.0

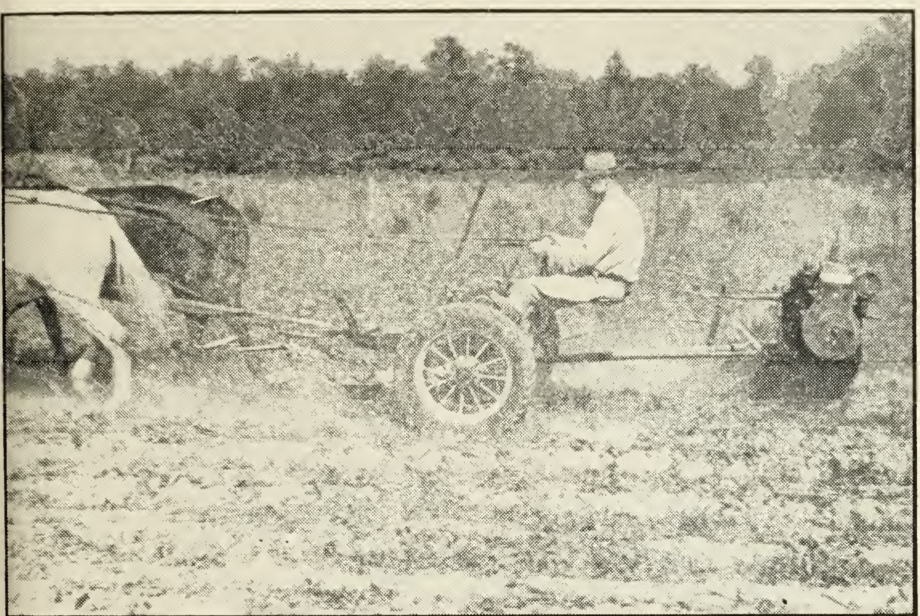


FIGURE 16—Mower with crushing machine attached, cutting and crushing sweetpotato vines for hay