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EXPERIMENTS RELATING TO THE TIME OF CUTTING ALFALFA

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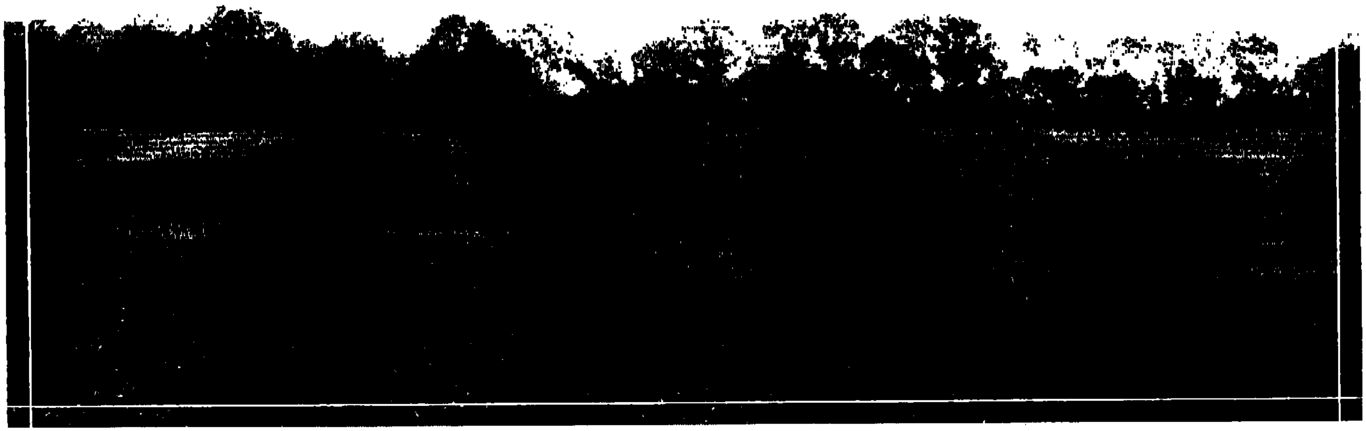

FIG. 1.—The plots used for the time-of-cutting experiments lie next to the fence in the background of the picture. At the extreme right and the extreme left are the bud-stage plots practically covered with bluegrass, crabgrass, and foxtail.

EXPERIMENTS RELATING TO TIME OF CUTTING ALFALFA[1]

S. C. SALMON, C. O. SWANSON and C. W. McCAMBELL

INTRODUCTION

The time of cutting alfalfa is one of the most important considerations in growing this crop. There is abundant evidence to show that the yield, the stand, the chemical composition, and the feeding value of the hay may be materially affected by varying the cutting time. Therefore, accurate information as to the effect of different frequencies of cutting should be of material assistance in determining the most profitable practice.

In Kansas, the prevailing practice has been to cut as nearly in the tenth-bloom stage as possible, or if blooms fail to set, when the crown buds put forth shoots. It is frequently impossible to cut at exactly what is considered the ideal time and, since there is a prevailing opinion that cutting off the crown shoots is injurious, the tendency has been to cut before rather than after the tenth-bloom stage. On the other hand, certain observations have indicated that cutting early is more injurious than delayed cutting and it seemed desirable, therefore, to investigate this and related questions.

REVIEW OF LITERATURE

Several experiments designed to determine the effect of time of cutting on the yield, composition, and feeding value of alfalfa hay have been reported. Numerous opinions, based on field observations rather than on definitely planned experiments, have also found their way into print and no doubt have influenced current practices. An exhaustive review of the literature will not be attempted in this bulletin, but an effort will be made to mention those experiments and observations which have been of most importance in determining the usual method of procedure in general farm practice.

Probably the most extensive of early experiments, at least, in this country, are those of Foster and Merrill (1899) of the Utah Agri-

ACKNOWLEDGMENTS.—The agronomic phase of this experiment was outlined by L. E. Call and was in charge of Ralph Kenney from its inception in 1914 to 1916. Since 1916 the work has been supervised by S. C. Salmon. The analytical work has been done by C. O. Swanson and W. L. Latshaw and the feeding tests have been conducted by C. W. McCampbell.

1. Contribution No. 156 from the Department of Agronomy, No. 106 from the Department of Chemistry, and No. 75 from the Department of Animal Husbandry.

cultural Experiment Station who compared the yield, proportion of leaves, stems, and blossoms, the digestible matter, and the feeding value of alfalfa cut at three different stages of growth. These stages were: (1) When the blossoms first appeared; (2) when in full bloom; and (3) when fully half the blossoms had fallen. Three crops annually were secured from the first; two full crops and a short crop from the second; and two crops from the third. The largest annual yields per acre and the greatest amount of beef per acre, and also per unit of hay, were secured from the earliest cutting and the least from the latest cutting. The early cut hay contained the highest per cent of protein and fat and a larger proportion of leaves. The authors conclude that "taking all points into consideration, both separately and collectively, including everything that pertains to the largest yield and highest feeding value, the tests favor cutting alfalfa for cattle feeding when the first blooms appear."

Harcourt (1900) states that in experiments conducted in Ontario, Canada, "a much larger amount of digestible matter was obtained by cutting when the plants were about one-third in blossom than by cutting either two weeks earlier or two weeks later."

Cottrell (1902) observed that in Kansas alfalfa cut in one-tenth bloom grew vigorously throughout the season and made three cuttings and an aftermath, while a similar area cut after full bloom gave a low yield the first cutting and did not grow sufficiently thereafter to yield a good second cutting. He expressed the opinion that alfalfa should be cut when not more than one-tenth of the plants have come into bloom. "Cut at this early stage the yield of hay for the season will be much greater than if the alfalfa is cut near maturity and every pound of hay secured will be worth more for feed." He observed further that "early cutting invigorates the plants."

Snyder and Hummel (1903) state that in Minnesota "alfalfa should be cut when one-third of the blossoms have appeared because at this stage it will yield the largest amounts of the several nutrients in the most valuable forms."

Bennett (1902) concluded that "when a few blooms appear over the field is the proper stage for best hay for all stock except perhaps work stock. In that case a little later is better, but not for the vigor of the alfalfa."

Headden (1906) expressed the belief that in Colorado "the best hay for feeding purposes is obtained by cutting when the plant is in full bloom." He noted further "that the chemical composition of the hay produced is not so materially affected by the condition of the plants at the time of cutting as we are wont to think" and in support of this contention gave the composition of hay cut at different stages of growth in which the differences were "not big enough to produce differences which come under the notice of the feeder."

Ten Eyck (1908) compared four stages of cutting at the Kansas Agricultural Experiment Station, viz.: first bloom, tenth bloom, half bloom, and full bloom. The plots were one-third acre each in area and were duplicated. The yields for the single season of the experiment including some immature hay cut late were 4.69, 5.35, 4.52, and 5.99 tons per acre respectively, all calculated to a uniform moisture content of 17 per cent. Four full crops were secured from all except the full-bloom plots on which only three were obtained. The yield for the first cutting increased with delay in cutting but the "succeeding crops were very irregular in yield, the growth of the crop seemingly being more dependent upon weather and soil conditions at time of cutting the preceding crop than upon stage of maturity of the alfalfa when harvested."

Hughes (1913) recommended cutting in Iowa "early in the blooming period (when it is from one-tenth to one-fourth in bloom). Hay of better quality is secured and the following growth comes on more quickly than when cutting is delayed. If cutting is delayed until the new shoots have made sufficient growth to be cut off the growth of the next crop will be seriously checked."

Williams and Kyle (1907) state that it seems to be the experience in Ohio that the growth of alfalfa may be injured for the rest of the season either by cutting when too young (before blossoms appear) or by allowing the crop to become too old before cutting.

Porter and Dynes (1914) noted that if alfalfa is cut before the young shoots appear the succeeding cutting is likely to be materially reduced while if allowed to stand too long the stems become woody and the hay deteriorates in quality.

McCampbell (1912) found that to make hay "suitable for horses at hard work, alfalfa must be allowed to become rather mature before cutting; in fact the field should be in full bloom before the mower is started." When so handled and properly fed, it was found to be one of the cheapest and most satisfactory feeds.

Freeman (1914) says that alfalfa "will maintain a stand for a greater length of time and be more vigorous when regularly cut than when it is neglected or allowed to go to seed. In ordinary practice the maximum yield and quality of hay is obtained where the crop is regularly cut when about one-fifth to one-third of the plants are in bloom, or when new shoots begin to appear at the bases of the stems." He states further that when "the hay is to be fed to draft or driving animals it should be allowed to reach midflower before cutting; but care should be taken to cut before the new growth starting at the base of the old stems gets long enough to be clipped by the mower. If this occurs, recovery of growth is greatly retarded and the subsequent yield for that year is seriously affected."

Briggs and Shantz (1915) compared the water requirement and yields of Grimm alfalfa grown in plots at Akron, Colo., when clipped every week during the growing season and when cut in the usual way. The yield of dry matter and the total amount of water used during the growing season were greatly reduced by frequent cutting. The water requirement *i. e.,* the ratio of the water used to the dry matter produced, was about the same in each case. The authors suggest that the total consumption of water in a dry season "can be controlled to a considerable extent by pasturage or frequent clipping without serious injury to the alfalfa plants."

Clark (1917) points out that the alfalfa plant grows by adding onto the tip and if this growing tip is cut off it sets the plant back to the extent that it must form a new growing tip before growth can be continued. Cutting when the plants are about one-tenth in bloom or when new growth begins to appear at the crown is recommended for California conditions.

Kiesselbach (1918) compared normal with earlier than normal and later than normal cutting for three seasons at the Nebraska Agricultural Experiment Station. The normal cutting produced 5.57 tons per acre as compared with 3.70 for the earlier than normal, and 3.47 for the later than normal. In the fourth season all plots were cut at the normal stage of growth. The plot which had in preceding years been cut at the normal stage of growth produced 3.4 tons as compared with 3.2 for the plot that had been cut earlier than normal and 3.1 for the plot that had been cut later than normal. It was observed that "there was a marked weakening of plants and thinning of stand where alfalfa was cut too frequently."

Bean (1922) reported the average yields for two years of alfalfa cut at three different stages of growth at the Washington Irrigation Branch Station. The yields for the three-fourths-bloom stage were

8.1 tons per acre, the one-half-bloom stage 7.8 tons per acre, and where cut just before blooming 6.7 tons per acre.

Garver (1922) has reported the effect on root development and on mortality of the plants of harvesting three, seven, and eighteen times during the first season of growth following seeding in August. The mortality during the winter was 17 per cent for the plot harvested three times, 92 per cent for the plot harvested seven times, and 98 per cent for the plot harvested eighteen times. "The plants from the plot harvested three times during the season showed a much larger and stronger root growth than plants from the plots harvested seven and eighteen times."

Russell and Morrison (1923) recommended, as a result of experiments conducted at the Wisconsin Agricultural Experiment Station for three years with three varieties, that "generally speaking alfalfa should be cut as near the full-bloom stage as possible without getting the hay too coarse. Early cutting thinned the stand, weakened the plants, and permitted the encroachment of weeds. It was found that, contrary to common opinion, cutting off the crown shoots, which occurs when cutting is delayed, does not injure the stand."

It would appear from this brief review that experiments so far conducted are by no means in perfect agreement regarding the best time to cut or even as to the specific effect of any time or stage of cutting on the yield, add permanence of the stand. It is generally admitted that the protein content and feeding value of the hay tends to become less as cutting is delayed.

EXPERIMENTAL DATA

GENERAL METHODS

The experiments which are the basis of this report consisted of cutting alfalfa in four stages of growth designated as "bud stage," "tenth-bloom stage," "full-bloom stage," and "seed stage." The first refers to the condition of the flower buds, the plots being cut when these buds were well formed but before any blossoms appeared. In the absence of blossoms the plots were cut in a comparable stage of growth as judged by the condition of the plants. The seed stage plots were cut when the seed pods were well formed but before they were matured. The second and third stages are self-explanatory. As a rule the crown shoots were several inches high in plots cut in the full-bloom and seed stages, and were about one to one and one-half inches high in the tenth-bloom plots. They had not made their appearance in the bud stage plots at time of cutting.

Nine plots were used for this work. Three, distributed at uniform intervals, were cut in the tenth-bloom stage, and two were cut in each of the other stages. The plots were 169 by 62 feet, but an area 169 by 27 feet only, or approximately one-tenth acre, was harvested for yield, the remainder of the plots constituting a border, being harvested at the same time but not weighed. The purpose of this border was to prevent the spread of leaf spot, *Pyrenopeziza Medicaginus* (Lib.) sacc., and other fungus diseases which developed to a greater degree on the plots allowed to stand and easily spread to contiguous plots.

Samples consisting of from ten to twenty pounds of the green alfalfa were taken, weighed, and immediately turned to the Department of Chemistry for analyses. Similar samples were also taken of the field-cured hay. The yields were computed to a uniform moisture content of 10 per cent as determined from these samples. The per cent of grass in the hay was also determined from these samples.

The stand or number of plants and number of stems per acre was determined by making counts of two quadrats (4 by 4 feet) located in each plot, one having been located in 1914 when the experiments were started and the other in 1915. Counts were made in the spring by carefully scratching the soil away from each plant in each quadrat in order to secure an accurate count. The number of stems was determined after each cutting by harvesting each quadrat separate from the plot and counting the number of stems harvested.

The plots were first laid out in the spring of 1914 in a field which had been sown to alfalfa in 1912. Manure was applied to all plots in January, 1915, at the rate of about eight tons per acre. The plots received no other treatment during the course of the experiment.

The experiment was located on ground with a gentle and uniform slope, the plots extending up and down the slope. (Fig. 1.) permanent iron stakes driven in flush with the surface of the ground were used to locate the corners and white wooden stakes were also set up to facilitate cutting.

The time of last cutting in the fall was usually so determined that all plots were cut at or near the same time, thus assuring that all received the same protection during the winter. In many cases all plots did not reach exactly the proper stage of development as planned, but the error introduced thereby is believed to be small. The yields of such immature cuttings are included in the totals.

The feeding experiments conducted by the Department of Animal Husbandry were with hay from fields on the Agronomy Farm, cut in stages of growth to conform to that of the plots. The reason for this was (1) insufficient hay from the plots, and (2) the large per cent of grass in certain plots. Since the per cent of grass is a very inconstant factor it seemed best to conduct the feeding experiments with the pure alfalfa hay. This fact must be considered in interpreting the results.

The experiment as originally planned was discontinued at the end of the 1921 season because the condition of certain plots made it impossible to secure normal results. They were harvested as individual plots, however, in 1922 and in 1923 and some of the data secured in those years are presented in emphasizing certain points.

THE PROBABLE ERRORS OF THE EXPERIMENT

A more general recognition of the importance of soil variability and other sources of error in field experiments in recent years emphasizes the desirability of measuring such errors and taking them into account in interpreting results. In the present case the number of plots of each treatment (three for the tenth-bloom plots and only two for the others) is so small that no reliance can be placed in probable errors for any single comparison when computed by Bessel's or Peter's formulas. Since the treatment was the same for each plot each year the use of Student's method is also of questionable value. In such cases there is no satisfactory way of determining whether the odds in favor of a given treatment are due to the treatment or to a systematic *(i. e.,* constant from year to year) soil difference. The "probable error of the experiment'' as suggested by Hays (1923) seems to offer a way out of the difficulty. Apparently there is no sufficient reason, however, for computing the deviations and the probable errors on a percentage basis. This would entail much extra work and is based upon an assumption which in the present case appears false; viz., that the deviations and the probable errors vary directly with the yields or other determinations as the case may be. A casual perusal of the data in Tables VII and IX will show that there is no definite tendency in that direction. It would seem, therefore, that an arithmetical average of the probable. errors for any given observation might be used rather than a probable error based upon the percentage deviations.

Regardless of which of these two methods is employed there are certain limitations in the application of a "probable error of an experiment" which should be recognized. One which may lead to error is the undoubted fact that the magnitude of the probable error depends to some extent upon the treatment of the plots. It cannot be said, for example, that the probable error of plots cut in the bud stage will always be the same as for those cut in tenth bloom or full bloom. If the general principle be accepted that the response of crop plants to variability of the soil depends upon the variation in the limiting factor, then it must be admitted that the variability and hence the probable error will be different for different crops, varieties, and treatments since the limiting factor will be different.

It would appear that the use of the "probable error of the experiment" rather than the probable errors of the individual treatment is justified when, because of the small number of replications, the former is a closer approximation to the truth than the latter, or when both lead to essentially the same result. In the latter case the probable error of the experiment will usually be found more convenient to apply in interpreting the results. Used in a general way as an approximate measure of the soil variability, the probable error computed in this way may be of considerable value in interpreting experimental results.

In the present case the probable errors of the yields and of the number of plants per acre have been computed by this method. In the study of root diameters, the probable errors were calculated in the usual way by Basel's formula, the numbers dealt with being large enough to give fairly reliable results.

DATES OF CUTTING

The dates of cutting, number of cuttings for each season and each stage of cutting, and the average number for all seasons are recorded in Table I.

Three full cuttings were secured each year from the seed-stage plots. The average number for the others were 5.1 for the bud stage, 4.5 for the tenth bloom, and 3.9 for the full-bloom stages. The average intervals between cuttings were 30.8 days for the bud stage, 35.2 days for the tenth bloom, 39.8 days for the full bloom, and 51.1 days for the seed stage plots.

TABLE I.—Dates of cutting alfalfa, 1914 to 1921.

YEAR.	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.	Average.
Bud Stage (Plots 1 and 6).									
Cutting: 1	5–13	5–7	5–22	5–23	5–20	5–20	5–29	6–6	5–21
2	6–4	6–15	6–16	6–26	6–15	6–18	6–29	7–1	6–19
3	6–26	7–8	7–11	7–17	7–8	7–18	8–2	7–28	7–15
4	7–28	8–4	8–1	8–10	8–5	8–19	9–1	8–30	8–12
5	8–31	9–25	9–5	9–17	10–7	10–16	10–8	10–11	9–25
6	10–5	......	10–25	......	......	......	......	......	10–15
Days between cuttings (a),	29	35.2	31.2	29.2	27.5	29.7	33	31.7	30.8
Tenth-bloom Stage (Plots 2, 5 and 9).									
Cutting: 1	5–26	5–22	5–29	6–6	5–27	5–28	6–5	6–6	5–30
2	6–22	7–1	7–6	7–2	6–26	6–30	6–29	7–7	7–0
3	7–28	8–4	8–4	8–4	7–19	8–4	8–2	8–11	8–2
4	8–31	9–25	9–18	9–17	8–19	9–9	9–1	......	9–8
5	10–5	......	10–25	......	10–17	10–16	10–8	10–11	10–14
Days between cuttings (a),	33	42	37.2	34.3	35.8	35.3	31.3	33.0	35.2
Full-bloom Stage (Plots 3 and 7).									
Cutting: 1	6–4	6–3	6–6	6–16	6–4	6–9	6–14	6–20	7–0
2	7–11	7–8	7–17	7–17	7–3	7–11	7–22	7–22	7–14
3	8–10	8–18	8–24	8–22	8–5	8–19	8–26	9–8	8–20
4	10–5	10–11	10–11	10–8	9–25	10–16	b9–1	10–11	10–4
Days between cuttings (a),	41	43.3	42.3	38.0	37.7	43	36.5	37.6	39.8
Seed Stage (Plots 4 and 8).									
Cutting: 1	6–30	6–14	6–16	6–23	6–19	6–18	6–29	7–1	6–23
2	8–4	8–4	7–26	7–30	8–5	8–6	8–2	8–15	8–4
3	10–2	10–11	9–5	9–21	10–7	10–16	10–8	10–11	10–3
4	......	......	b10–25	......	......	......	......	......	......
Days between cuttings (a),	47	59.5	40.5	45.0	55.0	60.0	50.5	51	51.1

(a) This line gives the average interval in days between full cuttings.
(b) Immature hay.

Effect on Stand

Perhaps the most striking and unexpected result of the experiment is the effect of frequent cutting on the stand. The number of plants per acre was determined in the spring of each year (except 1917 and 1918) usually after the first cutting. This was done by counting the number in each of two permanently located quadrats. The results are given in Table II. In a similar way the number of stems was determined after each cutting. The number of stems reported in Table III is the average for all cuttings during the season. The data relating to the number of stems per plant calculated from the data in Tables II and III are given in Table IV.

TABLE II.—Relation of time of cutting to number of plants per acre.

STAGE OF CUTTING.	Number of plants per acre (000 omitted).							Loss 1914, to 1922.
	1914.	1915.	1916.	1919.	1920.	1921.	1922.	
								Per cent.
Bud stage.........	562	410	166	182	148	168	129	77.1
Tenth bloom......	534	323	263	214	173	201	85	84.1
Full bloom........	447	362	223	183	175	195	159	64.4
Seed stage........	427	346	249	218	174	204	197	53.9

TABLE III.—Relation of time of cutting to number of stems per acre, 1915 to 1921.

STAGE OF CUTTING.	Number of stems per acre (000 omitted).							Loss, 1915 to 1922.
	1915.	1916.	1917.	1918.	1919.	1920.	1921.	
								Per cent.
Bud stage.........	1,790	1,170	1,728	1,109	1,182	1,166	882	50.8
Tenth bloom......	1,920	1,755	2,438	1,250	1,296	1,141	695	63.8
Full bloom........	1,888	1,725	1,723	1,578	1,353	1,341	1,010	46.5
Seed stage........	1,450	1,715	1,164	1,540	1,821	1,506	1,262	13.0

TABLE IV.—Relation of time of cutting to number of stems per plant.

STAGE OF CUTTING.	Number of stems per plant.					Average
	1915.	1916.	1919.	1920.	1921.	
Bud stage.....	3.2	7.1	6.5	7.9	6.8	6.3
Tenth bloom.......................	3.8	6.7	6.1	6.6	8.2	6.3
Full bloom.........................	4.2	7.7	7.4	7.7	6.4	6.7
Seed stage.............	3.4	6.9	8.0	8.7	6.4	6.7

The probable error of the stand counts for a single plot calculated as previously explained is 10,233 plants per acre. Hence the probable error for the determinations of stand for the bud stage, full-bloom, and seed-stage cuttings, of which there were two plots each, is $\frac{10{,}233}{\sqrt{2}} = 7259$. Likewise for the tenth bloom cuttings of which there were three plots, the probable error is $\frac{10{,}233}{\sqrt{3}} = 5915$. The least statistically significant difference therefore for any comparisons of the former would be $7259\sqrt{2} \times \mathbf{3.2} = 32{,}746$ and for any comparison with the tenth-bloom plots $\sqrt{72592+59152} \times 3.2 = 30,$-400. Since the determination is approximate only and since the factor 3.2 is purely arbitrary, it would seem sufficient in the present case to consider any differences in stand of less than about 10,000 per acre as probably due to chance and any of less than about 30,000 per acre as not statistically significant.

From Table II it is evident that there was a heavy mortality of alfalfa plants, in no case being less than 50 per cent of the number in the field when the plots were laid out. Of special significance, however, is the very heavy loss in the bud-stage and tenth-bloom plots, constituting as it does 77.1 and 84.1 per cent respectively of the original number. The loss was made up to some extent by a greater production of stems per plant, especially in the seed-stage plots. In fact preceding the season of 1921 there was no indication of a decrease in the number of stems per acre in the seed-stage plots and their appearance indicated a full stand.

The very marked decrease in the stand of the tenth-bloom plots from the spring of 1921 to the spring of 1922 calls for an explanation. Previous to 1921 the stand was good. There had been some encroachment of bluegrass, and foxtail and crabgrass occasionally appeared. In April, 1921, when the alfalfa was about 6 inches high, it was frozen to the ground. Following this freeze there occurred a severe attack of pea aphids, *Illinoia pisi* (Kalb.), which remained on the alfalfa in sufficient numbers to prevent any growth for a period of a month or more. When they disappeared and the alfalfa resumed growth, it was apparent that the tenth-bloom plots had been injured much more severely than any of the others. This is shown by the fact that in the spring of 1922 there were only 85,000 plants per acre compared with 201,000 the preceding year. No reason can be assigned for this greater injury as compared with other plots.

There was a gradual loss of plants on the seed-stage plots and to a lesser degree on the full-bloom plots. The major loss in the bud-stage plots took place during the first two years of the experiment. The apparent gain on the bud-stage plots in 1919 and on all plots in 1921 should probably be attributed to experimental error. Although the field appeared to be uniform in stand when the experiment was begun, it is evident from Table II that there were rather marked variations. It is fortunate, however, that the highest number of plants per acre were recorded for the bud-stage plots and the least for the seed-stage plots, thereby emphasizing the deleterious effect of frequent cutting. In other words, any conclusion based on the observed losses would err, if at all, in being too conservative.

Encroachment of Grasses

One of the first visible effects of the early cutting was the encroachment of foxtail, *Chaetochloa viridis* (L) Scribn., crabgrass, *Syntherisma sanguinalis* (L) Dulac, and bluegrass, *Poa pratensis* L. These appeared first in the bud-stage plots in July, 1915; *i. e.,* in the second year of the experiment, and in general increased from year to year thereafter. The annual grasses usually appeared first to be followed in succeeding years by bluegrass. The amount of annual grasses depended primarily upon seasonal and weather conditions when the alfalfa was cut. Table V gives the per cent of grass hay harvested with the alfalfa. No grass was found in any of the plots in 1914.

In general it appears that the grasses were able to encroach upon the alfalfa as the latter was weakened or killed. As the alfalfa plants died out beyond the capacity of the remaining plants to take their place by branching, there was a tendency for annual grasses and bluegrass to take their place. Also the ability of the alfalfa plants to hold their own against this encroachment varied inversely as the frequency of cutting. Thus while a considerable proportion of the latter cuttings of the bud-stage plots consisted of grass in 1915, 1916 and 1917 no grass appeared in any other plots prior to 1918. A small percentage appeared in the tenth bloom plots in 1918 and increased to a large amount following the severe injury to those plots in the spring of 1921.

A very slight amount of grass made its appearance in plot 7 cut in full bloom in 1919. This consisted of annual grasses, however, which did not reappear in 1920. Grass first appeared in the seed-stage plots in 1921.

TABLE V.—Per cent of grass in hay in different cuttings, 1914 to 1921.

PLOT AND CUTTING NUMBER.	Per cent of grass in hay.						
	1915.	1916.	1917.	1918.	1919.	1920.	1921.
Bud Stage—							
Plot 1.							
1						11.1	17.4
2							36.8
3		17			24.9		46.1
4	35.3	40	30.8			28.1	79.7
5	85.1		42.9	79.4	48.0	7.2	
Plot 6.							
1							7.1
2							37.5
3		25			28.2		48.1
4	35.3	50	40.0				87.3
5	75.0		47.4	90.9	47.2	15.6	
One-tenth Bloom Stage—							
Plot 2.							
1							6.9
2							49.2
3							77.9
4					2.5	6.6	
5				14.5	28.7	6.4	
Plot 5.							
1							8.4
2							70.4
3							73.3
4						7.5	
5				25.7	28.7	16.1	
Plot 8.							
1						0.8	18.3
2							88.4
3							88.4
4					33.7	22.4	
5				26.2		18.1	
Full-bloom Stage—							
Plot 3.							
1							
2							5.2
3							39.2
4							
5							
Plot 7.							
1							6.4
2							80.0
3							80.0
4					1.4		
5							
Seed Stage—							
Plot 4.							
1							
2							2.6
3							17.5
Plot 9.							
1							17.6
2							13.7
3							26.5

Total Growth During the Season

The height of the alfalfa plants on each plot was measured at each cutting and totalled for each season. In the case of the full-bloom and seed-stage plots the height of the new shoots was also measured and added to the total of the original growth. The results are presented in Table VI.

TABLE VI.—Relation of time of cutting to total growth of alfalfa during the season.

TIME OF CUTTING.	Annual growth in inches.								Average.
	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.	
Bud stage	71.0	99.0	98.0	a68.0	53.3	70.5	61.8	41.0	70.2
Tenth bloom	66.0	106.0	38.0	79.2	65.5	70.8	51.2	32.0	63.6
Full bloom	67.0	100.5	44.0	68.0	56.3	72.0	55.0	28.7	61.4
Seed stage	53.0	93.5	72.0	82.3	57.0	72.5	50.5	38.0	64.8

(a) No data for first cutting.

The greatest average growth for eight years is recorded for the bud-stage plots and the least for the full bloom. Considering the difficulty in accurately measuring the height of alfalfa growing in the field, it is doubtful if the differences between the tenth bloom, full bloom, and seed stage are significant.

Yields of Hay

The total yields of hay for each season, including the grass harvested with the hay, have been calculated to a uniform moisture content of 10 per cent and recorded in Table VII. Table VIII shows the total quantities of alfalfa and of grass in the hay cut during the eight years of the experiment.

TABLE VII.—Total yields of hay; 10 per cent moisture basis, 1914 to 1921.

STAGE OF CUTTING.	Yield of hay—tons per acre.								Average.
	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.	
Bud stage—									
Plot 1	3.68	4.68	4.38	3.73	2.00	3.57	2.34	2.29	3.33
Plot 6	3.26	4.17	4.06	3.21	1.76	3.23	2.40	3.09	3.15
Average	3.47±.142	4.43±.189	4.22±.108	3.47±.175	1.88±.081	3.40±.115	2.37±.020	2.69±.270	3.24±.0540
Tenth bloom—									
Plot 2	3.62	5.82	5.43	3.48	1.89	3.73	2.20	2.15	3.54
Plot 5	3.42	5.58	5.55	3.16	2.43	3.60	2.45	2.66	3.61
Plot 8	3.09	4.43	4.47	2.77	2.02	3.38	2.19	2.25	3.07
Average	3.38±.104	5.28±.289	5.15±.234	3.14±.138	2.11±.109	3.57±.069	2.28±.057	2.35±.105	3.41±.0554
Full bloom—									
Plot 3	2.99	6.20	6.02	3.47	2.13	3.25	2.86	1.77	3.58
Plot 7	2.39	6.38	5.85	3.20	1.78	3.15	2.36	2.33	3.43
Average	2.68±.202	6.29±.061	5.94±.057	3.34±.091	1.96±.118	3.20±.034	2.61±.169	2.05±.189	3.51±.0461
Seed stage—									
Plot 4	2.30	5.12	5.01	3.39	1.68	3.52	1.85	1.91	3.09
Plot 9	1.95	4.10	5.19	3.04	1.44	2.94	1.64	1.87	2.77
Average	2.13±.118	4.61±.344	5.10±.061	3.22±.118	1.56±.081	3.23±.196	1.75±.071	1.89±.013	2.93±.0559

The probable error of the average for all years was calculated by the formula $E = \frac{\sqrt{E_1^2 + E_2^2 + \ldots + E_n^2}}{N}$ adapted from Mellor (1909, p. 444).

TABLE VIII.—Yields of pure alfalfa and grass hay; 10 per cent moisture basis, 1914 to 1921.

Stage of Cutting and Description of Hay.	Yield—tons per acre.								Average.
	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.	
Bud stage—									
Alfalfa	3.46	3.53	3.57	2.53	1.75	2.72	2.16	1.52	2.65
Grass	0.00	0.90	0.65	0.94	.13	0.68	0.21	1.17	0.59
Total	3.46	4.43	4.22	3.47	1.88	3.40	2.37	2.69	3.24
Tenth bloom—									
Alfalfa	3.38	5.26	5.15	3.14	2.05	3.39	2.16	1.11	3.21
Grass	0.00	0.00	0.00	0.00	0.06	0.18	0.12	1.24	0.20
Total	3.38	5.26	5.15	3.14	2.11	3.57	2.28	2.35	3.41
Full bloom—									
Alfalfa	2.69	6.29	5.94	3.34	1.95	3.20	2.61	1.44	3.43
Grass	0.00	0.00	0.00	0.00	0.00	trace	0.00	0.61	0.08
Total	2.69	6.29	5.94	3.34	1.95	3.20	2.61	2.05	3.51
Seed stage—									
Alfalfa	2.13	4.61	5.10	3.22	1.56	3.23	1.75	1.70	2.91
Grass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.02
Total	2.13	4.61	5.10	3.22	1.56	3.23	1.75	1.89	2.93

The probable errors have been calculated by Bessel's formula for each year and are given following the average yields for each stage of cutting. Those given in the last column of Table VII were calculated by the formula for the probable error of an arithmetical mean as given by Mellor (1909, p. 444).

The average (weighted) probable error for a single plot for the experiment as a whole for the eight-year period *(i.e.,* the probable error of the experiment) is found to be $\pm$ .0806 tons. The probable error of the mean of two plots is, therefore,

$$E_m = \frac{.0806}{\sqrt{2}} = \pm .057$$

and for three plots

$$E_m = \frac{.0806}{\sqrt{3}} = \pm .046$$

The probable error of the difference in average yields between any treatments of which there were two plots (viz., bud stage, full bloom and seed stage) would therefore be $.057\sqrt{2} = .0806$, and the least difference that can be considered statistically significant would be $.0806 \times 3.2 = .258$ tons.

In a similar way the probable error of a difference between the average yields of the tenth-bloom plots of which there were three and a n yother treatment would be $\sqrt{.057^2 + .046^2} = .0737$ tons and the least statistically significant difference $.0737 \times 3.2 =$ 236 tons.

Since these values are nearly alike and are based upon assumptions only approximately true, it is perhaps sufficiently accurate to consider any difference in average yields of more than .25 tons as statistically significant and any of less than .08 tons as due to chance. In the discussion which follows it is assumed that the probable errors for the yields of grass-free alfalfa (Table VIII) are the same as for the total yields although the calculations are based upon the later. It is reasonably certain that no serious error is introduced thereby.

It will be observed that the bud-stage plots have produced less grass-free alfalfa than any other and less total hay than any except those cut in the seed stage. The differences in relation to the probable error are such that they cannot be considered as due to chance except possibly the difference in total yield of the bud stage and tenth bloom which is only about twice the probable error.

The full-bloom plots have produced the highest yields both of grass-free alfalfa and of total hay, the differences in all cases being greater than the probable error and except for the comparison with tenth bloom statistically significant.

Cutting at seed stage has produced the lowest total yields of any treatment and excepting the bud stage the lowest yields of grass-free alfalfa. The differences in all cases are statistically significant.

Stated in another way the differences in average yield of total and of grass-free hay as given in Tables VII and VIII are in all cases greater than the probable error and excepting the differences in yield of total hay between tenth bloom and bud stage and between tenth bloom and full bloom and of grass-free hay between tenth bloom and full bloom are statistically significant.

Perhaps the relation between frequency of cutting and yield can be seen more clearly if presented graphically. This has been done in figure 2 in which the abscissa represent the average number of days between cuttings as recorded in Table I and the ordinates the yields of grass-free hay. While the experiment did not extend beyond the limits of 30.8 and 51.1 days corresponding to yields of 3.24 and 2.91 tons it is probable that the curve $Y = 3.46 - .0066 (X - 41.3)^2$ represents fairly well what might be expected somewhat beyond these limits. The curve is therefore extended to the two ton per acre point at both ends.

The significance of these results can be appreciated only when differences in yield are considered in connection with other effects of varying the time of cutting. Thus the frequent cutting of the

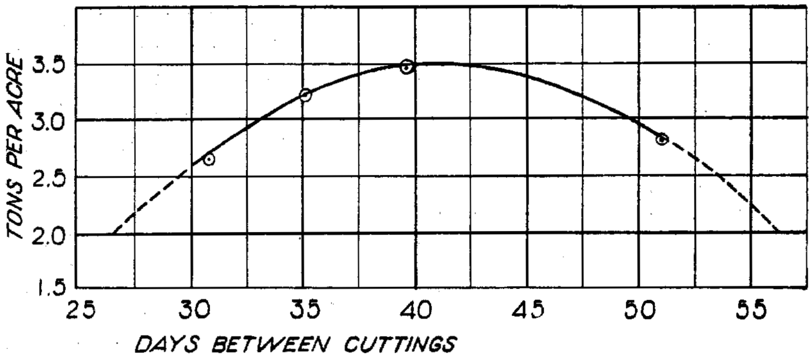

FIG. 2.—Curve showing the relation between the interval between cutting (X) and the yield of grass-free alfalfa (Y). Bud stage corresponds to an average interval of 30.8, tenth bloom, 35.2, full bloom 39.8, and seed stage 51.1 days. The equation of the curve, $Y = 3.46 - 0.0066\,(X - 41.3)^2$, approximately represents what may normally be expected between the limits of intervals of about 25 and 55 days.[2]

bud-stage and tenth-bloom plots has weakened the plants, reduced the stand, permitted the encroachment of grass, and reduced the yield, while permitting the plants to go to full bloom has maintained the stand in good condition, prevented grass from getting a start, and has produced the highest yields of any treatment. Although cutting in the seed stage has maintained the stand in better condition than any other treatment, the yields are low, and as will be pointed out later, the quality of hay poor.

It is perhaps also significant that the effect of frequent cutting on yield was most apparent in the early years of the experiment, if the first year, during which there was no apparent injury to the plants, be excepted. Thus, the average yields of pure alfalfa hay for the second and third years (1915 and 1916) were 3.55 tons per acre for the bud stage, 5.21 tons for the tenth bloom, 6.12 for the full bloom, and 4.86 for the seed-stage plots. The seasons of 1917 and 1918 were very dry for alfalfa and no doubt this factor reduced the differences in yield that might normally be expected. By this time the field was seven years old and approaching or perhaps past that age when the largest yields are to be expected. It is probably such factors as these that explain the failure of the full bloom plots to produce as large yields, in comparison with the more frequent cuttings, as might be expected from a consideration of the stand.

Another factor which should be mentioned is the damage that

2. Credit is due Prof. C. E. Pearce of the Division of Engineering, Kansas State Agricultural College for assistance in calculating the equation of this curve.

has somtimes occurred from leaf spot. This normally injured the full-bloom plots the most, due no doubt to the longer period of growth and the opportunity for development, of the fungus. In farm practice infected fields would be cut as soon as general infection appears, but in the present case the plots were allowed to reach their specified stage of development according to the plan of the experiment.

It is therefore quite possible that cutting in full bloom when there is no leaf spot infection and earlier when infection appears would give larger yields than those recorded.

There is some evidence in favor of the view that frequent cutting stimulates growth. Thus it may be pointed out that in the first year of the experiment before the plants were weakened by the frequent cutting the highest yields were secured from those plots which were cut the most often, and the data in Table VI indicate rather clearly that the plants in the bud-stage plots made the greatest total linear growth.

Further information relating to the effect of frequent cutting on the yield, permanence of stand, and composition of the hay has been recently supplied by Moses (1924) who investigated these phases at the Kansas station. Eleven different treatments consisting of 10 plots each, uniformly distributed in a 13-year-old alfalfa field were compared. Considerable grass had already made its appearance in this field. The plots were 6 by 10 feet. One set of plots was left uncut during the season. The remainder were cut during the season of 1923 as indicated and with the results shown in Table IX.

The probable error of the yield, based upon the ten plots of each cutting, was calculated by Bessel's formula. Since the number of plots is small, it is perhaps as accurate to use the means of all determinations and consider it as the "probable error of the experiment" as previously discussed. This is found to be 166 pounds per acre which may be taken to mean that in general, differences of 214 pounds or less per acre (*i.e.,* $166 \times \sqrt{2}$) are due to chance, and that differences of less than 685 pounds per acre (214×3.2) cannot be considered statistically significant. The probable errors were also calculated for the number of plants killed during the season and found to be about 1.4 per cent for each determination given in Table IX. This would indicate that differences of less than about six per cent cannot be considered statistically significant.

TABLE IX.—Relation of frequency of cutting to yield, stand, and protein content of hay in 1923.

FREQUENCY AND STAGE OF CUTTING.	Number of cuttings during the season.	Yields of air-dry hay—pounds per acre.		Grass in hay (a).	Leaves (a).	Protein content of hay (a).	Plants killed during the summer.
		Total—Alfalfa and grass.	Alfalfa alone.				
				Per cent.	Per cent.	Per cent.	Per cent.
Cut every 10 days	9	5,028	4,717 ±79	6.2	62.4	26.4	81.2
Cut every 20 days	6	6,890	6,537 ±152	5.1	59.8	22.5	37.1
Cut in bud stage	(b) 5	8,466	6,942 ±270	18.0	48.6	18.5	5.8
Cut in tenth bloom	(b) 4	7,525	7,101 ±91	5.6	53.1	18.7	7.4
Cut in full bloom	(b) 4	6,177	5,306 ±158	14.1	46.1	18.1	5.1
Cut in seed stage	(b) 3	5,645	5,229 ±171	7.4	47.2	17.7	0.9
First two cuttings in bud stage, later cuttings in full bloom	(b) 4	8,169	6,178 ±162	24.4	44.3	18.3	5.9
First two cuttings in full bloom, later cuttings in bud stage	4	6,618	6,618 ±124	0.0	53.5	19.5	10.7
First cutting in full bloom, second in tenth bloom and last two cuttings in bud stage	4	7,107	6,448 ±216	9.3	52.1	17.8	6.9
First cutting in bud stage, second in tenth bloom, and last two in full bloom	4	7,527	6,244 ±237	17.0	45.7	18.3	5.1

(a) Weighted averages in all cases.
(b) Last cutting failed to reach completely the stage indicated.

Without doubt the most important fact brought out in Table IX is the pronounced effect of very frequent cutting on stand. It will be observed that cutting every ten days killed more than 80 per cent of the plants. (Fig. 3.) Over 37 per cent were killed by cutting every twenty days. Other differences indicated are probably within the limits of experimental error.

The highest yields of alfalfa alone were secured from cutting in tenth bloom and of total crop including grass from cutting in the bud stage. These yields are significantly greater than those secured from less frequent cuttings. The yields of the full-bloom plots were somewhat reduced, however, by attacks of leaf spot and garden web worm *(Loxostege similalis* Gn.) which injured other cuttings but very little. The high yields of the bud and tenth-bloom cuttings again suggest that frequent cutting stimulates growth until the vigor of the plants is affected.

One of the primary purposes of this later experiment was to determine the effect on the alfalfa plants of cutting the first crop of the season early and the second and subsequent crops somewhat later and vice versa. It may be possible for example, to cut the first crop in bud stage or before and permit the plants to recuperate by delaying the other cuttings of the season, thereby preventing the damage to the stand that would result from continuous early cutting. Such a combination would frequently permit harvesting the first crop at a more favorable period of the year, and as will be shown later, result in a better quality of hay for the total crop of the season.

The results of a single year are not sufficient to settle this problem but it will be observed that cutting the first or the first and second crops in the bud stage and subsequent crops in tenth or full bloom caused no apparent injury to the stand and produced high yields as compared with other treatments. Considerable grass was present but this consisted of annual grasses such as foxtail and crabgrass and occurred in material quantities in the third cutting only. It is doubtful if in this case it indicated any deterioration in stand. This point is being investigated more exhaustively.

Altogether it seems that the yield is the resultant of a number of different factors, some of which favor frequent cutting and others which do not. This probably explains the rather divergent views previously noted regarding the best time to cut in different states. There can be no reasonable doubt that under the conditions of this experiment the predominating factor affecting yield is the injury to

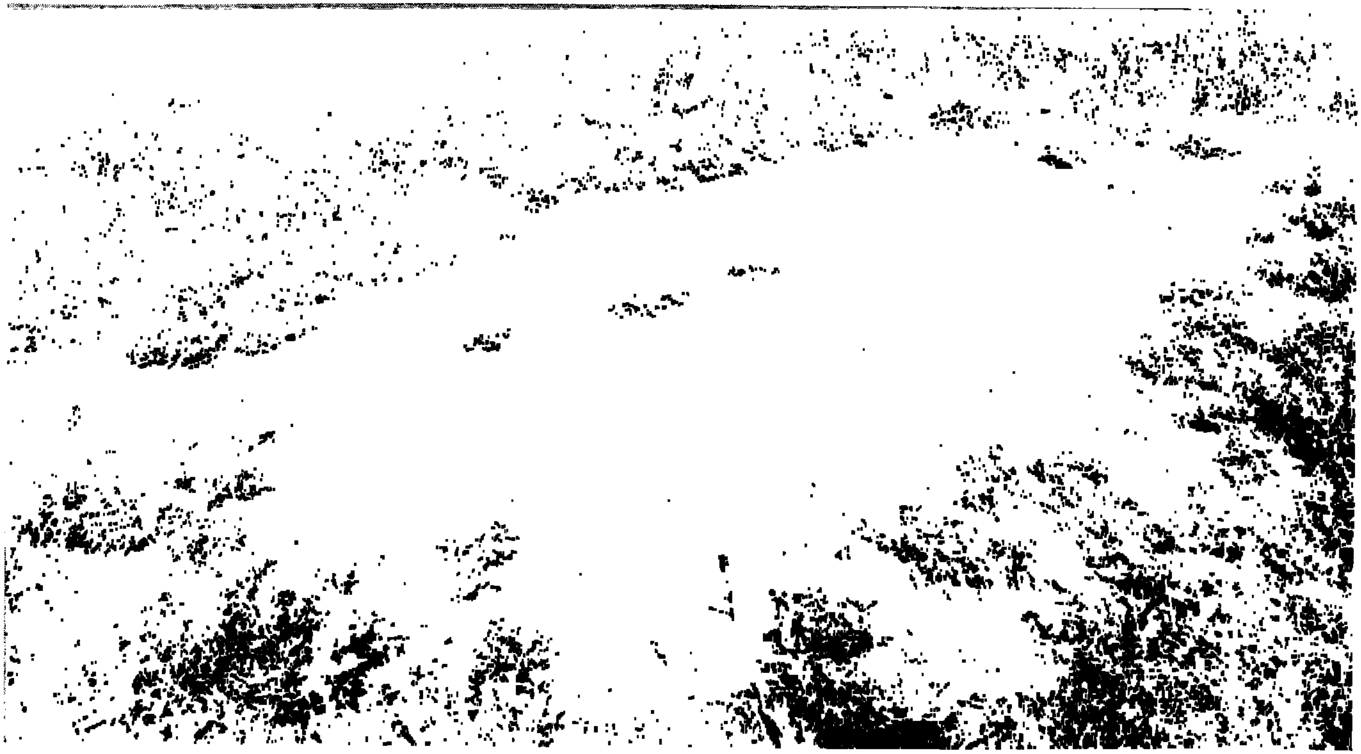

FIG. 3.—A plot of alfalfa, 6 by 8 feet, which had a good stand in May, 1923, but which was practically killed out during the summer by cutting every 10 days.

the plants and a consequent reduction in stand with frequent or early cutting. Any practice which fails to take this factor into consideration probably will not give satisfactory results.

Residual Effect of Frequent Cutting

As previously mentioned, yields were secured in 1922 and in 1923 although the experiment so far as it related to the original purpose was discontinued in 1921. In 1922 an attempt was made to harvest the plots according to the original plan but it was found that, because of the injury to certain of the plots and the age of the field as a whole, growth was in many cases abnormal and the results could mean little so far as comparing different stages of cutting were concerned.

For example, because of lack of vigor and delayed growth the tenth-bloom plots in every case were cut on the same dates as the bud-stage plots. Accordingly in 1923 all plots were harvested at the same time in order to determine the residual effect of frequent cutting. Three cuttings mere secured. The yields are given in Table X.

TABLE X.—Yields in 1922 and 1923, showing residual effect of frequent cutting.

STAGE OF CUTTING IN PREVIOUS SEASONS.	Yield of hay—tons per acre.	
	1922.	1923.
Bud stage	1.99±.14	2.47±.07
Tenth bloom	2.31±.26	2.61±.15
Full bloom	2.92±.07	3.11±.17
Seed stage	2.29±.08	2.99±.30

The results are consistent with those of previous years in showing the deleterious effect of frequent cutting.

The application of these results to farm practice will be discussed after the presentation of the chemical and feeding data.

Roots

In 1915, the second year of the experiment, an excavation was made to a depth of about four feet in each plot in order to study the relation, if any, between the stage of cutting and the development, of the roots. Large healthy roots were found in all plots but only in the bud-stage plots were dead and decaying roots observed. In each of these plots six such roots in an area of approximately 20 square feet were found, thus supporting other facts previously recorded which indicate a decided detrimental effect from frequent cutting.

Similar excavations were made in the fall of 1922. The primary purpose at that time was to find if there was a difference in the depth of penetration of the roots on the different plots. It was found that at a depth of about 18 feet, the roots encountered a more or less permanent water table which prevented further growth downward. Roots were found at this depth in all cases and judging from their size (1 to 2 mm. in diameter) were capable of penetrating further had soil conditions been favorable. No differences related to the treatment of the plots were observed.

The roots excavated from the different plots in 1915 were taken to the laboratory and their diameters measured at depths of three and fifteen inches below the crown. In 1923 a similar study was made of approximately one hundred roots from each plot selected at random as the plots were plowed. In this case, however, only one measurement, viz., at three inches below the crown was made, The diameters as determined are shown in Table XI. The probable errors in this table have been calculated by Bessel's formula in the usual way, the number of determinations being considered adequate for this purpose.

TABLE XI.—Relation of time of cutting alfalfa to diameter of roots.

STAGE OF CUTTING.	Number of roots measured.	Root measurements in inches, 1915.		Number of roots measured.	Root measurements in inches, 1923.
		Diameter three inches below crown.	Diameter fifteen inches below crown.		Diameter three inches below crown.
Bud stage—					
Plot 1	34	.262±.011	.115±.006	114	.569±.009
Plot 6	57	.204±.005	.076±.004	114	.553±.008
Tenth bloom—					
Plot 2	41	.301±.011	.128±.002	113	.572±.008
Plot 5	94	.248±.001	.110±.002	115	.572±.009
Plot 8	60	.264±.007	.119±.003	113	.532±.010
Full bloom—					
Plot 3	36	.264±.010	.120±.005	114	.563±.008
Plot 7	49	.227±.001	.082±.005	117	.585±.009
Seed stage—					
Plot 4	96	.254±.007	.124±.012	114	.640±.009
Plot 9	60	.249±.006	.111±.003	115	.578±.008

TABLE XI.—*Concluded:* Summary.

STAGE OF CUTTING.	Diameter in inches in 1915.		Diameter in inches in 1923.
	Three inches below crown.	Fifteen inches below crown.	Three inches below crown.
Bud stage	.233±.006	.096±.002	.561±.006
Tenth bloom	.271±.005	.119±.002	.559±.005
Full bloom	.246±.005	.101±.003	.574±.006
Seed stage	.252±.005	.118±.006	.609±.006

The roots from the bud-stage plots at three inches below the crown appear to have been significantly smaller than those from the other stages of cutting in 1915. In 1923, those from plants cut in the bud and tenth-bloom stages or from the plots which had been most severely injured were distinctly the smallest. However, the differences between plots of the same treatment as shown in Table XI are rather marked and reduce somewhat the confidence which may be placed in these results.

CHEMICAL ANALYSES

Sampling and Preparation for Analysis

The samples of green alfalfa collected as previously described were weighed on a spring balance having an accuracy of about 0.01 lb. and taken to the chemical laboratory. The samples were then reweighed on a scale, accurate to five grams, and spread on screen wire hung several feet from the floor in an attic and allowed to dry. At this time a small sub-sample of the green alfalfa was taken which, as soon as wilted, was separated into leaves and stems. When thoroughly dry, weights of both leaves and stems of the small sample and total weights were determined, which, together with green weights, furnished the data for calculating the moisture lost by the alfalfa in becoming air-dry, and also the proportion of leaves and stems.

The large sample was cut into lengths of one-eighth to one-half inch long by means of a small clover cutter. The cut material was thoroughly mixed and quartered until a two-quart sub-sample was obtained. This was placed in a Mason jar and a part used for the determination of moisture in the air-dry material. In determining the moisture 100 gram samples were dried to constant weight in a steam oven. This usually required twenty-four hours. The remainder of the sub-sample was ground in a drug mill until it was fairly fine. From this a four-ounce sample was taken for the chemical analysis. This was first ground in a Brown sample grinder and then in a Merker mill to pass a millimeter sieve. The sample of stems was cut and ground like the main sample; the leaves were ground direct.

In 1914, 1915, and 1919 the feed constituents were determined for all the separate cuttings. In the other years analyses were made from composite samples to represent the different stages. In the years 1914 and 1915 the separate cuttings, and in 1916 and 1917 the composite samples were analyzed for phosphorus, potassium, calcium, and magnesium, in addition to the feed constituents.

When grass was present the percentage was usually determined from the small sub-samples used for separation into leaves and stems. In some cases the percentage of grass was determined on the whole sample.

The samples of field-cured hay were handled in the same way except that no sub-samples were taken for separation into leaves and stems.

Moisture Content of Green and Cured Hay

The per cent of moisture in green alfalfa and in field-cured and attic-cured hay are given in Table XII.

TABLE XII.—Per cent of moisture in alfalfa.

Condition of hay.		Per cent moisture.						
		Cutting number.						
Crop.	Stage of cutting.	1.	2.	3.	4.	5.	6.	Av. (a)
Green alfalfa	Bud stage	73.6	73.8	74.1	73.9	65.2	69.3	71.7
	Tenth bloom	72.4	73.2	69.0	70.3	69.7	......	70.9
	Full bloom	71.4	70.9	67.1	67.7	......	......	69.3
	Seed stage	66.3	65.6	63.1	60.1	......	......	63.8
Field-cured hay	Bud stage	24.2	20.1	21.1	20.8	16.9	21.8	20.8
	Tenth bloom	22.0	17.4	19.6	20.4	19.1	......	19.7
	Full bloom	18.1	18.7	22.0	18.0	......	......	19.2
	Seed stage	12.9	14.9	14.3	......	......	......	14.0
Attic-cured hay	Bud stage	6.7	7.1	7.1	7.5	7.1	8.3	7.3
	Tenth bloom	7.2	7.2	7.4	7.4	7.6	......	7.4
	Full bloom	7.2	7.4	7.5	7.7	......	......	7.5
	Seed stage	7.6	7.2	7.9	......	......	......	7.6

(a) Not a weighted average.

These figures are the averages for eight years. The percentages of moisture in the green and attic-cured alfalfa, especially the latter, were fairly constant for the different years. The moisture content of green alfalfa was highest in the bud stage and decreased for each succeeding stage, the greatest decrease being in the seed stage. The field-cured hay showed the greatest variation in moisture. This was partly due to the necessity of stacking under conditions favoring the best recovery of hay, and as the quantities were small, the stacking could sometimes be done when the moisture content was higher than would be advisable in farm practice.

Proportion of Leaves and Stems

The average relative proportion of leaves and stems for each year for the alfalfa cut at the four stages of growth are given in Table XIII.

TABLE XIII.—Proportion of leaves and stems in alfalfa cut at different stages of growth.

YEAR.	Bud stage.		Tenth bloom.		Full bloom.		Seed stage.	
	Leaves.	Stems.	Leaves.	Stems.	Leaves.	Stems.	Leaves.	Stems.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1914	57.6	42.4	56.4	43.6	51.5	48.2	43.5	56.5
1915	47.9	52.1	41.5	58.5	37.7	62.4	36.6	63.4
1916	48.8	51.2	41.4	58.6	39.6	60.4	39.5	60.5
1917	52.0	48.0	50.4	49.6	50.8	49.2	43.0	57.1
1918	52.5	47.5	53.1	46.9	53.4	46.7	47.9	52.2
1919	55.0	44.0	54.0	46.0	51.0	48.0	38.0	62.0
1920	57.0	43.0	59.0	39.0	51.0	49.0	36.0	65.0
1921	56.0	44.0	53.0	47.0	52.0	48.0	48.0	52.0
Average	53.4	46.5	51.1	48.7	48.4	51.5	41.6	58.6

There was a consistent decrease in the proportion of leaves as cutting was delayed. Thus when cut in the bud stage 53.4 per cent of the crop consisted of leaves as compared with 51.1, 48.4, and 41.6 for the tenth bloom, full bloom, and seed stages respectively. The difference between the first three stages was so small that the per cent of leaves probably need not be a primary consideration in determining the time of cutting, but from the full bloom to the seed stage the decrease was significant, especially when the high protein content of the leaves, as discussed later, is considered.

The proportion of leaves and stems in the separate cuttings for the eight years are given in Table XIV. There was a tendency for the proportion of leaves to increase as the season advanced, this relation being especially pronounced in the bud-stage cuttings, and least pronounced in the seed-stage cuttings. Thus in the bud-stage plots the leaves of the first cutting averaged 49 per cent as

TABLE XIV.—Proportion of leaves and stems by separate cuttings.

STAGE OF CUTTING.	Cutting number.	Average per cent of leaves.	Average per cent of stems.
Bud stage	1	49	51
	2	51	49
	3	53	47
	4	57	43
	5	55	45
	6	65	35
Tenth bloom	1	47	53
	2	49	51
	3	55	45
	4	53	47
	5	58	42
Full bloom	1	43	57
	2	50	50
	3	50	50
	4	51	49
Seed stage	1	38	62
	2	40	60
	3	42	58

compared with 55 per cent for the fifth cutting and 65 per cent for the sixth. In a similar way the tenth-bloom plots varied from 47 per cent for the first cutting to 58 per cent for the fifth or last cutting; the full-bloom plots from 43 per cent for the first cutting to 51 per cent for the fourth cutting; and the seed stage from 38 per cent for the first cutting to 42 per cent for the third or last cutting.

It also is of interest to note that the second, third, and fourth cuttings from the full-bloom plots contained a higher per cent of leaves than the first and second cuttings of the bud stage and tenth-bloom plots. Since the value of alfalfa hay depends greatly on the percentage of leaves it follows that delayed cutting during the later part of the season will cause less reduction in quality of hay than a similar delay in the early part of the season.

Yield of Leaves and Stems per Acre

The yield of dry matter per acre in leaves and stems and for the whole crop for various cuttings is given in Table XV. In all cases the largest yields were secured from the first cutting of the season with a more or less consistent decrease with each cutting as the season advanced. Approximately two-fifths of the crop was secured in the first cutting in the bud, tenth-bloom and full-bloom stages and nearly half the crop in the first cutting of the seed stage.

TABLE XV.—Yield of dry matter in leaves and stems per acre by cuttings.

MATERIAL.	Stage of cutting.	Pounds per acre.						
		Cutting number.						
		1.	2.	3.	4.	5.	6.	Total.
Leaves	Bud stage	887	652	501	271	147	50	2,508
	Tenth bloom	1,047	851	546	355	137	......	2,936
	Full bloom	1,055	876	746	311	......	......	2,988
	Seed stage	942	736	459	......	......	......	2,137
Stems	Bud stage	923	627	444	204	121	27	2,346
	Tenth bloom	1,180	886	446	314	100	......	2,926
	Full bloom	1,399	876	611	299	......	......	3,185
	Seed stage	1,592	1,104	332	......	......	......	3,026
Whole plant	Bud stage	1,810	1,279	945	475	268	77	4,854
	Tenth bloom	2,227	1,737	992	669	237	......	5,862
	Full bloom	2,454	1,572	1,357	610	......	......	6,073
	Seed stage	2,534	1,840	791	......	......	......	(a) 5,294

(a) Includes a cutting of immature hay in one season.

Feed Constituents in the Hay

The percentages of feed constituents, calculated on the moisture-free basis, found in the alfalfa sampled when green and in field-cured hay are presented in Table XVI. The data recorded are analyses of composite samples representing eight crops.

TABLE XVI.—Feed constituents in alfalfa hay cut at different stages of growth.

MATERIAL.	Stage of cutting.	Ash.	Crude protein.	Pure protein (a).	Crude fiber.	Nitrogen-free extract.	Ether extract.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Leaves sampled green.	Bud stage	11.53	26.58	17.60	15.71	43.29	2.88
	Tenth bloom	10.88	25.75	18.11	16.05	43.99	3.33
	Full bloom	10.81	24.14	17.35	15.47	46.23	3.34
	Seed stage	10.63	22.99	17.67	16.71	46.05	3.62
Stems sampled green.	Bud stage	8.84	13.39	8.75	37.84	38.44	1.48
	Tenth bloom	8.09	12.35	8.30	38.48	39.75	1.33
	Full bloom	7.48	11.53	8.08	40.02	39.70	1.27
	Seed stage	6.98	10.54	7.75	40.41	40.65	1.41
Whole plant sampled green.	Bud stage	10.45	19.78	14.06	25.88	41.61	2.28
	Tenth bloom	10.23	18.92	13.43	28.00	40.58	2.28
	Full bloom	9.56	17.63	12.86	28.32	42.15	2.34
	Seed stage	8.69	16.04	11.93	31.53	41.38	2.36
Field-cured hay.	Bud stage	8.65	18.37	15.32	23.35	38.92	1.82
	Tenth bloom	8.35	17.85	14.83	24.09	38.92	1.77
	Full bloom	7.99	16.21	13.39	25.80	38.90	1.79
	Seed stage	6.95	14.08	11.07	30.49	37.28	1.73

(a) Under this term is included the protein obtained by Stutzer's method, or such protein as is coagulated by copper hydroxide.

The percentages of ash and of protein, both crude and pure, in the whole plant were largest for the bud-stage hay and decreased consistently with the later cuttings. Conversely, the percentage of crude fiber was least in the bud stage and increased with the later stages of cutting. There was very little variation in the ether extract, depending upon stage of cutting. However, such differences as are recorded indicate a tendency to increase as the plants become older.

On the whole, the composition of the leaves was more constant during the season than was the composition of the stems. The percentage of crude fiber in the leaves, for example, varied only one per cent, while the difference in the stems amounted to two and one-half per cent. There was also very little variation in the pure protein. Practically no variation in the ash content of the leaves was noted after the bud-stage cutting. It seems quite clear, therefore, that a considerable part of the difference in composition of alfalfa hay cut at different stages of growth, is due to the difference in the proportion of leaves and stems. Variation in the loss of leaves in harvesting, curing, and stacking or baling are also causes of differences in composition.

Composition of the Grass

The grass harvested with the alfalfa in 1919, 1920, and 1921 was analyzed and the average results are given in Table XVII.

TABLE XVII.—Composition of grass harvested with alfalfa in 1919, 1920 and 1921; calculated to the basis of dry matter.

STAGE OF CUTTING.	Ash.	Total protein.	Pure protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Bud stage	10.65	14.59	10.72	28.10	44.26	2.40
Tenth bloom	10.80	15.00	10.95	29.30	42.80	2.30
Full bloom	9.55	13.16	8.75	25.92	49.24	2.13
Seed stage	9.70	15.54	11.59	30.26	42.92	1.58

It will be noted that the composition of the grass varied little for the various stages of cutting, and also that grass differs from alfalfa mainly in a somewhat lower protein content. It compares in composition with alfalfa cut in the seed stage.

The Relation of Stage of Cutting to Pure Protein

The percentages of crude and pure protein as given in Table XVI show a definite relation between the two. This is more plainly indicated in Table XVIII in which the differences between the two as well as the percentages of pure protein in per cent of total protein are presented. The alfalfa sampled green dried slower than that sampled as hay because the former was dried in the open, usually in sunshine, where there was a free movement of air, while that sampled green was, as a rule, brought to the laboratory in the evening and remained under cover until cured. Also, in the laboratory it was necessary to spread the alfalfa much thicker than it would ordinarily be laid in the swath after the mower.

TABLE XVIII.—Crude and pure protein in alfalfa sampled green and in the leaves, stems, and whole plant sampled as hay.

MATERIAL.	Stage of cutting.	Total protein.	Pure protein.	Difference.	Per cent of pure protein in total protein.
		Per cent.	*Per cent.*	*Per cent.*	
Whole plant sampled green . . .	Bud stage	19.9	14.1	5.8	71.0
	Tenth bloom	18.9	13.4	5.5	71.0
	Full bloom	17.6	12.9	4.7	73.3
	Seed stage	16.0	11.9	4.1	74.4
Leaves sampled as hay	Bud stage	26.6	17.6	9.0	66.2
	Tenth bloom	25.8	18.1	7.7	70.3
	Full bloom	24.1	17.4	6.7	72.2
	Seed stage	23.0	17.7	5.3	76.9
Stems sampled as hay	Bud stage	13.4	8.8	4.6	65.7
	Tenth bloom	12.4	8.3	4.1	67.0
	Full bloom	11.5	8.1	3.4	70.4
	Seed stage	10.5	7.8	2.7	74.3
Whole plant sampled as hay . . .	Bud stage	18.4	15.3	3.1	83.2
	Tenth bloom	17.9	14.8	3.1	82.7
	Full bloom	16.2	13.4	2.8	82.6
	Seed stage	14.1	11.1	3.0	78.6

The largest per cent of pure protein was obtained when the alfalfa was cured in the shade. The average for all samples of the whole plant cured in the shade was 72.3 as compared with 82.0 per cent for that cured in the sun. With respect to stage of cutting, the proportion of pure protein in the alfalfa cured in the field was largest in the bud stage and decreased with less frequent cutting. This probably means that the less mature plants are more profoundly affected by conditions of drying than are the more mature plants. The hay cured in the sun contained a larger per cent of pure protein than that cured in the shade in spite of the fact that the former had lost some leaves containing a somewhat greater per cent of pure protein than the stems. Probably the explanation lies in the fact that the longer period of drying in the shade prolonged the vital activities of the plant cells during which time the proteins were broken down by the action of proteolytic enzymes.

Feed Constituents in the Different Cuttings

Each of the separate cuttings for the years 1914, 1915, and 1919 were analyzed for the different feed constituents. The average results based on dry matter are presented in Table XIX.

TABLE XIX.—Feed constituents in the separate cuttings.

CUTTING NUMBER.	Per cent of ash.	Per cent of crude protein.	Per cent of crude fiber.	Per cent of nitrogen-free extract.	Per cent of ether extract.
Bud Stage—					
1	11.55	23.09	22.96	39.60	2.85
2	12.01	21.89	29.00	38.87	1.73
3	10.68	21.15	27.37	38.86	1.89
4	10.97	20.23	26.81	39.50	2.53
5	10.56	19.21	23.50	44.34	2.30
6	11.96	22.88	22.28	39.11	3.54
Tenth-bloom Stage—					
1	10.11	17.78	31.39	37.43	3.19
2	9.92	18.90	30.54	38.56	2.01
3	10.16	17.80	35.23	34.06	2.53
4	10.31	20.62	26.51	40.11	2.21
5	10.32	22.04	23.12	41.54	2.72
Full-bloom Stage—					
1	9.34	15.73	34.09	37.84	2.86
2	9.22	18.13	29.88	39.73	2.81
3	9.51	18.23	27.12	42.33	2.55
4	11.02	19.80	25.43	39.82	3.83
Seed Stage—					
1	8.44	15.36	33.77	39.65	2.37
2	8.26	14.92	33.42	40.41	2.52
3	10.16	17.77	28.80	39.67	3.26

The figures show that in the bud stage the composition remained practically constant for all the constituents throughout the season. In the other stages there was a progressive increase in protein both total and pure as the season advanced. The crude fiber showed a marked progressive decrease in the later cuttings. The leaves and stems of these separate cuttings were also analyzed, and it was found that the composition of each remained practically constant throughout the season. This probably indicates that the progressive increase in protein and decrease in crude fiber in the later cuttings, as compared with the earlier, were due to a larger proportion of leaves and a smaller proportion of stems in the later cuttings. It seems probable that the composition of alfalfa hay is influenced more by the proportion of leaves and stems than by any other factor considered in this study.

Pounds of Feed Constituents per Acre

The feed constituents expressed as pounds per acre were calculated from the average chemical composition given in Table XVI and the yield of dry matter as given in Table XV. The results are given in

Table XX. The data for the leaves were calculated from the averages of the different years, and those for the stems were obtained by difference.

The total amount of ether extract and protein per acre was largest in the tenth and full-bloom stages, which also produced the largest amount of dry matter per acre as indicated in Table XV. The leaves contained from one and one-half to two times as much protein as the stems, while the stems contained from two to four times as much crude fiber. About twice as much ether extract was produced in the leaves as in the stems.

TABLE XX.—Feed constituents per acre.

MATERIAL.	Stage of cutting.	Pounds per acre.				
		Ash.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.
Leaves	Bud stage	289	640	394	1,086	72
	Tenth bloom	319	756	471	1,292	98
	Full bloom	323	721	462	1,381	100
	Seed stage	227	491	357	984	78
Stems	Bud stage	218	322	862	934	39
	Tenth bloom	281	353	1,170	1,086	36
	Full bloom	267	367	1,286	1,221	44
	Seed stage	233	358	1,312	1,207	47
Whole plant	Bud stage	507	962	1,256	2,020	111
	Tenth bloom	600	1,109	1,641	2,378	134
	Full bloom	590	1,088	1,748	2,602	144
	Seed stage	460	849	1,669	2,191	125

Pounds of Feed Constituents per Acre in the Different Cuttings

The feed constituents produced per acre in the different cuttings were calculated for the years 1914, 1915, and 1919. The results are given in Table XXI.

The largest amounts of all feed constituents were produced in the first cutting of all the stages and the amount decreased regularly in the succeeding stages. Thus while the quality of hay may be better in the later cuttings, the amount of feed constituents obtained per acre is much less.

TABLE XXI.—Pounds of feed constituents produced per acre in the different cuttings.

CUTTING NUMBER.	Pounds per acre.				
	Ash.	Crude protein.	Crude fiber.	Nitrogen-free extract	Ether extract.
Bud Stage—					
1	209	418	416	717	516
2	154	280	371	497	22
3	101	200	259	367	18
4	52	96	127	158	12
5	28	52	63	119	6
6	9	18	17	30	3
Tenth-bloom Stage—					
1	225	396	699	834	71
2	172	328	531	670	35
3	101	177	350	338	25
4	69	138	177	268	15
5	25	52	55	99	7
Full-bloom Stage—					
1	229	386	837	929	70
2	162	318	524	696	49
3	129	247	368	574	34
4	67	121	155	243	23
Seed Stage—					
1	214	389	856	100	60
2	152	274	614	744	46
3	80	141	228	314	26
4	11	19	43	52	3

Fertilizer Elements in Alfalfa Hay

The nitrogen, phosphorus, potassium, calcium, and magnesium removed in the hay were determined in each of the four years from 1914 to 1917. The averages, expressed as a per cent of the crop, are given in Table XXII and as pounds per acre in Table XXIII.

TABLE XXII.—Fertilizer elements in alfalfa hay.

MATERIAL.	Stage of cutting.	Nitrogen.	Phosphorus.	Potassium.	Calcium.	Magnesium.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Leaves sampled green	Bud stage	4.44	.30	3.00	2.01	.30
	Tenth bloom	4.15	.26	2.71	2.10	.32
	Full bloom	3.85	.24	2.51	2.14	.29
	Seed stage	3.72	.25	2.37	2.36	.29
Stems sampled green	Bud stage	2.24	.22	3.45	.86	.17
	Tenth bloom	1.84	.17	2.96	.81	.17
	Full bloom	1.72	.14	2.61	.83	.17
	Seed stage	1.59	.14	2.50	.87	.17
Whole plant sampled green	Bud stage	3.26	.27	3.31	1.36	.26
	Tenth bloom	3.00	.23	2.97	1.46	.25
	Full bloom	2.74	.19	2.62	1.47	.23
	Seed stage	2.54	.20	2.43	1.45	.22
Whole plant field cured	Bud stage	2.97	.21	2.86	1.21	.25
	Tenth bloom	2.73	.20	2.71	1.28	.23
	Full bloom	2.43	.18	2.48	1.25	.23
	Seed stage	2.16	.18	2.30	1.21	.19

The largest per cent of nitrogen, potassium, and magnesium was in general found in the bud stage plots and usually least for the seed stage plots. Approximately the reverse was found with respect to the calcium content. The largest amount of phosphorus was also found in the bud stage plots but there was no decrease after full bloom. Phosphorus is one of the elements very intimately associated with new growth. After full bloom comparatively little new growth takes place and hence there is less need for phosphorus.

The leaves contained more than twice as much nitrogen, two and one-half times as much calcium, and considerably more phosphorus but less potassium than the stems. There was very little change in magnesium content coincident with different stages of cutting.

Phosphorus, potassium, calcium, and magnesium were determined in the separate cuttings of 1914 and 1915. No significant differences were observed except such as were probably due to differences in the relative amounts of leaves and stems.

The data in Table XXIII show that alfalfa is a very heavy feeder on mineral elements. As much phosphorus was removed from the soil annually as would be removed by 50 to 60 bushels of wheat or 80 to 100 bushels of corn per acre, and the removal of the other mineral elements was larger than in any grain crop.

TABLE XXIII.—Pounds of fertilizer elements removed per acre by alfalfa.

MATERIAL.	Stage of cutting.	Nitrogen.	Phosphorus.	Potassium.	Calcium.	Magnesium.
Leaves	Bud stage	145	10	99	65	10
	Tenth bloom	143	9	95	71	11
	Full bloom	134	8	88	74	10
	Seed stage	102	7	67	64	7
Stems	Bud stage	70	7	108	26	6
	Tenth bloom	77	7	127	33	7
	Full bloom	82	6	124	37	7
	Seed stage	65	6	105	34	7
Whole plant (a)	Bud stage	209	17	212	86	16
	Tenth bloom	227	17	227	108	18
	Full bloom	222	15	217	116	18
	Seed stage	173	14	170	97	15

(a) The figures for the whole plant do not in all cases equal the sums of the figures for leaves and stems since each were calculated independently and not by difference. The separation into leaves and stems involves considerable error which accounts for most of the discrepancy.

Loss of Leaves in Harvesting

The samples of green alfalfa cured in the shade suffered no loss. The samples taken at the time of stacking, however, had lost some leaves. The data given in Table XVI show that the leaves contain approximately twice as much protein as the stems. Loss of leaves would, therefore, diminish the percentage of protein. The data also show that field-cured alfalfa contained from 1 to 2 per cent less protein than that cured in the laboratory where there was no loss of leaves. This makes it possible to calculate approximately the loss of leaves which takes place in the handling of alfalfa during hay making. The method of calculation used is as follows:

Let x = number of pounds of leaves lost.
a = per cent of protein in alfalfa cured in the laboratory.
b = per cent of protein in alfalfa cured in the field.
c = per cent of protein in the leaves.

If the calculation be made on the basis of 100 pounds of hay, then

$100 - x$ = the weight of 100 pounds of the original hay less the leaves lost in harvesting.

$\frac{b}{100}(100 - x)$ = pounds of protein in the field-cured hay from 100 pounds of the original hay.

$\frac{c}{100}x$ or $\frac{cx}{100}$ = pounds of protein lost in the leaves from 100 pounds of the original hay.

$$\frac{b}{100}(100 - x) + \frac{cx}{100} = a$$

$$b(100 - x) + cx = 100a$$

$$100b - bx + cx = 100a$$

$$cx - bx = 100a - 100b$$

$$x(c - b) = 100a - 100b$$

$$x = \frac{100a - 100b}{c - b}$$

Substituting the known values of *a, b,* and *c* in the above equation, the value of x, *i.e.,* the loss of leaves in the crop expressed as a per cent is obtained. This has been done for each stage of cutting each year up to 1920 and the results are presented in Table XXIV.

The loss of leaves based on the yield of leaves varied from about 2 per cent as a minimum for the tenth bloom in 1917 to 34 per cent for the seed stage in 1918.

In 1914 the loss of leaves was calculated for each cutting. The results are presented in Table XXV. The loss was greatest with the later cuttings, amounting to nearly half the leaves in some of the last cuttings of the season.

TABLE XXIV.—Leaves lost in harvesting, 1914 to 1920.

YEAR.	Per cent of leaves and of total crop lost as leaves.									
	Bud stage.		Tenth bloom.		Full bloom.		Seed stage.		Average.	
	Per cent of leaves.	Per cent of total crop.	Per cent of leaves.	Per cent of total crop.	Per cent of leaves.	Per cent of total crop.	Per cent of leaves.	Per cent of total crop.	Per cent of leaves.	Per cent of total crop.
1914......	25.0	14.4	19.7	11.0	23.9	12.7	25.8	11.7	23.6	12.4
1915......	20.8	10.0	7.2	3.0	11.8	4.5	13.8	5.1	13.4	5.6
1916......	13.9	6.2	25.7	10.6	18.8	7.4	20.1	8.0	19.6	8.0
1917......	8.6	4.5	2.3	1.2	22.7	11.6	30.0	12.9	15.9	7.5
1918......	15.4	8.1	10.4	5.5	32.5	17.4	34.4	16.5	23.2	11.9
1919......	31.2	17.2	17.3	9.2	13.5	6.9	8.1	3.0	17.5	9.1
1920......	18.9	10.5	19.1	10.5	19.2	10.5	23.0	8.2	20.1	9.9
Average...	19.1	10.1	14.5	7.3	20.4	10.1	22.2	9.3	19.0	9.2

TABLE XXV.—Loss of leaves in different cuttings in 1914.

CUTTING NUMBER.	Per cent of leaves and per cent of total crop lost as leaves.							
	Bud stage.		Tenth bloom.		Full bloom.		Seed stage.	
	Leaves.	Total crop.	Leaves.	Total crop.	Leaves.	Total crop.	Leaves.	Total crop.
1................	7.8	4.0	5.6	2.9	6.9	3.2	17.0	7.1
2................	32.1	18.4	17.7	10.7	29.7	17.4	16.2	6.6
3................	14.7	8.3	9.8	5.9	23.7	12.0	44.1	21.4
4................	14.1	9.4	25.2	13.9	35.1	18.4	....	....
5................	32.8	18.8	40.1	21.6	....	....	....	....
6................	48.8	27.2	....	....	....	....	....	....

RELATIVE FEEDING VALUE OF ALFALFA CUT AT DIFFERENT STAGES OF MATURITY

Feeding tests to determine the relative value for feed of the alfalfa cut in the different stages of growth were begun in 1919 with steer calves dropped the preceding spring. Four groups of five animals of approximately the same size, age, breeding, conformation, and quality were used. Each group was fed the same kind of hay for a definite period of time during three successive winters. When not being used in this test the cattle received uniform feed, care, and attention.

The average of three weights of each individual, taken at the same hour on successive days under identical conditions as to feed and water, at the beginning and end of each test were used as the initial and final weights for each group. They were weighed in groups at the end of each 30-day period as the test progressed. No feed other than alfalfa hay, except salt *ad libitum,* was available. The animals had free access to clean water at all times. The quarters in which they were kept consisted of a shed 20 feet long, 12 feet deep, and 7 feet high, opening toward the south into a pen 20 feet wide and 50 feet long.

During the time the test was in progress, these four groups of cattle were fed different kinds of alfalfa hay as follows: (1) Alfalfa hay cut in the bud stage, (2) alfalfa hay cut in the tenth-bloom stage, (3) alfalfa hay cut in the full-bloom stage, and (4) alfalfa hay cut in the seed stage. Digestion trials were conducted each year. In these trials, quantities of hay cut at the indicated stages of maturity were fed to steers representative of the groups as a whole. The hay was fed for a seven-day preliminary period before the digestion trial proper began. The latter lasted another seven days. Steers Nos. 1 and 2 were fed bud-stage hay at the same time that steers Nos. 3 and 4 were fed tenth-bloom hay. When this trial was completed a digestion trial was run on steers Nos. 1 and 2 with full-bloom stage hay and steers Nos. 3 and 4 with seed-stage hay.

The results of the first winter's test extending over a period of 90 days are given in Table XXVI.

TABLE XXVI.—Results of feeding alfalfa hay, cut at different stages of growth, to yearling steers.

CUTTING STAGE OF ALFALFA.	Average initial weight.	Average final weight.	Total gain per steer.	Average daily gain.	Average daily feed eaten.	Feed for 100 pounds gain.
Bud stage	439.6	536.1	96.5	1.07	10.29	959.3
Tenth bloom	440.0	508.5	68.5	.76	10.29	1,351.2
Full bloom	441.6	499.5	57.9	.63	10.29	1,600.3
Seed stage	440.3	483.5	43.2	.48	10.29	2,143.5

The composition of the hay used in the first season is given in Table XXVII and the coefficients of digestibility are shown in Table XXVIII.

The results of the second winter's trial extending over a period of 60 days during which the same cattle, now approaching two years of age, were fed the same kind of hay that each received the previous winter, are given in Table XXIX.

TABLE XXVII.—Analysis of hay used the first year in feeding trials with alfalfa hay cut at different stages of growth.

CUTTING STAGE OF ALFALFA.	Composition—dry weight.						
	Dry matter.	Crude protein.	Albuminoid protein.	Ether extract.	Crude fiber.	Nitrogen-free extract.	Ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Bud stage.................	93.94	20.25	16.56	1.97	26.61	35.96	9.15
Tenth bloom..............	93.75	15.19	12.63	1.77	29.71	38.96	8.13
Full bloom................	94.01	15.19	11.31	1.50	33.08	35.89	8.36
Seed stage................	93.58	10.75	8.31	1.25	39.60	35.11	6.87

TABLE XXVIII.—Coefficients of digestibility of alfalfa hay cut at different stages of growth.

CUTTING STAGE OF ALFALFA.	Dry matter.	Crude protein.	Albuminoid protein.	Ether extract.	Crude fiber.	Nitrogen-free extract.	Ash.
Bud stage.................	57.28	78.82	72.63	39.15	32.15	52.80	64.38
Tenth bloom..............	63.75	73.02	70.23	27.45	48.94	68.41	57.44
Full bloom................	58.63	76.06	72.15	34.13	48.15	62.74	60.50
Seed stage................	56.53	66.88	60.70	30.30	47.2	57.32	56.99

TABLE XXIX.—Results of feeding alfalfa hay cut at different stages of growth to two-year-old steers.

CUTTING STAGE OF ALFALFA.	Average initial weight.	Average final weight.	Total gain per steer.	Average daily gain.	Average daily feed eaten.	Feed for 100 pound gain.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Bud stage..................	842.3	929.7	87.4	1.45	21.83	1,495.4
Tenth bloom..............	843.9	904.4	60.5	1.01	21.83	2,164.1
Full bloom................	806.7	886.0	79.3	1.32	21.83	1,651.3
Seed stage................	772.4	804.0	31.6	.53	18.68	3,546.8

The analyses of the hay and the coefficients of digestibility of the hay used in the second year's trials are given in Tables XXX and XXXI, respectively.

TABLE XXX.—Analyses of the hay used the second year in feeding trials with alfalfa cut at different stages of growth.

CUTTING STAGE OF ALFALFA.	Composition—dry weight.						
	Dry matter.	Crude protein.	Albuminoid protein.	Ether extract.	Crude fiber.	Nitrogen-free extract.	Ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Bud stage	93.15	25.05	18.60	2.07	19.23	35.15	11.65
Tenth bloom	93.54	17.50	15.10	2.31	26.84	37.87	9.02
Full bloom	93.88	18.60	15.18	2.05	25.73	38.63	8.87
Seed stage	93.14	15.69	13.20	1.77	33.90	33.63	8.15

TABLE XXXI.—Coefficients of digestibility of alfalfa hay cut at different stages of growth and used for feeding two-year-old steers.

CUTTING STAGE OF ALFALFA.	Dry matter.	Crude protein.	Albuminoid protein.	Ether extract.	Crude fiber.	Nitrogen-free extract.	Ash.
Bud stage	61.99	82.57	79.36	35.93	26.87	70.99	70.43
Tenth bloom	63.79	76.24	75.19	50.73	47.73	70.59	61.75
Full bloom	58.07	73.60	71.10	33.27	382	67.46	56.38
Seed stage	48.04	65.77	62.49	43.27	37.88	52.42	39.15

The results of the third winter's work extending over a period of 90 days during which the same cattle now approaching three years of age, were fed the same kind of hay that each received the previous winters, are given in Table XXXII.

TABLE XXXII.—Results of feeding alfalfa hay cut in different stages of growth to three-year-old steers.

CUTTING STAGE OF ALFALFA.	Average initial weight.	Average final weight.	Total gain per steer.	Average daily gain.	Average daily feed eaten.	Feed for 100 pound gain.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Bud stage	1,148.7	1,240.1	91.4	1.02	24.70	2,430.4
Tenth bloom	1,150.9	1,232.0	81.1	.90	24.70	2,742.2
Full bloom	1,106.4	1,175.1	68.7	.76	24.70	3,237.4
Seed stage	1,067.6	1,104.4	36.8	.41	24.70	6,040.8

Table XXXIII gives the analysis of the hay used in these trials and Table XXXIV the coefficients of digestibility.

TABLE XXXIII.—Analysis of the hay used the third year in feeding trials with alfalfa cut at different stages of growth.

CUTTING STAGE OF ALFALFA.	Composition—dry weight.						
	Dry matter.	Crude protein.	Albuminoid protein.	Ether extract.	Crude fiber.	Nitrogen-free extract.	Ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Bud stage	93.63	15.38	10.96	1.10	28.20	40.27	8.68
Tenth bloom	93.47	13.43	9.70	1.20	30.61	40.81	7.42
Full bloom	93.69	13.94	10.20	1.88	30.83	39.20	7.84
Seed stage	94.05	12.81	9.38	1.29	32.19	40.42	7.34

TABLE XXXIV.—Coefficients of digestibility of alfalfa cut at different stages of growth and used for feeding three-year-old steers.

CUTTING STAGE OF ALFALFA.	Dry matter.	Crude protein.	Albuminoid protein.	Ether extract.	Crude fiber.	Nitrogen-free extract.	Ash.
Bud stage	61.3	72.1	66.1	—14.49	47.3	74.6	46.0
Tenth bloom	60.6	69.9	62.5	— 3.56	46.6	71.8	50.4
Full bloom	58.6	71.8	65.9	+23.99	41.4	69.7	55.5
Seed stage	56.3	67.9	64.4	+27.18	38.2	69.7	53.5

Table XXXV gives the average amount of feed required to produce one hundred pounds of gain as calculated from the results of all three years.

TABLE XXXV.—Average feed required to produce 100 pounds of gain.

CUTTING STAGE OF ALFALFA.	Feed required to produce 100 pounds gain.
	Pounds.
Bud stage	1,628
Tenth bloom	2,086
Full bloom	2,163
Seed stage	3,910

As previously noted, the hay used in these feeding trials was not obtained from the experimental plots but from fields on the Agronomy farm cut as nearly as possible at the same stage of growth as were the different plots. A comparison of the data in Tables XXVIII, XXXI, and XXXIV with that in Tables XVII and XIX will show that there was a greater variation in the protein content of the hay fed the first two years than in that harvested from the plots. The hay fed in the third year of the feeding trial, however, was more uniform in protein content than that from the plots. The hay fed, however, was probably representative of what may reasonably be expected from cutting at the designated stages of growth.

In every case the bud-stage hay proved more efficient, and the seed-stage hay less efficient than any other in producing gains. In two out of the three trials the tenth-bloom hay proved more efficient than the full-bloom hay. In the second year's trial the full-bloom hay produced more pounds of gain per hundred pounds of feed than the tenth bloom. This is probably explained by the fact that the tenth-bloom hay used that season was rained upon and, judging from general appearance, was much inferior to the full-bloom hay which was in excellent condition. The general opinion that the feeding value of alfalfa hay for cattle decreases with delayed cutting is supported by these data.

SUMMARY AND CONCLUSIONS

To summarize briefly, cutting in the bud stage markedly decreased the vigor of growth, the stand, and the yield of alfalfa hay and permitted the encroachment of grasses. The effect was clearly apparent the second year of the experiment. Cutting when the plants reached the tenth-bloom stage also injured the plants, reduced the stand, and permitted the encroachment of grasses, but this result was not apparent until much later.

Permitting the plants to reach the full-bloom stage before cutting maintained the vigor of the plants and the stand to a very satisfactory degree for eight years after the beginning of the experiment or until the field was eleven years old. Leaf spot caused more damage to these plants than in plots cut more frequently but, in spite of this, cutting in full bloom has produced the highest total yields of hay and the highest yields of alfalfa hay excluding the grass hay.

Delaying cutting until the seed stage reduced the yield but not the stand or apparent vigor of the plants. The seed-stage plots and those cut in full bloom were more successful than any others in maintaining the stand of alfalfa and obstructing the encroachment of grasses. There was no apparent injury to the alfalfa plants as a result of cutting off the new shoots. In fact, it was frequently observed that the full-bloom and seed-stage plots were the most prompt to recover after cutting.

There is some evidence for the belief that frequent cutting stimulates a more rapid growth and results in a larger yield until that point is reached where the plants are weakened by repeated early cutting, after which the yields are reduced. If this proves to be true, it may explain the divergent results secured in different parts of the country and perhaps make it possible to determine more accurately the most favorable time to cut.

Determinations of the proportion of leaves and stems indicate a considerable decrease in the proportion of the leaves harvested as cutting becomes less frequent. Since the leaves contain much more protein than the stems this bears an important relation to the protein content of the hay as a whole. It was also found that the proportion of leaves in any season tended to be greater for the later cuttings than for the earlier cuttings. Since, however, the first cutting made up a large proportion of the total crop, the effect of these differences on the total crop was not great.

Chemical analyses of the hay secured from different stages of cutting show that the ash and protein content expressed as a per cent decreased quite markedly as cutting was delayed. The crude fiber, on the other hand, was least for the bud stage and increased with delay in cutting Ether extract was found to be but little influenced by the time of cutting being practically constant for all stages.

The way in which the alfalfa was cured seemed to have a marked effect on the percentage of pure protein as compared with the total or crude protein. This is explained on the assumption that the cells of the plant retain their vitality for a considerable length of time, when the hay is cured in the shade, in which case the proteins are broken down by proteolytic enzymes.

Analyses of the fertilizer elements show that large quantities of these elements were removed from the soil by alfalfa. While the proportion of these elements varied somewhat according to the stage of cutting, the differences were not sufficient to influence the time of cutting.

The loss of leaves occurring in harvesting and caring for the crop was calculated and found to vary from 2.3 per cent to more than 34 per cent; or, based on the total crop, from 1.2 to 17.4 per cent. No definite correlation was evident between loss of leaves and the time of cutting, the loss probably depending more on the way the crop was handled and the weather conditions at the time of haying. The fact to be emphasized is that such losses may be very large.

Feeding tests conducted for three years showed beyond reasonable doubt that the feeding value of alfalfa hay decreases materially with delay in cutting, the best hay for feeding beef steers being that cut in the bud stage and the poorest that allowed to reach the seed stage. The amount of hay required to produce a pound of gain was nearly two and one-half times as great for the latter as for the former.

It may be concluded from the foregoing that the best time to cut alfalfa for hay under practical farm conditions will depend upon a number of circumstances such as (1) the use to be made of the hay, or the class of animals to which it is to be fed, (2) the length of time it is desired to maintain the stand, (3) the prevalence of leaf spot and factors controlling its growth, (4) the weather, and (5) the requirements of other farm work.

Perhaps the points most worthy of emphasis are (1) the reduction in stand and the replacement of the alfalfa by grass as a result of early and frequent cutting and (2) the fact that late or infrequent cutting does not injure the stand but does result in a loss of leaves and a hay of lower protein content and poorer quality.

Considering all factors it is doubtful if any farmer can afford to cut continuously or even generally earlier than tenth bloom in fields which it is desired to maintain in alfalfa. On the other hand it is doubtful if the difference in yield in favor of full bloom cutting is sufficient to justify delaying the beginning of cutting until that stage of growth is reached, especially in view of the poorer quality of hay and a lower yield if cutting is unexpectedly delayed by bad weather or other factors. Where the crop can be harvested promptly a safe plan will be to permit the alfalfa to reach the one-fourth or one-half bloom stage before cutting is begun. If the mowers must be started in some fields before a safe stage is reached, injury can perhaps be prevented by seeing to it that the same field is not cut early for successive crops. If the hay is to be fed to horses the best practice, without doubt, is to cut when the plants are approximately in full bloom.

The results secured to date suggest the possibility of cutting the first crop early, *i.e.,* when in tenth-bloom or in the bud stage and delay successive cuttings in the same season until the crop reaches full bloom or nearly so. While definite and conclusive experimental data are lacking it is quite probable that permitting the second and later crops to reach full bloom will prevent the damage which would otherwise result from the early cutting of the first crop. This arrangement would often permit harvesting the first crop before it makes an objectionably rank growth thereby improving its quality and making it easier to cure. It would also perhaps permit cutting the first crop at a more convenient time or at least allow a wider choice in time of cutting than present practices permit. Since the second and later crops are generally more leafy than the first crop and since protein content and quality of hay depend largely on the percentage of leaves, it follows that permitting these crops to reach a later stage of growth would not seriously interfere with securing a good quality of hay. The net result would be a better quality and perhaps a larger total yield of hay than can be secured by any other practice that will at the same time maintain the stand.

Although not studied specificlly in this experiment, it is probably better to cut alfalfa that has become badly infested with leaf spot or is stunted by dry weather than to wait for it to reach the stage of growth which otherwise would be desired:

LITERATURE CITED

BEAN, R. P.
1922. EXPERIMENTAL WORK WITH FARM CROPS. *In* 32nd Ann. Rept. (Bul. 175) Wash. Agr. Expt. Sta., p. 51.

BENNETT, R. L.
1902. ALFALFA. Ark. Agr. Expt. Sta. Bul. **75**: 125-129.

BRIGGS, LYMAN J. and SHANTZ, H. L.
1915. EFFECT OF FREQUENT CUTTING ON THE WATER REQUIREMENT OF ALFALFA AND ITS BEARING ON PASTURAGE. U. S. Dept. Agr. Bul. **228**: 1-6. Figs. 2.

CLARKE, WARREN T.
1917. ALFALFA. Cal. Agr. Expt. Sta. Cir. **87**: 1-11.

COTTRELL, H. M.
1902. GROWING ALFALFA IN KANSAS. Kan. Agr. Expt. Sta. Bul. **114**: 51-85. Figs. 10.

FOSTER, LUTHER and MERRILL, LEWIS A.
1899. ALFALFA OR LUCERNE: THE CUTTING TIME. ITS FEEDING VALUE. Utah Agr. Expt. Sta. Bul. **61**: 160-175.

FREEMAN, GEO. F.
1914. ALFALFA IN THE SOUTHWEST. Ariz. Agr. Expt. Sta. Bul. **73**: 219-320. Figs. 19.

GARVER, SAMUEL
1922. ALFALFA ROOT STUDIES. U. S. Dept. Agr. Bul. **1087**: 1-28. Figs. 19.

HARCOURT, R.
1900. LUCERNE OR ALFALFA: COMPOSITION AND DIGESTIBILITY. Ontario Dept. of Agr. Bul. **111**: 1-19. Figs. 7.

HAYES, H. K.
1923. CONTROLLING EXPERIMENTAL ERROR IN NURSERY TRIALS. Jour. Amer. Soc. Agron. Vol. 15, No. 5, pp. 177-192.

HEADDEN, W. P.
1906. ALFALFA. Col. Agr. Expt. Sta. Bul. **110**: 1-16.

HUGHES, H. D.
1913. ALFALFA MANAGEMENT IN IOWA. Iowa Agr. Expt. Sta. Bul. **137**: 1-72. Figs. 33.

KIESSELBACH, T. A.
1918. FORAGE CROPS. Neb. Agr. Expt. Sta. Bul. **169**: 1-36. Figs. 7.

McCAMPBELL, C. W.
1912. FEEDING WORK HORSES. Kan. Agr. Expt. Sta. Bul. **186**: 1-70. Figs. 14.

MELLOR, J. W.
1909. HIGHER MATHEMATIC FOR STUDENTS OF CHEMISTRY AND PHYSICS. 444 pp. Longman's Green and Company, New York.

MOSES, DUDLEY BERTIE DAVID
1924. THE EFFECT OF TIME OF CUTTING UPON THE YIELD AND QUALITY OF ALFALFA HAY. Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science. Kansas State Agricultural College. Unpublished.

PORTER, W. R. and DYNES, O. W.
1914. FACTS ABOUT ALFALFA PRODUCTION. No. Dak. Farmers Inst. Monthly, Vol. 14, No. 2, pp. 21-27.

RUSSELL, H. L. and MORRISON, F. B.
1923. SCIENCE SERVES WISCONSIN FARMS. Wis. Agr. Expt. Sta. Bul. **352**: 1-124. Figs. 53. Reference, pp. 33-35.

SNYDER, HARRY and HUMMEL, J. A.
1903. ALFALFA, ITS CHEMICAL DEVELOPMENT, FEEDING VALUE, AND DIGESTIBILITY. Minn. Agr. Expt. Sta. Bul. **80**: 162-170.

TEN EYCK, A. M.
1908. ALFALFA. Kan. Agr. Expt. Sta. Bul. **155**: 181-346. Figs. 60. Reference, p. 239.

WILLIAMS, C. G. and KYLE, C. H.
1907. ALFALFA IN OHIO. Ohio Agr. Expt. Sta. Bul. **181**: 111-135. Reference, p. 133.

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