TITLE Influence Of Heigth And Frequency Of Cutting Upon The Growth Of Smooth Brome Grass, Orchard Grass And Kentucky Bluegrass

AUTHOR Charles Worth Hodgson DATE 1941

UNIVERSITY Michigan State College

DEGREE Ph.D. PUBLICATION NO. 414

INFLUENCE OF HEIGHT AND FREQUENCY OF CUTTING UPON THE GROWTH OF SMOOTH BROME GRASS, ORCHARD GRASS AND KENTUCKY BLUEGRASS

A THESIS

Submitted to the Faculty of Michigan State College

in Partial Fulfilment for the Degree

of Doctor of Philosophy

in Farm Crops

by

Charles Worth Hodgson

East Lansing, Michigan

1941

TABLE OF CONTENTS

INFLUENCE OF HEIGHT AND FREQUENCY OF CUTTING UPON THE GROWTH OF SMOOTH BROME GRASS, ORCHARD GRASS AND KENTUCKY BLUEGRASS.

In recent years there has been an increased interest in grass culture and in the management of pasture grasses. Studies of the response of many species of forage plants to various cutting treatments have revealed that short and frequently repeated defoliations result in decreased yields of forage and in decreased root growth.

Gordon and Sampson (3), 1/ Leukel and Coleman (5), and Leukel and Barnette (6) give rather extensive reviews of the literature pertaining to the effects of cutting and other treatments upon the production of top growth and root reserves by forage plants.

The present paper deals with the influence of height and frequency of cutting upon the growth of smooth brome grass (Bromus inermis), orchard grass (Dactylis glomerata), and Kentucky bluegrass (Poa pratensis). Chemical analyses were made of some of the clipped herbage. One phase of the experiment was conducted in the greenhouse and a second phase was carried on in the field.

GREENHOUSE STUDIES

Materials and Methods

In November, 1937, segments of smooth brome grass and orchard grass were collected from the field nursery at Michigan State College, East

---

1/ Figures in parenthesis refer to Literature Cited, P. 18.

Lansing, and set out in quartz sand in ten-inch clay pots in the greenhouse. Eight segments were placed in each orchard grass pot; and 16 segments, with 2 at each place, were placed in each of the brome grass pots.

All plants were regularly watered and given a nutrient solution containing KH_2PO_4, $Ca(NO_3)_2$ and $MgSO_4$. No artificial light was used. The temperature ranged from 60° to 80° F. during the winter months and sometimes went as high as 100° F. during the following summer. The plants began to head out in January, 1939. Because of irregular light conditions in the greenhouse, there was considerable lack of uniformity among the plants located in different parts of the greenhouse.

No nutrient solution was given the plants from the first week in March until the beginning of the cutting period in order to give the plants an opportunity to store up some carbohydrate reserves. Water was supplied as before. After the first cutting, all plants received nutrient solution once or twice per week, depending upon the weather--twice during the best growing weather.

Cutting began on April 13, 1938. Some of the plants were still in the late bloom stage at this time. The plants of each species were arranged in sets of four cultures each, care being taken that the sets would be comparable with each other within a given species. Four cultures were washed free of sand, the roots separated from the tops, and green and dry weights taken for each. These were designated as "initial checks".

Each of the following cutting treatments was replicated four times

in each species:

Height of Cutting above Sand	Length of Interval Between Cuttings			
1 inch	1 week	2 weeks	4 weeks	8 weeks
3 inches	1 "	2 "	4 "	8 "
6 "	1 "	2 "	4 "	8 "
9 "	1 "	2 "	4 "	8 "
12 "	1 "	2 "	4 "	8 "
Final check	Not cut but washed free of sand at the close of the experiment.			

The method of cutting consisted of raising the leaves and cutting them off, along with the stems, at the designated height. Green and dry weights were recorded for all portions of tops removed. Drying was accomplished by forced air at 60° to 70° C. in an oven. Representative dry samples were kept for future chemical analyses.

On August 9 and 10, 1938, all cultures, including the final checks, were washed free of sand. The roots were separated from the tops, and fresh and dry weights were determined for each. The rhizomes of the brome grass were also removed and weighed.

Forage Yields

In the case of the plants which were cut once every week, the shorter the plants were cut the greater the yield of forage at the beginning of the cutting period. As the cutting treatments continued, however, the plants which were cut at one inch decreased in forage production, while the yields from the plants which were cut at the higher levels increased for a time. By the end of the cutting period the plants which were cut at one inch every week had almost ceased to produce any

new growth.

Before cutting was begun, all plants were relatively low in nitrogen and relatively high in carbohydrates. This condition was conducive to a slow rate of vegetative growth. Close cutting and the application of nitrogen (supplied in the nutrient solution) each acted to reduce the proportion of carbohydrates to nitrogen in the plants and thus to stimulate the rate of growth, at least for a time. The plants which were cut frequently at one inch, however, soon exhausted their reserve supply of carbohydrates and were unable to supply sufficient carbohydrates for a maximum rate of growth because of limited photosynthetic tissue. As a result these plants gradually decreased in forage yields and were slowly starving to death.

The plants which were cut weekly at three inches also suffered from a deficiency of carbohydrates, but not so severely as did those cut at one inch per week.

The proportion of carbohydrates to nitrogen in the plants which were cut at the higher levels (6, 9, and 12 inches) was too high at the beginning of the cutting period for maximum growth; but, after these plants had had time to absorb and to assimilate more nitrogen, their rates of growth increased and were maintained above that of the plants which were cut at one inch per week. The relatively high yields produced during the latter part of the cutting period by the plants which were cut at the higher levels were made possible because these plants possessed enough photosynthetic area with which to manufacture an adequate supply of carbohydrates for growth.

When the plants were cut once every two weeks and once every four

weeks, respectively, the influence of height of cutting upon the rate of top growth followed the same general trend as in the case of those which were cut once every week, except that close cutting was not so severe on the plants because they had more time between cuttings in which to produce photosynthetic tissue and to manufacture carbohydrates.

Close cutting once every eight weeks did not appear to reduce the vigor of the plants. The closer the plants were cut, the more forage they yielded above the cutting level, but the less growth they made below that level.

The total yield of forage made above the cutting level and also the sum of that produced above and below the cutting level are given in Tables 1 and 2, respectively.

TABLE 1. Total Yield of Forage in Grams of Dry Weight Produced Above the Cutting Level During the Entire Cutting Period. (Average of four cultures)

Species and Cutting Height	Cut Every Week	Cut Every Two Weeks	Cut Every Four Weeks	Cut Every Eight Weeks
Brome Grass				
1 inch	10.40	27.84	46.11	60.53
3 inches	33.26	44.80	52.13	58.80
6 "	39.24	37.40	43.46	52.30
9 "	35.61	28.01	41.69	22.16
12 "	18.33	17.69	13.62	19.32
Orchard Grass				
1 inch	14.21	32.39	61.26	74.23
3 inches	40.63	47.04	69.37	69.31
6 "	49.24	49.60	55.84	64.65
9 "	47.77	55.07	51.11	48.66
12 "	29.72	34.18	30.51	38.51

Table 1 shows that the greatest production above the cutting level

was made by those plants which were cut at one or three inches every four weeks or at one, 3, or 6 inches every eight weeks, while the smallest yeild was produced by the plants which were cut at one inch every week. In the case of the plants which were cut at 12 inches, only a relatively small proportion of the total forage produced extended above the cutting level.

TABLE 2. Total Yield of Forage in Grams of Dry Weight Produced Both Above and Below the Cutting Level. (Average of four cultures.)

Species and Cutting Height	Cut Every Week	Cut Every Two Weeks	Cut Every Four Weeks	Cut Every Eight Weeks	Check
Brome Grass					
Initial Check					32.90
1 inch	39.57	56.78	77.11	97.76	
3 inches	67.14	77.75	85.61	91.95	
6 "	89.24	88.08	85.44	101.15	
9 "	90.09	92.16	95.92	78.86	
12 "	72.13	81.92	75.15	91.07	
Final Check					72.38
Orchard Grass					
Initial Check					49.40
1 inch	50.01	67.39	103.01	119.28	
3 inches	77.87	92.37	136.05	130.29	
6 "	96.67	111.88	119.74	137.28	
9 "	122.45	121.12	101.11	122.39	
12 "	119.20	116.73	125.54	130.54	
Final Check					99.50

The total yield (Table 2) produced by the plants which were cut at one inch and, to a certain extent, those which were cut at 3 inches increased as the interval of time between cuttings was lengthened. Several of the cutting treatments resulted in greater total yields than was made by the final check, indicating a stimulating effect of cutting

upon plant growth.

Yields of Roots and Rhizomes

The dry weights of the roots produced by the variously treated plants are summarized in Table 3. These data show that the plants

TABLE 3. Dry Weight of Roots in Grams. (Average of four cultures.)

Cutting Treatment	Brome Grass	Orchard Grass
Initial Check	22.63	18.30
1 inch per week	2.41	7.33
3 inches per week	13.07	15.17
6 " " "	25.00	21.67
9 " " "	31.00	36.83
12 " " "	22.17	34.83
1 inch every 2 wks.	6.77	14.33
3 inches every 2 wks.	14.47	17.17
6 " " " "	34.50	29.00
9 " " " "	42.33	36.00
12 " " " "	37.00	33.67
1 inch every 4 wks.	13.50	16.90
3 inches every 4 wks.	19.67	29.63
6 " " " "	28.60	27.33
9 " " " "	37.33	32.83
12 " " " "	36.33	35.67
1 inch every 8 wks.	33.50	35.50
3 inches every 8 wks.	35.83	27.83
6 " " " "	30.60	34.33
9 " " " "	37.78	43.83
12 " " " "	40.70	40.33
Final Check	36.13	28.33

which were cut at one, 3, or 6 inches every week; one or 3 inches every two weeks; and one inch (and 3 inches in brome grass) every four weeks sustained some root injury as a result of the top-cutting treatment that they received. As has been indicated previously in this report,

frequent close cutting prevented the plants from manufacturing enough carbohydrates for their growth needs. This resulted in a depletion of their root reserves, a slow rate of root growth, and, in extreme cases, death and disintegration of some of the existing roots.

The low yield of roots produced by the brome grass plants which were cut at 12 inches every week is very difficult to explain.

It is interesting to note that, although orchard grass outyielded brome grass in forage, many of the cutting treatments resulted in a lower production of roots by orchard grass than by the corresponding brome grass cultures.

Table 4 gives the production of brome grass rhizomes. Although the average dry weight of rhizomes per culture was considerably greater following some treatments than following others, when all four cultures of each treatment are considered, frequent cutting resulted in a low production of rhizomes, while less severe cutting had no consistent influence upon the yield of rhizomes.

Chemical Data

In obtaining samples of the clippings for chemical analyses, composite samples were prepared as follows: all of the samples of forage which had been removed during the first month from the brome grass plants cut at one inch were placed in a single container. Those removed during the second month were placed in a second container, and so on for the third and fourth months, respectively. The same procedure was followed with each of the other cutting treatments in brome grass, and also with each of the cutting treatments in orchard grass. The dry, composite samples were finely ground and kept in stoppered bottles

until analyzed.

TABLE 4. Dry Weight of Brome Grass Rhizomes Per Culture (Weight in Grams)

Cutting Treatment	Culture Number 1	2	3	4	Average
Initial Check	1.34	0.13	0.54	2.60	1.15
1 inch per week	----	0.96	----	0.64	0.40
3 inches per week	1.00	1.50	----	0.11	0.65
6 inches per week	6.50	----	3.00	1.29	2.70
9 " " "	----	5.00	1.24	15.50	5.44
12 " " "	1.80	0.54	10.00	3.50	3.96
1 inch every 2 weeks	----	0.77	0.65	0.87	0.57
3 inches " " "	0.60	3.20	0.44	2.80	1.76
6 " " " "	2.00	4.00	6.30	1.11	3.35
9 " " " "	4.00	7.80	----	8.70	5.13
12 " " " "	0.98	0.92	5.00	13.00	4.98
1 inch every 4 weeks	0.27	4 20	0.71	4.00	2.30
3 inches " " "	0.91	6.80	2.00	5.80	3.88
6 " " " "	3.60	2.80	4.40	6.10	4.23
9 " " " "	1.50	3.50	1.34	4.80	4.79
12 " " " "	6.50	5.50	4.00	9.00	6.25
1 inch every 8 weeks	0.17	0.06	3.80	4.40	2.11
3 inches " " "	----	3.30	0.12	0.72	1.04
6 " " " "	1.00	1.64	1.32	15.00	4.74
9 " " " "	1.20	1.14	1.70	7.00	2.76
12 " " " "	0.40	2.50	1.00	8.00	2.98
Final Check	3.50	1.70	2.40	4.40	3.00

A large number of the forage samples were analyzed for crude protein, phosphorus, and calcium; and several were analyzed for freereducing sugars, total soluble sugars, soluble starches and dextrins, and insoluble starch.

Some of these data are presented in Table 5. The initial checks were relatively low in crude protein and relatively high in soluble

carbohydrates, as a result of having received no nutrient solution for several weeks just preceding the start of the cutting period.

TABLE 5. Percentage of Crude Protein, Total Soluble Sugars, and Dextrins and Soluble Starches in Forage Samples. (Moisture-free basis)

Cutting Treatment	Month* Sample Was Collected	Crude Protein		Total Soluble Sugars		Dextrins and Soluble Starches	
		Brome	Orchard	Brome	Orchard	Brome	Orchard
Weekly at 1"	1st	35.83	28.83	1.04	1.64	0.00	0.10
" " 3"	1st	33.60	24.92	0.39	1.18	0.00	0.00
" " 3"	4th	33.41	30.09	0.34	0.27	0.00	0.00
Bi-weekly at 3"	1st	30.25	22.89	4.52	3.27	0.00	0.00
" " 3"	4th	32.30	28.00	1.31	0.52	0.00	0.00
" " 6"	4th	29.49	23.03	0.52	0.87	0.00	0.11
Monthly at 1"	1st	25.25	19.19	8.00	8.14	0.24	0.29
" " 3"	4th	28.24	22.00	2.08	1.77	0.35	0.10
Bi-monthly at 3"	1st two	22.02	14.98	6.60	6.75	0.12	0.10
" " 9"	1st two	24.21	15.98	6.87	6.67	0.00	0.00
Initial Check		11.43	10.60	10.28	5.37	4.42	1.80
Final Check		15.18	16.49	1.82	0.52	3.76	1.60

*One month equals four weeks

The presence of nitrogen in the nutrient solution resulted in the clipped forage samples, and also the final checks, being higher in crude protein than were the initial checks. Frequency of cutting also affected the protein content of the forage. The more frequently the plants were cut, the higher their protein content.

The tops of those plants which were cut at one or 3 inches every week were very low in soluble carbohydrates soon after the beginning of the cutting period. Those which were cut less frequently had appreciable amounts of soluble carbohydrates in their tops during the first month, and also during the second month in the case of the plants

which were cut once every eight weeks. At the end of the fourth month, the tops of all plants that were analyzed, even the final checks, were quite low in soluble carbohydrates. The data indicate a gradual using up of the surplus carbohydrates, with the speed of carbohydrate depletion increasing with increase in severity of cutting treatment.

Most of the soluble carbohydrates were in the form of sugar. No insoluble, or true, starch was found in any of the forage samples.

FIELD STUDIES

On August 16, 1937, a series of field plots was sown on the Michigan State College Farm, near East Lansing. There were two plots of each of the following:

Smooth brome grass

Orchard grass

Alfalfa - smooth brome grass mixture

Alfalfa - orchard grass mixture

Kentucky bluegrass

Kentucky bluegrass - white clover mixture

In the spring of 1938, these plots were each divided into four equal parts, 15 feet long and 10 feet wide. One of these smaller areas in each plot was cut at approximately one inch above the ground with a power-driven lawn mower; a second and third were cut at 3 and 6 inches, respectively, with a horse-drawn mower; and the fourth was left to be cut later for hay in the usual manner.

The plots which were cut at one, 3, and 6 inches, respectively, were cut seven times during 1938. During 1939 the plots which were cut at one inch were cut six times, while those which were cut at 3 and 6

inches were cut only five times each. The length of interval between successive cuttings depended upon the rate of forage growth and increased as the rate of growth decreased. The hay plots were cut twice each season.

The total yields of forage, in pounds of dry matter, harvested from these plots in 1938 and 1939 are given in Table 6. These yields are also calculated on the acre basis. With one exception (the pure Kentucky bluegrass plots in 1938), the plots which were cut at 3 inches outyielded those that were cut at 6 inches; and in many instances, the plots cut at one inch outyielded those cut at six inches.

With a few exceptions, the hay plots far outyielded the corresponding plots which were cut more frequently. Hay yields were considerably greater when alfalfa was present than in plots containing no alfalfa. The low yields produced by the pure grass plots in 1939 reflected the deficiency of soil nitrogen as well as the dry season. The darker green color and more vigorous growth of the grasses when growing with a legume indicated that the legume was making some additional nitrogen available to the grasses.

On all but the alfalfa and the alfalfa-grass hay plots, most of the annual forage was produced before the middle of June. The second cuttings of alfalfa and of alfalfa-grass hays were only about one-half as large as the corresponding first cuttings.

Judging from the thinning out of the stands, all species, except bluegrass and white clover, were injured some by frequent cutting at one inch, although the forage yields from these plots compared favorably with those made by the plots which were cut at higher levels.

TABLE 6. Summary of Total Seasonal Yields of Forage in Pounds of Dry Matter (Average of Two Plots.)

Species	Cutting Height	1938 Per Plot	1938 Per Acre Basis	1939 Per Plot	1939 Per Acre Basis
Brome Grass	1 inch	6.87	1995.05	3.96	1149.98
" "	3 inches	9.14	2654.26	4.60	1335.84
" "	6 "	8.78	2549.71	3.54	1028.02
" "	hay	11.77	3418.01	4.40	1277.76
Orchard Grass	1 inch	5.44	1579.78	3.20	929.28
" "	3 inches	7.77	2256.41	2.67	775.37
" "	6 "	5.96	1730.78	1.09	316.54
" "	hay	8.86	2572.94	3.08	894.43
Alfalfa	1 inch	8.20	2381.28	4.30	1248.72
"	3 inches	9.42	2735.57	5.25	1524.60
"	6 "	7.89	2291.26	4.70	1364.88
"	hay	13.26	3850.70	10.99	3191.50
Alfalfa-Brome	1 inch	8.54	2480.02	5.20	1510.08
" "	3 inches	13.01	3778.10	6.23	1809.19
" "	6 "	9.36	2718.14	5.73	1663.99
" "	hay	14.55	4225.32	16.27	4724.81
Alfalfa-Orchard	1 inch	10.58	3072.43	5.84	1695.94
" "	3 inches	11.66	3386.06	4.77	1385.21
" "	6 "	10.33	2999.83	3.99	1158.70
" "	hay	14.18	4117.87	13.32	3868.13
Ky. Bluegrass	1 inch	2.20	638.88	1.82	528.53
" "	3 inches	4.29	1245.82	1.72	499.49
" "	6 "	4.29	1245.82	0.77	223.61
" "	hay	5.46	1885.58	2.38	691.15
Ky. Bluegrass and White Clover	1 inch	4.60	1335.84	3.38	981.55
"	3 inches	6.91	2006.66	3.93	1141.27
"	6 "	5.63	1634.95	1.79	519.82
"	hay	8.62	2503.25	4.12	1196.45

Cutting at 3 inches reduced the stand of alfalfa but caused no permanent injury to the grasses. Cutting at 6 inches did not reduce the

thickness of any of the stands, because adequate photosynthetic tissue remained below the cutting level to supply the carbohydrate requirements of the plants. Kentucky bluegrass and white clover produced considerable green tissue close to the ground and were able to manufacture sufficient carbohydrates to maintain plant vigor when cut at a height of only one inch.

DISCUSSION

Although close cutting of grasses usually results in an increase in the rate of plant growth for a short time, frequent repetition of such treatment causes a gradual decline in plant vigor, forage yield, and root production, due to carbohydrate deficiency. Carbohydrate deficiency occurs after the plant has used up its carbohydrate reserves and is unable to supply sufficient carbohydrates because of the frequent removal of its photosynthetic tissue. This condition was more acute in the greenhouse than in the field because the supplies of moisture and nitrogen were more adequate in the greenhouse, resulting in a more rapid depletion of the carbohydrate reserves. Also, because of the different methods used in cutting, the greenhouse plants which were cut at one inch were more nearly defoliated than were those cut at one inch in the field. In the greenhouse the leaves were raised and cut off at the designated height, whereas, in the field, leaves that were lying flat on the ground escaped cutting.

Low-growing forage plants, such as Kentucky bluegrass and white clover, produce more photosynthetic tissue close to the ground than is the case with more upright plants, such as smooth brome grass, orchard grass, and alfalfa. As a result of this green growth close to the

ground, the Kentucky bluegrass and white clover stands were not noticeably injured by frequent cutting at a height of one inch with a lawn mower.

While cutting does not exactly simulate grazing, the present experiment does give some indications as to how forage plants may respond to different systems of grazing. Kentucky bluegrass and white clover can be grazed continuously at a lower level than can smooth brome grass, orchard grass, and alfalfa without permanent injury to the stand. The annual yield of dry matter produced by most tame pastures is lower, under any system of grazing, than could be obtained if the forage were harvested for hay.

Under the climatic conditions prevailing in southern Michigan, there is very little growth of perennial grasses and shallow-rooted legumes, such as white clover, during the hot, dry months of July and August. Alfalfa, having a deep root system, does make some growth during this period, but at a slower rate than during May and June.

The published results of several experiments (Carrier and Oakley (2), Hein and Cook (4), and others) indicate that alternate grazing has very little advantage, if any, over continuous grazing. The results of the present experiment, with grasses in the greenhouse and with alfalfa in the field, however, indicate that where moisture is sufficient to keep the forage plants growing throughout the entire grazing season, some system of rotation grazing which allows for each pasture to be grazed relatively close, followed by a rest period sufficiently long for the plants to make a good recovery, will give a greater yield of higher quality forage than can be obtained under any intensity of

continuous grazing. Such systems of rotation grazing are now being practiced on some of the irrigated pastures of the Far West.

Available nitrogen is one of the most common limiting factors in the growth of pasture grasses. It is also one of the most expensive nutrients to supply in the form of commercial fertilizer. This available nitrogen can often be more cheaply furnished to grasses by legumes growing with the grasses. Wherever practicable, the aim should be to establish and maintain a mixture of legumes and grasses rather than a straight grass pasture.

The chemical analyses in the present experiment are not very comprehensive, but they do indicate that young, rapidly growing grass, well supplied with nitrogen and moisture, is very high in crude protein content and relatively low in soluble carbohydrates. Perhaps this is one reason why such forage is often lower in feeding value than grass which is a little more advanced in maturity.

Archibald (1), Willard (7), and others have suggested that differences in palatability among certain forage species were associated with differences in chemical composition. Most of the investigators who have compared smooth brome grass and orchard grass in palatability have considered brome the more palatable, especially in the later stages of growth. In the present experiment, brome grass samples were generally somewhat higher than orchard grass in crude protein and calcium; and, in some instances, brome grass also had a higher sugar content. These differences did not appear great enough, however, to account for any marked differences in palatability.

SUMMARY

Smooth brome grass and orchard grass were cut at heights of 1, 3, 6, 9, and 12 inches and at intervals of 1, 2, 4, and 8 weeks in the greenhouse. In the field they were grown alone and in mixtures with alfalfa and were cut from five to seven times per year at heights of 1, 3, and 6 inches and twice for hay. The field trials also included plots of Kentucky bluegrass and a mixture of bluegrass and white clover.

Frequent close cutting in the greenhouse stimulated the growth of forage for a short time but soon resulted in decreased yields of both forage and roots. The other cutting treatments in the greenhouse did not have any marked effects upon the total yield of forage or underground parts.

In the field plots, cutting for hay resulted in the greatest seasonal yields of forage; but the plots which were cut at 3 inches outyielded those cut at 6 inches. Legumes, by supplying nitrogen, had a stimulating influence upon the growth of the grasses.

The chemical data indicate that young, rapidly growing grasses, well supplied with nitrogen and moisture, are very high in crude protein but relatively low in soluble carbohydrates.

LITERATURE CITED

1. Archibald, J. G., "Studies in the Chemistry of Pasture Grasses." Massachusetts Agricultural Experiment Station Bulletin 347 (annual report), page 23, 1937.

2. Carrier, L. and R. A. Oakley, "The Management of Bluegrass Pastures." Virginia Agricultural Experiment Station Bulletin 204, 1914.

3. Gordon, A. and A. W. Sampson, "Composition of Common Foothill Plants as a Factor in Range Management." California Agricultural Experiment Station Bulletin 627, 1939.

4. Hein, M. A. and A. C. Cook, "Effect of Method and Rate of Grazing on Beef Production and Plant Population of Pastures at Beltsville, Maryland." U.S.D.A. Technical Bulletin 538, 1937.

5. Leukel, W. A. and J. M. Coleman, "Growth Behavior and Maintenance of Organic Foods in Bahia Grass." Florida Agricultural Experiment Station Technical Bulletin 219, 1930.

6. Leukel, W. A. and R. M. Barnette, "Cutting Experiments with Bahia Grass Grown in Lysimeters." Florida Agricultural Experiment Station Technical Bulletin 286, 1935.

7. Willard, H. S., "Factors Influencing the Palatability of Hay." Wyoming Agricultural Experiment Station Bulletin 199, 1933.