HAY AND THE FACTORS THAT INFLUENCE ITS CURING

Thesis for Degree of M. S.

Fred Henry Otto Kaufmann

1926

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A Thesis Prepared by FRED HENRY OTTO KAUFMANN in Partial Fulfillment of the Requirements for the Degree of Master of Science, Department of Farm Crops.

MICHIGAN STATE COLLEGE OF AGRICULTURE AND APPLIED SCIENCE.

1926.

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ACKNOWLEDGEMENT.

The writer wishes to express his sincerest appreciation and gratitude to all those who have in one way or another assisted in the development of this problem.

Special appreciation is due Professor C. R. Megee and Professor J. F. Cox, who made the work possible; Professor C. R. Megee, for helpful and valuable criticisms offered in the final review of the work; Dr. E. A. Bessey, Dr. R. P. Hibbard, and Mr. H. Clements, for their valuable suggestions pertaining to the plant physiology of the problem.; Professor J. R. Duncan and Professor H. R. Pettigrove for their kindly advice; and Mr. Ralph Hudson for his courteous cooperation in the field.

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Introduction.

Hay has always occupied a very prominent position in agriculture, and in the United Stated it is today the second leading agricultural crop. Where 60 years ago, in 1866, we were producing 21½ million tons of hay valued at over 220 million dollars, we are now having an annual yield of 98 million tons of all kinds of hay with a value on the farm unbaled of over 12 hundred million dollars. Further this hay crop constitutes 24% of the total production of all coarse forage and has a feed value that is equivalent to the maintenance of 14 million live stock units for an entire year. The production of this tremendous crop requires an approximate annual acreage of 73 million acres which alone is 20% of the entire acreage given over to harvested crops in the United States.

Likewise, the hay acreage, production, and value in the state of Michigan are very large, the annual hay crop yielding more than 5 million tons valued at over 60 million dollars and grown on more than 1/3 of the total area devoted to agricultural crops in this state.

In the handling of this tremendous hay crop, a problem of outstanding importance that confronts the producer is that of curing it. The difference between properly and improperly cured hay very frequently means a difference of two dollars to ten dollars per ton in price or an equal difference in home feeding value. It is ex-

tremely essential, therefore, that the farmer in preparing his hay for his own use, or for the market, should use such methods of curing as will produce the best quality of hay, most economically. Any information, therefore, which will shed additional light upon the processes going on in hay while it is curing and which will more clearly emphasize the need for recommended curing methods, manifestly is very valuable and the work conducted in obtaining such information certainly justifiable.

Object of the Work.

The purpose for which this problem was undertaken is of a two-fold nature.

First, to gather and compile into one report a review of the distribution of the kinds of hay grown in the United States and in Michigan and also a review of the marketing of hay in the United States.

Second, to secure a more complete understanding, by means of experimental work, of the nature and extent to which certain factors influence the curing of hay.

Distribution of Hay in the United States.

From a study of the distribution of the acreage upon which the tremendous hay crop of the United States is produced, it at once becomes clear that comparatively little hay is grown in the far western parts of this country and that the regions of outstanding hay production, as shown in Figure 1, are in the Middle Atlantic and North Central States. These 15 states have a combined acreage of 47,779,000 acres or 64% of the nation's hay lands. Records, represented in Table 1,

Table 1.

Five Leading States in Acreage of Hay
in the United States
1866-1924*

Year	States	Acreage	Year	State	Acreage
1866	New York	3,966,264	1870	New York	3,651,219
	Pennsylvania	1,642,363		Pennsylvania	2,103,076
	Illinois	1,591,880		Illinois	1,605,932
	Ohio	1,510,615		Ohio	1,467,938
	Maine	1,197,215		Iowa	1,194,029
1875	New York	4,188,034	1880	New York	4,853,769
	Illinois	2,226,277		Pennsylvania	2,548,935
	Pennsylvania	2,181,818		Iowa	2,007,887
	Ohio	1,727,282		Illinois	1,790,021
	Iowa	1,422,222		Ohio	1,782,581

Table 1 Cont'd.

Year	States	Acreage	Year	State	Acreage
1885	New York	4,962,158	1890	New York	6,066,431
	Iowa	3,787,500		Iowa	5,410,931
	Illinois	3,306,250		Pennsylvania	3,382,550
	Kansas	3,040,000		Illinois	3,276,206
	Pennsylvania	2,738,572		Kansas	3,088,496
1895	New York	4,873,320	1900	New York	4,356,064
	Iowa	4,270,910		Iowa	3,750,727
	Kansas	3,372,007		Kansas	3,284,018
	Pennsylvania	2,843,611		Pennsylvania	2,557,475
	Missouri	2,329,731		Missouri	2,258,682
1905	New York	4,717,641	1910	New York	4,811,000
	Pennsylvania	3,072,021		Iowa	3,600,000
	Iowa	3,038,352		Pennsylvania	3,212,000
	Missouri	2,812,731		Ohio	2,840,000
	Illinois	2,664,682		Illinois	2,795,000
1915	New York	4,500,000	1920	New York	4,386,000
	Pennsylvania	3,100,000		Illinois	3,264,000
	Iowa	3,098,000		Ohio	3,150,000
	Missouri	3,050,000		Missouri	3,147,000
	Ohio	2,812,000		Iowa	3,021,000
1924	New York	4,944,000			
	Illinois	3,674,000			
	Missouri	3,476,000			
	Ohio	3,344,000			
	Wisconsin	3,203,000			

* These figures taken from U.S.D.A. Bureau of Statistics Bul. 63 – and U.S.D.A.Year Books.

Map of the United States

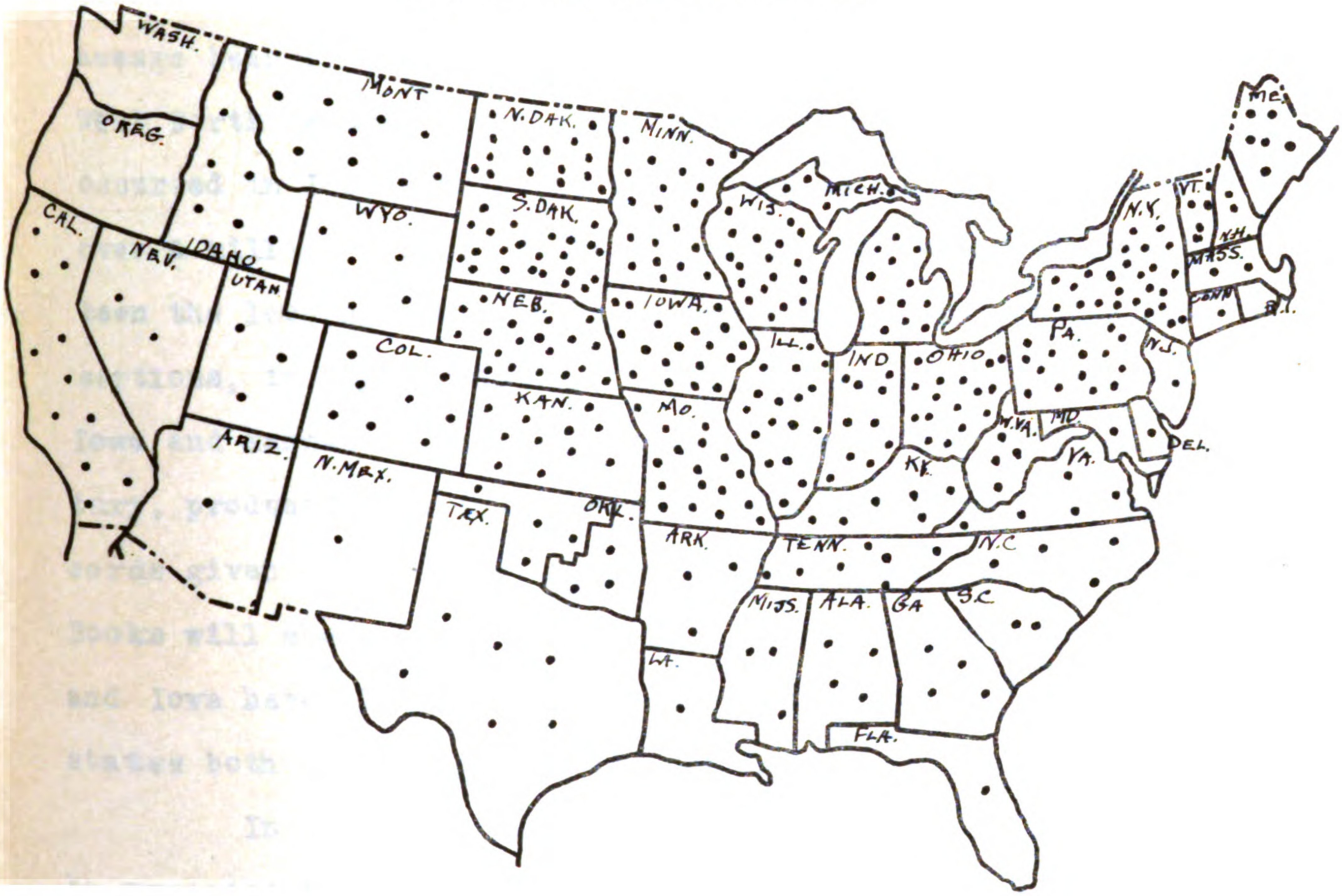

Figure I

Distribution of the Total Hay Acreage in 1923

(Each dot represents 20,000 Acres)

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show that ever since 1866, which is as far back as statistical reports go, have the five states leading in hay aceage been of the Middle Atlantic, East North Central and West North Central Divisions. The one exception to this occurred in 1866 when Maine took fifth in hay acreage with over a million acres. Since 1866 also, New York has always been the leading state in hay acreage and, with but two exceptions, in hay production. These two exceptions were Iowa and Kansas which, towards the close of the 19th Century, produced more than New York in actual tonnage as records given in the U. S. Department of Agriculture Year Books will show. Next to New York, Pennsylvania, Illinois, and Iowa have always ranked consistently high as hay growing states both in acreage and production.

In view of this regional distribution it is only to be expected that the leading kinds of hay grown on these acreages will be those that are especially adapted to the climatic and soil conditions of these regions, and it is interesting to note just to what extent each kind of hay is grown. The hay crop most extensively grown in the United States, as shown in Figure 2, is timothy and clover mixed which occupies an area of 15,596,000 acres or 20.7% of the entire hay crop. 20.6% of the total hay acreage is devoted to growing wild hay. 14.5% is given over to timothy production and on only 13.2% of the acreage do we grow alfalfa hay. This condition exists in spite of the well-known

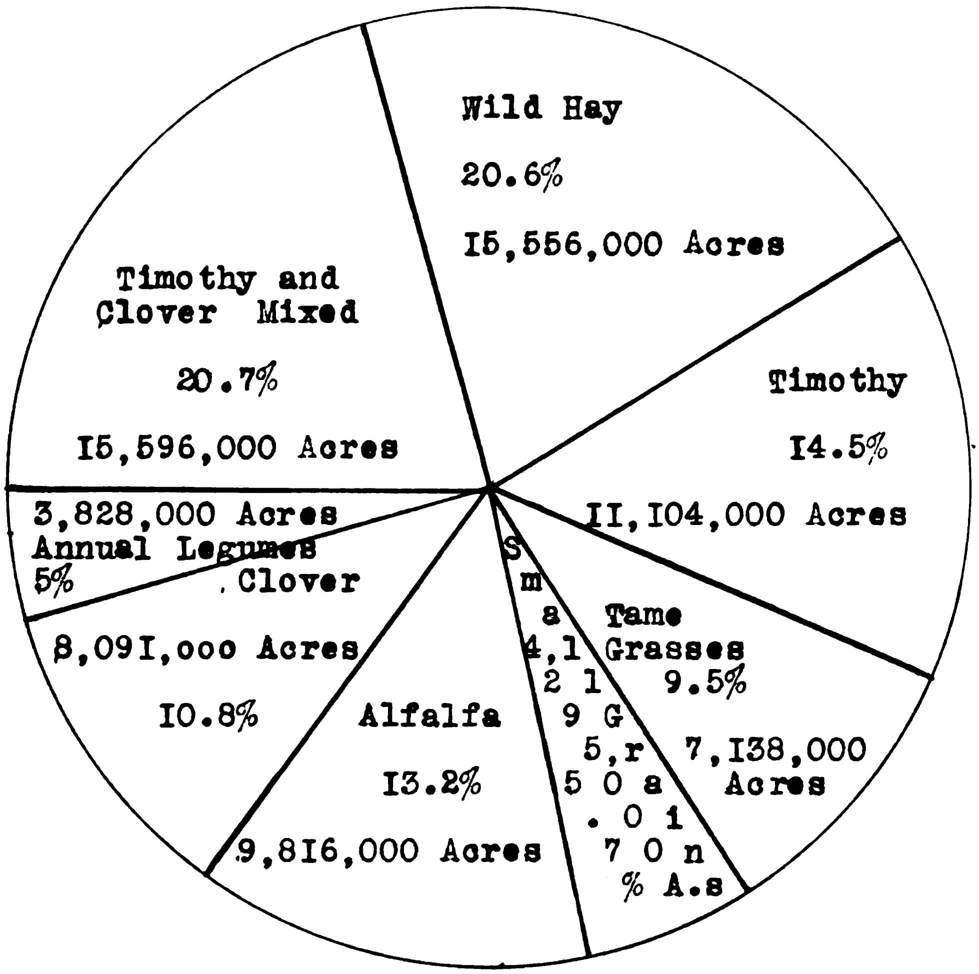
Figure 2

Composition of the United States Hay Crop

in 1923

Total Acreage

75,424,000 Acres



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fact that Alfalfa produces as much as 489 pounds of digestible protein to the acre, timothy and clover mixed hay only 116 pounds, wild hay no more than 88 pounds, and timothy, of which over 11 million acres are grown, merely 75 pounds of digestible protein to the acre. Yet with this large acreage, timothy yields less than ½ the tonnage that alfalfa produces annually and can maintain only less than a third as many live stock units as alfalfa does with its comparatively small acreage. The value of an increased alfalfa acreage is only too apparent.

The various types of forage crops grown for hay making purposes are conveniently divided into the following 8 classes or kinds: alfalfa, timothy, timothy and clover mixed, clover, wild and prairie hay, miscellaneous grasses, small grains cut green, and annual legumes.

[2] Alfalfa covers an acreage as reported for 1923, and, as already indicated, of over 9 million acres. However, because of its large yields and high feeding value it ranks first among the forage crops used for hay. The large alfalfa acreages, as shown in Figure 3, are in the North West Central, Mountain, and Pacific states which have always been the leading states in this regard.

The 18 states that make up these geographic divisions together have an alfalfa acreage of 8 million acres which is 81.6% of the entire acreage devoted to alfalfa growing in this country.

The three leading states in alfalfa production are Nebraska with 1, 163,000 acres, California with 981,000

Map of the United States

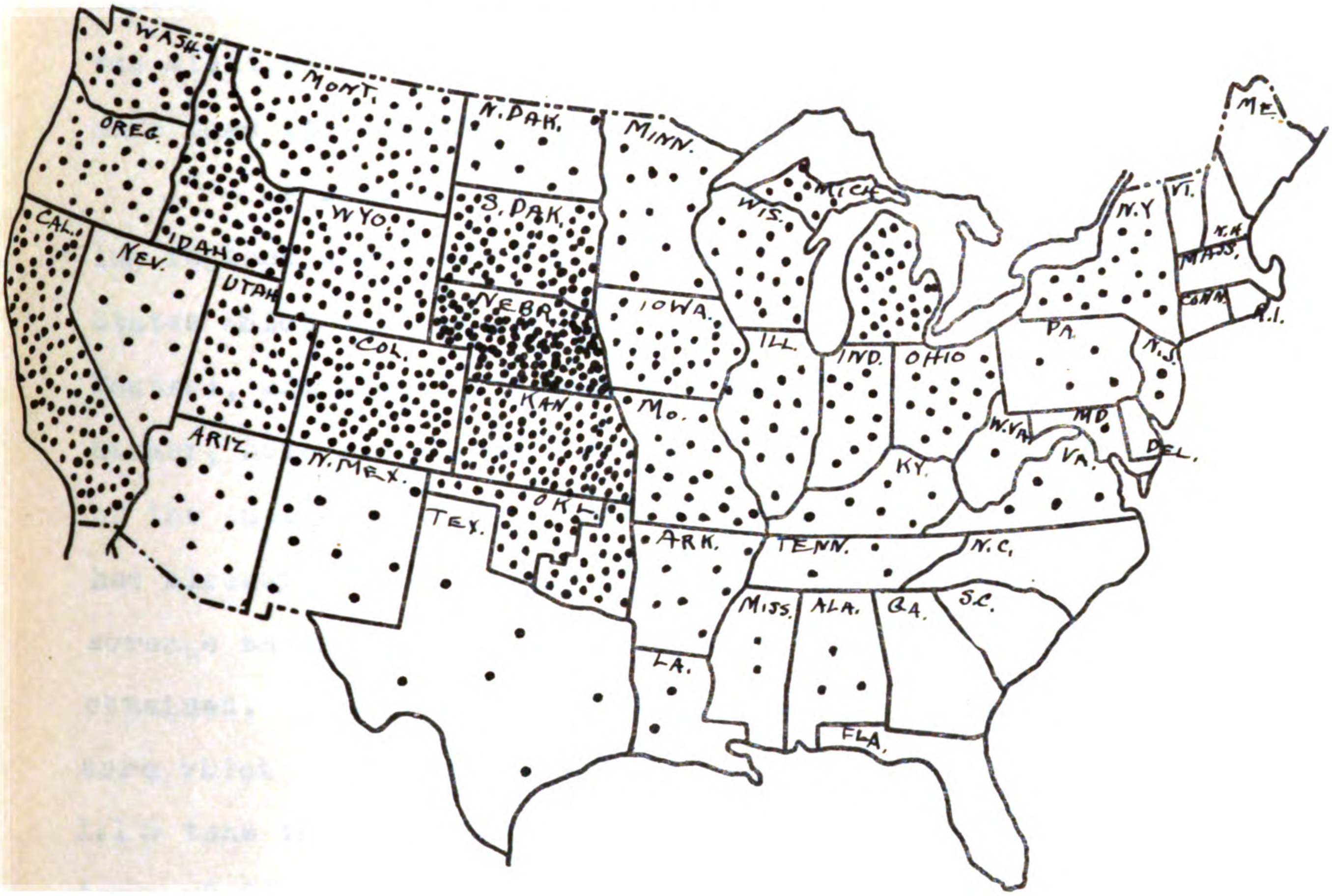

Figure 3

Distribution of the Alfalfa Hay Acreage in 1923

(Each dot represents 20,000 Acres)

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acres, and Kansas with 885,000 acres as reported for 1923. During the same year the leading alfalfa state of the east was Michigan with an acreage of 338,000 acres, 100,000 acres more than its nearest competitor for that year, Iowa.

As illustrated in Figure 4, the large timothy growing regions are located in the Northeastern ¼ of the United States which includes the North East Central, North West Central, and Middle Atlantic states. These states, 15 in number, have a combined acreage of 9,479,000 acres or 86% of the entire timothy acreage of the country. Attention has already been called to the fact that with this large acreage an annual production of only 12,776,000 tons is obtained. This, of course, is due to the low yield per acre which for timothy throughout the United States was 1.15 tons in 1923, whereas, for alfalfa it was almost 3 tons, 2.65 tons to be exact. The four states which in 1923 produced over a million acres of timothy are New York with 1,313,000 acres, Ohio with 1,310,000 acres, Missouri with 1,142,000 acres, and Illinois with 1,004,000 acres.

As with timothy, almost all of the 15,596,000 acres devoted to the growing of clover and timothy mixed hay are located in the northeastern one quarter of the United States. More specifically, the acreage centers itself in the Middle Atlantic states, North Central states, Minnesota, Iowa, and Missouri, as shown in Figure 5. These states with a combined acreage of 11,

Map of the United States

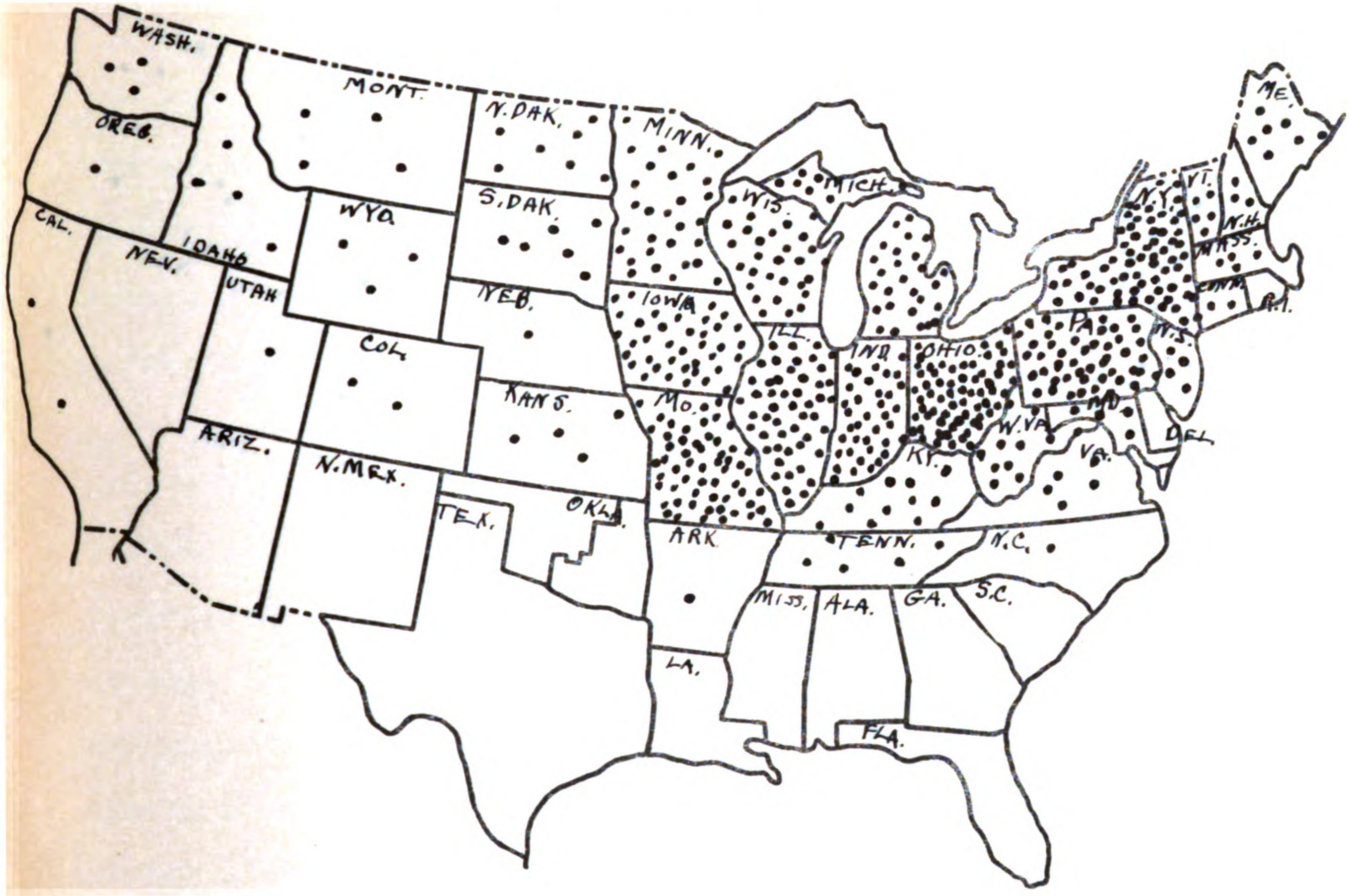

Figure 4

Distribution of the Timothy Hay Acreage in 1923

(Each dot represents 20,000 Acres)

Map of the United States

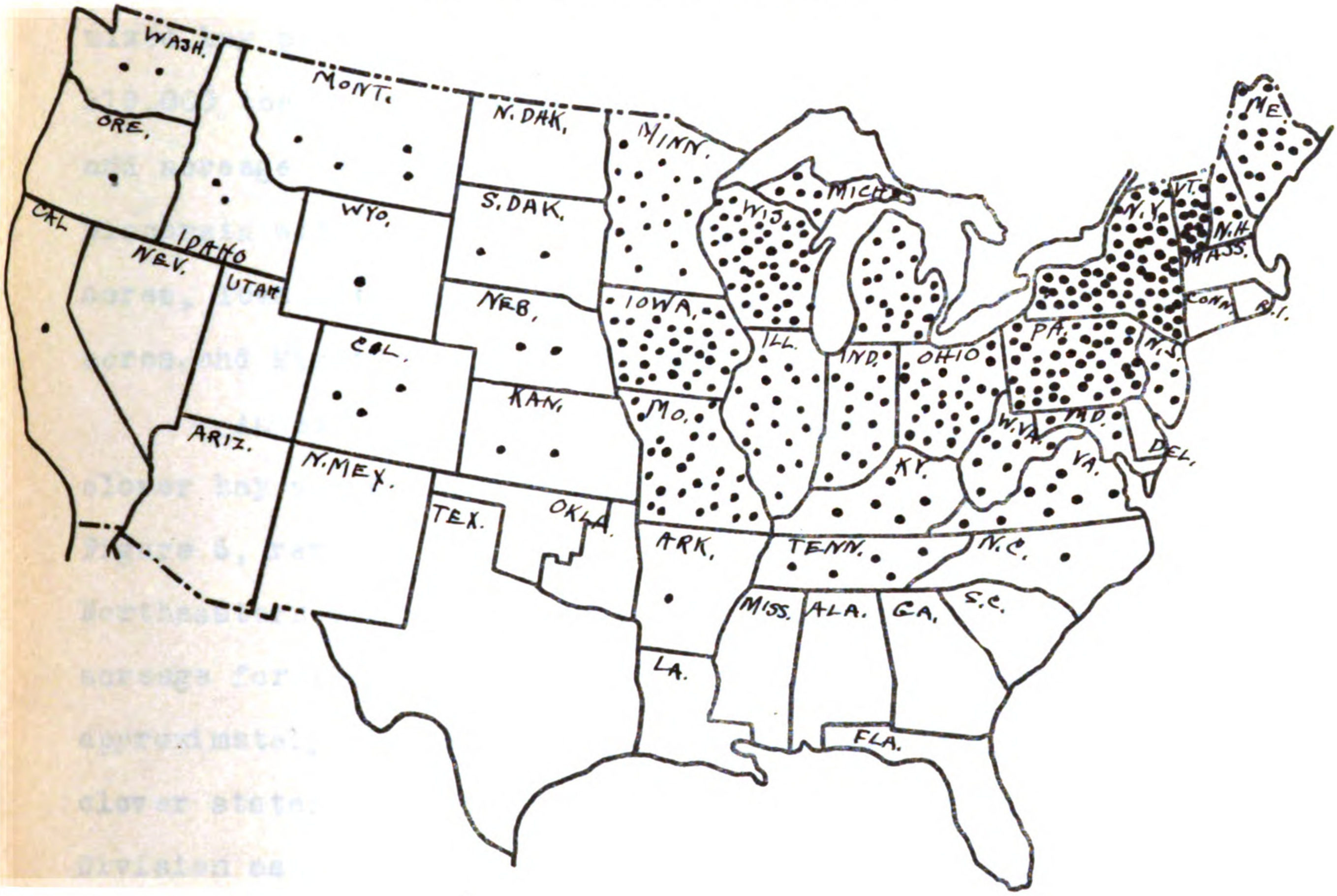

Figure 5

Distribution of the Clover and Timothy Mixed

Hay Acreage in 1923

(Each dot represents 40,000 Acres)

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Wisconsin with 1,62

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819,000 acres grow 73.3% of all the timothy and clover mixed hay produced in this country or approximately 14, 819,000 tons. The states that are high in the production and acreage of this hay are New York with 2,256,000 acres, Wisconsin with 1,625,000 acres, Pennsylvania with 1,560,000 acres, Iowa with 1,240,000 acres, Michigan with 1,123,000 acres, and Missouri with 1,002,000 acres.

An examination of graphic representation of the clover hay acreage distribution in the U. S., given in Figure 6, reveals another hay crop grown primarily in the Northeastern one quarter of the United States. The entire acreage for 1923 was 8,091,000 acres with a production of approximately 10,789,000 tons of hay. The outstanding clover states are those located in the North East Central Division as Ohio, Indiana, Illinois, Michigan, Wisconsin, as well as Iowa, Missouri and New York. Michigan during 1923 lead the other states in clover hay acreage with 808,000 acres and Iowa was second with 801,000 acres leading in the production of this hay with 1,153,000 tons. Ohio came third with 780,000 acres, Illinois fourth with 773,000 acres and Wisconsin fifth with 668,000 acres.

The term clover hay, as referred to here, means not only hay made from red and alsike clover but also that prepared from crimson clover, bur clover, sweet clover, and lespedeza. It is estimated that 65% of the clover hay

Map of the United States

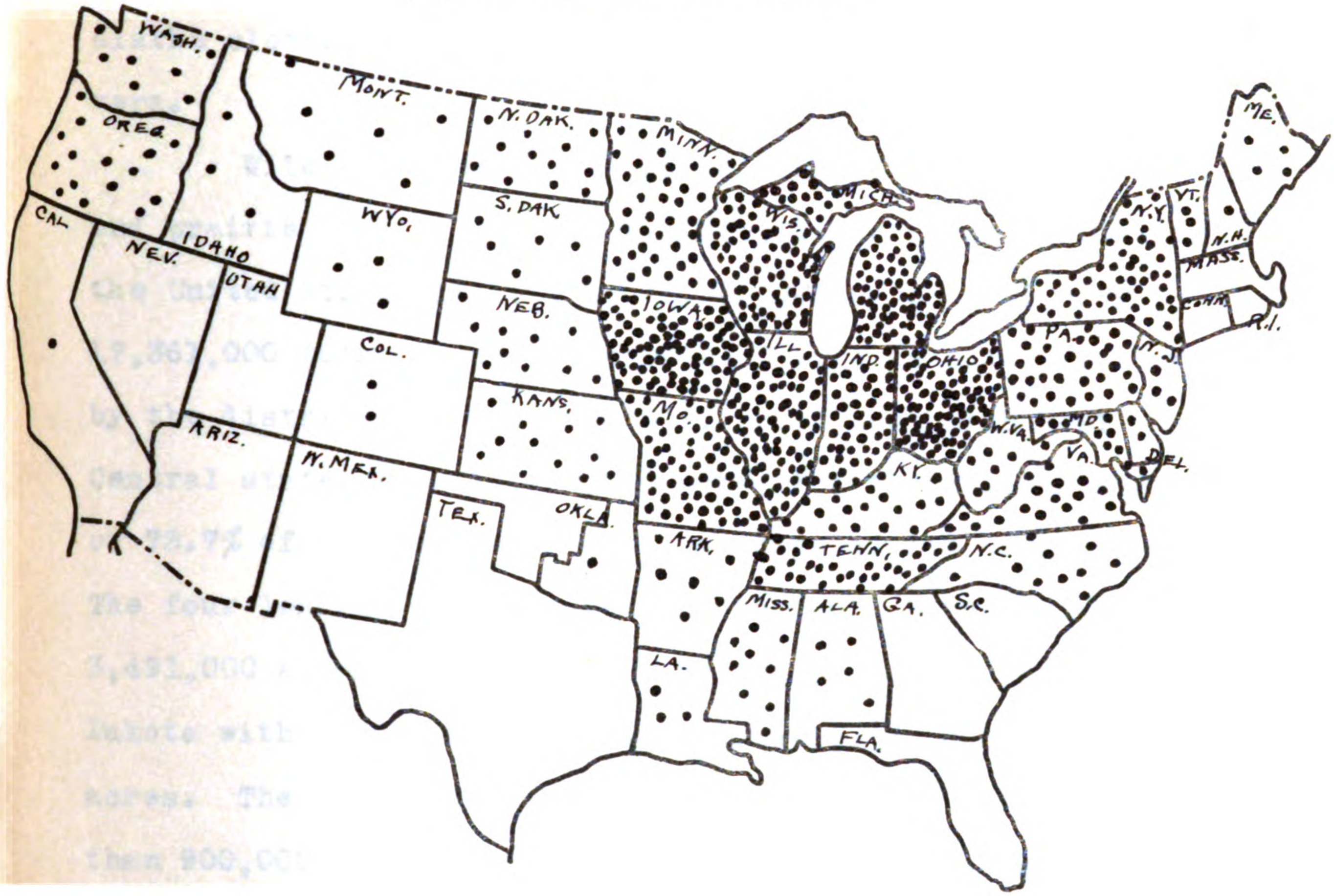

Figure 6

Distribution of the Clover Hay Acreage in 1923

(Each dot represents 10,000 Acres)

grown in the main clover area is red clover, 30 per cent is alsike clover, and 15 per cent is made up of the other clovers.

Wild and prairie hay sometimes quoted as wild, salt, and prairie hay, or merely wild hay, occupied an acreage in the United States in 1923 of 15,556,000 acres producing 17,361,000 tons of hay. The bulk of this acreage, as shown by the distribution map Figure 7, is in the North West Central states with 11,468,000 acres for these seven states or 73.7% of the entire wild hay acreage of the country. The four leading wild hay states are South Dakota with 3,491,000 acres, Nebraska with 2,296,000 acres, North Dakota with 2,222,000 acres and Minnesota with 2,041,000 acres. The next nearest competitor is Kansas with less than 900,000 acres showing that the four states just mentioned bear the brunt of the production of the wild, salt, and prairie hay of this country. The grasses that come into this wild hay classification are of many kinds.[3] Blue joint, blue stem, Indian grass and switch grass are common to the eastern part of this hay region, while western wheat grass, slender wheat grass, and side-oats grama predominate in the western part with bunch wheat grass and Nevada blue grass in the Rocky Mountain area, and wild oats in California. The production of tame hay, next to wild hay in importance, is rather evenly distributed throughout this country. As indicated by Figure 8

Map of the United States

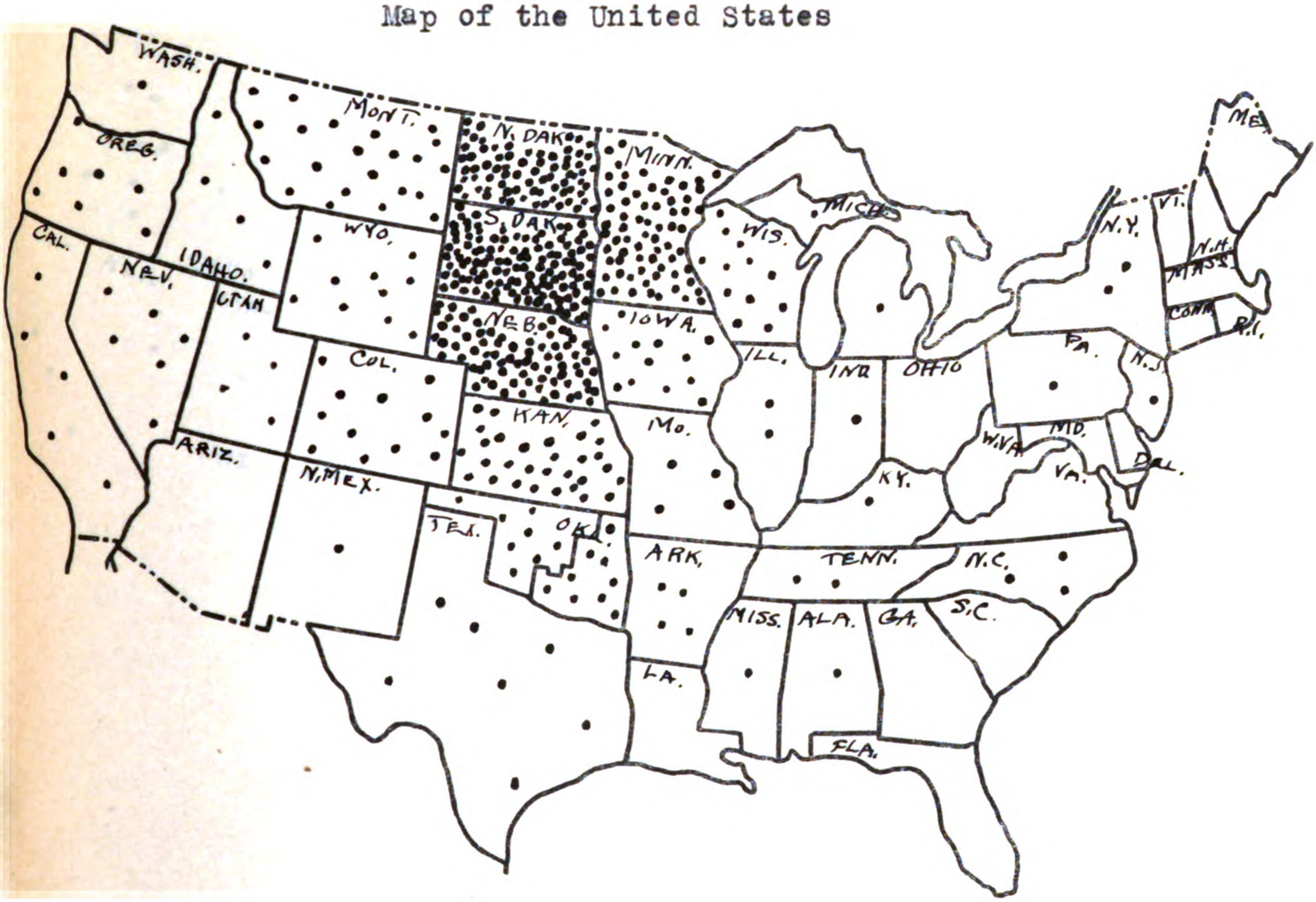

Figure 7

Distribution of the Wild Hay Acreage in 1923

(Each dot represents 30,000 Acres)

Map of the United States

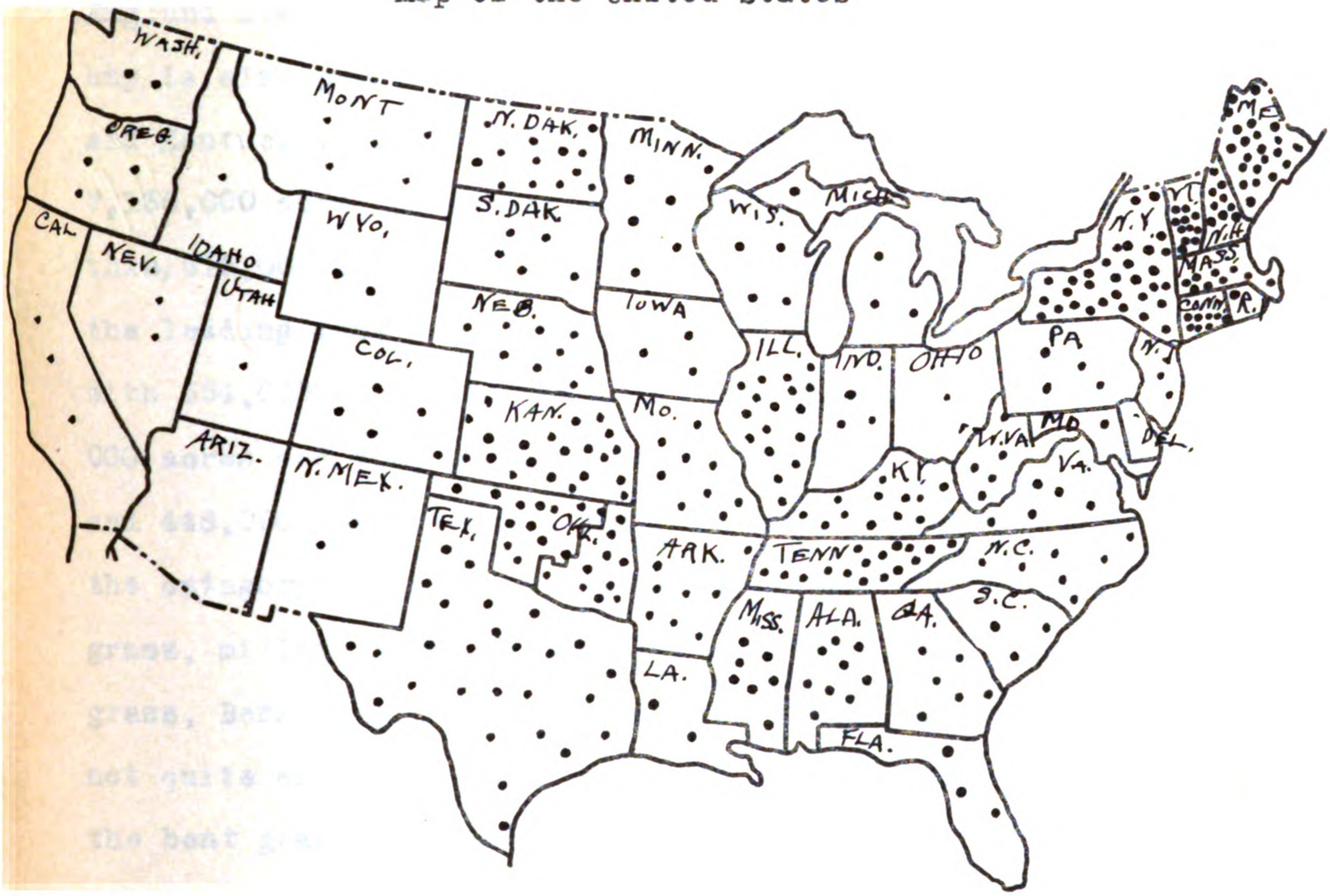

Figure 8

Distribution of the Miscellaneous Tame Hay

Acreage in 1923

(Each dot represents 20,000 Acres)

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the area of heaviest production is located in the New England States and Eastern New York. Considerable tame hay is also produced in southeastern Illinois, Tennessee, and Kentucky. The total tame hay acreage in 1923 was 7,138,000 acres producing 9,566,000 tons of hay. Of this, 615,000 acres with 510,000 tons placed New York as the leading tame hay state. Next in order were Texas with 554,000 acres and 877,000 tons, Oklahoma with 468,000 acres and 782,000 tons, and Maine with 435,000 acres and 448,000 tons of hay. The main grasses coming under the catagory of tame hay grasses are: red top, orchard grass, millet, Kentucky blue grass, Sudan grass, crab grass, Bermuda grass, Johnson grass and other grasses not quite as well known. Red top, orchard grass, and the bent grasses appear mainly in the New England and Middle Atlantic States with red top particularly in southern Indiana and Illinois. Johnson grass, crab grass, and Bermuda grass are the principal tame hay grasses for the South Atlantic States, the Gulf States, and Texas. Millet and Sudan grass are the leading ones in the Great Plains and Prairie States, while blue grass and orchard grass occupy most of the tame hay acreage in Kentucky, Tennessee, Virginia, and West Virginia.

The largest acreage of grains cut green for hay occurs in three states, viz. California, Oregon, and Washington, as indicated in Figure 9. These three states with a combined acreage of 1,833,000 acres produce as much as

Map of the United States

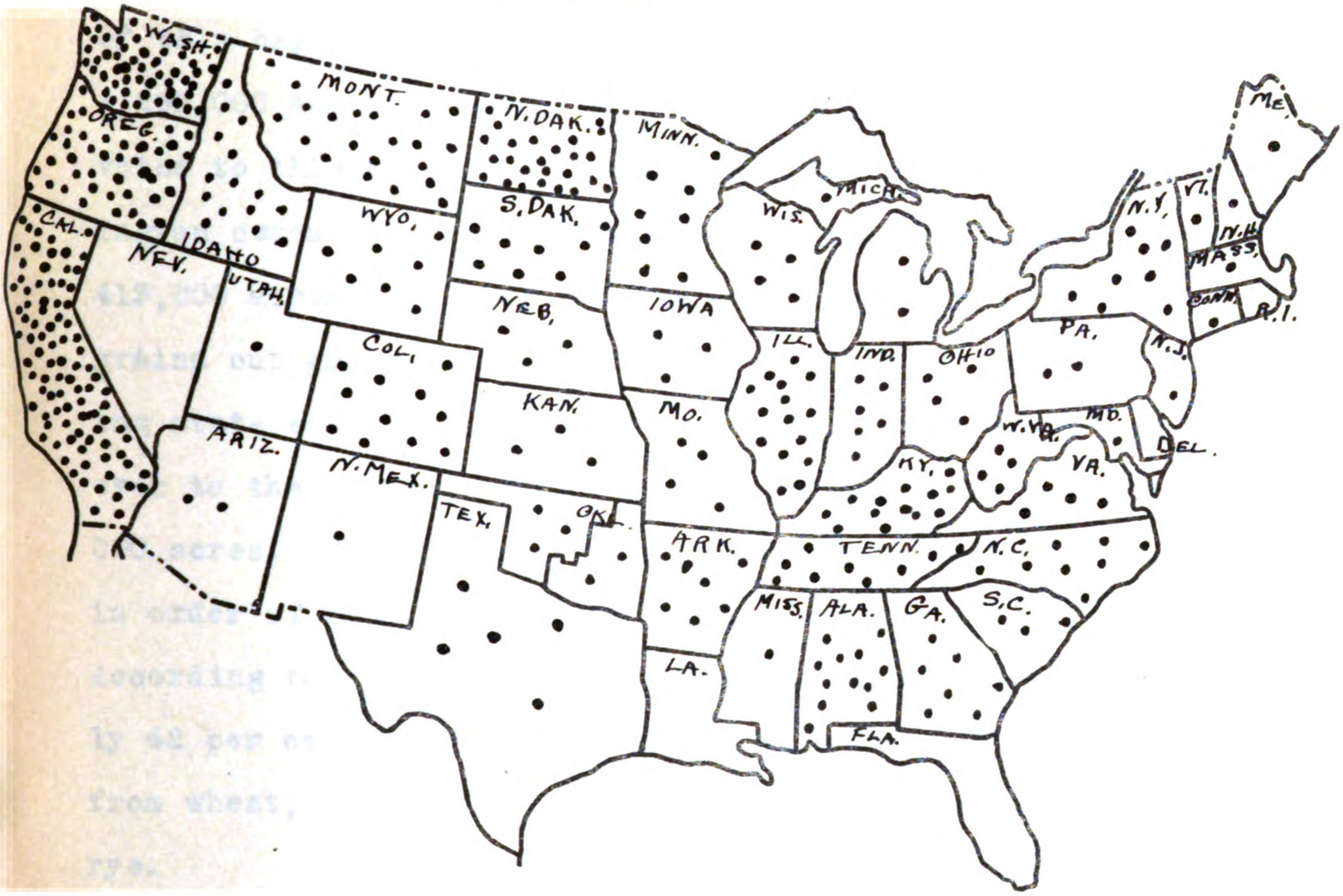

Figure 9

Distribution of the Grains Cut Green for Hay

Acreage in 1923

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2,780,000 tons of hay or 47.3% of the nation's crop of grains cut green for hay. The total crop for the country of this hay amounted in 1923 to 5,876,000 tons, grown on 4,295,000 acres of land. The state leading in acreage devoted to this hay is California with 930,000 acres, Washington comes next with 490,000 acres, and Oregon third with 413,000 acres. To show the comparative insignificance of grains cut green for hay in Eastern United States the leading state east of the Mississippi river in acreage given over to the growing of this hay is Indiana with only 947,000 acres. The grains grown for hay making purposes are, in order of importance, oats, wheat, rye and barley. According to estimations that have been made, approximately 42 per cent of the grain hay is from oats, 31 per cent from wheat, 24 per cent from barley, and 3 per cent from rye.

The remaining hay acreage, 3,828,000 acres, is given over to the growing of 4,037,000 tons of hay prepared from annual legumes, which constitute the eighth hay class. This production, as shown in Figure 10, centers in the Southeastern one quarter of the United States which includes the South Atlantic and East South Central States. The highest ranking state in point of annual legume hay acreage is Georgia with 562,000 acres. Alabama is second with 404,000 acres and North Carolina is third with 386,000 acres closeely followed by South Carolina with 339,000 acres. The principle annual legumes grown for hay are cowpeas, soybeans,

Map of the United States

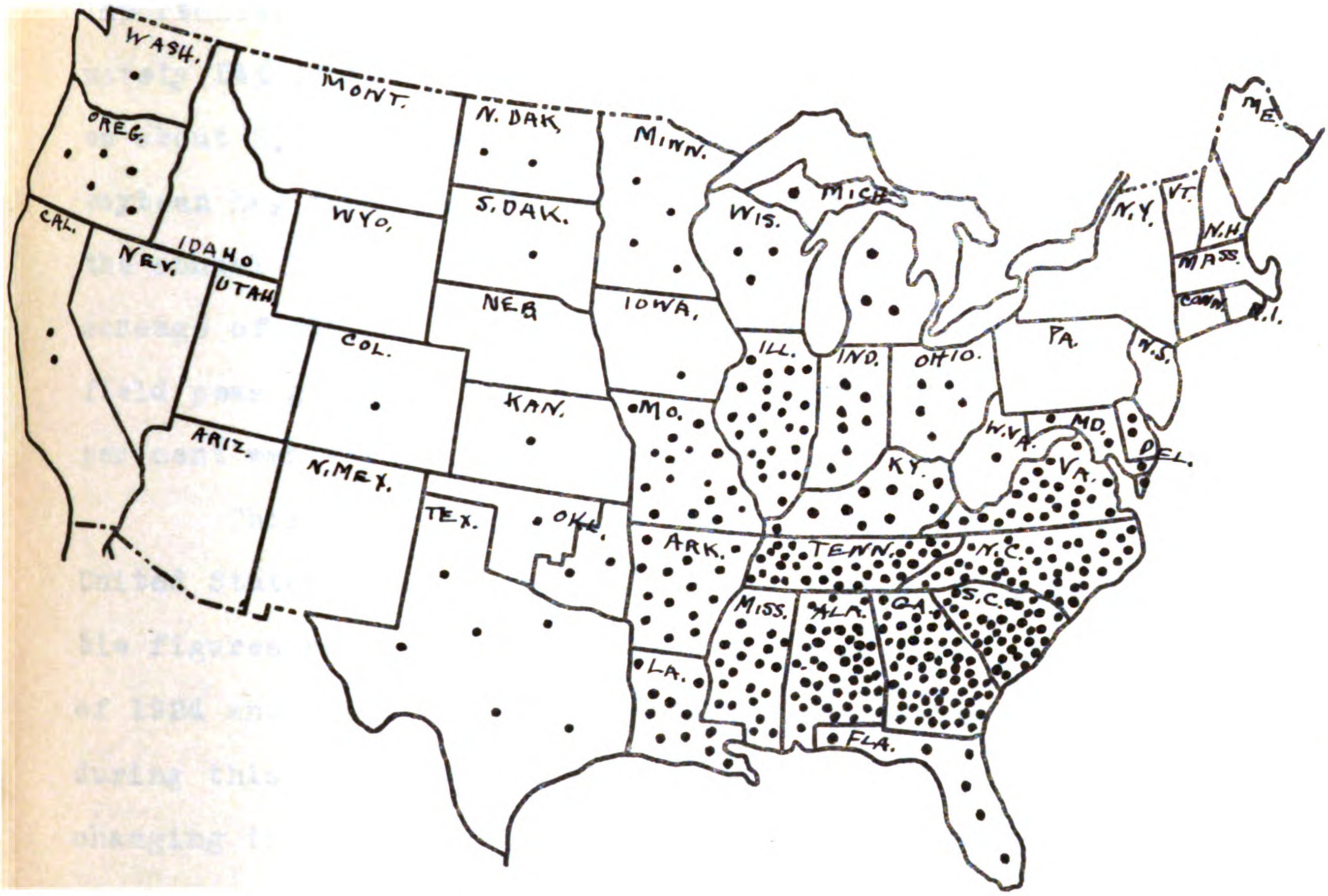

Figure IO

Distribition of the Annual Legume Hay Acreage

in I923

(Each dot represents IO,000 Acres)

field peas, peanuts, and vetch, named in order of their importance. Available figures show that in 1923 approximately 54% of the annual legume hay was Cowpea hay grown on about 2,065,000 acres. For the same year 21% was soybean hay from 794,000 acres. In 1919 8.7 per cent of the annual legume hay came from peanuts on an estimated acreage of 307,000 acres, 1.7 per cent was prepared from field peas grown for hay on about 60,000 acres, and .8 per cent was vetch hay from about 30,000 acres.

This in brief presents the hay situation in the United States as it approximately was during 1923, reliable figures not being available for the more recent years of 1924 and 1925. However, whatever changes have occurred during this time have had little, if any, effect upon changing the relative position and importance of the various crops reported upon. Figures used have been taken from the Agricultural year books of the United States Department of Agriculture, particularly the year book issued in 1924, and from the United States Department of Agriculture Statistical Bulletin Number 11 of April, 1925.

Distribution of Hay in Michigan.

The importance of hay production in the United States as a whole has already been alluded to. It has been pointed out that the hay crop is one of the leading agricultural crops of the country and second only to corn.

In the state of Michigan the hay crop occupies an even more significant position than in the United States at large. In Michigan hay is the greatest of any crop grown in the state and is second to no other. In 1924 more than 1/3 of the total area devoted to agricultural crops in this state was given over to the production of hay, yielding more than 5 million tons and valued at over 60 million dollars. The importance of the hay crop is only too apparent. Nor let it be forgotten that during the same year Michigan stood fifth among the highest hay producing states of the Union and at present is the leading alfalfa state east of the Mississippi River without exception.

The increase of hay production in Michigan has kept pace during the last 50 to 60 years with the advance and expansion of all agriculture of the state. During the past half century the acreage of hay has tripled itself from 937,661 acres in 1866, to 3,000,000 acres in 1925. At the same time the annual value of the crop has increased by over 500%, from eleven and a half million dollars in 1866 to over sixty millions in 1925.

A study of Table 2

Table 2.

Tame Hay Production in Michigan.

1866--1925 Inclusive.

	Acres	Tons	Dollars
1966	937,661	1,219,000	11,656,000
1867	1,059,230	1,377,000	15,925,000
1868	1,178,400	1,473,000	16,440,000
1869	1,033,333	1,550,000	15,721,000
1870	1,082,352	1,472,000	14,760,000
1871	919,642	1,030,000	16,052,000
1872	981,308	1,050,000	11,402,000
1873	885,652	1,018,000	13,130,000
1874	916,600	917,000	12,894,000
1875	1,016,868	1,220,000	15,423,000
1876	1,057,692	1,375,000	12,603,000
1877	878,788	1,160,000	9,704,000
1878	882,000	1,155,000	9,790,000
1879	662,951	809,000	10,159,000
1880	563,882	801,000	9,849,000
1881	1,151,473	1,324,000	17,413,000
1882	1,243,591	1,457,000	17,115,000
1883	1,280,899	1,768,000	16,439,000
1884	1,243,591	1,741,000	16,975,000
1885	1,256,027	1,507,000	16,142,000
1886	1,419,311	1,643,000	15,607,000
1887	1,433,504	1,720,000	18,578,000
1888	1,404,834	1,545,000	17,308,000

Table 2 Cont'd.

	Acres	Tons	Dollars
1889	2,024,736	2,385,000	19,081,000
1890	1,306,834	1,634,000	13,068,000
1891	1,319,902	1,518,000	16,697,000
1892	1,280,305	1,536,000	12,965,000
1893	1,280,305	1,869,000	17,122,000
1894	1,702,806	2,043,000	18,472,000
1895	1,243,048	721,000	9,437,000
1896	1,330,061	1,543,000	13,084,000
1897	1,409,865	2,101,000	16,280,000
1898	1,423,964	1,937,000	13,847,000
1899	1,352,766	1,650,000	14,028,000
1900	1,339,238	1,728,000	16,326,000
1901	2,215,724	2,792,000	24,038,000
1902	2,193,567	3,181,000	26,400,000
1903	2,215,503	3,035,000	27,105,000
1904	2,126,883	2,659,000	24,167,000
1905	2,084,345	3,043,000	23,432,000
1906	2,650,000	3,392,000	35,107,000
1907	2,597,000	3,246,000	40,575,000
1908	2,727,000	3,954,000	34,598,000
1909	2,592,000	3,207,000	36,560,000
1910	2,560,000	3,328,000	45,261,000
1911	2,395,000	2,778,000	47,226,000
1912	2,395,000	3,185,000	40,450,000
1913	2,400,000	3,520,000	33,012,000

Table 2 Cont'd.

	Acres	Tons	Dollars
1914	2,352,000	3,011,000	36,132,000
1915	2,470,000	3,458,000	42,188,000
1916	2,750,000	4,675,000	46,750,000
1917	2,558,000	3,837,000	65,996,000
1918	2,598,000	2,676,000	62,886,000
1919	2,817,000	3,380,000	75,092,000
1920	2,789,000	3,347,000	70,287,000
1921	2,873,000	2,873,000	37,349,000
1922	3,074,000	4,457,000	45,016,000
1923	3,105,000	3,912,033	56,724,000
1924	3,198,000	5,010,008	60,621,000
1925	3,006,000	2,971,000	49,022,000

giving the annual acreage, production, and value of tame hay in Michigan since 1866, reveals quite clearly, as summarized in Table 11, how the crop has been steadily increasing in prominence since that year. The increase has been quite gradual with the acreage hovering about the million mark up to the beginning of the twentieth century. Similarly the production in tons remained at about the million mark, and the value at an average of about 15 million dollars for the first 34 years from 1866 to 1900. There seems to have been a slight slump in the hay industry from 1870 to 1880 the acreage falling as low as 563,882 acres in 1880 with a production valued at less than 10 million dollars. The condition, however, had readjusted itself the following year, in 1861, with the average acreage, yield, and value. In 1901 acreage and tonnage jumped up to over 2 million and the value to about 24 million dollars. This remained the average for about five years when the increase again became noticeable bringing the acreage up to over 2½ million acres in 1910, with a production of over 3 million tons and a value exceeding 45 million dollars. In 1920, because of high prices, the hay crop for that year was valued far in excess of what it had been in previous years or has been since. With an acreage of 2,789,000 acres a crop of 3,347,000 tons was produced valued at over 70 million dollars. Further advance in acreage and production came about 4 years ago, when in 1922 over 3 million acres were

SHOWING THE ACREAGE, PRODUCTION, AND

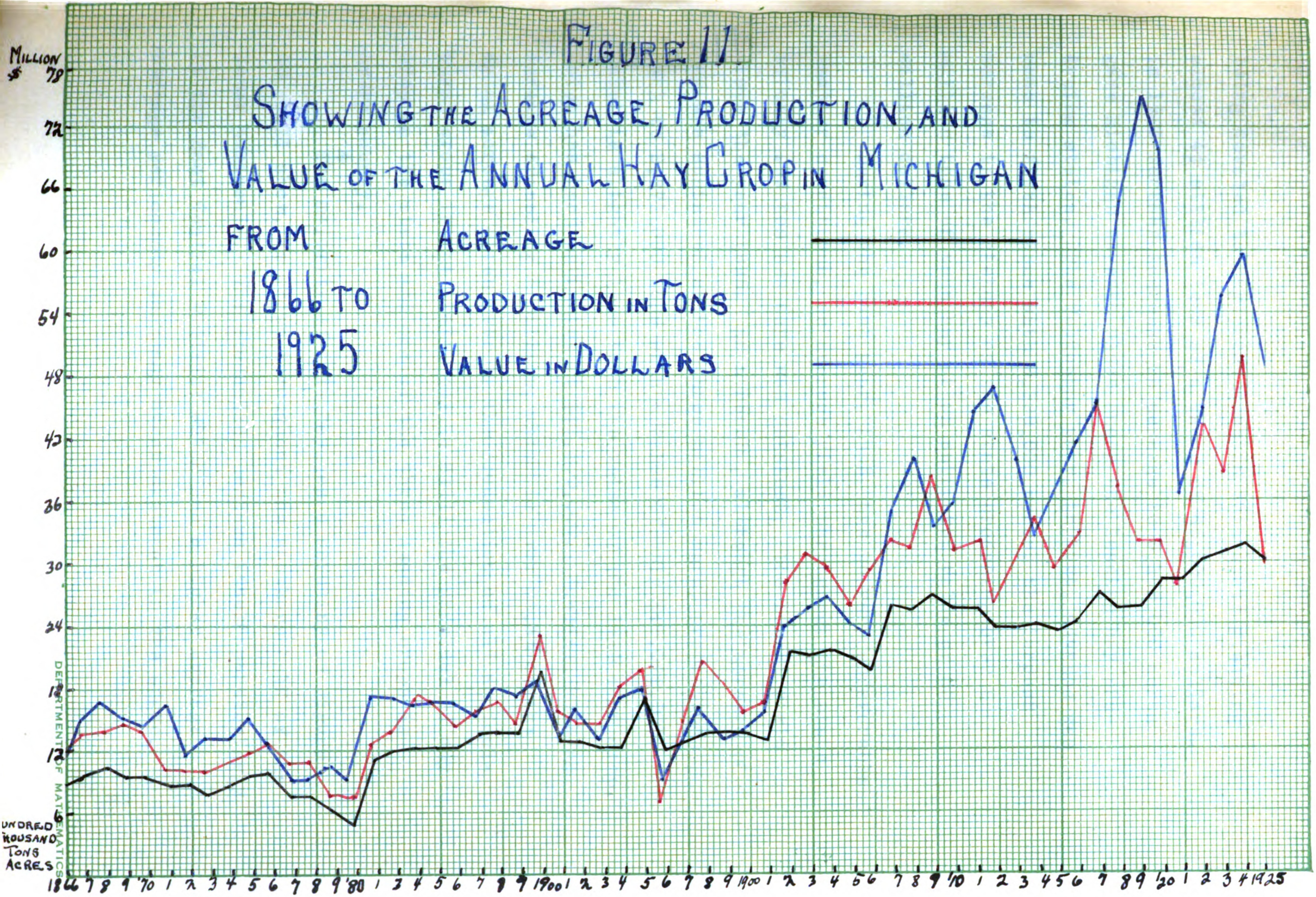
FIGURE 11
SHOWING THE ACREAGE, PRODUCTION, AND VALUE OF THE ANNUAL HAY CROP IN MICHIGAN
FROM 1866 TO 1925
ACREAGE
PRODUCTION IN TONS
VALUE IN DOLLARS
MILLION $
HUNDRED THOUSAND TONS ACRES
78
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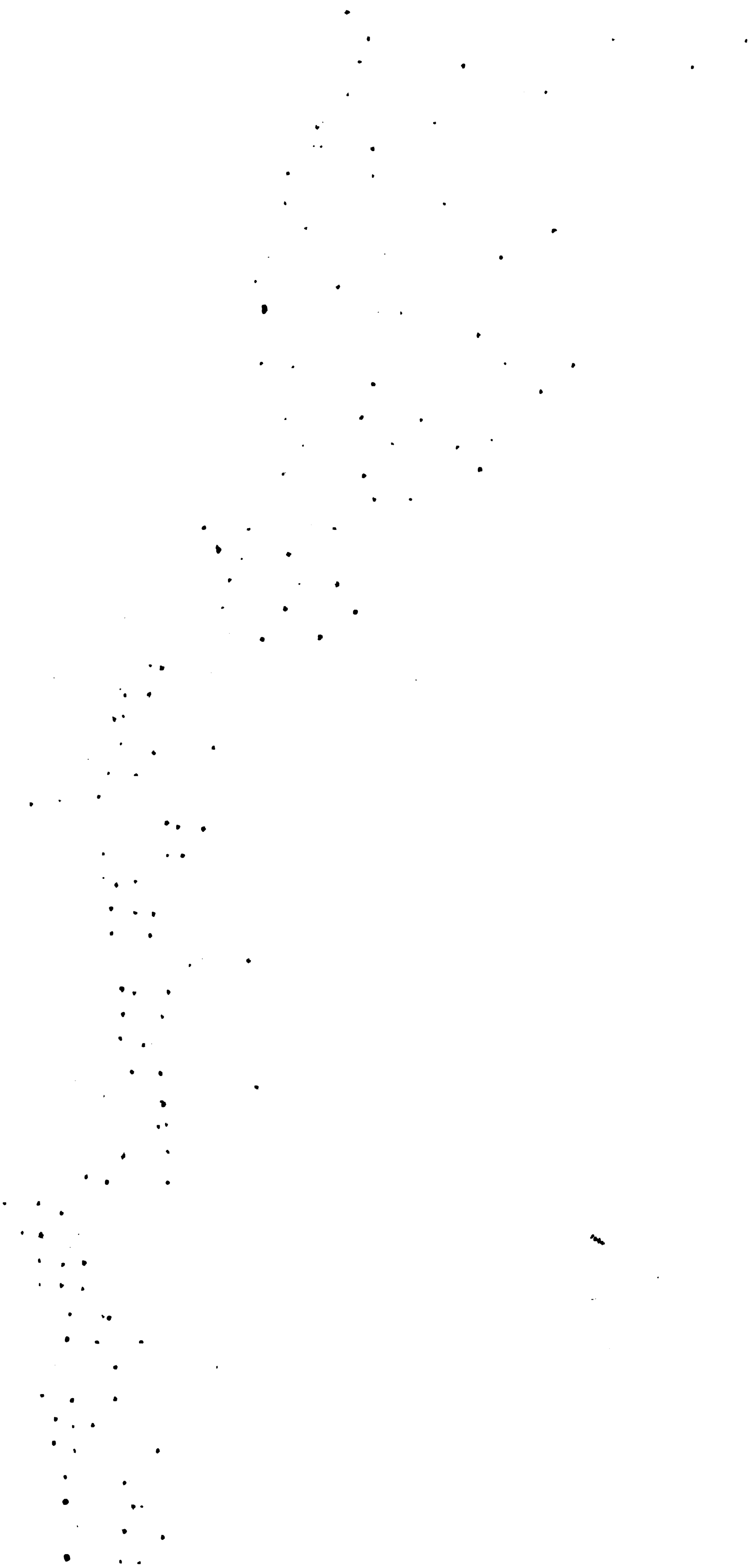
MICHIGAN AGRICULTURAL COLLEGE
DEPARTMENT OF MATHEMATICS



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being devoted to hay production in this state yielding almost 4½ million tons at a value of 45,000,000 dollars. In 1923 further increase in acreage to 3,105,000 acres gave Michigan seventh place among the leading hay producing states. The following year, in 1924, advance was made to fifth place with 3,198,000 acres, the largest acreage in the history of the state producing over 5 million tons of tame hay at an estimated value of 60 million dollars.

During the past year, 1925, due to very unfavorable weather conditions, an average yield throughout the state of only .99 ton per acre was obtained, the lowest yield since the year 1895. As a result, although the acreage of hay was sustained at the three million mark, production fell to 2,971,000 tons with a value of only $49,022,000 which is slightly less than the value of the 1925 corn crop, which has been estimated at $49,260,000. However, with an acreage exceeding 3 million, which is over 35.3% of the total acreage given over to the production of all agricultural crops in the state, hay is still the greatest of any crop in the state and one of the three leading crops in every county.[4]

The majority of this hay, as a scrutiny of Figure 12, will show, is grown throughout the southern half of the lower peninsula. The production centers itself particularly in the East Central District which has a higher average acreage per county than any other district in the state,

Figure I2

Distribution of the Total Tame Hay Acreage

in Michigan in I925

(Each dot represents 2,000 Acres)

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66,850 acres per county. In addition, this district also includes Sanilac County, the leading hay producing county in the state with 146,000 acres devoted to hay growing. Next in importance as a hay producing area is the Southeast District with St. Clair the second hay leading county and with an average of 64,160 acres to the county producing hay. The other leading hay producing districts are, in order of their importance, the Southern District with an average acreage of 50,090 acres to the county, the Southwest District with an average acreage of 49,286 acres to the county, and the Central District with an average acreage of 36,975 acres to the county.

The two leading counties in point of hay acreage have already been indicated as being Sanilac and St. Clair Counties. A list of the ten leading counties given in order of significance, with their corresponding acreage for the year 1925, will show what other counties lead in producing Michigan's hay crop.

1. Sanilac---------146,000 acres
2. St. Clair-------100,400 "
3. Tenawee--------- 88,200 "
4. Huron----------- 80,000 "
5. Washtenaw------- 73,900 "
6. Kent------------ 73,300 "
7. Lapeer---------- 68,200 "
8. Hillsdale------- 65,300 "
9. Genesee--------- 65,200 "
10. Tuscola--------- 63,800 "

Reference to Figure 12 will show that all of these 10 leading counties are to be found in the four leading hay districts: East Central, Southeast, Southern, and Southwest districts.

Now, just as in the United States at large, the hay produced is not all of one kind, so also in Michigan different types of forage plants are used in hay production. In Michigan seven types or kinds of hay are recognized: Alfalfa, Clover and timothy, clover, timothy, annual legumes, grains cut green for hay, miscellaneous tame hay grasses, and wild hay.

Alfalfa is mentioned first because, although not yet leading in point of acreage, the increasing use of it has been so phenomenal that this legume soon promises to become the foremost hay crop of the state. Whereas, other hay crops such as clover, timothy, miscellaneous tame hay, grasses, and wild hay have been falling off in point of acreage, the alfalfa crop has been making amazing strides. From only 1,087 acres in 1899 the alfalfa acreage of this state has increased to 448,000 acres in 1924 and from a production of 1,366 tons in 1899 to over a million tons (1,053,000) in 1924 an increase of almost one thousand per cent. Beginning with earliest available records, figures show the alfalfa acreage and production to have been continually increasing from year to year. The first ten years of the twentieth century witnessed an increase to

6,553 acres growing alfalfa. In 1919 this had become over 74,000 acres, in 1920 it jumped to 95 thousand, in 1921 to almost 150,000 acres, and each year thereafter the increase has been approximately 100,000 acres annually bringing the total up to 448,000 acres in 1924 as indicated. Similarly, the production of alfalfa has been advancing proportionately with an annual increase of 200,000 tons of hay since 1920 reaching beyond the million mark in 1924, as shown by the following figures taken from the Agricultural Census and from the Annual Crop Report for Michigan.

Table 3.

Alfalfa Acreage and Production.

Year	Acres	Tons
1899	1,087	1,366
1909	6,553	13,872
1919	74,059	118,571
1920	95,000	218,000
1921	143,000	322,000
1922	246,000	578,000
1923	338,000	710,000
1924	448,000	1,053,000

Figure 13 gives an indication as to where most of the alfalfa in Michigan, is produced. It will be seen that the alfalfa production is mainly in the two southern-

Figure I3

Distribution of the Alfalfa Hay Acreage

in Michigan in I925

(Each dot represents I,000 Acres)

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most tiers of counties, with the Southeast, Southern and Southwest Districts leading in this respect. The Southeast District with 107,500 acres devoted to alfalfa growing has the largest acreage of all districts in the state, averaging 10,750 acres for each county of that district. The Southern District is the second leading alfalfa growing area with 77,100 acres or an average of 7,019 acres for each county. Third in importance in the Southwest District devoting 40,100 acres to alfalfa production making an average of 5,729 acres for each county. Considerable alfalfa is also grown in the Northwest District particularly in Amtrim, Grand Traverse, and Charlevoix counties; the entire district has alfalfa acreage of 34,100 acres.

Lenawee leads all other counties of the state in alfalfa hay production with 32,500 acres. The other counties competing with Lenawee for first place in alfalfa acreage are, in the order of their importance: Monroe second with 20,900 acres, Washtenaw third with 16,300 acres, Hillsdale fourth with 16,200 acres, and St. Joseph fifth with 14,900 acres.

The leading hay crop in Michigan in point of acreage, is clover and timothy mixed, 1,456,000 acres having been given over to its production in 1925. Although the acreage of this hay has been significantly large yet available figures indicate that it has been

steadily declining, shown in the accompanying table.

Table 4.

Clover and Timothy Mixed Hay Acreage and Production in Michigan.

Years	Acres	Tons
1909	1,625,229	1,991,618
1919	1,852,789	2,044,711
1920	1,436,000	1,651,000
1921	1,312,000	1,207,000
1922	1,291,000	1,782,000
1923	1,123,000	1,291,000
1924	1,150,000	1,725,000

In 1909 the clover and timothy mixed hay acreage had been 1,625,229 acres with a yield of 1,991,618 tons of hay. The advance within the next ten years increased the acreage to 1,852,789 acres and the production proportionately. From then on, however, the acreage and production decreased year after year to 1436,000 acres in 1920; 1,312,000 in 1921; 1,291,000 acres in 1922, and 1,123,000 acres in 1923 with a slight increase in 1924 to 1,150,000 acres and a production of 1,725,000 tons of hay.

A survey of the distribution of clover and timothy mixed hay in Michigan Figure 14 reveals that the main areas of production of this hay lie in general, in the Thumb and in the territory westward to Lake Michigan. The production is most intensified in the East Central District in which

Figure I4

Distribution of the Clover and Timothy Mixed Hay

Acreage in Michigan in I925

(Each dot represents 2,000 Acres)

an area of approximately 290,000 acres is given over to the production of clover and timothy mixed hay, making an average of 48,333 acres for each county. The Southeast District ranks second in this respect with an average acreage to the county of 30,100 acres. The Southern District is third in clover and timothy production with an average of 26,363 acres to each county. There is a considerable acreage of this mixed hay in certain regions of the Upper Peninsula, especially the eastern extremity where Chippewa County has about 60,000 acres seeded to this crop placing it fourth among the counties in this regard as will be seen. A consideration of the leading clover and timothy counties helps verify this acreage distribution.

Sanilac County, located in the East Central District, is the outstanding county with an approximate clover and timothy hay acreage of 107,000 acres. St. Clair County, of the Southeast District, follows with 71,000 acres, Huron County in the East Central District is third with 67,000 acres, Chippewa County in the Upper Peninsula is fourth with 60,000 acres, and Genesee of the Southeast District comes fifth with 45,000 acres devoted to this crop.

Clover hay, the second leading hay crop of Michigan, was supported in 1925 on 714,000 acres. This acreage is somewhat less than that of 1924 when a production of over a million tons (1,160,000 tons) was had on approximately 800,000 acres. This represents an increase, as shown in Table 5,

Table 5.

Clover Hay Acreage and Production in Michigan.

Year.	Acres.	Tons.
1899	225,636	264,312
1909	168,180	216,862
1919	120,299	131,517
1920	541,000	611,000
1921	584,000	526,000
1922	738,000	1,033,000
1923	808,000	953,000
1924	800,000	1,160,000

of almost 400% over the 225,636 acres that grew a clover crop of 264,312 tons in 1899. This acreage was doubled during the first twenty years and then increased further very rapidly as follows: By 1920, clover occupied 541,000 acres with a production of 611,000 tons of hay. In 1921, 584,000 acres were reached and increased to 738,000 acres in 1922 with a bumper crop of a million tons (1,033,000 tons). The highest clover acreage ever reached was 808,000 acres in 1923 though the crop was somewhat lower than the preceding year. The acreage then declined to 800,000 in 1924 and to 714,000 in 1925 as already mentioned.

Most of the clover crop, as will be seen by consulting Figure 15, is grown largely in the South Central part of the state, in the thumb district, and in the Southern

Figure I5

Distribution of the Clover Hay Acreage

in Michigan in I925

(Each dot represents 500 Acres)

tier of counties bordering Indiana and Ohio. The real clover growing section confines itself primarily to the Southern, Southeast, and East Central Districts. The Southern District placed first in 1925 with an average clover acreage per county of 6,682 acres; the Southeast District follows with an average of 6,280 acres per county; and the East Central District ranks third, in this comparison, with an average of 5750 acres to the county.

As one would expect, the five leading clover counties of 1925 are to be found in these districts. Lenawee, the leading alfalfa county, also leads the counties of Michigan in clover hay production with approximately 13,300 acres. Saginaw county comes a close second with 11,800 acres devoted to clover growing. Eaton county and Branch county both vie for third place with a reported 10,000 acres for each. Shiawassee follows closely with 9,600 acres growing clover in 1925.

The Timothy hay crop, which in 1909 was second only to timothy and clover in point of acreage, has since then fallen off very consistently, undoubtedly caused by its loss in popularity due to its proven inferiority to alfalfa and clover. At the present time timothy is fourth among the crops of the state with a reported acreage of only 355,000 acres for 1925. The highest acreage ever held by timothy and the largest crop ever

produced by it in Michigan was in 1909 when 749,563 acres were growing it, with a production of929,165 tons of hay as given in Table 6.

Table 6.

Timothy Hay Acreage and Production in Michigan.

Year.	Acres.	Tons.
1909	749,563	929,165
1919	655,784	718,012
1920	643,000	772,000
1921	655,000	603,000
1922	676,000	913,000
1923	686,000	755,000
1924	640,000	832,000

This had fallen within the next ten years to 655,784 acres in 1919 with a production of 718,012 tons. The decrease continued with 643,000 acres in 1920, but changed within the following three years from 40,000 acres to 686,000 acres in 1923. In 1924 the acreage was again reduced falling to 640,000 acres and a yield of 832,000 tons, and retreating to as low an acreage as 355,000 acres in 1925, as already indicated.

Referring to Figure 16, it will be seen that again as in the case of alfalfa, timothy and clover, and clover, the timothy hay acreage is confined largely to the Southern half of the lower peninsula of Michigan and more particu-

Figure I6

Distribution of the Timothy Hay Acreage

in Michigan in I925

(Each dot represents I,000 Acres)

larly along the eastern boundary of the state below Huron County with quite an acreage bordering Lake Michigan in Ottawa County and vicinity.

Over half of this acreage, 58% in fact, is located in three districts, the Southeast, Southwest, and East Central Districts. The Southeast is the leading timothy hay district with 101,900 acres or an average of 10,190 acres for the county. The Southwest District comes second with an average acreage per county of 19,014 acres for 1925. The East Central District follows in as third with an average of 8,650 acres per county.

Sanilac County, already mentioned as the leading timothy and clover hay county, also leads in the production of timothy with a reported acreage for 1925 of 31,800 acres. In the same manner, St. Clair takes second place in this comparison with 18,900 acres growing timothy just as it ranks second in timothy and clover growing. Ottawa county comes third with 14,100 acres, Kent County fourth with 13,900 acres, and Lenawee fifth with 13,300 acres. It will be noticed that these five leading timothy hay counties are located in the three districts mentioned, viz: Southeast, Southwest, and East Central Districts.

The fifth hay crop of importance is the miscellaneous tame hay crop which includes primarily such grasses as Millet, Sudan grass, red top and orchard grass as will be seen from Table 7.

Table 7.

Miscellaneous Tame Hay Acreage and Production in Michigan.

Year	Acres	Tons
1899	1,926,131	2,167,808
1909	22,908	26,760
1919	47,931	50,581
1920	40,000	47,000
1921	81,000	106,000
1922	83,000	102,000
1923	87,000	122,000
1924	96,000	144,000

The miscellaneous tame hay grasses have been gaining in prominence ever since 1909 despite a slight drop from 96 to 54,000 acres in 1925. In 1909 the miscellaneous tame hay crop was occupying an acreage of 22,908 acres with a volume of 26,760 tons of hay. Within the following ten years, thereafter, these figures had increased by more than 200% bringing the acreage to 47,931 acres in 1919 and a production of 50,581 tons. A slight falling off in 1920 was overcome in 1921 with an acreage of 81,000 which increased to 83,000 in 1922 and 87,000 in 1923 with proportionate increases in production. In 1924 the peak was reached with 96,000 acres devoted to the growing of 144,000 tons of miscellaneous tame hay grasses. All through these years emergency hay crops, especially Millet and Sudan grass, had been gaining in popularity to a remarkable extent, explaining this consistent rise in acreage and production.

Very little of miscellaneous tame hay is grown in the Upper Peninsula with perhaps the exception of Houghton County. This acreage is rather evenly distributed throughout the lower peninsula of this state as the graphic representation of this condition, Figure I7, shows. However, the acreage is considerably heavier in Charlevoix County and vicinity, as well as further south along the Lake Michigan Coast from Mason to Berrien Counties. The heaviest producing area is the Northwest District with I4,387 acres or an average of I,438 acres to the county given over to producing miscellaneous tame hay grasses.

The West Central District is second in this regard with an average of I,I2I acres to the county. Closely following is the Southwest District with an average acreage per county of I,050 acres. The five counties leading in acreage of this hay crop in I925 were as follows in the order of their importance: Charlevoix with 7,849 acres; Allegan with 2,250 acres; Sanilac with I,936 acres; Houghton with I,877 acres; and Midland County with I,727 acres.

Of less importance than the miscellaneous tame hay crop is the wild hay crop composed primarily of wild, salt, and prairie hay. This crop, as figures in Table 8 show, has been gradually declining in the last

Figure I7

Distribution of the Miscellaneous Tame Hay

Acreage in Michigan in 1925

(Each dot represents 200 Acres)

Table 8

Wild Hay Acreage and Production in Michigan

Year	Acres	Tons
I899	59,5I2	69,388
I909	33,345	39,970
I9I9	49,856	57,97I
I920	50,000	64,000
I92I	55,000	60,000
I922	56,000	73,000
I923	52,000	62,000
I924	54,000	68,000
I925	4I,000	40,000

quarter century. In I925 an approximate acreage of 4I,000 acres of wild hay was reported with a yiald of about 40,000 tons. This is somewhat less than the acreage of 49,856 acres and yield of 57,97I tons obtained in I9I9, which, in turn, is considerably less than the I899 crop when 69,388 tons of wild hay were produced on 59,5I2 acres.

The acreage of this hay crop, as can be seen from Figure I8, is very evenly distributed throughout the state and more so than any preceeding crop discussed above. The one exception to this statement is Jackson County where almost 20% of all the wild hay of the state is grown. Jackson County is, therefore, the leading wild hay producing county of Michigan with a reported 8,066 acres.

Figure I8

Distribution of the Wild Hay Acreage

in Michigan in I925

(Each dot represents 200 Acres)

Next in significance in this connection, are in order of their importance, Washtenaw County with 2,666 acres, Houghton County with 2,017 acres, Ingham County with 1,840 acres, and fifth, Livingston County with 1,708 acres.

A small percentage of the hay acreage of Michigan is given over to the crop known as, grains cut green for hay. This crop occupied about 22,000 acres in 1925 and is grown somewhat more extensively in the western tier of Counties bordering Lake Michigan than elsewhere, as shown in Figure 19. In general, however, the distribution is exceedingly even, a few acres of grain being harvested green for hay in almost every county. The five counties which lead in growing grains that are cut green for hay are: Houghton County first, with a reported 1,090 acres; Manistee and Marquette Counties tieing for second and third place, with 900 acres each; Wayne county fourth with 840 acres; and Allegan county fifth with 800 acres.

Of even less significance, but still of growing importance, is the hay crop known as Annual Legumes. Although reported as occupying only 13,000 acres in 1925 this crop had reached 32,000 acres in 1924, as is to be seen from the figures given in Table 9.

Table 9.

Annual Legume Hay Acreage and Production in Michigan.

Year	Acres	Tons
1920	6,000	8,000

Figure I9

Distribution of the Acreage of Grains

Cut Green for Hay in Michigan in I925

(Each dot represents IOO Acres)

Table 9 Cont'd)

Year	Acres	Tons
1921	12,000	14,000
1922	25,000	33,000
1923	36,000	54,000
1924	32,000	51,000

The rise in use of annual legumes was almost phenomenal between the years of 1924 and 1920. During those four years the acreage increased by as high as 600% and the yield almost 700%. In 1920 Michigan was growing only 6,000 acres of annual legumes with a yield of 8,000 tons. The next year this acreage doubled itself to 12,000 acres with a 14,000 ton crop. This increase was repeated in 1923 bringing the acreage to 25,000 acres and the production to 33,000 ton. In 1923, 36,000 acres had been seeded to annual legumes and a hay crop of 54,000 tons harvested. There was a slight decline in 1924 leaving the acreage at 32,000 with a yield for that year of approximately 51,000 tons.

Thus we see that as a whole the hay crop of Michigan is gaining in importance and rising to larger acreages and higher production from year to year. Timothy, and timothy and clover are steadily declining in acreage as well as grains cut green for hay, the latter, especially, within the last two years.

Alfalfa with its phenomenal rise is largely taking the place of these decreasing acreages as are also the annual legume crop which has been making unusually large increases, the miscellaneous hay crop which has been advancing in acreage up to last year, and clover which up to 1924 was steadily increasing in acreage and production.

The leading hay county at present has been shown to be Sanilac County which is first in total tame hay production, first in clover and timothy mixed hay production, first in timothy hay production, and third in miscellaneous tame hay production. The leading alfalfa county in the state is Lenawee County which, in addition, is also first in clover production, third in production of total tame hay, and fifth in timothy growing. Jackson County leads in wild hay production, Charlevoix County in miscellaneous tame hay, and Houghton County in small grains cut green for hay. These are the counties that have been outstanding in adding to and increasing the Michigan hay acreage so that already in 1921 it was 60% greater than the acreage of any other crop and in 1924 occupied more than 1/3 of the total area devoted to agricultural crops in the state. It is a result of this that Michigan today ranks as the Fifth hay producing state of the Union and the greatest alfalfa growing state east of the Mississippi River.

Marketing.

A problem of outstanding influence in the hay industry is the marketing of this product. The average producer faces not only the difficulties confronting him in the curing of his hay, but must also give serious consideration to the details involved in the profitable disposal of whatever he wishes to sell. Familiarity with the mechanism of hay marketing means, in most cases, the difference between premium prices and only fair, or perhaps unreasonably low prices.

As a rule, the hay producing farmer is in a community where his neighbors are in the same business as himself. His market, therefore, is outside of and beyond this territory and the consumers, as a result, so distant that it is impractical for him to deal with them directly. The producer, consequently, turns to such men who, figuratively, bring the market to him. They are men who make a business of buying and selling hay and who can be classified as either country shippers, foreign speculators, outside buyers, or track buyers.[5]

In regions where farms are comparatively small and hay is produced in somewhat limited quantities, as from one half to four or five carloads per farm, the country shipper is most important. In many cases he is also the local grain shipper or perhaps the cattle buyer. His service is a very valuable one in that he provides a cash market for the farmer's hay, thereby relieving the farmer of the responsibility of finding a market. To serve this valuable function the country shipper must have his own warehouse, a reasonably large capital, and a knowledge of the profession. If he is in a minor section, he may handle on an average of from 10 to 15 carloads annually. If, however, he is in a hay producing area, he may handle from 100 to 500 carloads of hay per year. The size of his warehouse, therefore, depends naturally upon the quantity of hay that passes through his hands. The need of a warehouse is paramount. It enables the shipper to grade his hay and load the cars uniformly. True, the expense of this grading and reloading may range from $1.00 to $1.50 per ton, but it insures a reliable business and enables the shipper to satisfactorily fill orders as they come in with little confusion or loss of time. The practice of grading hay at the warehouse also tends to do away with "plugging of cars", that is, mixing poor quality of hay with high grade hay.

The annual turnover will also quite largely determine the amount of capital that the shipper requires. With a fairly large business and good shipping facilities from $3,000.00 to $5,000.00 is usually sufficient capital. This figure is no larger because of the fact that banks will usually advance 80% of the value of drafts held against shipments of hay. The necessity for this provision becomes apparent when it is remembered that the country shipper usually pays cash to the producer when delivery is made at the warehouse, but himself must wait a long period before he has the money returned to him when settlement is made with those who buy from him.

In addition to the capital and warehouse, the shipper must have the knowledge of what grades of hay are in demand and in what way these grades are interpreted on the market. Then too, he must be familiar with the finances and honesty of those who purchase from him. Endowed with these three qualifications, the country shipper can be of service to the producer and of profit to himself.

Occasionally the hay producer feels an urge to do business with foreign speculators. These are men who contract for hay at prices higher than those offered by the country shipper on the assumption that there will be a future rise in prices. This is well and good if market prices advance, for then the speculators live up to their contracts. However, if the market fails they have a habit of disappearing, leaving the producer stranded with his hay. The more humane speculators may turn the business over to the regular shipper if market prices drop, but even then the producer invariably sustains a painful loss.

A third agency which sometimes offers an opportunity to the farmer of selling his hay at top-notch prices is the so-called outside buyer. This is the name given to a country shipper who has come in from another territory to fill a large order which he was not able to complete in his

own territory. Such a buyer usually offers an exceptionally good price because of the pressure he is under to meet his contract.

Finally the producer can profitably dispose of his hay in still another channel and that is by selling to track buyers. Track buyers are agents who are employed by receivers and shippers located at the large hay terminal markets. These agents travel about the country from one section into another buying hay either from the shipper or directly from the farmers.

In endeavoring to reach a satisfactory agreement with any of these buyers of hay it is customary for the producer to contract his product in one of four forms. He may sell his hay while it is still standing as uncut hay, or while it is still in windrows or in cocks, or after it has been stored in the mow or stack, or also after it has been baled.

Marketing standing or uncut hay is commonly resorted to when the crop has become quite poor in quality due to neglect on the part of the producer to cut at the proper time. Selling hay in this manner is not particularly popular because of the difficulty of finding a purchaser and of coming to an agreement on the yield and price when a purchaser has been found. To be able to calculate the percentage of dry or marketable hay which a given acreage of standing hay will yield is far from simple, for it requires a knowledge of the extent to which different kinds of hay

will shrink while being cured. It has been found that during the curing process timothy drops from a moisture content of from 47%-78.7%, or an average of 61.6%, while it is standing to 12.8%, the average moisture content for cured barn or stack timothy hay. Similarly, the moisture content of red clover hay uncut is about 70% and during the curing process drops to about 10%, the percentage of moisture at the time of baling. Uncut alfalfa hay is said to have a moisture content of 73% which decreases to 8% by the time the hay has been baled.

Marketing hay while it is still in windrows or in the cock is rather uncommon. Hay contracted for in this manner usually goes to feeders of loose hay who buy enough for several months feedings. These men, to be able to manipulate a profitable bargain, must be familiar with the moisture content of hay at this stage and the extent to which it will shrink while in the stack or mow. Likewise the producer, in order to realize profit on his crop, must be in possession of this knowledge so as to be in a position to demand a fair price. It can be safely said that timothy cut in full bloom and in the windrow or cock ready to be stacked, has a moisture content of approximately 29%; if cut in late bloom or in the early seed stage it will contain only about 22% moisture. For the legume hays, as clover and alfalfa, these figures are considerably higher.[5]

A much more general practice than the two mentioned above is to market hay while it is in the barn or

stack, agreement on prices being made before the hay is baled. This practice, however, is not entirely without its difficulties even though rather extensively resorted to by the average country shipper. In looking over a mow or stack of hay to determine what price he shall offer for it, the shipper has no means of learning the condition of the hay which is underneath the surface. Naturally, his price is low enough to protect himself in case the quality of the hay inside proves to be of poorer quality than expected. The producer, being none too familiar with hay grades, can do little else but abide by the shipper's offer and accept his price. Both are taking chances. The shipper runs the risk of buying poorer hay than he judged it to be and then being unable to sell it for perhaps even the same price at which he bought. On the other hand, if the hay really is of excellent, uniform quality throughout, the producer may be getting only a fraction of the actual price to which he is justly entitled.

It follows from this then, that the most desirable time at which to sell hay is when it is in the bale. This enables the shipper to accurately judge the quality of the hay and to offer an honest, square price, relieving himself of the hazard of uncertainty and giving the producer a just return for his effort. Marketing hay which has been baled by the producer is a very common practice in the Black Belt of the South particularly with alfalfa and Johnson grass.

In coming to an agreement consideration is, of course, given to the cost of baling the hay and the cost of delivering it from the farm to the country shipper's warehouse or the side-tracked cars of foreign speculators, outside buyers, or track buyers. Collier and McClure estimate that it costs the average hay producer from $2.50 to $4.00 per ton to bale his hay. The cost of hauling or delivering hay is quoted per mile and is based on a decreasing rate as the distance of the haul increases. The following figures give the cost for hauls ranging from one to ten miles as approximated under average or normal conditions in 1921.

Table 10.

Cost of Hauling Hay.

Length of Haul	Range of Cost per Ton
1 mile	$.25 - $.35
2 "	.50 - .60
3 "	.75 - .80
4 "	.90 - 1.00
5 "	1 .10 - 1.25
6 "	1.25 - 1.35
7 "	1.35 - 1.50
8 "	1.50 - 1.75
9 "	1.75 - 2.00
10 "	1.75 - 2.00

It is manifestly evident that the producer has many factors to take into consideration in profitably disposing of this product and that he needs to exercise ex-

treme precautions and sound judgment in contracting for the sale of his hay.

Even more complex is the problem of the country shipper who after he has received the hay from the producers must send it into channels of consumption with such tactfulness as to enable him to offer the producer a fair price and himself realize a sizeable profit. The markets which the shipper seeks for his business can be divided into four classes, viz: consumers, wholesalers and distributors, trade-buyers, and the terminal markets.[6.]

Selling directly to consumers is a common practice wherever the shipper is located near a consuming territory. The methods employed in securing this trade are the usual ones of advertisements, correspondence, or visitation. It is desirable to market hay in this manner because it enables the shipper to sell at the highest price (since the sale is direct) and the consumer to purchase at the lowest price. The arrangement, however, is not without its disadvantages. As a rule, shippers find it difficult to maintain a good list of customers. But even when the patronage is satisfactory, the shipper's supply of hay may not correspond in kind or quality with the demand, as is quite frequently the case. Then too, due to the discrepencies and short-comings of advertising and corresponding there often ensues a lack of proper interpretations of grade terms which leads to no end of complications. In addition, the country-shipper is subject to considerable losses because of the fact that many customers take advantage of their privilege to refuse and reject the hay sent them by the shipper.

If, therefore, dealing directly with consumers involves too many difficulties, then the country shipper can sell to the wholesaler or distributor located at the terminal markets. To facilitate trading with these agencies the shipper employs either brokers or salesmen. These representatives locate at the principle markets and distributing points and sell directly to the wholesalers and distributors located there. The difference between brokers and salesmen is that the brokers remain in one market and sell hay on a brokerage or commission basis, while salesmen cover a large territory, traveling from market to market, and receive a salary in addition to whatever commission they realize. This practice of selling through brokers or salesmen is most common in the South.

If the country shipper is located in either New York, Ohio, Indiana, or Michigan, he very likely will sell to the so-called track-buyers. These are dealers who do not operate warehouses but handle, or bill, the hay they contract for directly from the loading track of the seller to the receiving station of the consumer. The track-buyers are able to carry on this method because of the provisions they make for exceptionally favorable distribution facilities. Because of comparatively small overhead expense, these men can offer very good prices which are usually taken advantage of by the small shippers who handle only a few cars

of hay.

When, as sometimes happens, none of these agencies which have been mentioned are available, the country shipper can market his hay at the terminal markets. Here the demand is usually maintained by two classes of buyers, namely: receivers and terminal market shippers. Receivers really are speculators buying merely when a raise in price is anticipated so as to sell at a price so much higher than the purchase price that excess profit is assured. Market shippers are those who make a business of providing the consuming areas with hay, usually realizing a profit of from one to two dollars per ton for this service.

To market hay at these large distributing points to advantage, country shippers must above all become familiar with the practices that are common at these hay centers. They should have a knowledge of the methods used in weighing, inspecting, and grading hay and they should familiarize themselves with the amount and kind of storage which is available. Particularly the shipper should know the details of the several different ways in which hay can be delivered. When the hay is delivered 'shipper's track', the whole sale is consumated right at the loading point. If necessary, hay can be sold while it is in transit to buyers in the section towards which the carloads of hay are traveling. Such an order is termed 'to arrive'. Under certain circumstances hay is often shipped to market without having been contracted for; then it is marked 'delivered' and all terms of sale

completed when the shipment reaches its destination. Whenever it is difficult to sell hay at all, it is sent to the markets and there sold to the highest bidder on special sale tracks or yards; such lots of hay are known as 'consignments'. Therefore, carloads of hay enroute from the country shipper to terminal markets are marked either as 'shipper's track', 'to arrive', 'delivered', or 'consignment'.

When hay has arrived in the large terminal markets from the country shippers, foreign speculators, outside buyers, and track buyers, certain methods must be employed to facilitate the enormous trading which ensues among the brokers and salesmen, agents of the wholesalers and distributors, and receivers and terminal market shippers. The method used at such hay markets as are located at Memphis, Indianapolis, St. Paul, and Pittsburgh is that of selling on the exchange floor. Here shipments are offered for sale and bids received on the basis of grade, description, and the appearance of small samples of hay that are exhibited on tables placed there for that purpose. It is on the exchange floor that daily cash-market prices are established upon which are based the bids made to country shippers and the offers of shipment received from them and others.

At Chicago, St. Louis, and Minneapolis the sales are conducted in the railroad yards at the opened car doors. Agreements are concluded by seller and buyer on the basis of

the quality of the hay that is visible from the car-door. It is understood, under these circumstances, that the cars are uniformly loaded. If found otherwise after a sale has been consummated, a part of the hay can be rejected and the remainder resold in a special yard which is provided for such rejected cars.

Plug track sales are conducted at Kansas City, Cincinnati, and Omaha. Here too, the sales are carried on in special railroad yards which in these markets are known as plug-yards. The yards take that name from the fact that a plug of from 15 to 50 bales of hay is removed from the car and placed on a platform before it, so that the buyer may carefully examine it and determine its exact value. In Kansas City and Omaha the sales are made privately. At Cincinnati, however, the hay is sold at auction, members of the board of governors of the plug-yards being the auctioneers. The cost of this plug-track sale service does not exceed $3.00 per car nor fall below $.75 per car.

In eastern and southern markets such as New York, Boston, and Baltimore the sales are conducted at warehouses where the hay can be unloaded and sorted into kinds and grades. The advantages of this system are evident. The sales can be managed regardless of weather, the dealers are able to see all of the hay, and for a reasonable cost the hay can be kept in storage if desired.

As a further systematizing of the hay commerce, the trade is usually regulated by commercial organizations

such as the Board of Trade, Merchants' Exchanges, and Hay and Grain Exchanges.[7] Membership in these organizations is made up of wholesalers, distributors, receivers, terminal market shippers, and hay dealers in general who are particularly interested in the hay trade. These Exchanges or Boards of Trade issue market reports, formulate and enforce trade rules, and supervise the weighing, inspection, and handling of the hay. This supervision is now to a large extent being replaced by the Government Federal Inspection.

With the growth of hay marketing in the last 55 years to the extremely complex commercial machinery it has now developed into, it has been found essential to adopt qualifying hay terms. To facilitate this, hay standards have been recommended and adopted and are now being applied under Federal Inspection. The first important step taken towards the standardization of the hay trade was executed in about 1908 when the National Hay Association adopted certain grades of hay for the standardization of timothy, timothy and clover mixed, clover, prairie hay, and alfalfa.[8] In naming these grades the terms commonly used were such as Choice, No. 1, No. 2, No. 3, and No-grade hay. Though a decided advance in the right direction, these grades with their qualifications were somewhat indefinite and left much room for misinterpretation. The following grades of timothy hay, with their explanations as used at that early date, illustrate the lack of definiteness in so many instances:

Choice Timothy Hay - Timothy not over 5% other grasses, properly cured, bright natural color, sound, well baled.

No. 1 Timothy Hay - Timothy not over 1/8 clover or other tame grasses, properly cured, good color, sound, well baled.

No. 2 Timothy Hay - Timothy not good enough for No. 1, not over 1/4 clover or other tame grasses, fair color, sound, well baled.

No. 3 Timothy Hay - Timothy not good enough for other grades, sound, well baled.

No-grade Hay - Badly cured, stained, thrashed, or in any way unsound.

With all their infirmities these standards took effect and by 1912 were being used by as many as 23 leading hay markets in the country. The system and its standards, with certain minor modifications, has been in use up to a comparatively recent date.[9] In 1923 the Secretary of Agriculture recommended standards for timothy, clover, and grass hays. Two years later, in July of 1925, similar standards were recommended for alfalfa and alfalfa mixed hay, Johnson and Johnson mixed hay, and prairie and prairie mixed hay. Under these recently adopted standards all hay is divided into four groups. Group 1 includes timothy, clover, and grass hays; Group 2 includes alfalfa and alfalfa mixed hay; Group 3 includes prairie hay; and Group 4 includes Johnson and Johnson mixed hay. Each group is then divided into classes describing the kind of hay or the mixtures of vari-

ous kinds, such as: Timothy, Timothy Light Clover Mixed, Timothy Medium Clover Mixed, and so on. These are accompanied with definite mixture percentages indicating exactly what percentage of other hay is permissible in each class. The classes in turn are divided into U. S. Grade No. 1, No. 2, No. 3, and Sample Grade on the basis of color and presence of foreign material, the grade, therefore, describing the quality of the hay. The terms used in the qualifications of these official hay standards leave little room for misinterpretation. Hence, when a country shipper notifies a terminal market wholesaler that he has three carloads of Timothy Medium Clover Mixed hay U. S. Grade No. 2 for sale, the wholesaler knows exactly what the nature of that hay is and can reach a swift and satisfactory agreement with the country shipper.

With this glimpse into the mechanism of the hay trade we come to the actual production, marketing, and consumption of the country's hay crop. The production of hay in the United States for dispersion into marketing channels centers itself mainly in three groups of states.[10] These three commercial hay growing sections include the extreme northeastern states in one group; the central Corn Belt states, Michigan, Wisconsin, and Minnesota in the other group; and the Mountain and Pacific Coast States in the third group.

The extreme northeastern states constitute an important hay growing section because it is there that most

of the large cities of the country are located. These cities, despite the constantly increasing number of motor driven vehicles, still employ horses to a considerable extent thereby maintaining the demand for enormous tonnages of hay, mainly timothy, that have been coming from that source. This hay growing section is also a great dairy region so that as a result the demand for hay, particularly timothy and clover hay to be used on the farm, is quite extensive from this source.

The central Corn Belt states together with Michigan, Wisconsin, and Minnesota have developed into an important commercial hay growing region because of the demand coming from its large cities, from home consumers, since this section includes the great dairy states, and from less local sources. Ohio and Michigan, for example, ship much of their hay to eastern cities.

The third important hay production area is that of the Mountain and Pacific Coast states. There is a good local market in this section because most of the land is devoted to the range industry; a large demand, therefore comes from the ranchmen who need hay as winter feeds. In addition to this, there is also quite a demand for hay from mining camps as well as from Alaska, Hawaii, and the Philippines along the western coast.

Now the kind or type of hay a producer is going to raise will depend quite largely upon the part of the country in which he is located, since each section experiences de-

mands for certain hay and can produce only certain types or kinds. As has been elsewhere already indicated in this work, the leading hay crop for Northeastern United States is timothy and clover hay mixed. Where soils are inclined to be quite wet, or a little more so than the average, alsike clover and red top are found to be most important as in New England, for example. In Kentucky and Virginia, on the other hand, orchard grass is the predominating hay crop.

In the West, alfalfa of course, is without question the leading hay crop. However, many other crops are cut and cured into market hay. In some localities, for instance, hooded barley is cut for hay. In the upper region of the Columbia River Basin wild oats are eminent, and even pure stands of wheat are made into hay. Along the eastern margin of the Western Plains area Sudan grass is the hay crop, while in the Plains Region sorghum is very important in this respect.

Although no standard hay crop is grown in the South, the most important one, as has already been shown, is cowpeas. Other important forage plants that are made into hay in this region are sorghum, Johnson grass, sheaf oats cut green, corn stover, and also some Bermuda grass. Hence, if the market hay producer is in the South, he will probably grow cowpeas for hay, in the North he would specialize in timothy and clover mixed, but if he were in the West his hay crop would be alfalfa.

The largest percentage of commercial hay growers naturally are those producing nothing else but hay on their land. Unfortunately, in many of these cases no steps are taken to maintain the fertility of the soil so that consequently the grade of hay produced each succeeding time is poorer than the one before. However, there is a constant increase in number of those producers who keep up the soil fertility by using fertilizers, growing leguminous crops, and practicing rotation of crops. These are the successful hay growers and the ones to whom must go the credit of producing the better grades of hay that appear on the market. A small percentage of hay comes from farmers who are feeding livestock and sell only their surplus hay. This product, too, is of satisfactory quality, since in livestock production the fertility of the soil is kept up, and meadows are maintained in a prosperous, vigorous condition.

The transportation of hay from these large production areas into the markets of consuming regions no longer is as simple as it was about 55 years ago. For previous to 1870 there was very little marketing of hay, and whatever hay had to be transported was never shipped more than 20 or 30 miles. That was when producer and consumer were one and whoever had need for hay grew it himself. Since then, however, transportation has become an immense problem[3]. Already in 1911 of the 67,071,000 tons of hay produced 8,182,662 tons were sent into markets as shown in Table 11.

Table 11.

Quantity and Percentage of Total Hay Crop Shipped on Railroads[3] (1911-1923).

Year	Quantity sold from the farm.	Shipments of hay originating on Class 1 railroads.	Percentage of total hay marketed that is shipped on railroads.
1911	8,182,662	6,306,745	77
1912	11,341,750	6,828,297	60
1913	10,293,270	7,144,455	69
1914	11,529,180	7,318,573	63
1915	14,480,500	7,649,093	52
1916	14,983,920	7,563,948	50
1917	13,781,460	8,730,229	63
1918	12,759,460	8,653,185	67
1919	15,190,200	7,857,168	51
1920	15,270,670	8,355,231	54
1921	14,036,290	5,420,791	38
1922	16,354,690	6,008,160	36
1923	15,460,770	6,263,906	40

This tonnage has increased year after year until in 1922 16,354,690 tons of hay were marketed. Large as this tonnage of marketed hay is, it yet represents only about 14.5% of all hay produced; one can imagine the enormity of of the shipping problem if all hay produced were marketed. At the present time from 80% to 85% of the nation's hay crop is consumed locally and from 15% to 20% is marketed, shipped out of the county in which it is produced. The significance

of the situation is that about 16 million tons of hay with a farm value of approximately 200 million dollars must be marketed annually in the United States. The transportation of this vast market commodity was once largely, though not entirely, effected by railroads. In 1911, for example, 77% of the total hay marketed was done so over the railroads. The percentage continued to decrease until in 1922 only 36% of hay marketed was shipped on railroads. This means for 1923 that out of the 15,460,770 tons of hay marketed only about 6,263,906 tons were shipped to market over railroad lines. This decrease is largely to be accounted for by the raise in freight rates instigating the use of motor trucks and steam ships. At many of the large markets that are within trucking distance of producing area a considerable percentage of the hay marketed is delivered with motor trucks. Much of the Western alfalfa that is sent to meet the demands of Eastern markets is transported by Pacific Coast shippers by way of the Panama Canal since the rate over this route is only $12.00 as compared with $30.00 per ton by railroad.

Hay markets are quite numerous throughout the United States and almost every large city is the seat of one.[6] The more important markets of the East are as follows: Baltimore, Maryland; Washington, D.C.; Boston, Massachusetts; New York and Buffalo, New York; Philadelphia and Pittsburgh, Pennsylvania; Cincinnati, Cleveland, and Columbus, Ohio; Detroit, Michigan; Indianapolis, Indiana; Chicago and Peoria, Illinois; and Milwaukee, Wisconsin.

The leading hay markets of the South are located at Jacksonville, Pensacola, and Tampa, Florida; Ft. Worth, Galveston, Houston, and San Antonio, Texas; New Orleans and Shreveport, Louisiana; Jackson, Mississippi; Birmingham, Mobile and Montgomery, Alabama; Atlanta, Augusta, Macon, and Savannah, Georgia; Charleston and Columbia, South Carolina; Little Rock, Arkansas; Raleigh and Wilmington, North Carolina; Memphis and Chattanooga, Tennessee; Norfolk and Richmond, Virginia; and Louisville, Kentucky.

In the West the principal hay markets are to be found at Seattle and Spokane, Washington; Los Angeles and San Francisco, California; Portland, Oregon; Boise and Pocatello, Idaho; Ogden and Salt Lake City, Utah; Phoenix, Arizona; Butte, Montana; Denver and Pueblo, Colorado; Omaha, Nebraska; Kansas City, Kansas; Duluth, Minneapolis, and St. Paul, Minnesota; Des Moines and Sioux City, Iowa; and St. Louis, and St. Joseph, Missouri.

[2] Available figures show that of these the largest market is at Kansas City where the reported receipts for 1923 amounted to 265,068 short tons of hay. St. Louis and Chicago are next in importance. St. Louis with receipts of 141,296 short tons of hay and Chicago with 140,905 short tons. Other hay markets in order of their importance are: Cincinnati, St. Louis, New York, San Francisco, Boston, Peoria, Minneapolis, Baltimore, and Milwaukee.

The kinds of hay received at these markets are,

quite naturally, in keeping with kinds grown in the production areas in or near which these markets are located.[6] Hence the kind of hay received in the principal markets of the Northeastern states is timothy as well as some timothy and clover mixed. This also holds true for the markets of the Southeastern states; there, however, are received in addition peanut hay, Bermuda grass, Johnson grass, and Lespedeza. West of the Mississippi River, as one would expect, alfalfa and prairie hay are the principal hays received at the markets and along the west coast grain hay, as well as alfalfa, also is quite important.

The consumers represented at these markets, and into whose possession the hay finally terminates, are principally of two types, viz: the country or non-urban consumers and the city consumers. As is to be expected, it is to the country consumers that most of the hay marketed finds its way.[7] The demand from these consumers is particularly extensive in those areas which do not produce sufficient hay to meet their own requirements and which are, therefore, known as consuming areas. There are six consuming areas that are at present recognized as such. These six areas are, briefly: the New England dairying section; the mining sections of Pennsylvania; Michigan and Wisconsin; the section south of the Ohio and Potomac rivers and east of the Mississippi river; certain sections of Louisiana, Texas, and New Mexico; and the non-producing sections west of the Rocky Mountains.

Most of the hay used by the city consumers goes to the maintenance of horses. The best quality and highest grades of hay disposed of through this channel, are purchased by the owners of fancy driving and saddle horses who demand and will pay a premium for the best obtainable hay. In contrast to these are the low grade feeders who buy the cheap, poor hay for use in transient and sales stables where the minimum of care and attention is given to the animals and the one outstanding thought is the saving of money. In addition to these two types of city consumers are the economical buyers who maintain a demand for the medium grades of hay. Such grades are usually quite as nourishing as the choicer grades but are cheaper in price due perhaps to poor color or mixtures with other grasses or legumes.

Knowledge of this kind is an important factor in aiding the producer to determine what kind of hay he shall grow, how it needs to be handled to be marketed, who are the most reliable dealers, and what markets are most likely to give him the highest returns for his kind of hay.

Methods of Curing.

The practice of curing hay is no new one. It has not become a major farm operation just within the last few centuries. No indeed, for the history of hay making goes as far back as the history of mankind itself. The honor of being the original hay maker undoubtedly goes to the pika or cony.[3] This small, active rodent cut off fine-stemmed grassed and other plants, gathered them together, and cured them in sunny places among the rocks of its habitat. What is more, the pika performed its work so well that the hay retained the color and fragrance characteristic of the green grasses.

It is thought that man's first attempt at curing hay came about rather accidentally. The common occupation in those very early days was, of course, that of driving herbivorous animals from one region into another, thereby keeping them supplied with sufficient feed. Occasionally, they came to territories where forage was wanting and where only the dried up stalks of previous season's pasture plants remained. The discovery that the livestock consumed these dried stalks with almost as much relish as they did green forage and thrived on it led to the curing of forage plants. This not only enabled the storage of hay so that it could be held over to be used during the poor forage season of each year, but it also made the forage more easily trans-

portable from regions of plentiful pasturage to those lacking it.

As time went on and mankind progressed in civilization, hay making was accomplished with greater facility than before and even became a highly respected activity. In fact, during the time of the Roman Empire, before the Christian Era, it was considered quite lawful to spend holidays and days of worship at work in the meadows curing hay. As civilization gradually spread over the European continent, agriculture with all its farm enterprises, kept pace with the movement.

When North America was discovered it was but natural that the people who settled there should soon begin tilling the soil and practicing the method of farming that they had so successfully used in their mother country.[11] The difficulties encountered by these early settlers have been told and retold and bear no repeating here. But it is of interest to note that one of the first and important problems that the Northern settlers had to solve was that of providing feed for their livestock during the winter. Haymaking, therefore, became a very common practice during the colonial times and a regular occupation of the New Englanders. Consequently, all colonists who came to New England expecting to engage in agriculture, were supplied with scythes, forks, and rakes for haying. In this connection it is interesting to observe that the order for tools and implements, which the secretary for the Dutch West India Company requested in 1662 to

be sent to the Colony on the Delaware River, included, among other things, 12 two-pronged hay and grain forks and 12 hay knives.

With the growth of cities and the development of the dairy industry throughout various sections of the country, a demand for certain kinds of hay began to manifest itself and before long, large tonnages of hay began moving from producing areas to regions from which the demand was coming. The complex machinery of marketing soon began to take form and gradually the business of making hay took on the proportions of an industry so that today the American farmer is growing a crop of 98 million tons valued at over 12 hundred million dollars.

In preparing this tremendous tonnage of hay for home use or for shipment to the markets, those who are producing the hay will usually cure it in one of three ways: in the swath, in cocks, or in windrows. Just which method any single farmer will use depends largely upon the kind of hay he is growing, because grass hays, such as timothy, red top, and others, cure out quickly, having long, thin leaves and hollow stems; whereas, legume hays, with almost 50% of the plant by weight in leaves and with solid, sappy stems, require a long time for curing. Therefore, for example, if the hay producer is in the timothy region of the North, he will be growing timothy hay and, undoubtedly, will cure it in the swath. If, however, he is growing legume hay, he will cure it either in cocks or, if there is a scarcity of time and labor which most farmer's experience, he will cure it in windrows.

Whatever the method employed, it is justified if, with a minimum amount of labor, time, and expense it not only reduces the moisture content to about 15% but also enables the retention of the natural green color and the saving of the greater percent of the leaves of the forage plants being cured for hay.

Curing in the swath is commonly practiced by those farmers producing grass hays. This is explained by the fact that timothy, and the other grasses, because of their hollow stems and long narrow leaves, dry out very quickly, as already mentioned. In favorable weather timothy, for example, can be cut in the morning and hauled to the stack or mow in the afternoon. This saves the damage caused by rain when hay needs to be left in the field for several days, as is done with legumes. In addition, the comparatively small use of machinery in curing in the swath makes this method very economical for curing grass hays.

Many farmers cure legume hay in much the same manner with the occasional use of a tedder to stir up the hay and hasten its drying after which the hay is windrowed with a side-delivery rake and loaded on to the racks with a hayloader. This system of curing legume hay however, is at the expense of excessive bleaching and loss of leaves and, therefore, is not recommended.

Curing hay in the cock is most extensively practiced in preparing alfalfa hay and is also considerably used with many of the other legumes. It is a practice that has been followed for such a long time that farmers seem reluctant to give up this custom for the windrow method, which cures hay more cheaply, more quickly, more efficiently, and with as good a quality, if not better, as that secured from the cock. The method of curing hay in the cock seems to have originated from a custom that was prevalent in England previous to 1884.[12] At that time, the hay was cocked up every night so that the leaves would absorb the least amount of dew or rain that might occur before the following morning. Every morning these heaps would be spread out and exposed to the sun to allow for further drying. This laborious process of throwing the hay into bunches at night and speading apart again early the next day was continued until the hay was thought to be cured. At present the procedure followed in curing hay in cocks is to allow the hay to lie in the swath, after mowing, until all surface moisture has evaporated. Then it is raked and piled by hand into cocks where it remains for from five to ten days until it is considered cured. Very often hay caps are used to protect the hay in case of rain. These are said to increase the quality of the hay, but it is questionable and somewhat in dispute as to whether the cost of hay caps and the labor involved in using them is entirely offset by the increase in the quality of hay resulting from their use. This general custom of curing hay in the cock is manifestly a very slow and expensive one and consequently is becoming less and less widespread in its use.

The introduction of the side-delivery rake and with it, the curing of hay in windrows, has come as a distinct measure of relief to producers of alfalfa and other legume hays. Where before, it required from five to ten days to cure these legume hays in cocks, this is now done with dispatch in from two to three days in the windrows. The side-delivery rake is a farm implement devised to form one or two swaths of hay at a time into long fluffy rows of hay through which the air can circulate freely and in which the greater percentage of the leaves are protected from direct exposure to the searing sun. Two different procedures of curing hay in the windrows are at present in use. One is to allow the hay to lie in the swath, after having been cut, until it has wilted and then form it into windrows with a side-delivery rake and leave until cured.[13] The other procedure, very effectively used in Michigan, is to follow the side-delivery rake after the mower as soon as possible, or even to mow and rake in the same operation.[14] In cases of rainfall the windrows are given a half turn after the rain has stopped and the surface hay and ground have dried. Half turning, once during curing, is also recommended for a heavy stand or when the weather is unusually hot, in order to facilitate a more uniform drying. An important factor favoring the curing of hay in windrows is the ease with which the finished product can be loaded into the hay racks

with a hay loader, a procedure impractical where hay has been cocked. The superiority of curing hay in the windrow is established and it is only a question of time until every ton of legume hay will be cured in that manner.

A very small percentage of the hay produced is cured by methods other than those mentioned above. In some vicinities, as in Washington[15] and Colorado,[16] a few tons of 'brown hay' or 'stack-burnt hay' are cured by stacking directly from the mower. Ensiling hay, a method advocated by the Italian Government and becoming popular with Italian farmers, has been experimented with somewhat in this country but has found little favor here.[17] Curing of hay by means of artificial heat, already under consideration as early as 1847,[18] and receiving considerable attention in England[19] has not yet been found to be of practical value for use in the United States.

EXPERIMENTAL WORK

A Review of Literature does not appear with this report, because up to the time of writing no scientific article pertaining to the phase of curing hay presented herewith had yet been published.

Preliminary Field Experiment

Number I

Purpose

This experiment was undertaken for the purpose of determining the nature and differences of loss of moisture from alfalfa plants being cured under conditions, herein known as Direct Sunlight, Medium Shade, Intense Shade, and Partial Exposure.

Material

The alfalfa plants used in this work were of the Hardigan Variety, obtained from the border plot of a series of varietal test plots. There was need for at least 700 alfalfa plants and these, at the time of cutting, were severed approximately two inches above the ground with a corn knife. The plants, after they were cut, had an average height of 18.37 inches as determined by the accurate measurements of twenty-two alfalfa plants the height of which, with figures given in inches, are as follows:- 21.50 inches, 17.50 inches, 16.50 inches, 17.50 inches, 15.00 inches, 17.00 inches, 21.50 inches, 19.00 inches, 15.75 inches, 16.00 inches, 17.75 inches, 16.25 inches, 18.00 inches, 21.75 inches, 22.50 inches, 17.75 inches, 18.50 inches, 20.75 inches, 16.50 inches, 20.25 inches, 16.50 inches, 20.25 inches, 19.50 inches, 19.00 inches. This gives an average height per plant, as mentioned, of 18.37 inches.

The conditions of direct Sunlight, Medium Shade, Intense Shade, and Partial Exposure were provided for in the following manner. For Direct Sunlight, alfalfa plants were simply deposited on the ground and left there directly exposed to the sunshine. Bunting draped over a wooden frame four feet long, two feet wide, and two and one half feet in heighth was used to effect Medium Shade. Intense Shade was obtained by draping a double thickness of burlap over a wooden frame of the size just mentioned. Partial Exposure was secured by placing double thicknesses of bunting over the upper half of alfalfa plants that had been placed on the ground. All of these four conditions were effected on freshly harrowed ground.

Thirty-one air-tight cans were used for taking the ten plants samples hourly and were kept in a burlap sack in a shady place while the experiment was in operation. The cans were number 2, plain tin, round Spencer friction cans, three and one half inches in diameter and four and three fourths inches high, equipped with friction caps, and manufactured by the American Can Company of New York.

An inclosed pan balance of the Torsion Balance type, Style 254, was used in making the periodical weighings of the 100 plants of each group.

Eosin was used for the staining phase of this experiment. It was prepared by dissolving 70 milligrams of the Eosin powder in 200 cubic centimeters of tap water. Twenty-two two dram glass vials, two and one fourth inches tall and one half inch in diameter were employed for the staining, the stem of each plant to be stained being inserted to within one eighth of an inch of the bottom of the vial, all vials being filled with Eosin up to the bottom of the corks. A perforation had been made through each cork sufficiently large to allow the easy passage of an alfalfa plant stem; after this perforation each cork was split lengthwise into two pieces. Parowax, heated over Sterno, canned heat, and allowed to cool until a scum had formed over its surface, was used in sealing each vial, the stems being slightly moved to prevent air-tight sealing and the consequent formation of a vacuum.

The Procedure.

At 7:30 A.M., June 5, 1926, 700 plants were cut off and divided into four lots of 175 plants each, each lot being placed under its respective environment, one under Direct Sunlight, another under Medium Shade, a third under Intense Shade, and a fourth under Partial Exposure. In each lot of plants 100 were kept apart, weighed at once, and weighed hourly thereafter five times during the forenoon and every one and one half hours during the afternoon, the results thus obtained being used to calculate the loss in grams, the rate of loss in percent, and the percentage of moisture content of the alfalfa plants under each of the conditions at the time of each weighing. The 75 plants remaining in each lot were used for moisture test purposes. Samples, ranging from 7 to 10 plants per sample, were taken

hourly five times during the forenoon and every hour and one half, or three times, during the afternoon from each of the four lots of plants. These samples were placed in air-tight cans and kept cool in the manner already referred to.

At approximately hour and a half intervals during the day individual plants were taken from each lot and treated in Eosin as described above. In addition, whenever weighings and samplings were made, the temperature of each of the four different conditions was taken and recorded.

The can samples of alfalfa plants were removed to the laboratory at the end of the day where the leaves were cut off at their junction with the petioles. The leaves from each sample were then weighed separately, and similarly the stems, and all dried in an electric oven for five hours at a heat of 110 degrees Centigrade. At the end of this period all samples were again weighed and the loss in weight used to calculate the moisture percentages of the leaves and stems.

Results.

An inspection of the results of this preliminary field experiment, represented in Tables, 12, 13, 14, and 15

Table 12.

Exp't. June 5, 1926.

DIRECT SUNLIGHT.

Loss of Moisture from alfalfa plants.

Table 12. Con't.

100 Plants Weighed Hourly.

Hour	Temperature °C.	Weight of Plants Grams	Loss in Grams	Percent Loss %	Moisture Content %
8:15	24	402	86	21.39	79.09
9:15	25	316	31	9.82	62.17
10:15	32	285	18	6.32	56.07
11:15	30	267	31	11.62	52.53
12:15	36	236	35	14.84	46.43
1:45	39	201	25	12.44	39.54
3:15	37	176	12	6.82	34.62
4:45	26	164			32.27

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Samples Taken for Moisture Test.

Number of Plants	Weight Before Heating Grams	Weight After Heating Grams	Loss in Weight Grams	Percent Moisture Content %	Hour
10	34.9	7.3	27.6	79.09	8:15
10	22.8	6.3	16.5	72.37	9:15
10	29.0	9.5	19.5	67.25	10:15
10	19.4	5.8	13.6	70.11	11:15
10	17.9	5.1	12.8	71.09	12:15
8	9.9	4.3	5.6	56.56	1:45
8	11.7	6.2	5.5	47.01	3:15
9	10.7	6.2	4.5	42.06	4:45

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Total-238-59.20%

Table 12. Con't.

Loss of Moisture by Leaves.

Hour	Number of Plants	Weight Before Drying Grams	Weight After Drying Grams	Loss in Weight Grams	Moisture Content %
8:15	10	14.4	2.9	11.5	79.87
9:15	10	9.8	2.9	6.9	70.41
10:15	10	11.9	3.6	8.3	69.75
11:15	10	9.2	2.8	6.4	69.57
12:15	10	7.7	2.4	5.3	68.84
1:45	8	3.9	1.9	2.0	51.29
3:15	8	4.8	3.4	1.4	29.17
4:45	9	4.2	3.2	1.0	23.81

Loss of Moisture by Stems.

Weight Before Drying Grams	Weight After Drying Grams	Loss in Weight Grams	Moisture Content %	Hour
20.5	4.4	16.1	80.49	8:15
13.0	3.4	9.6	73.85	9:15
17.1	5.9	11.2	65.50	10:15
10.2	3.0	7.2	70.59	11:15
10.2	2.7	7.5	73.53	12:15
6.0	2.4	3.6	60.00	1:45
6.9	2.8	4.1	59.43	3:15
6.5	3.0	3.5	53.85	4:45

Table 13.
Expt. June 5, 1926.

MEDIUM SHADE

Loss of Moisture from alfalfa plants.

100 Plants Weighed Hourly

Hour	Temperature °C.	Weight of plant Grams	Loss in Weight Grams	Percent loss %	Moisture Content %
8:30	15	372	54	14.52	80.82
9:30	20	318	28	8.81	69.08
10:30	21	290	9	3.11	63.00
11:30	25	281	12	4.27	61.05
12:30	24	269	12	4.47	60.06
2:00	21	257	10	3.89	55.84
3:30	23	247	8	3.24	52.75
5:00	21	239			51.91

Samples taken for Moisture test.

Number of Plants	Weight before heating grams	Weight after heating grams	Loss in weight grams	Moisture Content %	Hour
10	31.8	6.1	25.7	80.82	8:30
10	27.7	8.7	19.0	68.60	9:30
9	24.4	9.0	15.4	63.12	10:30
10	25.3	7.9	17.4	68.78	11:30
8	20.5	5.1	15.4	75.13	12:30
8	20.3	6.2	14.1	69.46	2:00
8	14.4	4.7	9.7	67.37	3:30
					5:00

Total 133-85.76%.

Table 13. Con't.

Loss of Moisture by Leaves.

Hour	Number of Plants	Weight Before Drying Grams	Weight After Drying Grams	Loss in weight grams	Moisture Content %
8:30	10	13.5	2.7	10.8	80.00
9:30	10	12.2	2.7	9.5	77.87
10:30	9	11.3	5.7	5.6	49.56
11:30	10	9.8	3.0	6.8	69.39
12:30	8	8.6	2.3	6.3	73.26
2:00	8	8.8	2.7	6.1	69.32
3:30	8	6.1	1.9	4.2	68.86

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Loss of Moisture by Stems

Weight before drying grams	Weight after drying grams	Loss in weight grams	Moisture content %	Hour
18.3	3.4	14.9	81.43	8:30
15.5	6.0	9.5	61.30	9:30
13.1	3.3	9.8	74.81	10:30
15.5	4.9	10.6	68.39	11:30
11.9	2.8	9.1	76.48	12:30
11.5	3.5	8.0	69.57	2:00
8.3	2.8	5.5	66.27	3:30

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Table 14.

Exp't. June 5, 1926.

INTENSE SHADE.

Loss of Moisture from alfalfa plants.

100 Plants weighed hourly.

Hour	Temperature °C.	Weight of plants grams	Loss in weight grams	Percent Loss %	Moisture Content %
8:45	14	447	46	10.29	72.33
9:45	15.5	401	26	6.49	65.24
10:45	18.0	375	18	4.80	60.68
11:45	18.5	357	11	3.08	57.77
12:45	19.0	346	14	4.05	55.98
2:15	21.0	332	13	3.92	53.72
3:45	20.0	319	8	2.51	51.62
5:15	19.0	311			50.32

Samples taken for Moisture test.

No. of Plants	Weight before heating grams	Weight after heating grams	Loss in weight grams.	Moisture Content %	Hour
10	41.4	11.5	29.9	72.23	8:45
10	41.7	9.6	32.1	76.97	9:45
10	22.7	6.4	16.3	71.81	10:45
7	27.2	10.0	17.2	63.24	11:45
8	23.9	6.6	17.3	72.39	12:45
8	19.8	5.3	14.5	73.24	2:15
8	12.3	3.9	8.4	68.30	3:45
8	21.0	6.2	14.8	70.48	5:15

Total 136 30.43%.

Table. 14. Con't.

Loss of Moisture by Leaves.

Hour	No. of Plants	Weight before drying grams	Weight after drying grams	Loss in weight grams	Moisture Content %
8:45	10	16.2	6.4	9.8	60.50
9:45	10	16.1	4.9	11.2	69.57
10:45	10	9.5	2.4	7.1	74.74
11:45	7	10.7	3.9	6.8	63.56
12:45	8	9.5	2.6	6.9	72.64
2:15	8	7.7	2.1	5.6	72.73
3:45	8	5.0	1.8	3.2	64.00
5:15	8	8.5	2.8	5.7	67.06

Loss of Moisture of Stems.

Weight before drying grams	Weight after drying grams	Loss in weight grams	Moisture Content %	Hour
25.2	5.1	20.1	79.77	8:45
25.6	4.7	20.9	81.65	9:45
13.2	4.0	9.2	69.70	10:45
16.5	6.1	10.4	63.04	11:45
14.4	4.0	10.4	72.23	12:45
12.1	3.2	8.9	73.56	2:15
7.3	2.1	5.2	71.24	3:45
12.5	3.4	9.1	72.80	5:15

Table 15.

Exp't. June 5, 1926.

PARTIAL EXPOSURE.

Loss of Moisture from alfalfa plants.

100 Plants weighed hourly.

Hour	Temperature °C.	Weight of Plant grams	Loss in Grams	Percent loss %	Moisture Content %
9:00	27	413	68	16.47	74.34
10:00	34	345	38	11.02	62.10
11:00	34	307	33	10.75	55.26
12:00	39	274	30	10.95	49.32
1:00	34	244	37	15.17	43.92
2:30	40	207	24	11.59	37.24
4:00	33	183	7	3.83	32.94
5:30		176			31.68

Samples taken for Moisture test.

No. of Plants	Weight before heating grams	Weight after heating grams	Loss in weight grams	Moisture Content %	Hour
10	41.3	10.6	30.7	74.34	9:00
10	23.3	6.0	17.3	74.25	10:00
10	26.8	8.5	18.3	68.29	11:00
7	13.5	4.4	9.1	67.41	12:00
8	13.8	4.6	9.2	66.67	1:00
9	16.2	6.2	10.0	61.73	2:30
8	9.2	5.7	3.5	38.05	4:00
8	10.4	4.5	5.9	56.74	5:30

Total 237 57.39%.

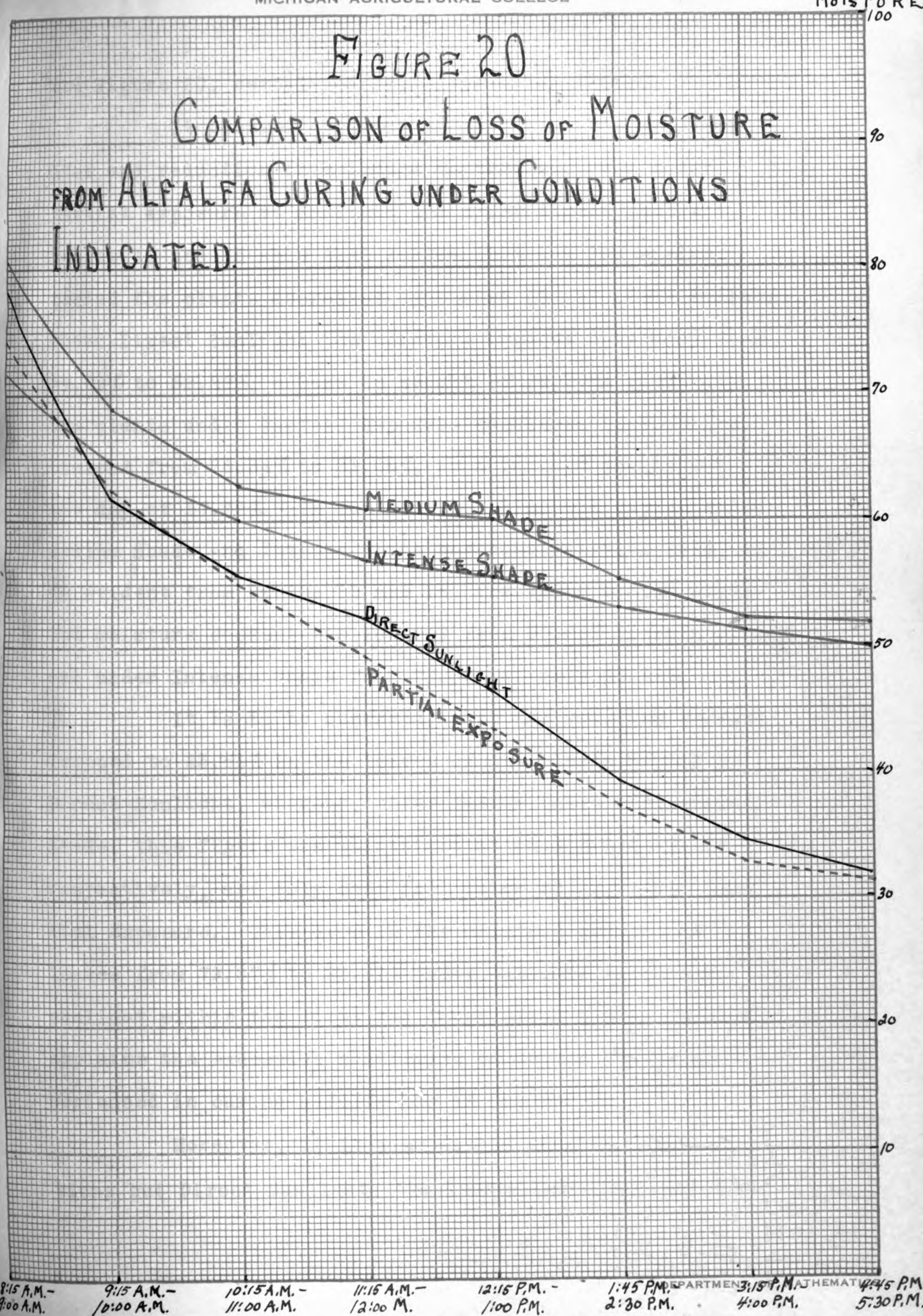
Table 15. Con't.

Loss of Moisture by leaves.

Hour	No. of plants	Weight before drying grams	Weight after drying grams	Loss in weight grams	Moisture Content %
9.00	10	17.4	5.1	12.3	70.69
10:00	10	10.5	2.9	7.6	72.39
11:00	10	11.3	4.1	7.2	63.72
12:00	7	5.6	2.1	3.5	62.50
1:00	8	5.9	2.0	3.9	66.11
2:30	9	7.1	2.9	4.2	59.16
4:00	8	3.6	2.8	.8	22.23
5:30	8	4.5	2.2	2.3	51.12

Loss of Moisture by stems.

Weight before drying grams	Weight after drying grams	Loss in weight grams	Moisture Content %	Hour
23.9	5.5	18.4	76.99	9:00
12.8	3.1	9.7	75.79	10:00
15.5	4.4	11.1	71.62	11:00
7.9	2.3	5.6	70.89	12:00
7.9	2.6	5.3	67.09	1:00
9.1	3.3	5.8	63.74	2:30
5.6	2.9	2.7	48.22	4:00
5.9	2.3	3.6	61.02	5:30


%
MOISTURE
100
90
80
70
60
50
40
30
20
10
FIGURE 20
COMPARISON OF LOSS OF MOISTURE
FROM ALFALFA CURING UNDER CONDITIONS
INDICATED.
MEDIUM SHADE
INTENSE SHADE
DIRECT SUNLIGHT
PARTIAL EXPOSURE
8:15 A.M.- 9:00 A.M.
9:15 A.M.- 10:00 A.M.
10:15 A.M.- 11:00 A.M.
11:15 A.M.- 12:00 M.
12:15 P.M.- 1:00 P.M.
1:45 P.M. 2:30 P.M.
3:15 P.M. 4:00 P.M.
4:45 P.M.- 5:30 P.M.

and Figure 20, reveal several interesting facts.

It becomes apparent at once that the greatest loss and reduction in moisture content occurred under partial exposure to sunlight and under direct sunlight. Tables 12 and 15 show that during this one day curing period the plants decreased by almost 60% of their weight. Under Direct Sunlight the moisture content decreased from 79.09% to 32.27%, a loss in weight of 59.20%; similarly, the plants under Partial Exposure decreased in moisture content from 74.34% to 31.68%, or a loss in weight for the day of 57.39%. In contrast to this, the curing under Medium Shade and Intense Shade was comparatively mild, as is evident from Tables 13 and 14, for under Medium Shade the moisture content was lowered from 80.82% to only 51.91% and under Intense Shade from 72.33% to only 50.32%.

It is to be observed, that the moisture content dropped to 23.81% in the leaves of the plants drying in Direct Sunlight, whereas, under Medium Shade and Intense Shade, this figure was maintained at 68.86% and 67.06% respectively, and only once fell below 51.12% under Partial Exposure. This drop in the moisture content of leaves from 79.87% to 23.81% under exposure to direct sunlight within the first ten hours after curing perhaps explains the excessive shattering of leaves always experienced in curing alfalfa hay in the swath.

Moreover, it is significant that in all conditions but Direct Sunlight, the leaves and stems dry down practically at the same rate with the moisture content hovering around the same mark. In Medium Shade, for example, the leaves, at the end of the period, had a moisture content of 68.86% and the stems 66.27%. In Direct Sunlight, however, the drying of the leaves goes on at a rate far exceeding that of the stems, so that at the end of this period the leaves have reached as low a moisture content as 23.81% while the stems still have 53.85%. This means dry, brittle leaves and green tough stems, a condition which, added to that of shattering, makes exposure to direct sunlight, as obtained in the swath particularly undesirable for curing alfalfa hay.

Further inspection reveals that the greatest rate of loss occurs during the first hour after cutting, following which there is a marked decrease in the rate of moisture loss which increases again after the second or third subsequent hour. For example, under Direct Sunlight the percent loss off moisture was 21.39% during the first hour and dropped to 6.32% in the third hour and by the fifth hour had recovered to a rate of loss of 14.84% again. Similarly, under Medium Shade during the first hour of drying the percent loss of moisture was 14.52% which dropped to 3.11% in the third hour and by the fifth hour had recovered to 4.47%. The results appearing in Tables 14 and 15 also further establish that fact.

Table 16.

The Effect of Sunlight, Shade, and Partial Exposure on the Ability of Alfalfa Plants to Take Up Eosin. *

June 5, 1926 Hour	Amount Stain taken up Cubic Centimtrs.	Height Reached by Stain inches.	Height of Plant Inches.
	DIRECT SUNLIGHT		
9:30	2 cc.	5½ in.	19 in.
11:00	1 "	¾ "	15 "
12.10	9/16 "	½ "	14 "
1:30	11/16 "	0 "	15 "
3:00	7/16 "	0 "	12½ "
4:30	6/16 "	1 "	14½ "
	MEDIUM SHADE		
10:00	1 7/8 cc.	4 in.	19 in.
11:00	1 1/16 "	1 "	16½ "
12:00	1 10/16 "	2¾ "	13¼ "
1:30	11/16 "	1¼ "	15½ "
3:00	11/16 "	1 3/8"	15¼ "
4:30	7/16 "	1 1/8 "	13¾ "
	INTENSE SHADE		
10:50	1 6/16 cc	8¼ in.	15½ in.
12.00	14/16 "	3¼ "	19¼ "
1:30	1 "	5/8 "	20. "
3:30	1 ¼ "	6 "	15¼ "
4:30	1 ¼ "	11.½ "	16 "
	PARTIAL EXPOSURE.		
10:50	1½ cc	1 in.	18 1/8 in.
12:00	13/16 "	1 1/8 "	14 "
1:30	7/8 "	3 3/8 "	17 6/8 "
3:00	13/16 "	1 ¾ "	17 "
4:30	3/8 "	1 5/8 "	16 5/8 "

* Plants were removed from stain during the early evening of June 7, 1926.

Table 16 shows what happened when plants from the four different lots were placed in stain at the hours indicated. Most stain was taken up and reached the highest points in those plants that were kept under Intense Shade. In contrast to this, the minimum amount of staining took place in the plants that were kept in Direct Sunlight. Between these extremes are the plants under Medium Shade and Partial Exposure which experienced only moderate staining, with those under Medium Shade somewhat in advance of the others. It is clear from this that the more the plants with their leaves are protected from direct exposure to sunlight the greater will be the activity of the plant sap in the fibrovascular system of the alfalfa and the greater will be the force which attracts the stain up through the stems and out into the leaves. It follows from this that to facilitate the greatest possible movement of moisture from the stems out into the leaves, where it is removed by transpiration, it is desirable to protect the plants and their leaves from excessive exposure to sunlight.

SUMMARY

1. The greatest reduction in moisture content took place under Partial Exposure and Direct Sunlight. Moisture loss under Medium Shade and Intense Shade was mild.

2. An excessive drying out, leading directly to shattering, occurs in the leaves of those alfalfa plants exposed to direct sunlight.

3. The rate of loss of moisture from the leaves was about the same as from the stems under conditions of

Medium Shade, Intense Shade and Partial Exposure. However, under Direct Sunlight, the leaves cured out far more rapidly than did the stems, leaving the stems green and juicy when the leaves were already sufficiently dry, obviously, a condition to be avoided in actual hay curing.

4. The greatest rate of moisture loss in alfalfa plants takes place during the first hour after cutting, decreases markedly during the following two hours, and then increases again.

5. The average moisture content of green, uncut alfalfa plants at this stage of maturity, in which they were 20.37 inches tall on an average and had not yet begun to flower, is 76.64%.

6. Exposure of alfalfa plants to direct sunlight greatly decreases the movement of moisture from the stems out into the leaves where the moisture is removed by transpiration.

Preliminary Field Experiment

Number 2

Purpose

This experiment was performed to determine whether a repetition of the work conducted in the First Preliminary Field Experiment, usimg similiar materials and technique, would produce the same results as obtained then.

Materials

The materials used in this experiment were the same as described above in the report of Preliminary Field Experiment Number I, with these exceptions.

Twelve hundred alfalfa plants were used on this occasion having an average length of 24.25 inches as taken from the careful measurements of twenty-nine plants, given in inches as follows:- 22.00 inches, 24.50 inches, 24.00 inches, 25.50 inches, 22.50 inches, 20.00 inches, 25.00 inches, 27.00 inches, 25.50 inches, 24.00 inches, 25.00 inches, 26.00 inches, 24.00 inches, 28.00 inches, 26.50 inches, 25.00 inches, 22.50 inches, 24.50 inches, 22.00 inches, 19.50 inches, 24.50 inches, 25.50 inches, 21.00 inches, 26.00 inches, 26.00 inches, 23.00 inches, 25.25 inches, 26.00 inches, and 21.25 inches. These figures give an average height, as mentioned, of 24.25 inches per plant.

Fourty air-tight, friction-cap cans, of the type described in the foregoing experiment, were used for the reason appearing in the account of the procedure shortly following.

The Eosin stain used was prepared by dissolving 280 milligrams of the Eosin powder in 400 cubic centimeters of tap water. This is double the strength of that used before for the sake of effecting a more conspicuous staining of the alfalfa plants.

The contrivances used to effect Medium and Intense Shade were again two wooden frames, this time, however, being five feet wide, five feet long and two and one half feet high. Over one of these a single thickness of white bunting was tacked into place and over the second a double thickness of burlap. To secure Partial Exposure double thicknesses of green colored bunting were used and placed over the upper half of the plants as before.

Procedure.

The experiment was started at seven o'clock of Wednesday morning June 16, 1926, by cutting the twelve hundred alfalfa plants. These were divided into four groups of three hundred plants each. Each group was at once transferred to its respective environment of either Direct Sunlight, Medium Shade, Intense Shade, or Partial Exposure by placing on freshly harrowed ground and covering with the frames for shade, with green bunting for partial exposure, and with no covering for direct exposure to the sun. Two sets of a hundred plants each were kept separate in each group and these weighed separately and regularly at the hours indicated, namely, every hour in the forenoon, every hour and a half in the afternoon, and on the following day once in the morning and once in the evening. The remaining one hundred plants in each group were used to take can samples of ten plants each for use in determining the moisture content of leaves and stems. In taking these samples, which was done at the intervals just mentioned, the leaves were at once separated from the stems with scissors at the junction of the leaves with the petioles and placed in a separate can properly labelled, the stems being placed in another can. These can samples were later taken to the laboratory, weighed, heated for five hours in an electric oven at 110 degrees Centigrade, weighed again, and the loss in weight used in calculating moisture content of the samples. Temperatures for each of the conditions were also taken regularly as given in the tables.

The staining tests were carried on employing the technique described in the report of the Preliminary Field Experiment Number 1. These tests were made from each group every hour from 7:30 to 11:30 A.M. and every hour and a half thereafter up to 4:00 o'clock P.M. The plants were removed at the end of the following day and the results determined and tabulated.

The weather during these two days was fair and clear on the first day with average June temperature and humidity, but was cloudy during the second day with increased humidity and lower temperature.

Results.

The results obtained and presented in Tables 17, 18, 19 and 20 and Figure 21 and summarized in Table 21

Table 17.

DIRECT SUNLIGHT

Set 1. Loss of Moisture from Alfalfa Plants

Time of day Hour	Temperature °C.	Weight of 100 plants grams	Loss in weight grams	Rate of Moisture Loss %	Moisture Content %
7:00	16.5	546	81	14.84	77.20
8:00	22.0	465	47	10.11	65.72
9:15	25.0	418	25	5.99	59.10
10:15	27.0	393	27	6.88	55.56
11:15	30.0	366	35	9.57	51.75
12:45	34.0	331	41	12.39	46.80
2:45	31.0	290	25	8.63	41.00
4:45	26.5	265	8	3.02	37.47
6/17 9:45	28.0	257	51	19.85	36.34
7:30	21.0	206			29.13

Table 17 Cont'd.

Set 2.

Hour	Weight of Plants Grams	Loss in Weight Grams	Rate of Moisture Loss %	Moisture Content %
7:00	674	87	12.91	77.20
8:00	587	46	7.83	67.23
9:15	541	40	7.40	61.97
10:15	501	27	5.39	57.38
11:15	474	26	5.49	54.29
12:45	448	67	14.96	51.31
2:45	381	34	8.93	43.64
4:45	347	15	4.33	39.74
6/17 9:45	332	61	18.38	31.04
7:30	271			

Loss of Moisture from Leaves and Stems.

Leaves

Time of day Hour	Initial weight grams	Weight after heating grams	Loss weight grams	Moisture Content %
7:00	20.1	4.4	15.7	78.11
8:00	21.3	5.6	15.7	73.71
9:15	15.2	4.5	10.7	70.40
10:15	21.7	6.5	15.2	70.05
11:15	24.5	7.8	16.7	68.17
12:45	22.0	7.6	14.4	65.46
2:45	11.7	4.8	6.9	58.98
4:45	13.2	6.6	6.6	50.00
6/7 9:45	10.8	5.4	5.4	50.00
7:30	6.9	4.8	2.1	30.44

Table 17 Con't.

Stems.

Time of day Hour	Initial weight grams	Weight after heating grams	Loss in weight grams	Moisture content %
7:00	25.5	6.0	19.5	76.48
8:00	23.1	5.6	17.5	75.76
9:15	19.7	5.7	14.0	71.07
10:15	28.1	4.6	23.5	83.63
11:15	27.2	7.5	19.7	72.43
12:45	32.3	10.1	22.2	68.74
2:45	18.2	6.6	11.6	63.74
4:45	20.5	8.1	12.4	60.49
6/17 9:45	16.7	6.9	9.8	58.69
7:30	13.5	7.0	6.5	48.15

Table 18.

MEDIUM SHADE

Set 1. Loss of Moisture from Alfalfa Plants

Time of day hour	Temperature °C.	Weight of 100 Plants grams	Loss in weight grams	Rate of moisture Loss %	Moisture Content %
7:30	18.5	633	56	8.85	77.20
8:30	20.0	577	34	5.90	70.37
9:30	21.0	543	27	4.98	66.22
10:30	25.0	516	25	4.85	62.93
11:30	28.0	491	42	8.56	59.88
1:30	27.0	449	32	7.13	54.76
3:30	25.0	417	18	4.32	50.86
5:30	21.0	399	27	6.77	48.66
6/17 10:00	25.0	372	59	15.87	45.37
7:30	21.0	313			38.17

Set 2.

Table 18 Con't.

Time of day hour	Weight of 100 Plants grams	Loss in weight grams	Rate of moisture loss	Moisture Content %
7:30	668	50	7.49	77.20
8:30	618	38	6.15	71.42
9:30	580	27	4.66	67.03
10:30	553	24	4.34	63.91
11:30	529	52	9.83	61.14
1:30	477	32	6.71	55.13
3:30	445	24	5.40	51.43
5:30	421	40	9.51	48.66
6/7 10:00	381	58	15.23	44.03
7:30	323			37.33

Loss of Moisture from leaves and Stems.

Leaves.

Time of day hour	Initial weight grams	Weight after heating grams	Loss in weight grams	Moisture content %
7:00	20.1	4.4	15.7	78.11
8:30	14.1	3.3	10.8	76.60
9:30	18.2	4.5	13.7	75.28
10:30	19.8	5.2	14.6	73.78
11:30	14.5	3.9	10.6	73.11
1:30	10.5	3.6	6.9	65.72
3:30	18.4	6.5	11.9	64.68
5:30	15.0	5.6	9.4	62.67
10:00	9.7	3.7	6.0	61.86
7:30	10.2	4.5	5.7	55.89

Table 18 Con't.

Stems.

Time of day hour	Initial Weight grams	Weight after heating grams	Loss in weight grams	Moisture content %
7:00	25.5	6.0	19.5	76.48
8:30	14.5	3.2	11.3	77.94
9:30	21.0	4.9	16.1	76.67
10:30	28.3	6.8	21.5	75.98
11:30	18.4	4.4	14.0	76.09
1:30	16.2	4.2	12.0	74.08
3:30	29.3	8.9	20.4	69.63
5:30	24.2	7.9	16.3	67.36
10:00	14.2	5.1	9.1	64.09
7:30	16.2	6.2	10.0	61.73

Table 19.

INTENSE SHADE.

Set 1. Loss of Moisture from Alfalfa Plants.

Time of day (hour)	Tempera-ture °C.	Weight of 100 plants grams	Loss in weight grams	Rate of Moisture loss %	Moisture Content %
7:45	16.0	636	32	5.03	77.20
8:45	18.0	604	23	3.81	73.31
9:45	20.0	581	19	3.28	70.52
10:45	23.0	562	20	3.56	68.22
11:45	23.0	542	30	5.54	65.79
1:45	23.0	512	21	4.11	62.15
3:45	22.0	491	17	3.47	59.60
5:45	21.0	474	36	7.60	57.54
6/17 10:15	23.0	438	58	13.25	53.17
7:30	21.0	380			46.13

Table 19. Con't.

Set 2.

Time of day (hour)	Weight of 100 Plants grams	Loss in weight grams	Rate of moisture loss %	Moisture content %
7:45	639	28	4.39	77.20
8:45	611	19	3.11	73.82
9:45	592	29	4.90	71.52
10:45	563	18	3.20	68.02
11:45	545	28	5.14	65.84
1:45	517	23	4.45	62.46
3:45	494	18	3.65	59.68
5:45	476	36	7.57	57.51
6/17 10:15	440	64	14.55	53.16
7:30	376			45.43

Loss of Moisture from Leaves and Stems.

Leaves.

Time of day (hour)	Initial weight grams	Weight after heating grams	Loss in weight grams	Moisture content %
7:00	20.1	4.4	15.7	78.11
8:45	12.3	3.0	9.3	75.60
9:45	19.7	5.0	14.7	74.62
10:45	19.8	4.9	14.9	74.25
11:45	14.9	3.9	11.0	73.83
1:45	15.6	4.2	11.4	73.08
3:45	16.8	5.0	11.8	70.24
5:45	15.3	5.0	10.3	67.33
10:15	8.1	3.1	5.0	61.73
7:30	5.8	2.8	3.0	51.72

Table 19 Con't.

Stems.

Time of day (hour)	Initial weight grams	Weight after heating grams	Loss in weight grams	Moisture content %
7:00	25.5	6.0	19.5	76.48
8:45	16.2	3.9	12.3	75.93
9:45	24.1	5.9	18.2	75.52
10:45	25.2	6.2	19.0	75.40
11:45	20.2	4.7	15.5	76.74
1:45	22.0	5.6	16.4	74.55
3:45	25.2	6.5	18.7	74.21
5:45	20.9	6.0	14.9	71.30
10:15	11.0	3.7	7.3	66.37
7:30	8.5	3.5	5.0	58.83

Table 20.

Set 1.

PARTIAL EXPOSURE

Loss of Moisture from Alfalfa Plants

Time of day (hour)	Temperature °C.	Weight of 100 Plants grams	Loss in weight grams	Rate of moisture loss %	Moisture content %
8:00	19.0	631	51	8.09	77.20
9:00	21.0	580	31	5.35	70.96
10:00	25.0	549	38	6.92	67.17
11:00	29.0	511	35	6.85	62.51
12:00	28.0	476	62	13.03	58.23
2:15	28.0	414	45	10.86	50.65
4:15	35.0	369	14	3.80	45.14
6:15	22.0	355	16	4.51	43.43
6/17 10:45	35.0	339	57	16.82	41.48
7:30	21.0	282			34.51

Table 20 Con't.

Set 2.

Time of day hour	Weight of 100 plants grams	Loss in weight grams	Rate of moisture loss %	Moisture content %
8:00	622	38	6.11	77.20
9:00	584	30	5.14	72.48
10:00	554	39	7.04	68.75
11:00	515	36	7.00	63.92
12:00	479	71	14.83	59.45
2:15	408	45	11.03	50.64
4:15	363	17	4.69	45.05
6:15	346	22	6.36	42.95
6/17 10:45	324	60	18.52	40.21
7:30	264			32.77

Loss of Moisture from Leaves and Stems.

Leaves.

Time of day (hour)	Initial weight grams	Weight after heating grams	Loss in weight grams	Moisture content %
7:00	20.1	4.4	15.7	78.11
9:00	14.4	3.7	10.7	74.31
10:00	15.8	4.0	11.8	74.69
11:00	11.1	2.8	8.3	74.78
12:30	19.0	3.5	15.5	81.58
2:15	12.1	4.5	7.6	62.81
4:15	12.1	5.2	6.9	57.03
6:15	16.4	5.3	11.1	67.69
10:45	10.5	4.6	5.9	56.20
7:30	4.0	2.7	1.3	32.50

Table 20 Con't.

Stems.

Time of day (hour)	Initial weight grams	Weight after heating grams	Loss in weight grams	Moisture content %
7:00	25.5	6.0	19.5	76.48
9:00	19.9	4.5	15.4	77.39
10:00	25.8	5.3	20.5	79.46
11:00	14.0	3.2	10.8	77.15
12:30	18.7	5.1	13.6	72.73
2:15	16.4	4.8	11.6	70.74
4:15	21.3	6.8	14.5	68.08
6:15	18.8	5.2	13.6	72.35
10:45	15.7	6.3	9.4	59.88
7:30	8.3	3.4	4.9	59.04

Figure 21

Comparison of Moisture Content Decrease of Alfalfa under the Conditions Indicated

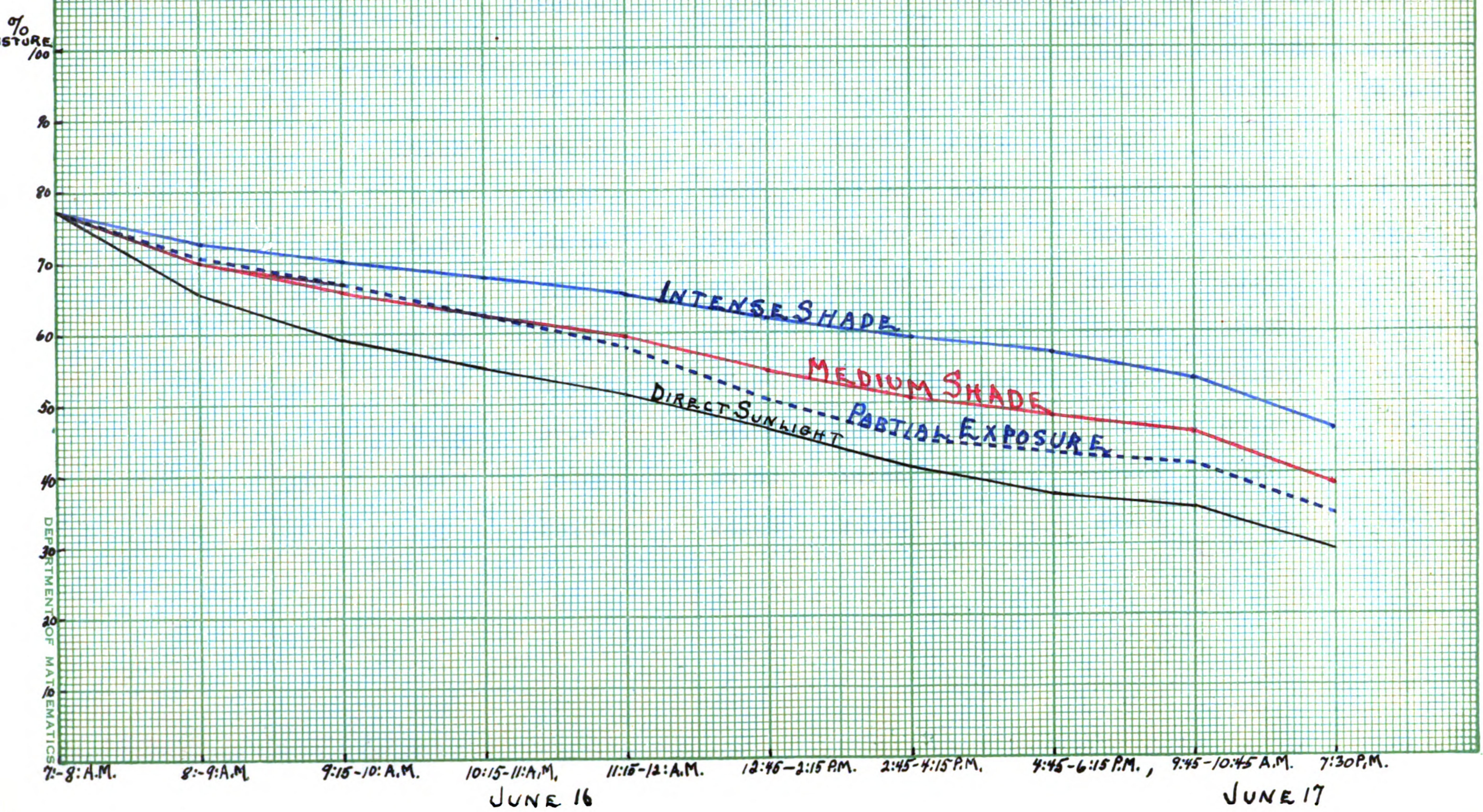


Table 21.

Comparison of the Results Obtained under the Four Conditions Indicated.

DIRECT SUNLIGHT Hour of the day 5/15	Humidity	Rate of moisture loss %	Moisture content of entire plant percent	Percent moisture in leaves of total moisture in plant	Same in stems	MEDIUM SHADE Rate of moisture loss percent	Moisture content of entire plant percent	Percent of moisture in leaves of total moisture in plants	Same in stems
7:-8:	68 %	14.84	77.20	44.61	55.39	6.85	77.20	44.61	55.39
8-9		10.11	65.72	47.29	52.71	5.90	70.37	48.87	51.13
9:15-10:00		5.99	59.10	49.92	50.08	4.98	66.22	45.98	54.02
10:15-11:00		6.88	55.50	39.28	60.72	4.65	62.98	40.45	59.55
11:15-12:00	50%	9.57	51.75	45.88	54.12	8.55	59.88	49.09	50.91
12:45-2:15		12.59	46.80	39.35	60.65	7.13	54.75	35.51	64.49
2:45-4:15	45%	8.65	41.00	37.30	62.70	4.52	50.80	36.85	63.15
4:45-5:15		5.02	37.47	34.74	65.26	5.77	45.00	33.58	66.42
5/17-9:45-10:45	98%	19.85	30.04	35.55	64.45	15.57	45.37	39.74	60.26
7:00	80%	....	29.13	24.42	75.58		38.17	30.31	69.69

Table 21 Cont.

INTENSE SHADE						PARTIAL EXPOSURE			
Hour of the day 6/16	Humidity	Rate of moisture loss percent	Moisture content of entire plant %	Percent moisture in leaves of total moisture in plants	Same in stems	Rate of moisture loss %	Moisture content of entire plant %	Percent moisture in leaves of total moisture in plants	Same in stems
7:-8:	65%	5.06	77.20	44.61	55.39	8.09	77.20	44.61	55.39
8-9		6.81	73.61	45.06	54.94	5.35	70.56	40.99	59.01
9:15-10:00		5.28	70.52	44.69	55.31	6.92	67.17	36.54	63.46
10:15-11:00		5.56	68.22	43.96	56.04	6.85	62.57	43.46	56.54
11:15-12:00	50%	5.54	65.79	41.51	58.49	13.05	58.26	53.25	46.75
12:45-2:15		4.11	62.15	41.01	58.99	10.86	50.65	39.59	60.41
2:45-4:15	45%	3.47	59.60	38.69	61.31	5.60	45.14	32.25	67.75
4:45-6:15		7.60	57.54	40.88	59.12	4.51	40.40	44.14	55.86
6/17 9:45-10:45	90%	13.25	53.17	40.36	59.64	10.52	41.40	38.57	61.43
7:00	80%		46.15	37.50	62.50		34.87	20.97	79.03

confirm the remarks made in the first experiment. On this occasion the most extensive drying occurred in those alfalfa plants that were directly and partially exposed to the sunlight with the former somewhat in the lead as will be seen from an inspection of Tables 17, 20, 21 and Figure 21. These also show that the moisture content dropped more moderately in medium shade and especially so in intense shade.

Further the leaves drop to a lower moisture content namely 30.44%, in the plants exposed to sunlight than in those under any other condition. The next lowest are the leaves of partially exposed plants in which the moisture content drops to 32.50%. It will be noticed that in the shaded plants the moisture content in the leaves is maintained above 50%. For leaves to dry out to as low as 30.44% even in two days allows for little wonder concerning the reasons for shattering in the swath.

Again, the greatest of moisture loss occurs during the first hour, drops down during the second and third, and recovers perceptibly at the fourth hour again. Examination of Tables 17, 18, 19, and 20 will reveal this fact clearly, fully substantiating a similar remark made in reporting Preliminary Field Experiment Number 1.

Attention is called to the tendency which comes to the foreground here and was also observed in the first experiment, namely that exposure to the rays of the sun increases the rate of moisture loss from the leaves markedly above that of the stem, so that the leaves dry before the stems do.

In Direct Sunlight and Partial Exposure, for instance, the differences between the moisture contents of the leaves and stems at the end of the two days are respectively 13.29% and 26.54%, the leaves having become that much drier during the length of time indicated. Away from the sunlight under Medium Shade and Intense Shade the differences in final moisture contents between leaves and stems are only 5.84% and 7.11% respectively. In the field this is to be interpreted as indicating an even curing of alfalfa plants, in the windrows and bunches with retention of leaves and an uneven curing, in the swath accompanied with shattering or loss of leaves.

The moisture content of green, uncut alfalfa plants at this stage where they have reached an average heighth of 26½ inches with flowers not yet formed and lower leaves still entirely green was found to be 77.20%. This is .64% higher than the 76.64% received for the younger alfalfa plants used in the First Preliminary Field Experiment. Apparently there is no correlation between the increase in maturity of alfalfa plants and the decrease of their moisture content.

Table 22.

The Effect of Sunlight, Shade, and Partial Exposure on the Ability of Alfalfa Plants to take up Eosin.

Table 22 Con't.

	DIRECT SUNLIGHT			MEDIUM SHADE.		
Hour at which stain was applied.	Stain ab-sorbed.	Height reached by stain in plant	Height of plant	Stain ab-sorbed	Height reached by stain in plant	Height of plant
7:30	8.+cc.	9½ in.	22 in.	8.+ cc.	9.5 in.	25½in.
8:30	7. "	6½ "	24½ "			
9:30	6.4 "	3¼ "	24. "	5.4 "	9.0 "	24. "
10:30	6.7 "	5½ "	25½ "	3.0 "	9.½ "	25. "
11:30	4.6 "	4. "	22½ "	8.0 "	10½ "	26. "
1:00	4.5 "	5. "	20. "	5.0 "	9. "	24. "
2:30	2.0 "	3½ "	25. "	4.8 "	8½ "	28. "
4:00	3.0 "	5¾ "	27. "	5.0 "	11½ "	26½ "

	INTENSE SHADE			PARTIAL EXPOSURE		
Hour at which stain was applied.	Stain ab-sorbed	Height reached by stain in plant	Height of plant	Stain ab-sorbed	Height reached by stain in plant	Height of plant
7:30	8.+ cc.	13½ in.	25. in.	F.		
8:30	5.8 "	8½ "	22½ "			
9:30	2.6 "	5½ "	24½ "	7.2 cc	5½ in.	26 in.
10:30	3.4 "	8. "	22. "	7.9 "	11. "	26 "
11:30	7.5 "	8½ "	19½ "	6.0 "	6½ "	23 "
1:00	3.2 "	7. "	24½ "	4.6 "	5½ "	25¼ "
2:30	8.0+ "	5. "	25½ "	3.2 "	4. "	26 "
4:00	3.6 "	3. "	21 "	4.3 "	3½ "	21¼ "

Table 22 gives the results secured from the staining tests of alfalfa plants with Eosin. There is not such a marked difference this time between the amount of stain taken up by those alfalfa plants exposed to sunlight and those shaded. However, the height reached by the stain in the plants shows that the exposure to direct sunlight considerably interfered with the maximum movement of moisture through the plant. For example, in the plants under Direct Sunlight the stain only attained a height of 3½ inches and 5¼ inches respectively in the last two tests, whereas, under Medium Shade the stain was attracted up into the plant to a height of 8½ inches and 11½ inches respectively in the last two tests.

<u>Summary.</u>

1. The moisture content decreased to the greatest extent in the alfalfa plants under Direct Sunlight, to a less extent in those under Partial Exposure, still less in those under Medium Shade, and decreased to the lowest extent in the plants under Intense Shade.

2. The leaves of alfalfa plants exposed to direct sunlight dried down in only two days curing, to a moisture content undesirably low because of the shattering that results from it.

3. The rate of moisture loss is at its greatest during the first hour, drops during the second and third hours and increases again beginning with the fourth hour.

4. Exposure to direct sunlight tends to increase the rate of drying of leaves above that of the stems result-

ing in uneven curing in the field. Protection from the sunlight enables leaves and stems to cure at approximately the same rate assuring even drying out.

5. Exposure to direct sunlight interferes with maximum movement of moisture in the plant from the stems into and out through the leaves, as shown by the staining tests.

6. The moisture content of green, uncut alfalfa plants in the stage of maturity described above is 77.20%.

Preliminary Field Experiment.

Number 3

Purpose

This experiment of staining alfalfa plants with Eosin solution at different stages under different conditions was conducted to test, a little more extensively than before, the effect that direct sunlight has upon the movement of moisture up the stems and out through the leaves.

Material

The Eosin solution was prepared by dissolving three and one half grams of powdered Eosin in five liters of tap water.

Two hundred 4-dram glass vials, which were used, were two and three fourths inches tall and five eights of an inch in diameter and were equipped with split corks perforated lengthwise with a sufficiently large bore to accommodate the stems of the alfalfa plants.

Two hundred plants were taken from the border alfalfa plot mentioned earlier in this work. The plants were in full bloom and after cut were of the length indicated in Tables 23 and 24.

Table 23.

DIRECT SUNLIGHT

Staining Alfalfa Plants with Eosin.

Cut in Air — Cut Under Stain

12:15 M. Temp. 45°C. Av. Am't. Stain-9.57 cc. Av. Hgt. 24.05 in.

No. of plants	height of plant	height reached by stain	stain used.	No. of plants	Height of plant	Height reached by stain	amount stain used.
1	23.5 in.	23.5 in.	8.0 cc.	6	26.5 in	26.5 in	14.7 cc

Table 23. Con't.

No. of plant	Height of plant	Height reached by stain	Stain used	No. of plant	Height of plant	Height reached by stain	Amount stain used
2	20.5 in.	20.5 in	10.0 cc.	7	25.5 in.	25.5 in.	9.9 cc.
3	27.0 "	26.0 "	11.6 "	8	27.5 "	27.5 "	6.0 "
4	25.0 "	25.0 "	7.9 "	9	21.0 "	21.0 "	9.0 "
5	26.0 "	26.0 "	9.4 "	10	25.5 "	21.0 "	9.1 "
Average		24.2 "	9.38"	Average		23.9 "	9.76"
12:30 M.-Temp 45°C. Av. Am't. Stain-8.35 cc. Av. Hgt. 22.80 in.							
1	25.5 In.	25.5 in.	14.1 cc	6	26.0 in.	26.0 in.	12.0 cc.
2	20.0 "	20.0 "	8.5 "	7	24.0 "	24.0 "	7.6 "
3	21.0 "	21.0 "	6.6 "	8	22.5 "	22.5 "	7.3 "
4	24.5 "	24.5 "	6.8 "	9	23.0 "	23.0 "	6.1 "
5	21.0 "	21.0 "	8.8 "	10	20.5 "	20.5 "	5.7 "
Average		22.4 "	8.96"	Average		23.2 ".	7.74"
12:45 M.- Av. Am't Stain - 7.94 cc. Av. Height-20.85 In.							
1	17.5 In.	17.5 in.	7.0 cc	6	18.5 in.	18.5 in.	4.8 cc.
2	23.0 "	23.0 "	9.1 "	7	26.0 "	26.0 "	14.5 "
3	24.0 "	24.0 "	8.4 "	8	22.5 "	22.5 "	7.8 "
4	21.0 "	21.0 "	4.0 "	9	16.5 "	16.5 "	9.3 "
5	20.0 "	20.0 "	9.4 "	10	19.5 "	19.5 "	5.1 "
Average		21.1 "	7.58"	Average		20.6 "	8.30".
1:00 P.M. Temp. 38°C. Av. Am't. Stain-8.03 cc. Av. Hgt. 18.5 In.							
1	20.0 in.	20.0 in	11.5 cc	6	19.0 in.	19.0 in	5.3 cc.
2	22.0 "	18.0 "	8.3 "	7	22.5 "	19.0 "	6.0 "
3	19.0 "	19.0 "	8.6 "	8	20.0 "	20.0 "	11.7 "
4	17.5 "	17.5 "	6.6 "	9	18.0 "	18.0 "	5.3 "
5	16.5 "	16.5 "	10.5 "	10	18.0 "	18.0 "	6.5 "
Average		18.2 "	9.10"	Average		18.8 "	6.96"

Table 23 Con't.

Cut in Air				Cut under Stain			
No. of plant	Height of plant inches	Height reached by stain inches	Amount Stain used cc.	Number of plant	Height of plant inches	Height reached by stain inches	Amount stain used cc.
1:30 P.M. Temp. 45°C-Av. Am't Stain-8.82 cc- Av. Height 19.15 in.							
1	20.5 in	20.5 in	9.5 cc	6	16.0 in	16.0 in	9.4cc
2	18.0 "	18.0 "	9.5 "	7	15.0 "	9.5 "	4.5 "
3	23.0 "	23.0 "	13.9 "	8	20.5 "	20.5 "	6.0 "
4	24.0 "	24.0 "	10.1 "	9	18.0 "	18.0 "	9.9 "
5	22.0 "	22.0 "	7.6 "	10	19.0 "	19.0 "	7.7"
Average		21.7 "	10.12"	Average		16.6 "	7.50"
2:00 P.M. Temp. 48°C Av. Am't Stain - 8.62 cc. Av. Height 17.9 in.							
1	21.0 in	17.5 in	6.4 cc	6	19.5 in	19.5 in	9.0 cc
2	18.0 "	18.0 "	12.9 "	7	19.5 "	16.5 "	5.7 "
3	18.5 "	18.5 "	7.3 "	8	19.0 "	19.0 "	11.4 "
4	19.0 "	19.0 "	8.0 "	9	17.5 "	17.5 "	11.3 "
5	16.5 "	16.5 "	6.4 "	10	19.5 "	17.0 "	7.8 "
Average		17.9 "	8.20"	Average		17.9 "	9.04"
2:30 P.M. Temp-45°C-Av. Am't. Stain-7.17 cc-Av. Height 16.95 in.							
1	23.0 in	20.5 in.	7.6 cc	6	12. in	17. in	6.7 cc
2	22.0 "	18.0 "	9.0 "	7	23.5 "	23.5 "	12.0 "
3	18.0 "	18.0 "	5.9 "	8	19.0 "	19.0 "	6.0 "
4	19.0 "	6.5 "	4.4"	9	20.0 "	12.0 "	3.5 "
5	21.0 "	21.0 "	8.1 "	10	22.5 "	19.0 "	8.5 "
Average		15.8 "	7.02	Average		18.1 "	7.34"
3:00 P.M.-Temp 54°C. Av. Am't Stain- 7.33 cc Av. Height 17.60 in.							
1	19.0 in	16.5 in	5.7 cc	6	21.0 in.	19.0 in	8.0 cc
2	23.0 "	20.0 "	4.9 "	7	20.0 "	16.5 "	5.8 "
3	19.5 "	16.0 "	6.9 "	8	18.0 "	16.0 "	11.2 "
4	18.0 "	15.0 "	8.3 "	9	22.0 "	18.5 "	7.8 "
5	20.0 "	20.0 "	8.0 "	10	21.0 "	18.5 "	5.7 "
Average		1[illegible].8 "	6.96"	Average		17.7 "	7.7 "

Table 23 Con't.

Cut in Air				Cut under Stain			
No. of plant	Height of plant inches	Height reached by stain inches	Amount Stain used cc.	No. of plant	Height of plant inches	Height reached by stain inches	Amount stain used. CC
4:00 P.M.	Temp 49°C-	Av. Am't	Stain-4.15 cc	Av. Height 11.00 in.			
1	17.5 in	12.5 in	5.8 cc	6	20.5 in	9.0 in	3.7 cc
2	20.0 "	14.0 "	3.6 "	7	18.0 "	7.5 "	4.0 "
3	18.0 "	14.5 "	6.2 "	8	22.0 "	9.0 "	3.5 "
4	18.5 "	13.5 "	3.7 "	9	16.5 "	4.0 "	2.8 "
5	20.0 "	20.0 "	5.3 "	10	19.0 "	6.0 "	3.1 "
	Average	14.9 "	4.92"		Average	7.1 "	3.38"
5:00 P.M.	Temp 43°C.	Av. Am't	Stain 6.44 cc.	Av. Height 14.17 in.			
1	20.0 in	11.5 in.	5.7 cc	6	16.0 in	7.5 in	5.5 cc
2	16.0 "	9.0 "	4.0 "	7	20.0 "	20.0 "	5.2 "
3	17.75"	15.25"	5.8"	8	19.0 "	19.0 "	9.3 "
4	21.0 "	19.00"	10.7"	9	17.0 "	17.0 "	7.8 "
5	17.0 "	17.0 "	6.1 "	10	18.0	6.5 "	4.3 "
	Average	14.35"	6.46"		Average	14.0 "	6.42"

Table 24.

SHADE.

Staining Alfalfa Plants with Eosin.

Cut in Air: No. of plant	Height of plant inches	Height reached by stain inches	Amount stain used cc.	Cut under Stain: No. of plant	Height of plant inches	Height reached by stain inches	Amount stain used cc.
12.15 M. Av. Am't Stain 8.03 cc. Av. Height 21.80 inches.							
1	22.0 in	22.0 in	8.2 cc	6	21.0 in.	21.0 in	7.5 cc
2	22.5 "	22.5 "	12.0 "	7	19.5 "	19.5 "	4.7 "
3	25.0 "	25.0 "	10.6 "	8	22.5 "	22.5 "	9.8 "
4	19.0 "	19.0 "	5.4 "	9	23.5 "	23.5 "	10.8 "
5	22.0 "	22.0 "	5.0 "	10	21.0 "	21.0 "	6.3 "
Average		22.1 "	8.24"	Average		21.5 "	7.82"
12:30 M. Temp 27°C- Av. Am't Stain. 7.71 cc. Av. Height 23.35 in.							
1	25.0 in	23.0 in	11.8 cc	6	21.0 in	21.0 in	7.0 cc
2	22.5 "	22.5 "	8.0 "	7	25.0 "	25.0 "	7.7 "
3	18.0 "	18.0 "	5.9 "	8	24.5 "	24.5 "	5.6 "
4	25.0 "	25.0 "	7.5 "	9	24.5 "	24.5 "	6.3 "
5	21.0 "	21.0 "	7.3 "	10	27.0 "	27.0 "	10.0 "
Average		21.9 "	8.10"	Average		24.8 "	7.32"
12:45 M. Av. Am't Stain 7.59 cc. Av. Height 20.85 in.							
1	25.0 in	24.0 in	8.7 cc	6	22.0 in	22.0 in	7.7 cc
2	22.5 "	22.5 "	11.7 "	7	20.5 "	20.5 "	7.0 "
3	23.0 "	23.0 "	7.4 "	8	21.0 "	21.0 "	6.3 "
4	19.0 "	19.0 "	6.2 "	9	20.0 "	20.0 "	7.6 "
5	22.0 "	22.0 "	5.8 "	10	14.5 "	14.5 "	5.5 "
Average		22.1 "	7.96"	Average		19.6 "	7.22"

Table 24 Con't.

Cut in Air				Cut under Stain			
No. of plant	Height of plant inches	Height reached by stain inches	Amount stain used cc.	No. of plant	Height of plant inches	Height reached by stain inches	Amount stain used cc.
1:00 P.M.	Temp 27°C.	Av. Am't Stain- 8.5 cc.			Av. Height 21.06 in		
1	21.0 in	21.0 in	7.6. cc	6	21.0 in.	21.0 in.	8.8 cc
2	21.5 "	21.5 "	6.0 "	7	23.0 "	23.0 "	12.0 "
3	21.5 "	21.5 "	9.0 "	8	19.5 "	19.5 "	7.0 "
4	20.0 "	20.0 "	7.9 "	9	20.0 "	20.0 "	7.0 "
5	25.0 "	25.0 "	15.0 "	10	18.0 "	18.0 "	4.8 "
Average		21.8 "	9.1 "	Average		20.3 "	7.92"
1:30 P.M.	Temp. 27°C.	Av. Am't Stain 8.33 cc.			Av. Hgt. 20.3 in.		
1	18.5 in	18.5 in	9.0 cc	6	15.5 in	15.5 in	7.0 cc
2	21.0 "	21.0 "	10.6 "	7	19.0 "	19.0 "	8.8 "
3	17.5 "	17.5 "	4.4 "	8	22.5 "	22.5 "	11.0 "
4	22.5 "	22.5 "	8.4 "	9	20.5 "	20.5 "	8.7 "
5	21.0 "	21.0 "	8.3 "	10	25.0 "	25.0 "	7.1 "
Average		20.1 "	8.14"	Average		20.5 "	8.52"
2:00 P.M.	Temp 28°C.	Av. Am't Stain 7.46 cc.			Av. Height 19.15 in.		
1	18.0 in	18.0 in	6.1 cc	6	18.5 in	18.5 in	12.0 cc
2	20.0 "	20.0 "	4.6 "	7	20.5 "	20.5 "	7.1 "
3	21.0 "	21.0 "	6.8 "	8	19.0 "	19.0 "	8.5 "
4	22.5 "	22.5 "	5.6 "	9	18.5 "	18.5 "	10.5 "
5	16.5 "	16.5 "	6.4 "	10	17.0 "	18.0 "	7.0 "
Average		19.60"	5.9"	Average		18.7 "	9.02"

Table 24 Con't.

No. of plant	Height of Plant inches	Height reached by stain inches	Amount of stain used cc.	No. of plant	Height of plant inches	Height reached by stain inches	Amount of stain used cc.
2:30 P.M.	Temp 28°C.	Av. Am't Stain 8.03 cc.			Av. Hgt. 19.40 in.		
1	22.0 in	22.0 in	7.6 cc	6	20.5 in	20.5 in	9.1 cc.
2	17.5 "	17.5 "	6.6 "	7	18.0 "	18.0 "	7.8 "
3	20.0 "	20.0 "	6.1 "	8	16.5 "	16.5 "	6.5 "
4	16.5 "	16.5 "	5.8 "	9	20.5 "	20.5 "	10.6 "
5	19.5 "	19.5 "	10.0 "	10	23.0 "	23.0 "	10.2 "
	Average	19.1 "	7.22"	Average		19.70"	8.84"
3:00 P.M.	Temp. 28°C.	Av. Am't Stain- 8.32 cc			Av. Height 19.65 in.		
1	18.0 in.	18.0 in	8.4 cc.	6	24.0 in	24.0 in	9.0 cc
2.	21.5 "	21.5 "	7.4 "	7	17.0 "	17.0 "	7.3 "
3.	24.0 "	24.0 "	15.0 "	8	16.5 "	16.5 "	7.7 "
4.	20.5 "	20.5 "	4.7 "	9	18.5 "	18.5 "	9.3 "
5.	20.5 "	16.5 "	9.4 "	10	16.0 "	16.0 "	5.0 "
	Average	20.9 "	8.98 "	Average		18.4 "	7.66 "
4:00 P.M.	Temp. 28°C.	Av. Am't Stain 8.26 cc.			Av. Hgt. 18.6 in.		
1	17.0 In.	17.0 in	9.0 cc	6	22.0 in	22.0 in	11.4 cc.
2	23.0 "	23.0 "	8.5 "	7	18.0 "	18.0 "	7.6 "
3	22.5 "	18.5 "	8.4 "	8	15.5 "	15.5 "	7.8 "
4	18.0 "	18.0 "	12.7 "	9	16.0 "	16.0 "	5.1 "
5	18.0 "	18.0 "	5.4 "	10	20.0 "	20.0 "	6.7 "
	Average	18.9 "	8.8 cc	Average		18.3 "	7.72"
5:00 P.M.	Temp. 27.5°C.	Av. Am't Stain 8.36 cc			Av. Hgt. 20.35 in		
1	23.0 in	23.0 in	8.0 cc	6	17.0 in	17.0 in	6.3 cc
2	19.0 "	19.0 "	14.8 "	7	20.5 "	20.5 "	8.6 "
3	19.0 "	19.0 "	7.3 "	8	20.0 "	20.0 "	6.5 "
4	19.0 "	19.0 "	6.0 "	9	20.0 "	20.0 "	7.6 "
5	22.0 "	22.0 "	10.2 "	10	24.0 "	20.0 "	8.0 "
	Average	20.4 "	9.32 "	Average		20.3 "	7.4 "

For Direct Sunlight the plants were placed in the open, on the stubble surface of an adjacent plot, directly exposed to the sun. For Shade the wooden frame described in the report of Preliminary Field Experiment Number 2, covered with two thicknesses of burlap, was placed over the plants to be kept shaded.

Procedure.

At 12:15 O'clock P.M., June 30, 1926, the two hundred alfalfa plants were cut, the first group of one hundred plants placed in Direct Sunlight and the second group placed in the Shade. At once ten plants were taken from each group and their stems inserted into the glass vials which had previously been filled with Eosin solution to the bottom of the corks. The stems of five plants of each group were, however, first dipped into a dish of Eosin solution and their ends clipped off under the stain to determine whether cutting under stain facilitates the movement of the stain up into the plants. This entire performance was repeated as shown in Tables 23 and 24, every fifteen minutes up to 1:00 o'clock P.M., every half hour thereafter up to 3:00 o'clock P.M., and every hour thereafter up to 5:00 o'clock, at which intervals temperatures were also taken and recorded. The plants stained were kept in an upright position by supporting in oblong metal boxes, one box for the group left exposed to the sun and another for the group kept in shade.

Immediately after five o'clock the plants were removed to the laboratory where they remained until the morning of July 2. Exactly 44 hours after the first ten plants from each group had been treated, they were removed from the vials and the other plants then removed in the order in which had been originally inserted into the vials, namely at fifteen minute intervals from 8:15 A.M. to 9:00 A.M., every half hour then until 11:00 A.M., and every hour following up to 1:00 P.M. In this manner every group of alfalfa plants had been left with the vials of stain exactly 44 hours. After the plants had been separated from the vials, the length of each plant and the distance up with the stain had been pulled in each was measured as well as the amount of stain in cubic centimeters taken up as manifested by the amount remaining in the vials. These results were then tabulated and are given in Tables 23 and 24 and summerized in Table 25 and Figure 22.

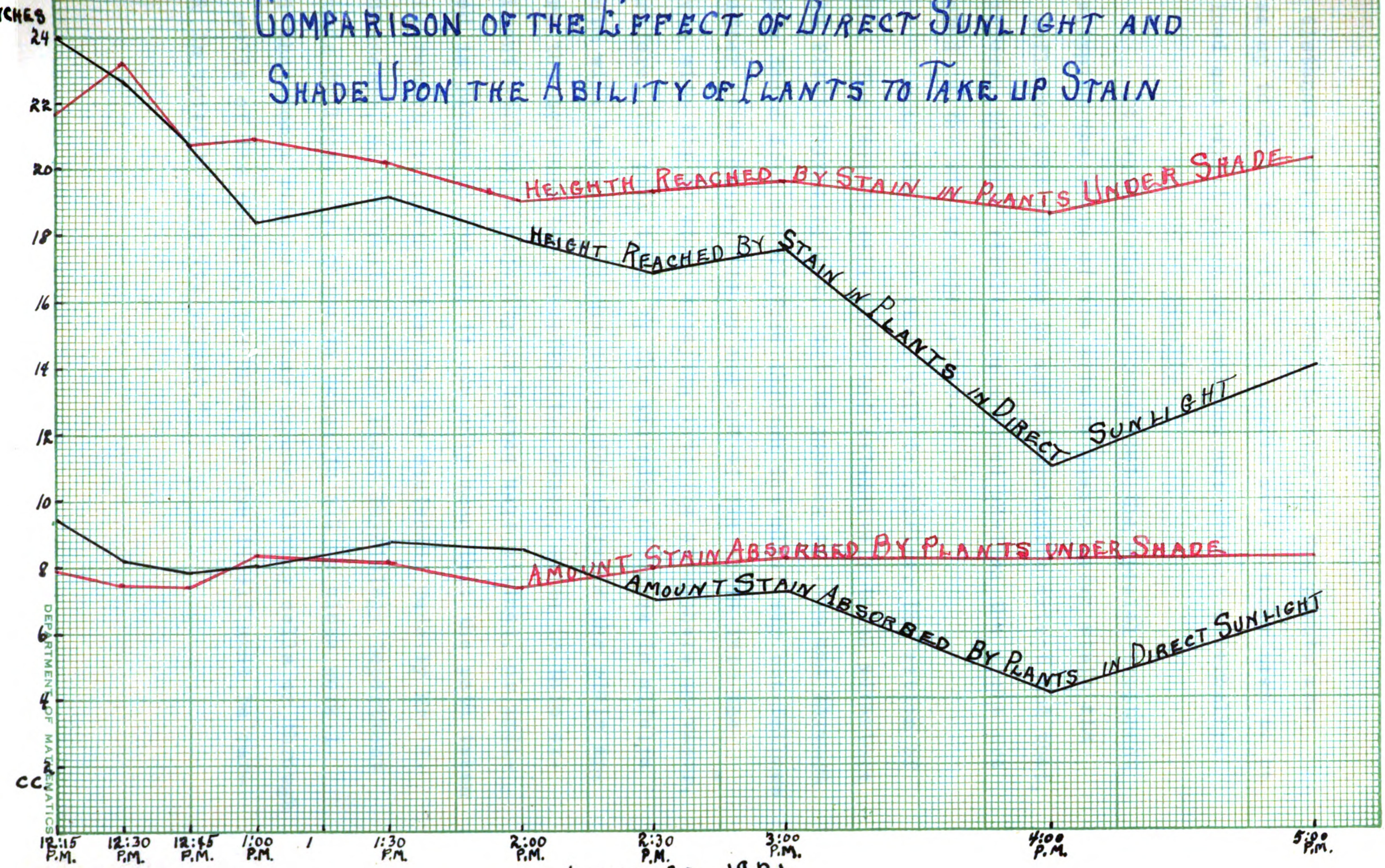
Table 25.

Summary of Tables 23 and 24, comparing averages of amount of stain taken up and height reached in alfalfa plants under Direct Sunlight and under Shade.

	Direct Sunlight			Shade.		
Time P.M. 6/30/26.	Temperature °C.	Amount of stain taken up Cub. C.	Height reached by stain inches	Temperature °C.	Amount of stain taken up Cub. C.	Height reached by stain inches.
12:15		9.57 cc	24.05 in		8.03 cc	21.80 in.
12:30	45	8.35 "	22.80 "	27.	7.71 "	23.35 "
12:45		7. 94 "	20.85 "		7.59 "	20.85 "
1:00	38	8.03 "	18.50 "	27.	8.50 "	21.06 "
1:30	45	8.82 "	19.15 "	27.	8.33 "	20.30 "
2:00	48	8.62 "	17.90 "	28.	7.46 "	19.15 "
2:30	45	7.17 "	16.95 "	28.	8.03 "	19.40 "
3:00	54	7.33 "	17.60 "	28.	8.32 "	19.65 "
4:00	49	4.15 "	11.0 "	28.	8.26 "	18.60 "
5:00	43	6.44 "	14.17 "	27.5	8.36 "	20.35 "

Figure 22

Comparison of the Effect of Direct Sunlight and Shade Upon the Ability of Plants to Take up Stain



The distances indicated in the staining of the plants are those up to which the stems and leaves were plainly seen to be stained and beyond which no staining was evident externally.

Results

It becomes clear at once that the special treatment of clipping the stems of the alfalfa plants under stain did not influence the staining to any recognizable extent and that, therefore, the same results are secured whether the stems are clipped in the air or under stain.

AT this point it is well to consider the action of Eosin. The fact is well known and extensively taken advantage of by Plant Physiologists, that in passing up into and through plants Eosin does not diffuse through the plant sap but follows up after it as it recedes up and out of the stems into the leaves with the moisture escaping into the atmosphere as vapor.* Therefore, the path taken by the escaping moisture in alfalfa plants will be marked by the stain, for wherever the stain appears the moisture has preceded it. Hence, since in this experiment such large majority of leaves were stained, as indicated in Tables 23 and 24, it can only mean that the path taken

*This remark is substantiated by the statement made by Mr. H. F. Clements, an instructor in the Plant Physiology Department of this College. Mr. Clements says:"In all my class work I find that Eosin will not diffuse through living cells or through the walls of the vessels, but that the dye itself must be carried in order to show its effect."

by much of the moisture in the drying of alfalfa plants is through the leaves

On the basis of this, it is very evident from the results obtained and represented in Tble 25 and Figure 22, that exposure to direct sunlight had a deleterious effect upon the leaves by lowering their capacity for giving off water and their subsequent ability of drawing up stain. For under the condition of Direct Sunlight the plants had been so effected that at the end of the day they were no longer able to raise the stain more than from II.00 inches to I4.I7 inches up the stems and leaves nor take up more than from 4.I5 to 6.44 cubic centimeters of stain. On the other hand, the plants whose leaves had been protected in the shade continued to take up stain from the beginning to the conclu- of this experiment with unbated intensity. At the beginning, for excample, the plants in the shade were taking up over 8 cubic centimeters of stain and as high as 2I.80 inches up the stems with their leaves; and at the conclusion the plants were still taking from 8.26 to 8.36 cubic centimeters of stain and up as high as from I8.60 to 20.35 inches.

Summary

I. Exposure to sunlight of cut alfalfa plants reduces the power of the leaves to give off moisture as manifested by their ability to take up stain.

2. Eosin performs equally well regardless of whether the stems of the alfalfa plants are cut in the air or under the stain.

Major Field Experiment.

Purpose.

The Major Field Experiment was carried on with alfalfa hay cured in the field under five different methods, viz.: hay cured in windrows made with a curved tooth, left-hand drive, side-delivery rake; hay cured in windrows with a straight tooth, left-hand drive, side-delivery rake; hay cured by bunching with a dump rake and after three and one half days built into cocks and allowed to remain there for a day; hay cured in the swath; hay cured in the swath for approximately three and one half days and then cocked. The experiment was conducted for the purpose of determining as fas as possible, first, how moisture is lost from forage plants in the process of curing into hay; and second, what influence different methods of curing have upon the rapidity of moisture loss and upon the manner in which the loss takes place, either through the leaves, through the stems, or about equally from both.

Description.

Cooperating with Mr. Ralph Hudson, who has charge of the College Farm, it was made possible to carry this experiment through under typical Michigan field conditions and with the kinds of hay making implements actually used by Michigan farmers.

The work was conducted in Field 21 of the Michigan State College Farm. In this field a very good stand of alfalfa had been secured, mowing of which was begun when the meadow was about 1/10 in bloom and the lower leaves of the alfalfa plants were just beginning to discolor. The section of the field used for the experiment in question was centrally located and in an area of the field in which an average growth had been made constituting a stand which yielded about a ton and one half of cured alfalfa hay to the acre, as near to the average of the state alfalfa hay yield as could be secured.

The project itself was started at three o'clock in the afternoon of Thursday, June 24, 1926, allowed to run its course the subsequent Friday, Saturday, Sunday, and Monday, terminating at about eleven o'clock in the forenoon of Tuesday, June 29, when the hay was hauled in. During this time the weather was also of about the average kind that the Michigan farmer in general has to contend with during the hay making season. There was a light shower during each of the first two nights of this period and two days of rather cloudy, cool weather. Reports from the Weather Bureau show that during the early morning of Friday, June 25, from about 1 to 2 A.M. a light shower took place with a rainfall amounting to ten hundredth of an inch. During the evening of the same day (Friday, June 25) a light rain fell approximately between the hours of 10 and 11 P.M. to the extent of nine hundredth of an inch. The Saturday and Sunday of this period were quite cloudy keeping the temperature down to an average of 17 degrees Centigrade during Saturday and to 22 degrees Centigrade during Sunday, from 8 to 13 degrees lower than

the average of the other days when a temperature as high as 36 degrees Centigrade was reached at times.

Reference has already been made to the five different methods under which the hay of this project was cured. These were arranged for as follows. Five swaths were cut with a mower mowing an eight foot swath, with the swath side by side running the width of the field. At once one of the swaths was raked into a windrow with a curved tooth, left-hand drive, side-delivery rake[1]; a second swath was windrowed with a straight tooth, left-hand drive, side delivery rake[2]; a third swath was bunched with a dump rake; and the fourth and fifth swaths were allowed to remain untouched. The cut alfalfa was left under these conditions until hauled,in, with these two exceptions. The bunched hay after approximately three and one half days was built into cocks each weighing about from 80 to 100 pounds and left there until harvested. The hay of one of the swaths also, after approximately three and one half days, was built into cocks of about the same size of those just mentioned, and then left untouched until hauled in.

These five swaths were mowed and the first three raked as described at three o'clock Thursday afternoon, June 24. Immediately samples of ten plants each were taken from the two windrows, the bunched hay, and from the swaths. This sampling was repeated at hourly intervals that afternoon

1. Manufactured by the John Deere Plow Company of Moline, Ill.
2. Manufactured by the Massey Harris Harvester Company of Batavia, N.Y.

until six o'clock and the following day, Friday, four times during the forenoon. During the rest of the period, samples were taken three times Friday afternoon, only once Saturday forenoon and Sunday afternoon because of the unsettled weather described above, once Monday forenoon, again Monday afternoon, and then shortly before the hay was hauled in Tuesday morning, June 29. The ten plants, chosen whenever a sample was taken, were selected to be as representative as possible, seven being taken from the inside of the windrows and bunches and three from the outside, since for this work it could be safely assumed that in the windrows and bunches about 70% of the plants were inside and about 30% on the outside of these formations. As soon as the ten plants were taken in each case the leaves were at once severed at the point of their junction with the petioles with the use of scissors. These leaves were then placed in an air-tight, friction top can and the stems similarly placed in another, each can being properly labeled. The cans used were number 2, plain tin, round Spencer friction cans, three and one half inches in diameter and four and three fourth inches high, equipped with friction caps, and manufactured by the American Can Company of New York. In conjunction with this, whenever a sample was taken the temperature was also taken and recorded in order that any differences that may exist in the temperature of hay cured under these various conditions might be made accessible.

In order to have these records as accurate as possible the therometers used were kept buried beneath the surface of the hay in all cases.

After the can samples of leaves and stems had been taken, they were removed to the laboratory at the end of each half day, the leaves and stems carefully weighed, and these then placed in an electric oven in which they were heated at 110 degrees Centigrade for five hours. Following this they were again weighed, the loss in weight determined, from which was calculated the moisture content of the leaves, of the stems, and of the entire plant for every hour at which the hay was sampled under the five methods as well as the percentage of the entire moisture of the plants to be found in the leaves and in the stems.

Results.

With the aid of these figures it has been possible to trace the loss of moisture from day to day during process not only of the plants, but also of the leaves and stems. Some idea is, therefore, obtained as to whether in this project the leaves and stems dry down at about the same rate, or whether the rate of moisture loss of one exceeds that of the other and how this holds true with the different methods of curing.

The results secured from curing alfalfa hay in windrows made with a curved tooth, left-hand drive, side-delivery rake are given herewith in Tables 26A and 26B and summarized in Figure 23.

Table 28 A

Curved Tooth Windrow Curing

Decrease in Moisture Content of Leaves and Stems of Hay Cured in Windrows Made with a Curved Tooth, Left-Hand Drive, Side-Delivery Rake.

	Leaves					Stems.			
Time	Tempera- ture °C.	Weight origi- nally grams	Weight after drying grams	Loss in Weight grams	Moisture Content %	Original Weight grams	Weight after drying grams	Loss in Weight grams	Moisture Content %
3:00	24	12.7	4.2	8.5	66.93	14.7	4.8	9.9	67.35
4:00	25	9.5	3.4	6.1	64.22	11.8	4.1	7.7	65.26
5:00	20	7.9	3.0	4.9	62.03	10.4	3.6	6.8	65.39
6/25 8:15	16	14.9	5.0	9.9	66.45	18.9	6.5	12.4	65.61
9:15	19	10.4	4.1	6.3	60.58	13.7	4.6	9.1	66.43
10:15	22	8.1	2.9	5.2	64.20	18.1	5.4	12.7	70.17
11:15	21	7.8	3.4	4.4	56.42	13.7	4.8	8.9	64.97
1:30	23	15.1	6.1	9.0	59.61	18.7	7.6	11.1	59.36
3:30	21	7.7	4.5	3.2	41.56	9.2	4.1	5.1	55.44
5:30	22	6.3	4.7	1.6	25.40	9.9	5.0	4.9	49.50
6/26 10:45	18	9.2	5.0	4.2	45.65	11.0	5.3	5.7	51.82
6/27 4:15	22	6.1	4.9	1.2	19.68	12.5	7.4	5.1	40.80
6/28 11:00	24	7.6	6.4	1.2	15.79	14.1	9.0	5.1	36.18
4:15	26.5	4.9	4.4	.5	10.21	10.9	7.6	3.3	30.28
6/29 9:45	28.5	4.4	3.9	.5	11.37	11.0	8.4	2.6	23.64

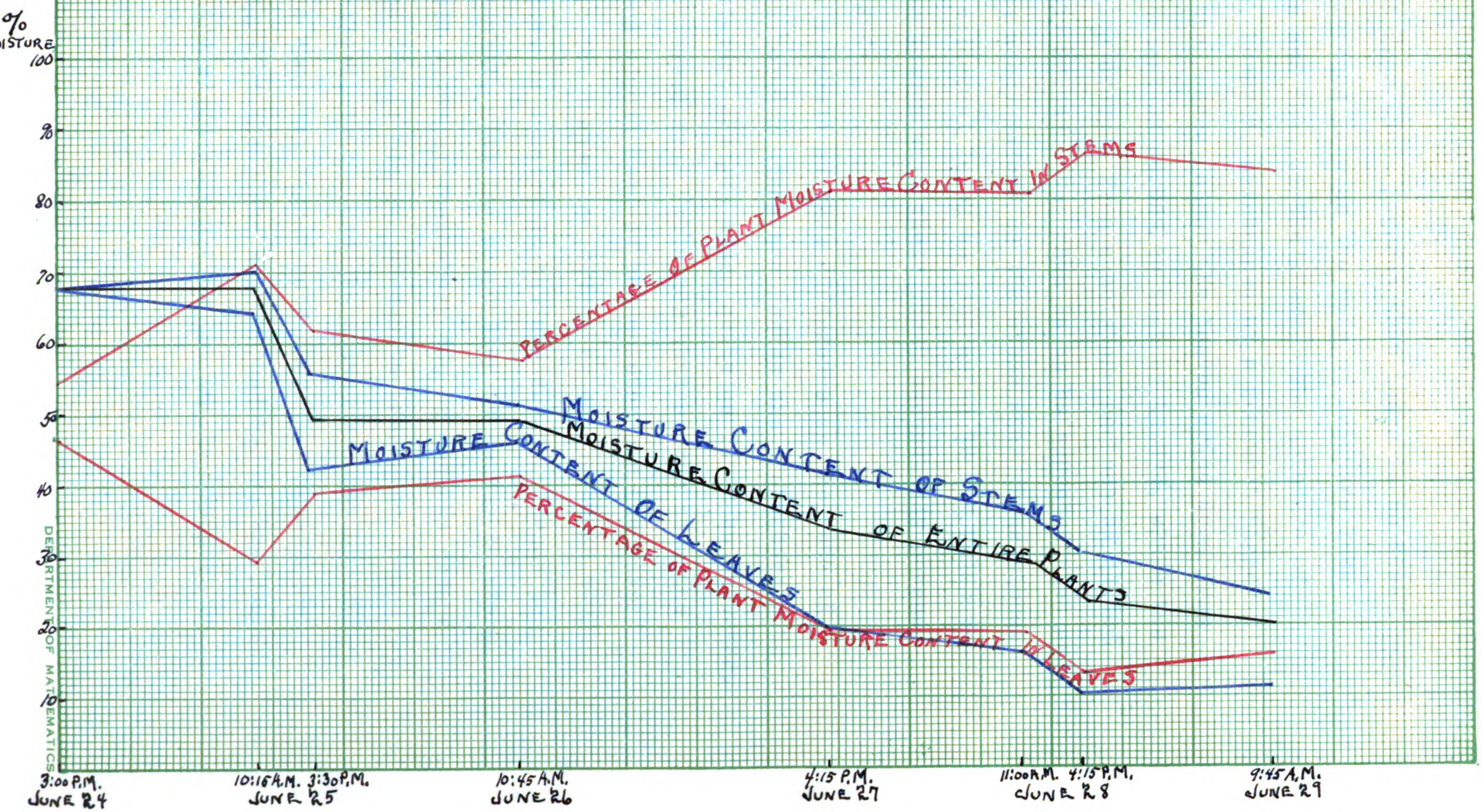
Table 26 B.

Decrease in Total Moisture Content of Plant and the Distribution of Total Moisture in Leaves and Stems. Under Conditions Noted in Table 26A.

	Entire Plant					Leaves		Stems.	
Time	Original weight grams	Weight after heating grams	Loss in weight	Moisture Content %	Weight of moisture in entire plant grams	Moisture weight grams	% of total plant moisture	Moisture grams	% of total plant moisture.
6/24 3:00	27.4	9.0	18.4	67.16	18.4	8.5	46.20	9.9	53.80
4:00	21.3	7.5	13.8	64.79	13.8	6.1	44.21	7.7	55.79
5:00	18.5	6.8	11.7	63.24	11.7	4.9	41.89	6.8	58.12
6/25 8:15	33.8	11.5	22.3	65.98	22.3	9.9	44.40	12.4	55.60
9:15	24.1	8.7	15.4	63.91	15.4	6.3	40.91	9.1	59.09
10:15	26.2	8.3	17.9	68.33	17.9	5.2	29.05	12.7	70.95
11:15	21.5	8.2	13.3	61.87	13.3	4.4	33.09	8.9	66.91
1:30	33.8	13.7	20.1	59.47	20.1	9.0	44.78	11.1	55.22
3:30	16.9	8.6	8.3	49.12	8.3	3.2	38.55	5.1	61.44
5:30	16.2	9.7	6.5	40.13	6.5	1.6	24.62	4.9	75.38
6/26 10:45	20.2	10.3	9.9	49.01	9.9	4.2	42.43	5.7	57.57
6/27 4:15	18.6	12.3	6.3	33.88	6.3	1.2	19.05	5.1	80.95
6/28 11:00	21.7	15.4	6.3	29.04	6.3	1.2	19.05	5.1	80.95
4:15	15.8	12.0	3.8	24.05	3.8	.5	13.16	3.3	86.84
6/29 9:45	15.4	12.3	3.1	20.13	3.1	.5	16.13	2.6	83.87

Figure 23

Moisture Analysis of Alfalfa Hay Cured in Windrows Made With Curved Tooth, Side-Delivery Rake



It is evident from these figures that there is no distinctive difference between the rate of moisture loss of the leaves and that of the stems. The moisture of the stems is, however, maintained at a somewhat higher figure than the leaves, since the leaves dried down from a moisture content of 66.93% to that of 11.37%, while the stems in curing dropped from a moisture content of 67.35% to one of only 23.64%. Yet this is to be expected when one considers the woody nature of the stems with their almost impermeable epidermal layer as contrasted to the delicate tissue of the leaves with their fine, exceedingly porous epidermal layer.

As a result of this difference in the rate of moisture loss between stems and leaves the distribution of the total moisture changes also, quite as is to be expected. It will be observed from Table 26B that at the time the plants are cut almost half of the moisture in the plant is located in the leaves, 46.20% to be exact, and 53.80% of the moisture is located in the stems. This tends to conform, somewhat, with the proportion of leaves to stems, for as is well known approximately 40% of alfalfa plants is leaves and 60% is stems. As curing proceeds, it naturally follows, that since the leaves are giving off moisture at a somewhat higher rate than the stems, less of the moisture of the plant will be located in the leaves and more in the stems at the time the hay is ready to be hauled in. That this is true, can be appreciated by the fact that on the morning of the fifth day, 16.13% of the moisture was located in the leaves and 83.87% in the stems.

Consideration given to the total moisture content of alfalfa undergoing curing in the curved tooth kind of windrow reveals in Table 26B a moisture content in green, uncured alfalfa of approximately 67.16% and which, during curing, drops to 20.13% moisture in alfalfa hay ready for the mow or stack. Closer analysis of these figures will show, moreover, that the greatest moisture loss occurs after the first four hours and, in this instance, during the second day of curing. For during Friday the moisture content of the hay dropped over 25%, more than ¼ of the total moisture, which is at least more than twice as great a rate of loss as occurred at any other time, regardless of the fact that during that day the temperature was not as consistently high as during Monday and Tuesday, June 28 and June 29 respectively.

Inspection of results represented in Tables 27A and 27B and Figure 24

Table 27A.

"Straight Tooth" Windrow Curing. Decrease in Moisture Content of Leaves and Stems of Alfalfa Hay Cured in Windrows Made With a Straight Tooth Left-hand Side Delivery Rake.

Leaves

Stems.

Time	Tempera-ture °C.	Original weight grams	Weight after drying grams	Loss in weight grams	Moisture content %	Original weight grams	Weight after drying grams	Loss in weight grams	Moisture content %
6/24 3:45	24	7.2	2.7	4.5	62.50	12.4	4.2	8.2	66.13
4:45	24	14.5	4.9	9.6	66.21	17.8	5.8	12.0	67.42
5:45	18	11.4	4.2	7.2	63.16	13.3	4.5	8.8	66.17
6/25 8:30	16	7.7	2.8	4.9	63.64	11.3	3.7	7.6	67.26
9:30	21	13.0	4.7	8.3	63.85	18.0	6.2	11.8	65.56
10:30	20	15.3	6.9	8.4	54.91	23.0	8.6	14.4	62.61
11:30	24	13.0	5.8	7.2	55.39	14.5	5.9	8.6	59.32
1:45	28	10.9	6.6	4.3	39.45	16.8	7.4	9.4	55.96
3:45	24	13.2	5.9	7.3	55.31	16.6	7.0	9.6	57.84
5:45	18	5.2	3.4	1.8	34.62	8.7	4.3	4.4	50.58
6/26 11:00	19	8.3	4.5	3.8	45.79	14.3	6.5	7.8	54.55
6/27 4:45	20	3.9	3.4	.5	12.83	9.6	6.1	3.5	36.46
6/28 11:30	24.5	6.2	5.5	.7	11.30	13.8	9.0	4.8	34.79
4:30	25.5	6.7	5.9	.8	11.95	12.4	8.6	3.8	30.65
6/29 10:00	32	3.9	3.3	.6	15.39	7.2	5.9	1.3	18.06

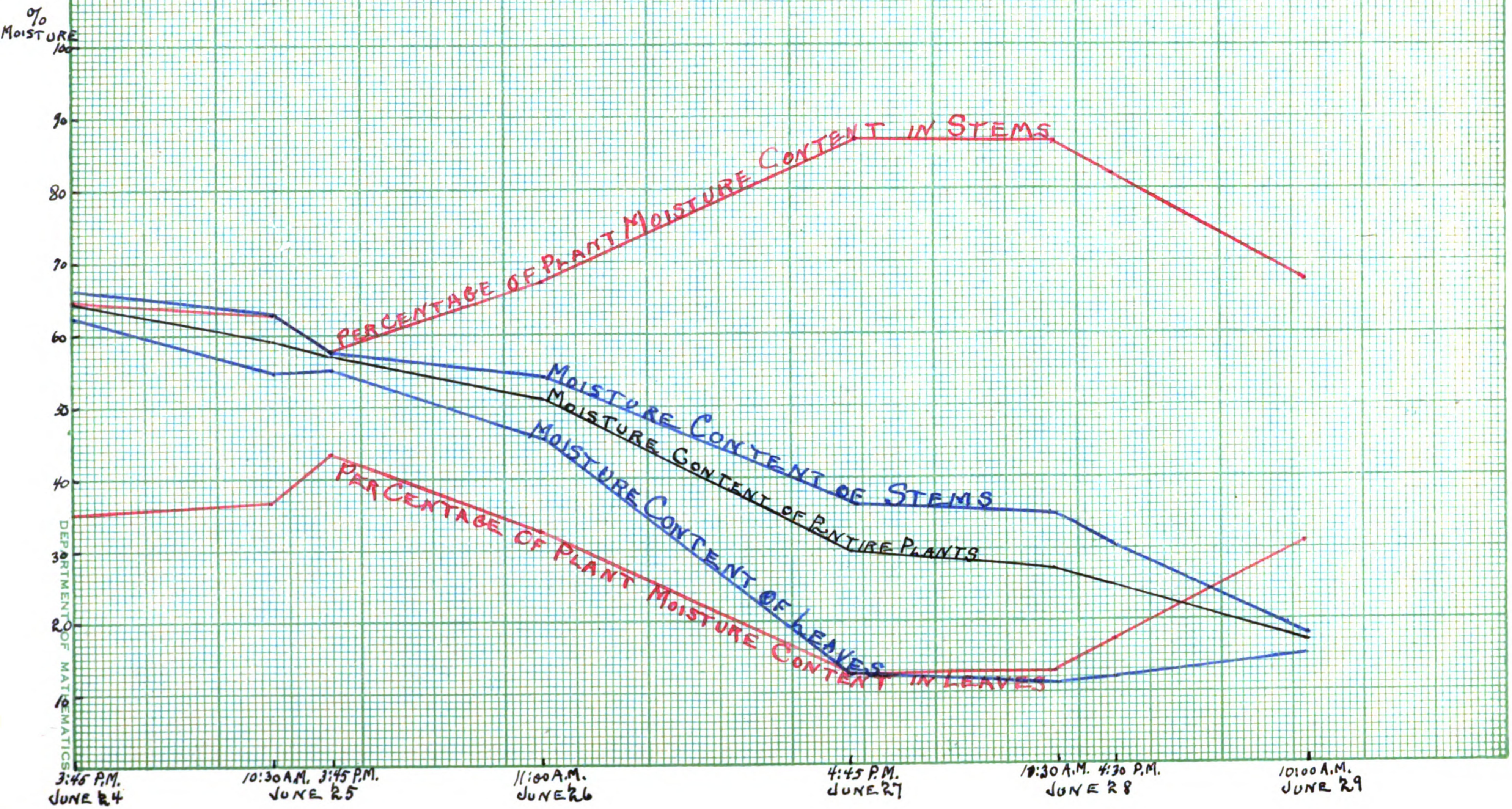
Table 27B.

Decrease in Total Moisture Content of Alfalfa Hay and the Distribution of this Moisture in Leaves and Stems Under Conditions Noted in Table 27A.

Time	Entire Plant: Original weight grams	Weight after heating grams	Loss in weight grams	Moisture content %	Leaves: Weight of moisture in entire plant grams	Moisture in grams	% of total plant moisture	Stems: Moisture grams	% of total plant moisture
6/24 3:45	19.6	6.9	12.7	64.80	12.7	4.5	35.44	8.2	64.56
4:45	32.3	10.7	21.6	66.88	21.6	9.6	44.45	12.0	55.55
5:45	24.7	8.7	16.0	64.78	16.0	7.2	45.00	8.8	55.00
6/25 8:30	19.0	6.5	12.5	65.79	12.5	4.9	39.20	7.6	60.80
9:30	31.0	10.9	20.1	64.84	20.1	8.3	41.30	11.8	58.70
10:30	38.3	15.5	22.8	59.54	22.8	8.4	36.85	14.4	63.15
11:30	27.5	11.7	15.8	57.46	15.8	7.2	45.57	8.6	54.43
1:45	27.7	14.0	13.7	49.46	13.7	4.3	31.39	9.4	68.61
3:45	29.8	12.9	16.9	57.72	16.9	7.3	43.20	9.6	56.80
5:45	13.9	7.7	6.2	44.61	6.2	1.8	29.04	4.4	70.96
6/26 11:00	22.6	11.0	11.6	51.33	11.6	3.8	32.76	7.8	67.24
6/27 4:45	13.5	9.5	4.0	29.63	4.0	.5	12.50	3.5	87.50
6/28 11:30	20.0	14.5	5.5	27.45	5.5	.7	12.73	4.8	87.27
4:30	19.1	14.5	4.6	24.09	4.6	.8	17.40	3.8	82.60
6/29 10:00	11.1	9.2	1.9	17.12	1.9	.6	31.58	1.3	68.42

Figure 24

Moisture Analysis of Alfalfa Hay Cured in Windrows Made with Straight Tooth, Side-Delivery Rake



and secured in curing alfalfa hay in windrows made by a straight tooth, left-hand drive, side-delivery rake, substantiate the remarks just concluded and show no difference in hay cured by the two types of windrows. The leaves cure down practically to the same extent as in the other windrow namely from a moisture content of 62.50% to one of 15.39% and similarly the stems cure out at about the same rate, from 66.13% moisture to 18.06%. These results also emphasize again that there is a tendency for the leaves to cure out more thoroughly than the stems and that, although when green over 40% of the moisture of the plant is located in the leaves, this drops until 31.58% of the * moisture is located in the leaves when the hay is cured.

In regards to the total moisture content of the hay, the differences at various stages of the curing in these windrows is exceedingly small so that these results do not substantiate the belief that hay in a "curved tooth" windrow cures out any differently than hay in a "straight tooth" windrow. The rate of curing again shows the greatest reduction of moisture occuring after the first four hours or during the second day in this instance.

The results given in Tables 28A, 28B, and Figure 25

* This is in keeping with the capacity manifested by the leaves of giving off moisture at a somewhat greater rate than the stems do.

[illegible]

CURING IN BUNCHES AND HAY COCKS.

Decrease in Moisture Content of Leaves and Stems of Alfalfa Hay Cured in Bunches made a Dump Rake and Later in Cocks.

	Leaves					Stems.			
Time	Temperature °C.	Original weight grams	Weight after drying grams	Loss in weight grams	Moisture content %	Original weight grams	Weight after drying grams	Loss in weight grams	Moisture content %
6/24 3:30	28	18.4	6.3	12.1	65.77	16.1	5.6	10.5	65.22
4:30	25	13.0	5.3	7.7	59.24	10.5	4.1	6.4	60.95
5:30	24.5	14.0	5.6	8.4	59.99	11.5	4.4	7.1	61.74
6/25 7:45	14.	10.5	4.5	6.0	57.15	9.6	3.7	5.9	61.46
8:45	17.	14.7	5.8	8.9	60.55	13.4	5.0	8.4	62.69
9:45	21.	15.3	6.9	8.4	54.91	15.4	6.1	9.3	60.39
10:45	22.5	13.4	6.3	7.1	52.99	15.7	6.3	9.4	59.88
1:00	30.	6.9	3.8	3.1	44.93	9.0	3.9	5.1	56.67
3:00	27.5	6.7	3.9	2.8	41.80	7.6	3.8	3.8	50.00
5:00	25.5	7.0	4.8	2.2	31.43	13.7	4.4	9.3	67.89
6/26 10:15	16.	11.6	5.9	5.7	49.14	12.6	5.8	6.8	53.97
6/27 8:30	26.	7.5	5.3	2.2	29.34	11.7	6.4	5.3	54.71
June 28 Bunches built into cocks 8:30 A.M.									
10:15	22.5	5.7	4.9	.8	14.04	11.5	6.6	4.9	42.61
3:15	27.	4.5	4.5	.2	4.45	9.2	6.9	2.3	25.00
6/29 9:30	25.	5.7	4.8	.9	15.79	9.8	7.1	2.7	27.55

Table 28B.

Decrease in Total Moisture Content of Alfalfa Hay and the Distribution of this Moisture in Leaves and Stems Under Conditions Noted in Table 28A.

Entire Plant

Time	Original weight grams	Weight after leaving grams	Loss in weight grams	Moisture content %	Weight of moisture in entire plant	Moisture grams	% of total plant moisture	Moisture grams	% of total plant moisture.
6/24 3:30	34.5	11.9	22.6	65.51	22.6	12.1	53.54	10.5	46.46
4:30	23.5	9.4	14.1	60.00	14.1	7.7	54.61	6.4	45.39
5:30	25.5	10.0	15.5	60.79	15.5	8.4	54.20	7.1	45.80
6/25 7:45	20.1	8.2	11.9	59.21	11.9	6.0	50.43	5.9	49.57
8:45	28.1	10.8	17.3	61.57	17.3	8.9	51.45	8.4	48.55
9:45	30.7	13.0	17.7	57.65	17.7	8.4	47.46	9.3	52.54
10:45	29.1	12.6	16.5	56.71	16.5	7.1	43.04	9.4	56.96
1:00	15.9	7.7	8.2	51.58	8.2	3.1	37.81	5.1	62.19
3:00	14.3	7.7	6.6	46.16	6.6	2.8	42.43	3.8	57.57
5:00	20.7	9.2	11.5	55.56	11.5	2.2	19.14	9.3	80.86
6/26 10:15	24.2	11.7	12.5	51.65	12.5	5.7	45.60	6.8	54.40
6/27 3:30	19.2	11.7	7.5	39.07	7.5	2.2	29.34	5.3	70.66
				Built into cocks at 8:30 June 27.					
June 28 10:15	17.2	11.5	5.7	33.14	5.7	.8	14.04	4.9	85.96
3:15	13.7	11.2	2.5	18.25	2.5	.2	8.00	2.3	92.00
6/29 [illegible]	15.5	11.9	3.6	23.23	3.6	.9	25.00	2.7	75.00

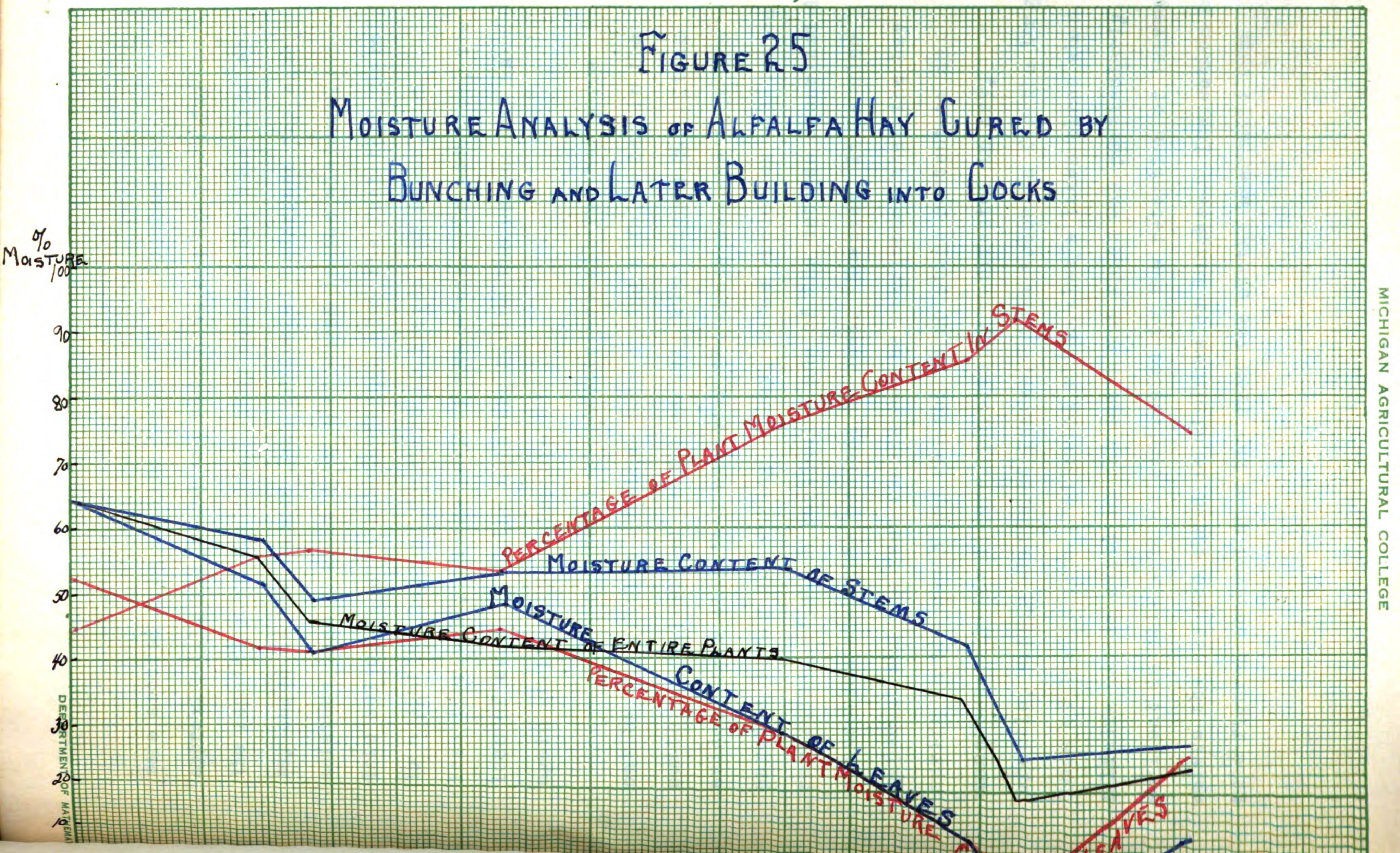


FIGURE 25
MOISTURE ANALYSIS OF ALFALFA HAY CURED BY
BUNCHING AND LATER BUILDING INTO COCKS
% MOISTURE
100
90
80
70
60
50
40
30
20
10
PERCENTAGE OF PLANT MOISTURE CONTENT IN STEMS
MOISTURE CONTENT OF STEMS
MOISTURE CONTENT OF ENTIRE PLANTS
MOISTURE CONTENT OF LEAVES
PERCENTAGE OF PLANT MOISTURE
LEAVES
DEPARTMENT OF MATHEMATICS
MICHIGAN AGRICULTURAL COLLEGE

were secured from alfalfa hay cured in bunches for approximately three and one half days and in cocks for the remainder of the time. They demonstrate that alfalfa hay cured in the manner just indicated undergoes the same moisture loss that it does when cured in the windrows. This set of figures substantiates also the fact that there is a similar loss of moisture in leaves and stems, but less thoroughly on the part of the stems. In addition, the loss of even ½ of the moisture during the second day is again strikingly noticeable.

These general statements are all further borne out by the results obtained from curing alfalfa hay in the swath as represented in Tables 29A, 29B, Figure 26. It is evident from this that whatever the processes are that are carried during the curing of hay, those processes will go on regardless of which particular one of the methods described in connection with this project is used. However, it is also apparent and the fact should not be overlooked that the hay curing in the swath was reduced in moisture content to an unnecessarily low figure, physically manifested in dry, brittle, easily shattered leaves. This accounts for the large loss of leaves from shattering which always takes place when alfalfa hay is cured in the swath and which was particularly evident in this work as contrasted to the retention of leaves where the hay was cured in windrows or bunches. Inspection of the figures secured when hay from the swaths was built into

Table [illegible]

CURING IN THE SWATH.

Decrease in Moisture Content of Leaves and Stems of Alfalfa Hay Cured in the Swath.

Time	Tempera-ture °C.	Leaves: Original weight grams	Leaves: Weight after drying grams	Leaves: Loss in weight grams	Leaves: Moisture content %	Stems: Original weight grams	Stems: Weight after drying grams	Stems: Loss in weight grams	Stems: Moisture content %
6/24 3:15	30	20.7	5.9	15.8	63.37	23.8	7.7	16.1	67.65
4:15	34	12.2	4.1	8.1	66.40	18.3	5.4	12.9	70.50
5:15	23	10.4	4.2	6.2	59.62	12.0	2.6	9.4	78.34
6/25 8:00	18	10.1	3.8	6.3	62.38	11.4	4.5	6.9	60.53
9:00	21	11.2	4.3	6.9	61.61	14.1	5.2	8.9	63.15
10:00	26	11.1	5.0	6.1	54.95	15.5	6.3	9.2	59.36
11:00	26.5	9.6	4.7	4.9	51.05	12.6	5.4	7.2	57.15
1:15	34	8.5	5.3	3.2	37.65	12.7	5.7	7.0	55.12
3:15	36	8.2	5.9	2.3	28.05	10.9	5.6	5.3	48.63
5:15	25	6.4	4.8	1.6	25.00	12.1	6.1	6.0	49.59
6/26 10:30	15	8.0	4.5	3.5	43.75	11.9	6.0	5.9	49.58
6/27 3:45	30.5	5.3	4.6	.7	13.21	9.9	6.1	3.8	38.39
6/28 10:45	26	5.0	4.4	.6	12.00	8.8	6.0	2.8	31.82
4:00	34	2.9	2.8	.1	3.45	8.5	6.4	2.1	24.71
6/29 9:30	34	4.2	3.7	.5	11.91	7.8	6.7	1.1	14.11
Hay built from swath into cocks June 28-8:30 A.M.									
6/2[illegible] 10:30	22.5	5.4	4.6	.8	14.82	9.1	6.0	3.1	34.07
3:00	27	5.4	4.7	.7	12.97	8.5	5.7	2.8	32.95
[illegible] 9:30	27	4.3	3.9	.4	9.31	8.4	6.5	1.9	22.62

Table 29B

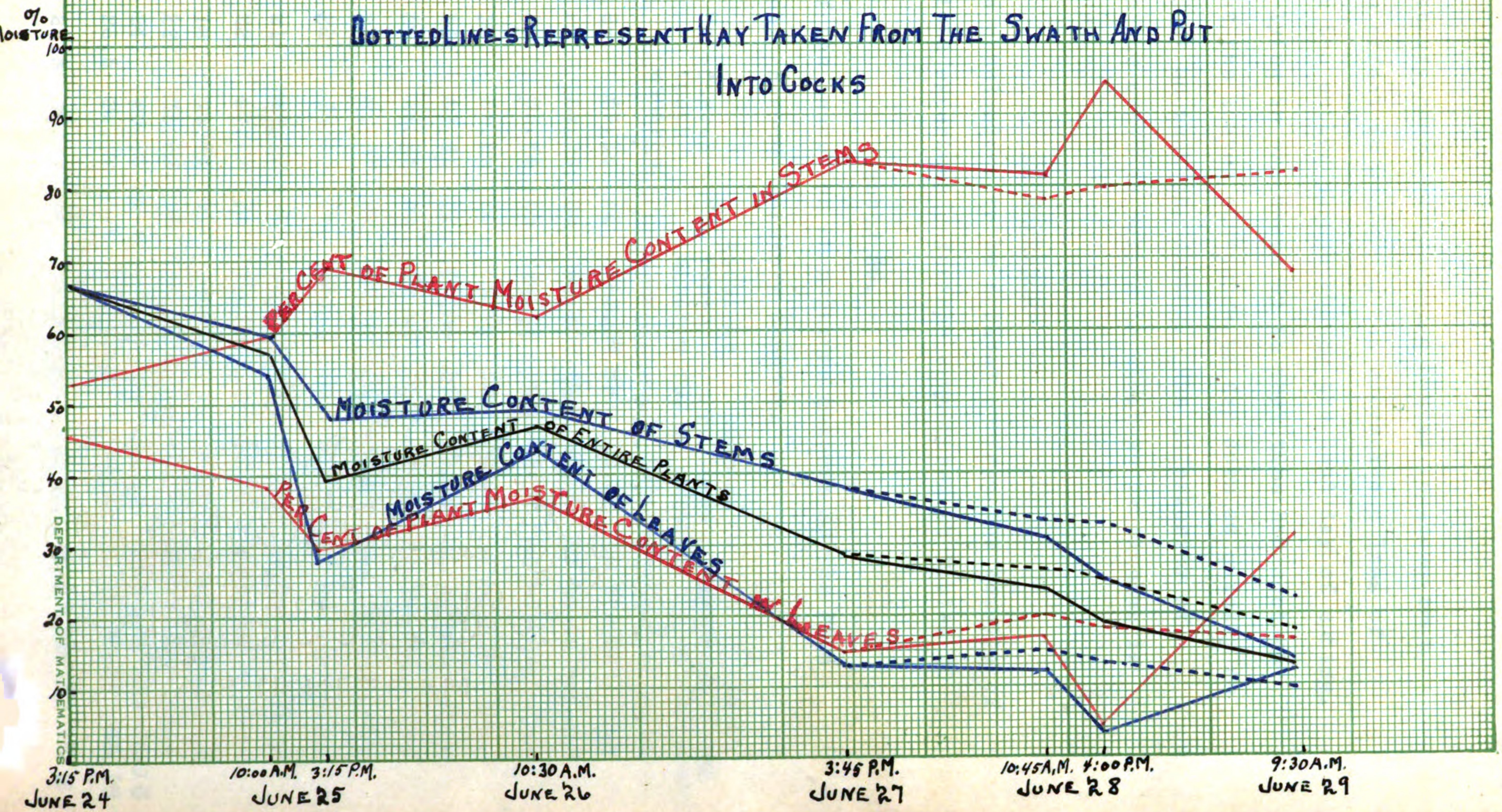
Decrease in Total Moisture Content of Alfalfa Hay and the Distribution of this Moisture in Leaves and Stems under Conditions Noted in Table 29A.

	Entire Plant				Leaves			Stems.	
Time	Original weight grams	Weight after heating grams	Loss in weight grams	Moisture content %	Weight of moisture in entire plant grams	Moisture grams	% of total plant moisture	Moisture grams	% of total plant moisture
6/24 3:15	44.5	14.6	29.9	67.20	29.9	13.8	46.16	16.1	53.84
4:15	30.5	9.5	21.0	68.86	21.0	8.1	38.58	12.9	61.42
5:15	22.4	6.8	15.6	69.65	15.6	6.2	39.75	9.4	60.25
6/25 8:00	21.5	8.3	13.2	61.40	13.2	6.3	47.73	6.9	52.27
9:00	25.3	9.5	15.8	62.45	15.8	6.9	43.68	8.9	56.32
10:00	26.6	11.3	15.3	57.52	15.3	6.1	39.87	9.2	60.13
11:00	22.2	10.1	12.1	54.51	12.1	4.9	40.50	7.2	59.50
1:15	21.2	11.0	10.2	48.12	10.2	3.2	31.38	7.0	68.62
3:15	19.1	11.5	7.6	39.80	7.6	2.3	30.27	5.3	69.73
5:15	18.5	10.9	7.6	41.09	7.6	1.6	21.06	6.0	78.94
6/26 10:00	19.9	10.5	9.4	47.24	9.4	3.5	37.24	5.9	62.76
6/27 3:45	15.2	10.7	4.5	29.61	4.5	.7	15.56	3.8	84.44
6/28 10:45	13.8	10.4	3.4	24.64	3.4	.6	17.65	2.8	82.35
4:00	11.4	9.2	2.2	19.30	2.2	.1	4.55	2.1	95.45
6/29 9:30	12.0	10.4	1.6	13.34	1.6	.5	31.25	1.1	68.75
			Hay built from swath into cocks June 28- 8:00 A.M.						
6/28 10:30	14.5	10.6	3.9	26.90	3.9	.8	20.52	3.1	79.48
3:30	13.9	10.4	3.5	25.18	3.5	.7	20.00	2.8	80.00
6/29 9:30	12.7	10.4	2.3	18.12	2.3	.4	17.40	1.9	82.60

Figure 26

Moisture Analysis of Alfalfa Hay Cured in the Swath

Dotted Lines Represent Hay Taken From The Swath And Put Into Cocks



cocks about thirty hours before being hauled in shows that this had some effect in retarding too excessive a loss of moisture from the entire plants during the last day of curing. But even so, lying in the swath up to that time had such an influence that the leaves continued to dry down as quickly as before with just as much shattering. The inferiority of curing hay in the swath to curing in windrows or bunches is only too apparent.

Conclusions.

The conclusions to be arrived at from the results of this major field experiment, further summarized in Tables 30 and 31

Table 30.

Comparison of the Reduction in Moisture Content of the Five During Methods. Percent Moisture Content.

Time	Humidity %	°C	Curved tooth windrow.	°C.	Straight tooth windrow	°C.	Bunches followed by cocks	°C	Swath	°C	Swath followed by cocks
6/24 3:)		24	67.16	24	64.80	28	65.51	30	67.20	--	---
4:)	37	23	64.79	24	66.88	25	60.00	24	68.86	--	---
5:)		20	63.94	18	64.78	24.5	60.79	23	69.65	--	---
6/25 7:45	83	16	65.98	16	65.79	14	59.21	16	61.40	--	----
8:45		19	63,91	21	64,84	17	61.57	21	62.46	--	----
9:45		22	68.33	20	59.54	21	57.66	23	57.52	--	----
10:45	62	21	61.87	24	57.46	22.5	56.71	26.5	54.51	--	----
1:		28	59.47	28	49.46	30	51.58	34	48.12	--	----
3:	40	21	49.12	24	56.72	27.5	46.16	36	39.80	--	----
5:		22	40.13	18	44.61	26.5	55.56	25	41.09	--	----
6/26 10:15	67	18	49.01	19	51.33	16	51.55	16	47.24	--	----
6/27 3:30	46+	22	33.88	20	29.63	26	39.07	20.5	29.61	--	----
6/28 10:15	75	24	29.04	24.5	27.49	22.5	33.14	28.	24.64	22.5	26.90
3:15	37	26.5	24.06	25.5	24.09	27	18.25	34	19.30	27	25.18
6/29 9:30	60	28.5	20.13	32	17.12	26	23.23	34	13.34	27	18.12

Table 30. Cont.

Note: Rain occurred on the morning of June 25 at from 12: to 1: A.M. to the extent of .10 of an inch; and occurred during the evening of June 25 from 10: to 11:00 P.M. to the extent of .09 of an inch.

Table 31.

Comparison of the Decrease in Moisture Content of the Leaves with that of the Stems.

	Moisture Percentage of Leaves				Moisture Percentage of Stems.			
Time	Curved tooth windrow	Straight tooth windrow	Bunches & ~~Swath~~ cocks	(Swath)	Curved tooth windrow	Straight tooth windrow	Bunches & cocks	Swath.
6/24 3:	66.93	62.50	65.77	66.67	67.35	66.13	65.22	67.65
4:	64.22	66.21	59.24	66.40	65.26	67.42	60.96	70.50
5:	62.03	63.16	59.99	59.62	65.39	66.17	61.74	78.34
6/25 7:45	66.45	63.64	57.15	62.38	65.61	67.26	61.46	60.53
8:45	60.58	63.85	60.55	61.61	66.43	65.56	62.69	63.13
9:45	64.20	54.91	54.91	54.96	70.17	62.61	60.39	59.36
10:45	56.42	55.39	52.89	51.05	64.97	59.32	59.88	57.15
1:	59.61	39.45	44.93	37.65	59.36	55.96	56.67	55.12
3:	41.56	55.31	41.80	28.05	55.44	57.84	50.00	48.63
5:	25.40	34.62	31.43	25.00	49.50	50.58	67.89	49.59
6/26 10:15	45.66	45.79	49.14	43.75	51.82	54.55	53.97	49.58
6/27 3:30	19.68	12.83	29.34	13.21	40.80	36.46	54.71	38.39
6/28 10:15	15.79	11.30	14.04	12.00-14.82/ cocks	36.18	34.79	42.61	31.82-34.07
3:15	10.21	11.95	4.45	3.45-12.97	30.28	30.65	25.00	24.71-33.9[illegible]
6/29 9:30	11.37	15.39	15.79	11.91-9.31	23.64	18.06	27.56	14.11-22.62/ cocks

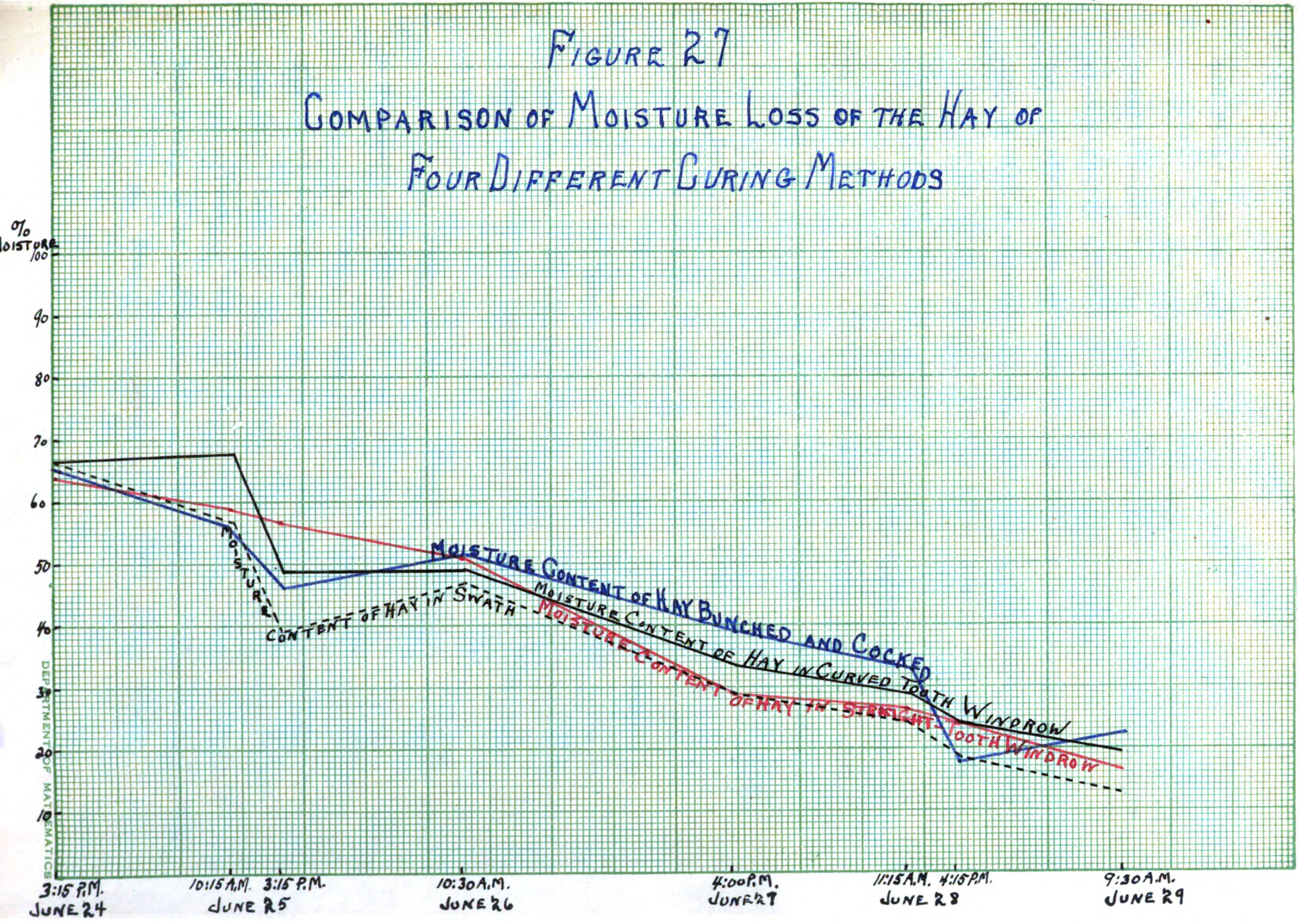


FIGURE 27
COMPARISON OF MOISTURE LOSS OF THE HAY OF
FOUR DIFFERENT CURING METHODS
% MOISTURE
100
90
80
70
60
50
40
30
20
10
3:15 P.M. JUNE 24
10:15 A.M. JUNE 25
3:15 P.M.
10:30 A.M. JUNE 26
4:00 P.M. JUNE 27
11:15 A.M. JUNE 28
4:15 P.M.
9:30 A.M. JUNE 29
MOISTURE CONTENT OF HAY BUNCHED AND COCKED
MOISTURE CONTENT OF HAY IN CURVED TOOTH WINDROW
MOISTURE CONTENT OF HAY IN SWATH
MOISTURE CONTENT OF HAY IN STRAIGHT TOOTH WINDROW

and Figure 27, are as follows:-

1. No significant differences exist between the results secured from curing alfalfa hay in either the windrow made directly after mowing with a curved tooth, left-hand drive, side-delivery rake, the windrow made directly after mowing with a straight tooth, left-hand drive, side-delivery rake, or in bunches made directly after mowing and cocked, three and one half days later.

2. Curing alfalfa hay in the swath results in too rapid a loss of moisture particularly in the leaves thereby causing an unnecessary amount of shattering. This effect is not counteracted even when the hay which has been in the swath for three and one half days is cocked 30 hours or less before actually being hauled in.

3. The rate of moisture loss from the stems is similar to that from the leaves in alfalfa plants protected from the sun. In plants exposed to the sun the rate of moisture loss from the leaves significantly exceeds that from the stems.

4. Stems do not dry down as thoroughly or to as low a moisture content as do the leaves.

5. The moisture content of green, uncured alfalfa plants at the stage of maturity at which the flowers are coming into bloom and the lower leaves are becoming discolored is approximately 65%. The moisture content of cured alfalfa hay ready to be hauled to the mow or stack is approximately 20%.

6. From 40% to 50%, of the moisture of green,

uncured alfalfa is located in the leaves. After the alfalfa has cured from 16.13% to 31.58% of the moisture is located in the leaves and from 68.57% to 83.87% in the stems.

7. The greatest moisture loss, over 25%, occurs after the first four hours of curing and, in this experiment, during the second day of curing.

Conclusions

The results secured from the experimental work conducted in connection with this thesis problem are of such a nature that the writer feels justified in formulating the following conclusions.

1. The leaves are an important agency in the removal of moisture from alfalfa plants being cured in the preparation for hay. This remark is warranted because:

a. Staining tests have shown the path taken by moisture in escaping from alfalfa plants to be through the leaves.

b. An even drying out of leaves and stems is secured when alfalfa plants are protected from exposure to the sun during the time of curing, whereas, the leaves dry excessively rapid and the stems comparatively slowly on those plants that are exposed to direct sunlight. For when a moisture percentage of 15% is assumed for the leaves under all conditions it has been shown that the stems of the plants in the windrows have from 18-22% moisture, whereas, those in the swath still have as high a moisture content as from 31-34%. This demonstrates that when the function of the leaves is destroyed by the searing action of the sun the normal loss of moisture from the stems is inhibited.

2. To secure comparatively even drying of the alfalfa plants and the retention of leaves alfalfa hay should be cured in windrows or in bunches that are later

cocked. Curing in the swath should not be practiced because it causes too rapid a loss of moisture from the leaves which become dry and brittle while the stems still have a high moisture content.

3. In this work alfalfa hay cured equally well in bunches that were later cocked as it did in windrows. Because of the time and labor saved by curing in windrows, a well established fact, the latter is obviously the method to be recommended.

4. In this work alfalfa hay cured equally well in windrows made with a curved tooth, left-hand drive, side delivery rake as it did in windrows made with a straight tooth, left-hand drive, side delivery rake.

5. While alfalfa hay is curing the greatest moisture loss seems to occur during the first hour immediately after cutting, and during the twelve hours of sunshine following the first half day, or four hours of curing.

6. The average moisture content of green, uncut alfalfa at the stage of maturity recommended for cutting namely, when 1/10 of the alfalfa is in bloom and the lower leaves are beginning to discolor, has been found to be 65.00%. The average moisture content of alfalfa hay, field cured, ready to be hauled to the mow or stack is 20.00%.

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