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THE EFFECT OF LATE SUMMER AND EARLY FALL CUTTING ON THE BEHAVIOR OF THE ALFALFA PLANT

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Val W. Silkett

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THE EFFECT OF LATE SUMMER AND EARLY FALL CUTTING ON THE BEHAVIOR OF THE ALFALFA PLANT

INTRODUCTION

Alfalfa is the most dependable forage crop grown in Michigan. It serves as a source of high-grade forage, providing both hay and pasture which are profitably utilized by all types of livestock. When alfalfa hay is properly cured it is rich in protein, as well as extremely palatable. The crop itself is valuable as a soil builder in most systems of farming, as an alfalfa sod turned under adds both nitrogen and organic matter to the soil. The acreage of alfalfa for Michigan in 1924 was reported as 321,000 acres. The 1934 census shows an acreage of 936,989 acres, an increase of over 200 per cent. Michigan now ranks first in the United States in the acreage of alfalfa grown and in the number of farms reporting production of the crop. In view of the fact that alfalfa is such an important crop, any investigation which will lead to improved cultural practices is justifiable.

Since alfalfa is included in many cropping systems, the acreage is spread over the entire State and it is quite natural that climatic conditions exert a great influence upon the number of cuttings obtained from a stand in a single season. Short growing seasons limit production to one cutting in the northern portion of the State, particularly the Upper Peninsula, whereas in the regions farther south, the practice of making two cuttings is generally followed. When hay is scarce and high in price, the farmer in central and southern Michigan often cuts alfalfa three times during the season. The third cutting frequently occurs during September or October. It has been observed in many cases where late summer and early fall cutting of alfalfa has been practiced that the yield has been reduced the following year and frequently the stand has been severely thinned. Winter killing is especially likely to occur when low temperatures of long duration have been experienced during the winter following the late cutting. Again, late cuttings have been made where no material injury to the stand occurred but a marked reduction in yield ensued the following year. Still other late cuttings have resulted in no apparent injury to the stand and no reduction in the yield of forage. In view of the drastic effects that late cutting often has, it is important that a thorough investigation be made concerning the reaction of the alfalfa plant to late cutting.

The following experiment was laid out with three major purposes in mind. First, the establishment of a date range or a period of time within which late cutting is likely to result in injury to the stand or yield. Second, the determination of dates within that range when the maximum and minimum injury to alfalfa occur from late cutting. Third, to make a study of the alfalfa plant in order to ascertain the responses of the plant to late cutting. The influence of late cutting upon the tops of the plants was investigated by studies of the crown bud formation, stem production, and yield. The per cent dry matter, per cent moisture, rate of respiration, and rate of hardening of the roots were also determined.

REVIEW OF LITERATURE

Variety trials, artificial freezing, respiration, dry matter and moisture relationships, size of roots, crown bud formation, and many other studies have been conducted with regard to the winter hardiness of alfalfa. Many studies have also been carried out to determine the cultural practices most suitable for alfalfa. Experiments dealing with planting, cutting, and curing practices have greatly aided in promoting alfalfa to the place it now holds in the agriculture of the United States. Nevertheless, there has been little investigation of the direct effect of late summer and early fall cutting upon the behavior of the alfalfa plant.

Frequency of cutting alfalfa during the summer season has been studied to determine its effect on the vitality of the crop. Granfield (8) states that frequent cutting in the bud stage or keeping the alfalfa cut through the fall results in a rapid depletion of the stand. Garver (6) found that plots of alfalfa at Redfield, South Dakota which were cut frequently during the growing season suffered almost complete mortality during the following winter. Moore and Graber (15), Salmon (20), Kiesselbach and Anderson (10) have presented similar results in regard to the effect of cutting the alfalfa plant.

Nelson (16), working in California with one-year old seedlings of alfalfa, found that cutting in the first year of growth reduced the diameter and retarded the growth of the roots. Willard (24), et al, recommends that the last cutting of the season be made early enough to allow root storage to take place in order to make sure that the plant will go into the winter season well protected against low temperatures. He also states that for Ohio, cutting in late September and early October is likely to be more injurious than cutting on November 1 when no exhaustive new growth can be initiated and after all root storage is complete. Graber (7), et al, in his studies on root reserves noted that frequent cuttings reduced the size of the root and lowered the root reserves. He states further that "new top growth is initiated, in a large measure, at the expense of previously deposited root reserves. .... There is some evidence to indicate that such slow growth as is so often observed in the medium hardy and especially the extremely hardy varieties of alfalfa and termed "fall dormancy' is also a period of some storage of root reserves. .... The susceptibility of the alfalfa plant to winter injury is increased by low percentages of dry matter and low concentrations of organic food reserves."

Peltier and Tysdal (19), working with two-year old alfalfa plants found a relationship between size of root and ability to resist winter injury. Within the same variety of alfalfa, large roots enhanced the chances for survival, whereas small roots were found to be more susceptible to severe winter injury. They also found that the number of crown buds and stems which a plant possessed was directly related to its chances for escaping winter injury, i.e., those plants having the greatest number of crown buds and stems were most likely to survive. Graber (7) also reports that frequent cutting tends to reduce the number of crown buds and the amount of top growth. Dexter (2), working with alfalfa, cabbage, wheat, and tomatoes, points out that a high available carbohydrate supply with restricted vegetative growth is essential before the cold temperature reaction of hardening plants will occur in an efficient manner.

No effort was made to include all published work dealing with winter hardiness in the review of literature. Harvey (9) has compiled a very complete bibliography of work dealing with low temperature relationships of plants, and Megee (14) has presented a comprehensive review of the theories of plant hardiness with respect to low temperature.

Dexter (5), et al, working with wheat, rye, and alfalfa, using hardy and non-hardy varieties, found that electrical conductivity methods used on prepared, artifically frozen material gave excellent indications of the relative susceptibility of the plants to injury from low temperatures. Megee (13), working with a hardy and a non-hardy variety of alfalfa, found that the electrical conductivity method as suggested by Dexter, et al, was useful in distinguishing relationship between winter hardiness and heat of wetting, swelling, moisture equivalent, freezing point, chemical composition, respiration, and amount and rate of loss of moisture in roots of hardy and non-hardy alfalfas. These methods did, however, indicate the rate of hardening of the two varieties and showed that a heavy application of fertilizer in late summer retarded hardening of the alfalfa plant.

Salmon (21), using methods of artificial refrigeration on potted plants, found that differences could be distinguished in the injury from low temperatures sustained by various varieties of wheat. Peltier and Tysdal (18) also used artificial freezing trials with excellent results on alfalfa seedlings as a means of determining winter hardiness. Newton (17), et al, using wheat, has been able to show a direct correlation between the rate of respiration and hardiness of different varieties at -7 degrees centigrade. In studies of expressed juice from wheat leaves, he found a direct correlation between catalase activity and hardiness. Martin (11), studying the respiratory rate of wheat and rye at low temperatures, found that at -10 degrees centigrade the rate of respiration was in inverse order to hardiness. Dexter (3) states that although hardy varieties of wheat may respire at a lower rate than tender varieties, there is no evidence to show that the hardened condition as such is especially characterized by a low respiratory rate. Steinmetz (23) showed that total solids in the sap and the quantity of press juice extracted from alfalfa roots at various pressures have no apparent relationship to the winter hardiness of the plant.

EXPERIMENTAL MATERIAL

This investigation was started in the late summer and early fall of 1934. A single linear block of plots was laid out on a two-year old stand of Hardigan alfalfa growing on a medium fertile Miami loam. Five cutting dates, replicated twice, were used with six checks. The block consisted of twenty-one plots (Fig. I). Each plot was 10 x 20 feet and represented an area of $\frac{1}{217.8}$ acre. An additional area was cut beyond the end of every plot to insure sufficient material for laboratory studies of the alfalfa roots. When cutting the alfalfa plants in the late summer and early fall, a small

Fig. 1
Diagram of the late cutting treatments as laid out in 1934 and 1935.

Check - Not Cut	1
September 1	2
September 15	3
September 30	4
Check - Not Cut	5
October 15	6
October 31	7
September 1	8
Check - Not Cut	9
September 15	10
September 30	11
October 15	12
Check - Not Cut	13
October 31	14
September 1	15
September 15	16
Check - Not Cut	17
September 30	18
October 15	19
October 31	20
Check - Not Cut	21

hand sickle was used and particular care was taken to cut all plots uniformly. Immediately after cutting, the severed tops were removed from the plots. During the fall and winter, when roots were removed from the supplementary areas for study and examination, great care was used so that the plants received a minimum of injury. The roots were dug at random in each area and carefully selected for uniformity in size and shape.

A similar set of plots was laid out in the fall of 1935 on a two-year old stand of Hardigan alfalfa. Virtually the same procedure was followed in 1935 as in the preceding year.

EXPERIMENTAL RESULTS

CROWN BUD FORMATION OF ALFALFA AS INFLUENCED BY LATE CUTTING

The stems which form the aerial portions of the alfalfa plant originate from buds formed at the crown. Any change in the behavior of the plant which influences the number of buds formed will also affect the stem production. The relationship between late cutting and crown bud formation was investigated in the following way:

At various times throughout the season, roots were dug at random from the several treatments and after being washed thoroughly, crown bud counts were made. The buds which had progressed far enough to produce foliage were not considered as buds. The data are presented by use of a weighted mean. The results are reported in Table 1.

Table 1. The mean number of buds per plant from plots of alfalfa cut in the late summer and early fall of 1935.

DATE OF CUTTING - 1935	MEAN NUMBER OF CROWN BUDS PER PLANT				
	Nov. 21	Nov. 28	Dec. 10	Dec. 13	Weighted Mean
Check - Not Cut	7.9	7.5	10.4	10.7	9.05
September 1	3.2	4.8	6.8	7.4	5.31
September 15	7.4	6.6	6.3	8.0	7.03
September 30	6.6	5.9	9.2	6.3	6.63
October 15	6.0	6.8	8.0	12.0	8.08
October 30	6.8	6.8	10.8	9.7	8.00

Cutting in September markedly reduces and retards the crown bud formation of the alfalfa plant. Data from crown bud studies presented in Table 1 show that all plants cut in September have fewer crown buds than plants not cut or the plants cut in October (Fig. 2). The maximum reduction in crown buds occurs from cutting on the first of September, whereas little reduction is evidenced by cutting in October. The vast differences in the plants from different cutting treatments are brought out much more clearly by photographs (Fig. 3) made of the plants at the time of sampling. Graph 1 presents a comparison of crown bud formation in 1935 with stem counts and yields from plots cut late in 1934. It will be noted from the graph that the maximum reduction in crown buds from late cutting occurs early in the month of September in 1935.

Observations throughout the season also showed that the plants which were not cut developed three distinct sets of crown buds. The first set was formed late in the summer and developed into a short top growth. The second set appeared in November and slowly formed a few leaves. The third set appeared in December and had not developed into foliage at the time of the last observation

Fig. 2. Roots showing the difference in crown bud formation for four cutting treatments. The tops have been trimmed back to show the bud development more clearly.

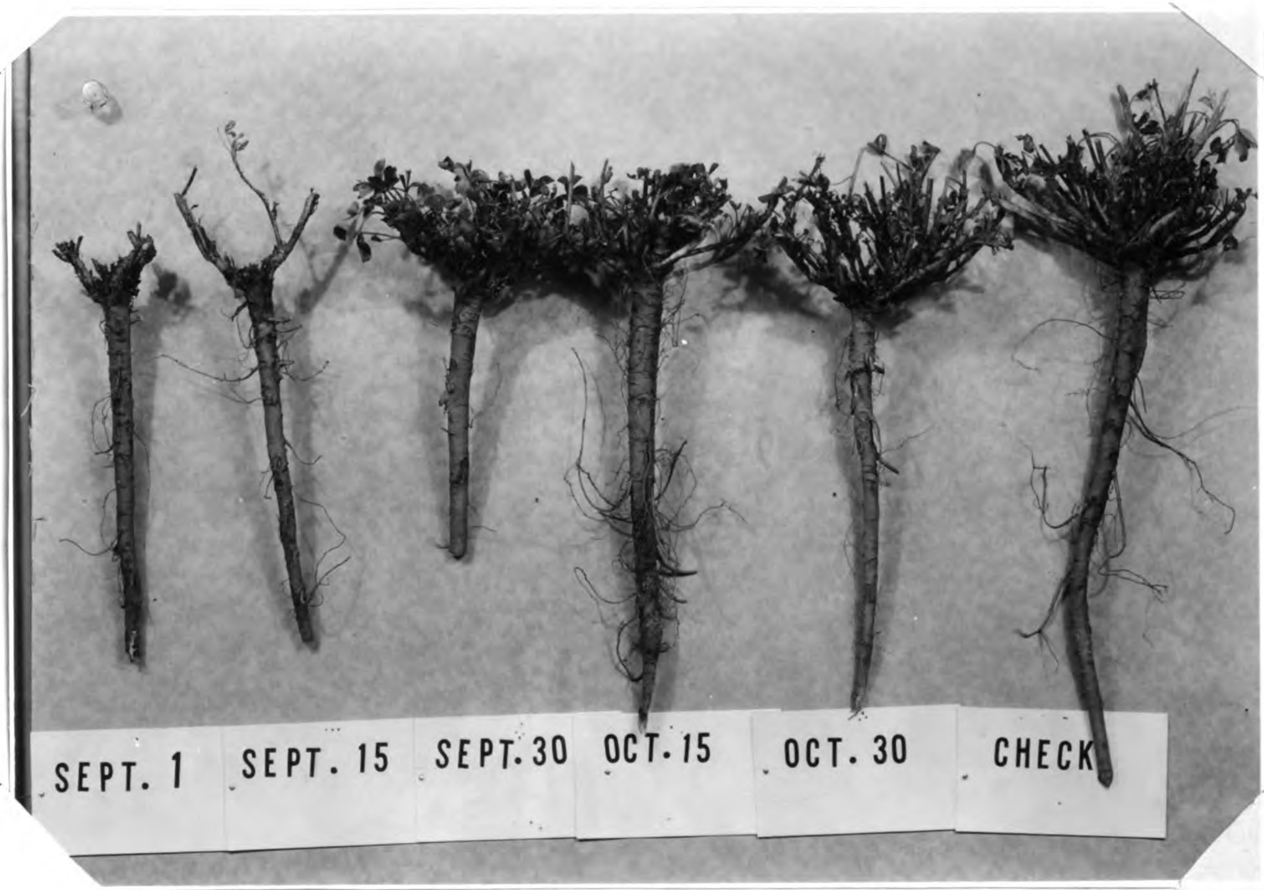

Fig. 3. Roots from cutting treatments showing the crown bud and foliage development of alfalfa plants cut in the late summer and early fall. Note the killing back of the growing parts of the plants cut on September 1 and 15.

on December 10. On the other hand, the first set of buds formed by plants cut in early September developed into a vigorous top growth. In November, these plants formed fewer crown buds than plants which were not cut and these buds did not develop into foliage. A third set of crown buds was not formed. Table 2 presents a summary of the observations made during the fall and early winter of 1935.

Table 2. Observations on crown bud formation and subsequent development of foliage during the fall and early winter of 1935.

DATE OF CUTTING - 1935	SEPTEMBER	NOVEMBER	DECEMBER
Check Not Cut	Numerous buds developing into foliage	Numerous buds developing into slight foliage	Numerous buds No foliage
September 1	Numerous buds rapidly developing into extensive foliage	Few buds No foliage	No buds
September 15	Numerous buds rapidly developing into extensive foliage	Few buds No foliage	No buds
September 30	Numerous buds slowly developing into foliage	Intermediate number of buds developing into slight foliage	Few buds No foliage
October 15	Numerous buds slowly developing into intermediate foliage	Intermediate number of buds developing into slight foliage	Intermediate number of buds No foliage
October 30	Numerous buds slowly developing into foliage	Numerous buds developing into slight foliage	Numerous buds No foliage

RELATIONSHIP BETWEEN LATE CUTTING OF ALFALFA AND STEM PRODUCTION

It has been observed in certain crops that stem production is dependent upon crown bud formation and is often closely associated with yield. In order to determine the effect of late cutting upon stem production and its subsequent relationship to the yield, three counts of the number of stems in three foot rows were made on each of the 1934 plots. These counts, made after the first hay crop of 1935 was removed, were averaged to obtain a single value for each plot and the values for triplicate plots were then averaged to obtain a mean for each treatment. Thus,a mean for a single cutting treatment represents an average of nine three foot lengths. A count of the plants within each of these lengths would have been highly desirable, but branching at the crowns and the difficulty of distinguishing individual plants prohibited an accurate study of this phase. The data from the stem counts are presented in Table 3.

Table 3. The mean number of stems per unit area for each treatment on June 18, 1935 from plants cut during the late summer and early fall of 1934.

PLOTS	1-5-9-13-17-21	2-8-15	3-10-16	4-11-18	6-12-19	7-14-20
DATE OF CUTTING - 1934	CHECK - NOT CUT	SEPT. 1	SEPT. 15	SEPT. 30	OCT. 15	OCT. 30
Number of Stems	91	96	66	73	104	83
	94	109	76	77	106	90
	111	78	80	71	73	94
	113					
	92					
	125					
Average	104	94	74	73	94	89

The major reduction in stem production clearly occurred when the alfalfa plants were cut on September 15 and 30 of 1934. It is not reasonable to expect the stem counts from plots cut late in 1934 to compare exactly with bud counts of plots cut late in 1935, yet in both cases, cutting in September has been the means of altering the plants' behavior. In 1935, however, the injury occurred toward the first half of September, whereas in 1934 the effect was confined to the middle and latter half of the month. Graphs 2 and 3 show the relative positions of the treatments for the two years with regard to the effect of late cutting on stem and crown bud production.

EFFECT OF LATE CUTTING UPON YIELD

Yield is the ultimate index of crop response to cultural treatment and weather conditions. It has already been proved that late cutting seriously affects crown bud formation and stem production of the alfalfa plant; therefore, as these two factors are closely associated with yield, it is important that the influence of late cutting upon forage production be determined. Yields from two hay crops were taken in the summer of 1935 from plots cut in the late summer and early fall of 1934. The alfalfa was cut with scythes and immediately raked and weighed before loss of weight by evaporation. Samples of the cut hay were taken for dry weight determination. The plants were found to contain 25 per cent dry matter at the time of cutting. The green weight was converted to cured hay at 15 per cent moisture by the use of a factor,and yield was reported in tons of cured hay per acre. The yields were then interpolated on the basis of check yields. The data were analyzed for significant differences by the application of the Student's pairing method and the use of Love's Z tables for the determination of odds. The yields of forage in the summer of 1935 are reported in Table 4.

The yield data for 1935 show a distinct and significant reduction in the first hay crop from the plots cut September 15 and 30 of 1934. No significant differences were found in the yields of the second cutting, but the total yields for the season show that cutting of alfalfa on September 15, 1934 significantly reduced the yield of forage over 1000 pounds per acre. The statistical analysis shows that it is very unlikely that the reductions occurring in the first crop from the plots cut September 15 and 30 or the reduction occurring in the total yield from the September 15 plot, is due to chance alone. The relative position of the different treatments with regard to forage yield in the first crop of 1935 is shown in Graph 3. It will be noted that the curve obtained by plotting stem counts in Graph 2 corresponds

Table 4. The influence of late summer and early fall cutting of alfalfa upon the yield of hay the following season.

DATE OF CUTTING - 1934	FIRST CUTTING			SECOND CUTTING			TOTAL		
	HAY - TONS PER ACRE 15% MOISTURE	DIFFERENCE	ODDS	HAY - TONS PER ACRE 15% MOISTURE	DIFFERENCE	ODDS	HAY - TONS PER ACRE 15% MOISTURE	DIFFERENCE	ODDS
Check - Not Cut	2.36	--	--	1.44	--	--	3.80	--	--
September 1	2.27	-.09	5:1	1.49	.05	5:1	3.76	-.04	2:1
September 15	1.95	-.41	102:1	1.34	-.10	7:1	3.29	-.51	66:1
September 30	1.91	-.45	48:1	1.24	-.20	7:1	3.15	-.65	32:1
October 15	2.14	-.22	13:1	1.26	-.18	6:1	3.40	-.40	28:1
October 30	2.19	-.17	27:1	1.33	-.11	8:1	3.52	-.28	1:1

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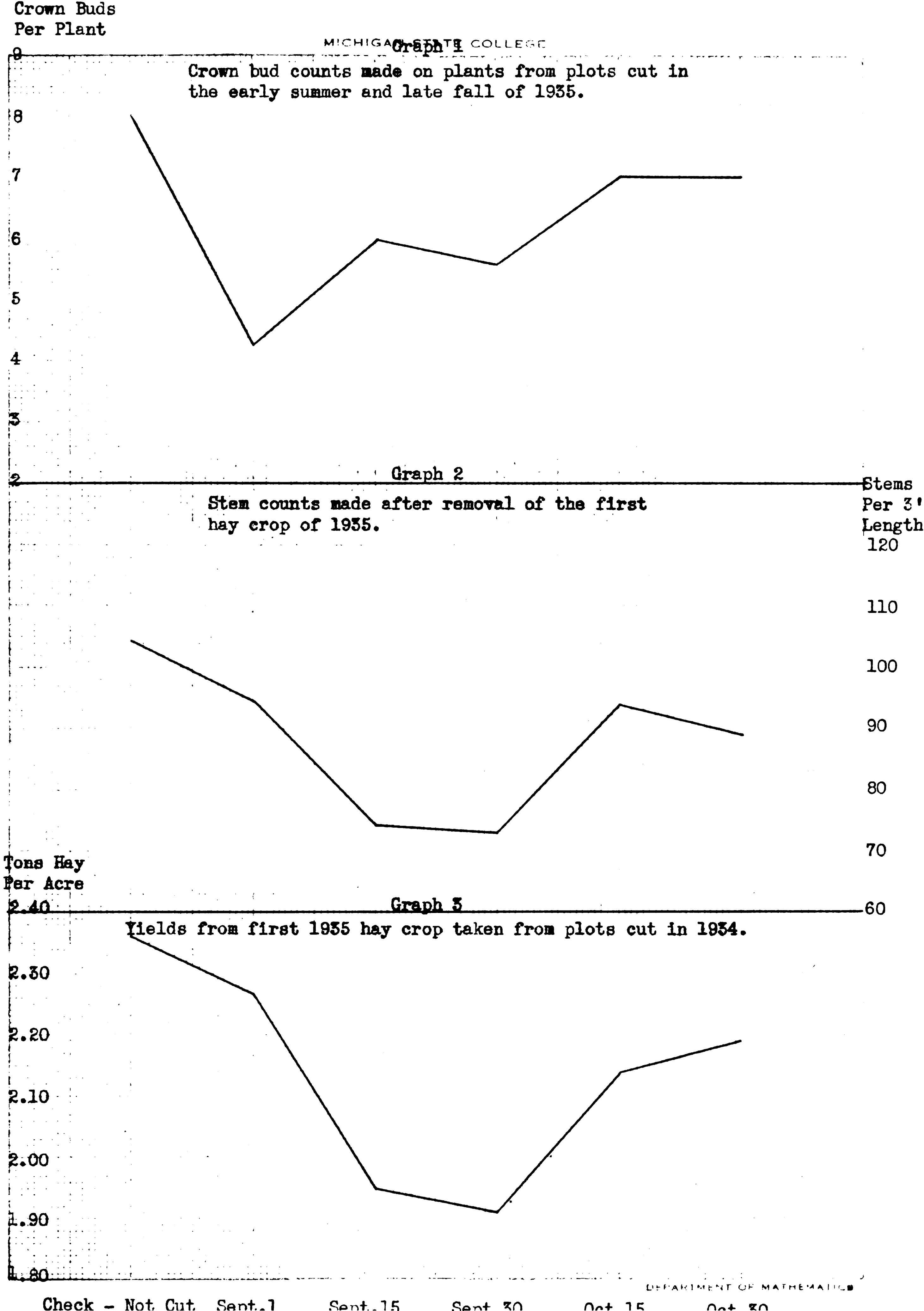

DEPARTMENT OF MATHEMATICS

very closely with that obtained by plotting the yields of the first cutting of 1935.

DRY MATTER AND MOISTURE RELATIONSHIPS OF THE ALFALFA ROOT AS INFLUENCED BY LATE CUTTING

Investigators are generally agreed that the moisture content of plants is highest during the active growing period, decreases to a minimum in the late fall and winter, and increases again when active growth is resumed. Since cutting alters the life cycle of the alfalfa plant, it was necessary not only to determine the effect of late cutting upon the percentages of moisture and dry matter, but also to obtain this information in order to prepare a sound basis for reporting other experimental phases of this problem. An electrically controlled oven with the temperature maintained at 90° centigrade was used in drying the samples to constant weight. Roots of uniform size were used, all samples were weighed to the second decimal place by use of a sensitive Torsion balance, and in every case the material remained in the oven twenty-four hours. The results are presented in Table 5.

The data show that striking differences have been produced by late cutting in dry matter and moisture relationships in the various treatments. In comparison with the check, the plants cut in September have undergone a reduction in the percentage of dry matter and an increase in the percentage of moisture, whereas the plants cut in October remain very nearly the same as the check. As the season progresses, it is interesting to note that the percentage of dry matter found in roots of plants which were not cut and plants cut in October is not maintained but decreases; on the other hand, the percentages for the plants cut in September tend to remain more or less constant. This fact indicates that late cutting alters the processes in such a way that the plant is unable to carry on the moisture and dry matter changes common to winter hardy alfalfa, as found by Megee (13) and Peltier and Tysdal (19).

Table 5. The percentage of moisture and dry matter in the roots of alfalfa plants cut during the late summer and early fall of 1935.

DATES	CHECK NOT CUT		SEPTEMBER 1		SEPTEMBER 15		SEPTEMBER 30		OCTOBER 15		OCTOBER 30	
	% DRY MATTER	% WATER	% DRY MATTER	% WATER	% DRY MATTER	% WATER	% DRY MATTER	% WATER	% DRY MATTER	% WATER	% DRY MATTER	% WATER
October 17	42.8	57.2	30.8	69.2	34.2	65.8	38.0	62.0	42.3	57.7	41.9	58.1
October 30	39.0	61.0	28.6	71.4	31.4	68.6	34.7	65.3	37.9	62.1	39.5	60.5
November 14	40.5	59.5	33.8	66.2	33.3	66.7	36.1	63.9	36.4	63.6	39.6	60.4
November 28	38.0	62.0	30.7	69.3	32.2	67.8	32.8	67.2	36.5	63.5	36.3	63.7
December 13	37.0	63.0	31.0	69.0	33.8	66.2	36.1	63.9	37.7	62.3	35.6	64.4
Average	39.4	60.6	30.9	69.1	32.9	67.1	35.5	64.5	38.1	61.9	38.6	61.4

CARBON DIOXIDE LIBERATION OF ALFALFA ROOTS AS EFFECTED BY LATE CUTTING

Carbon dioxide liberation through respiration is an indication of activity in the living plant. Tests were made on alternate weeks during the late summer, fall, and winter in an attempt to determine any relationship which might exist between the activity of vital processes of the plant and late cutting. The first carbon dioxide determinations were made on August 23, before hardening began, and the last determinations on December 10, at a time when the alfalfa plant was in an advanced stage of hardening. Material was prepared by removing the roots from the plot at random in such a way that a minimum of injury was suffered by the plants from handling. All adhering soil was carefully washed away, the dead tops and larger lateral roots were trimmed off, and duplicate 20 gram samples of the roots were placed in 500 cc. Erlenmeyer flasks. These flasks were then tightly closed with rubber stoppers fitted with intake and outlet tubes which were closed except when the flask was connected with the apparatus used for the collection of carbon dioxide. The flasks were kept in a dark, cold chamber and held at a temperature approximating that of the soil at the time of sampling. The train for the determination of carbon dioxide was set up as follows: Potassium hydroxide solution, distilled water, sample flask, sulfuric acid, phosphoric anhydride, ascarite, potassium hydroxide solution, and air pump (Fig. 4). Each sample was allotted five minutes in the train while the air was being drawn through at a rate sufficient to completely flush out the sample flask three times. The carbon dioxide was collected as it was drawn through an ascarite U-tube of known weight. All weights were made on a chemical balance and were read to the fourth decimal place. The results are reported in Table 6.

The carbon dioxide determinations, when placed on a dry matter basis, show that no great difference exists in respiration between plants of the different cutting treatments, and that there is no reduction in any case as

Fig. 4. The apparatus used to collect carbon dioxide from alfalfa roots. The train is set up as follows: Potassium hydroxide solution, distilled water, sample, sulfuric acid, phosphorus anhydride, ascarite, potassium hydroxide solution. The air pump is connected to the train by rubber tubing and cannot be seen at the left.

Table 6. The influence of late summer and early fall cutting of alfalfa upon the carbon dioxide liberation of the roots.

Date Of Cutting - 1935	CHECK - NOT CUT			SEPTEMBER 1			SEPTEMBER 15			SEPTEMBER 30			OCTOBER 15			OCTOBER 30		
DATE OF DETERMINATION	Av. Dry Mat. In Gms.	Av. CO_2 Per 20 Gm. Samp.	Gms. CO_2 Per Gm. Dry Mat.	Av. Dry Mat. In Gms.	Av. CO_2 Per 20 Gm. Samp.	Gms. CO_2 Per Gm. Dry Mat.	Av. Dry Mat. In Gms.	Av. CO_2 Per 20 Gm. Samp.	Gms. CO_2 Per Gm. Dry Mat.	Av. Dry Mat. In Gms.	Av. CO_2 Per 20 Gm. Samp.	Gms. CO_2 Per Gm. Dry Mat.	Av. Dry Mat. In Gms.	Av. CO_2 Per 20 Gm. Samp.	Gms. CO_2 Per Gm. Dry Mat.	Av. Dry Mat. In Gms.	Av. CO_2 Per 20 Gm. Samp.	Gms. CO_2 Per Gm. Dry Mat.
August 23	8.24	.0230	.0027															
September 15	8.20	.0211	.0025	8.10	.0223	.0027												
September 24	8.42	.0354	.0042	7.10	.0192	.0027	7.62	.0241	.0031									
October 7	8.56	.0315	.0036	6.16	.0178	.0028	6.84	.0198	.0028	7.60	.0227	.0029						
October 24	7.80	.0215	.0027	5.72	.0175	.0030	6.28	.0144	.0022	6.94	.0160	.0023	7.58	.0177	.0023			
November 8	8.10	.0234	.0028	6.76	.0168	.0024	6.66	.0161	.0024	7.22	.0209	.0028	7.28	.0186	.0025	7.92	.0214	.0027
November 22	7.60	.0229	.0030	6.14	.0149	.0024	6.44	.0152	.0023	6.56	.0154	.0023	7.30	.0182	.0024	7.26	.0197	.0027
December 10	7.40	.0242	.0032	6.20	.0167	.0026	6.76	.0162	.0023	7.22	.0195	.0027	7.54	.0188	.0024	7.12	.0220	.0030

the season progresses or as the plant hardens.

THE EFFECT OF LATE SUMMER AND EARLY FALL CUTTING OF ALFALFA UPON ITS SUSCEPTIBILITY TO INJURY FROM LOW TEMPERATURES

Injury from low temperatures increases the permeability of the co-called "plasma membrane" of the cell and allows electrolytes to pass out more readily. Electrical conductivity was used to determine the effect of late cutting on the degree of hardening reached by alfalfa plants cut at various dates in the late summer and early fall. Roots of uniform size were selected from plants dug at random from each treatment and thoroughly washed in cold water. The upper eight inches of the roots were used, with the crown severed and all lateral roots removed. The roots were cut into $\frac{3}{4}$ inch pieces and, after being thoroughly mixed to insure uniformity, 10 gram samples were weighed out into pyrex test tubes. These samples were frozen by placing the tubes in a slush of alcohol and water inside a refrigeration chamber which was held to a variation of less than 1° centigrade. As the tubes were removed from the slush, 75 cc. of distilled water was added to each sample and the tubes were then placed in a 2° centigrade bath in which no temperature variation could be observed with the usual chemical thermometer read to $\frac{1}{2}$ degree. Eighteen to twenty hours were allowed for the electrolytes to diffuse into the surrounding water, after which the electrical conductivity readings were taken by means of a modified Wheatstone bridge. The readings were taken in resistance ohms and were later converted into conductivity by use of the formula:

$$\frac{1}{\text{resistance ohms}} = \text{mhos conductivity}$$

Conductivity is expressed in mhos ($\times 10^{-6}$). After making conductivity determinations, following freezing and exosmosis, the roots were boiled for thirty minutes and electrical conductivity readings were made again, after allowing eighteen to twenty hours to elapse for exosmosis to take place. Results from electrical conductivity trials are reported in Tables 7 and 8.

Table 7. The relative injury, by freezing, of alfalfa roots cut in the late summer and early fall as shown by liberation of electrolytes.

DATE OF CUTTING - 1935	MHOS PER GRAM OF DRY MATTER				
	-3° OCT. 17	-3° OCT. 30	-8° NOV. 14	-8° NOV. 28	-8° DEC. 13
Check - Not Cut	19.29	13.66	31.31	18.79	24.00
September 1	55.60	25.58	45.51	43.71	46.08
September 15	38.14	24.49	45.04	35.83	44.34
September 30	26.76	17.11	36.13	29.50	31.96
October 15	25.45	14.26	32.96	21.34	25.63
October 30	21.69	13.09	30.30	18.99	24.78

The data show that freezing the roots of alfalfa caused liberation of more electrolytes from plants cut in September, especially September 1 and 15, than from any other treatment. The narrowing of the differences in the data obtained from trials on October 30 and November 14 was due to the temperature to which the roots were exposed. This serves to emphasize the necessity of carefulness in the handling of plant tissue used in electrical conductivity trials. The plants were too far advanced in hardening on October 30 to be materially injured by exposure to a temperature of -3° centigrade for six hours. A temperature of -8° centigrade with an exposure of five and one-half hours on November 14 was too extreme and all samples were severely injured. In both cases, although the ranking was not markedly changed, the differences were reduced. It was found that the subjection of a few samples, selected from the material to be used later in experimental trials, to various lengths of exposure at a specified temperature aids greatly in determining the most suitable length of time for freezing. This should be done not more than twenty-four hours before the actual experiment is begun.

Table 8. Electrical conductivity measurement of the total free extractable salts liberated by boiling the roots of alfalfa plants cut in the late summer and early fall of 1935.

DATE OF CUTTING - 1935	TOTAL SALTS EXTRACTED BY BOILING. MHOS PER GRAM OF WATER				
	OCT. 17	OCT. 30	NOV. 14	NOV. 28	DEC. 13
Check - Not Cut	57.13	53.17	44.62	38.53	37.68
September 1	57.04	56.79	52.70	43.33	39.89
September 15	57.70	57.53	47.58	41.94	39.40
September 30	50.67	51.63	45.35	38.49	37.59
October 15	56.12	54.29	45.75	37.84	38.82
October 30	55.82	56.35	46.42	37.82	40.86

Killing the roots by boiling causes increased permeability of the plasma membrane and allows exosmosis of the free extractable salts which the cells contain. Table 8 shows that the total salts per gram of moisture which can be extracted from the alfalfa root by boiling is the same for all dates of cutting. Little variation is apparent on any date of trial. A greater total amount of salts can be extracted from the roots of plants cut in September, due to the higher moisture content; but, actually, no difference exists in the concentrations of salt per gram of moisture.

SUMMARY

The investigation reported in this paper is a study of the effect of late summer and early fall cutting upon the behavior of the alfalfa plant. Data were collected from plots of alfalfa cut on September 1, 15, and 30, and October 15 and 30, 1934, and from a similar set of plots in 1935. The effect of late cutting upon crown bud formation, stem production, forage production, per cent of moisture, per cent of dry matter, rate of respiration, and rate of hardening was determined. The data show that:

Alfalfa plants cut in September developed fewer crown buds per plant than those which were not cut or were cut during October.

Less stems were produced by the plants cut in September when active growth was resumed in the following spring.

The yield of the first crop of forage was significantly less the following year from alfalfa plants which were cut in September. No consistent differences occurred in the second crop, but the total yield of hay from the plants cut on September 15 was significantly less than that of plants which were not cut on this date.

Roots of alfalfa plants cut in September were lower in percentage of dry matter and higher in percentage of moisture than those of plants which were not cut or were cut in October.

There were no significant differences in the quantity of carbon dioxide liberated from the roots of alfalfa plants which were cut and those which were not cut. No effect was evidenced by hardening or late cutting upon carbon dioxide liberation.

Electrical conductivity determinations show that alfalfa plants cut in September are more susceptible to winter injury. This is further borne out by observations made in the spring of 1936, which showed severe winter killing and heaving of plants cut during September, 1935.

Seasonal weather conditions influenced the exact date of cutting upon which maximum injury to the alfalfa plant resulted.

Although it was not the object of this paper to deal with root reserves, however the lower percentage of dry matter in the roots indicated that cutting during September induced the plants to draw upon the energy reserves of the root to initiate new growth.

CONCLUSIONS

Alfalfa plants cut in September produce fewer crown buds, fewer stems, are more susceptible to winter injury,and yield less hay the following season than plants cut during October or plants not cut during the late summer and fall.

September is the period during which cutting of alfalfa usually results in maximum injury.

The exact date upon which cutting of the alfalfa plant results in maximum injury depends upon seasonal weather conditions and may vary from early to late September.

Alfalfa plants cut during late October usually show little effect from removal of top growth.

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