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EFFECT OF CUTTING INTERVAL AND STAGE OF MATURITY ON THE DIGESTIBILITY AND YIELD OF ALFALFA [1, 2]

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THE goal of the alfalfa producer is to obtain the largest yield of high quality forage consistent with reasonable stand survival. Peterson and Hagan (1953) demonstrated that the largest total yield of dry matter for the season was obtained when alfalfa and grass were clipped at a five-week interval in comparison with either two-, three- or four-week cutting intervals. Jones *et al.* (1953) have shown that the dry matter yield per acre increases per cutting up until the time of full bloom which may be as long as 50 to 60 days after the previous cutting; but from the quality standpoint and seasonal production per acre, the protein and carotene content decline and the fiber and lignin increase as the alfalfa becomes more mature and as the cutting interval is lengthened.

Numerous investigations have been conducted on the effect of cutting time on the feeding value of the hay, seasonal yield, and survival of the stand. Dawson *et al.* (1940) have reviewed the early literature on this subject. Sotola (1927) summarized the recommendations available at that time as follows: "Recommendations favor the early bloom stages—7 for 1/10 bloom, 4 for early bloom, 2 for 1/4 bloom, 4 for 1/3 bloom and 2 for full bloom". The difficulty in assessing this earlier work is that no definite system was used in describing stage of maturity. Kivimäe (1959) has recently reviewed the literature on the effect of maturity on chemical composition and digestibility of forage crops. He reports on the effect of cutting, season and chemical composition on digestibility of red clover and timothy.

Reid *et al.* (1958) discussed the influence of cutting date on digestibility based on the Cornell studies which demonstrate the superiority of early-cut forages over those harvested late. They also point out the fallacy of using dry matter yield as a single index of productiveness.

The studies reported in this paper were designed to determine the effect on yield and digestibility of alfalfa cut at varying calendar intervals as well as according to definitely described stages of maturity. Yield of dry matter and protein from alfalfa cut at four stages of maturity over three seasons is reported as well as the effect on yield during the fourth season when all plots were cut at the same stage of maturity.

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Experimental Methods

Studies on the Effect of Cutting Interval Upon Yield and Digestibility. When alfalfa is used for pasture or for soilage, a definite schedule of cutting or pasture rotation is essential to a sound forage production pro-

TABLE 1. STAGE OF MATURITY OF ALFALFA WHEN CLIPPED

		Cutting interval			
Harvest dates		Three weeks	Four weeks	Five weeks	Six weeks
April	14	First cutting removed			
	21				
	28				
May	5	Pre-bud			
	12		Early bud		
	19			9% bloom	
	26	Pre-bud			65% bloom
June	2				
	9		Bud		
	16	Pre-bud			
	23			53% bloom	
	30				
July	7	Pre-bud	14% bloom		Full bloom
	14				
	21				
	28	Pre-bud		60% bloom	
		Early bud			
August	4		20–30% bloom		
	11				
	18	Pre-bud			Full bloom
	25				
September	1		Late bud	33% bloom	
	8	Pre-bud			
	15				
	22				
	29	Pre-bud	Bud		20% bloom
October	6			Bud	
Seasonal average		Pre-bud	5% bloom	31% bloom	71% bloom

gram with properly scheduled irrigation and recovery periods. The first study was therefore on a calendar basis. Seasonal differences in yield will result in an excess of forage during the fast growing season on this type of schedule for pasture or soilage, but the surplus can be either harvested for silage or hay and fed later.

For this study a uniform second-year stand of California Common alfalfa was selected. The first crop of hay was harvested from the tract on April 14, 1954 and discarded. Following the removal of the first crop, the area was divided into 24 blocks, 20 × 25 ft. in size and randomized into four treatments with six replications. The clipping schedule and the stage of maturity of the alfalfa at each clipping are shown in table 1. The alfalfa was irrigated eight times during the course of the experiment so water was not a limiting factor at any time.

On the morning of each cutting date, six 25-culm samples (one from each replication) were taken per treatment. The stage of maturity was determined by counting the number of culms which had reached a particular stage of growth and were described as pre-bud, bud or a percent of bloom. For example, if 10 culms out of a 100-culm sample showed flowers, it was called 10% bloom (figure 1). The six samples were oven-dried and analyzed for carotene and nitrogen. In the afternoon following sampling, the plots were mowed with a regular mowing machine. For yield determination, a six-ft. swath, 20 ft. in length, was cut and weighed for total green weight and a five-lb. sample from each replicate was retained for dry matter determination. The remaining material from each replication was collected on canvas and dried in the shade for the digestion trials. The green material was turned as often as necessary to insure proper curing. When dry enough it was chopped and further dried until completely cured and then stored in paper bags. For the feeding tests,

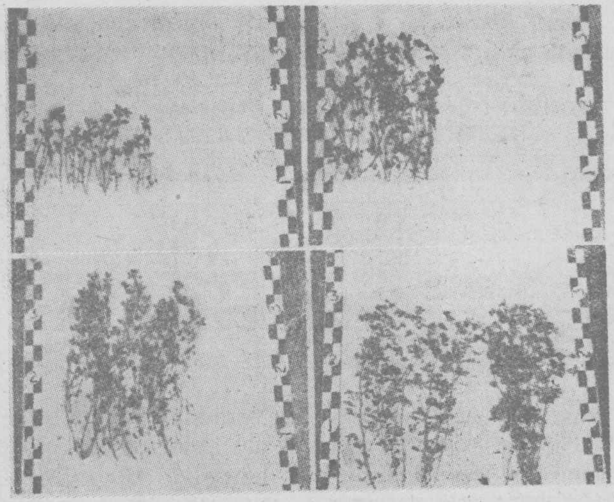

Figure 1. Stages of maturity of alfalfa.
Upper left: Pre-bud.
Upper right: Bud.
Lower left: 1/10 bloom.
Lower right: 1/2 bloom.

proportional amounts based on the yield of each cutting were carefully blended to provide a uniform feed from each cutting interval.

For the digestion trials, wethers in a 4 × 4 Latin square design were used. Seven-day preliminary periods and seven-day collection periods were used. All chemical analyses were by A.O.A.C. methods (1955). Total digestible nutrients were calculated by the conventional method. The lignin analyses were made by the method of Ellis *et al.* (1946). True digestibility of protein was calculated by multiplying the factor of .02811 by the dry matter intake in grams to obtain the metabolic protein in the feces (Blaxter and Mitchell, 1948).

Effect of Stage of Maturity on Digestibility, Yield and Stand Survival. Cutting the alfalfa on a calendar basis as described above resulted in hay

TABLE 2. DESCRIPTION OF ALFALFA USED (SECOND CUTTING) IN THE 1955 DIGESTION TRIAL

Stage of maturity	Date cut	Days' growth	Height, in.
Pre-bud	5/8	18	15
1% bud	5/12	22	21
62% bud	5/16	26	26
11% bloom	5/21	31	35
46% bloom	5/26	36	38
96% bloom	6/3	43	42

of widely varying quality because the stage of maturity at cutting differed within the cutting intervals (table 1). Yield also dropped markedly as the season progressed, particularly with the shorter cutting intervals. Two additional studies were designed to study the effect on digestibility and yield when alfalfa was cut by stage of maturity. The first was to determine the effect of six stages of maturity on digestibility. The second was to study over a period of four years the effect of continued cutting of alfalfa at four stages of maturity on yield, chemical composition and stand survival.

For the digestibility studies another field of California Common alfalfa was selected. The entire field was mowed on April 20, 1955 to establish a uniform starting date. The forage for feeding was harvested on the dates and at the stages of maturity shown in table 2.

The material for each treatment was cut with a forage harvester and taken immediately to a commercial dehydrator, where it was dried and ground. The ground forage was then bagged and later pelleted into 3/8-inch pellets. For digestion trials, wethers in a 6 × 6 Latin square design were employed. Again, seven-day preliminary periods with seven-day collection periods were used. Total digestible nutrients were obtained by the digestible organic matter method of Lofgreen (1953).

For yield and stand survival studies a new seeding of Caliverde alfalfa was selected for a four-year trial on the effect of harvesting at pre-bud,

bud, 1/10 bloom and 1/2 bloom stages of maturity. Plots 20 × 30 ft were replicated six times for each stage of maturity. Each spring the first cutting was taken from all plots at the same time without regard to stage of maturity. This removed the winter growth and provided a uniform starting date for all plots. Except in 1955 when the first cutting on the new stand was mainly weeds, yield and composition of this material were recorded, but as this forage was not of the same quality as that obtained by cutting at the specified stages of maturity, yield data are reported

TABLE 3. CUTTING DATES OF ALFALFA HARVESTED AT FOUR STAGES OF MATURITY

Cutting number	Stage of maturity			
	Pre-bud	Bud	1/10 bloom	1/2 bloom
1955				
1	May 26	May 26	May 26	May 26
2	June 16	June 22	June 29	July 6
3	July 8	July 18	July 29	Aug. 10
4	28	Aug. 12	Aug. 30	Sept. 20
5	Aug. 18	Sept. 9	Oct. 11	Oct. 11[a]
6	Sept. 9	Oct 11		
7	Oct. 11			
1956				
1	Apr. 9	Apr. 9	Apr. 9	Apr. 9
2	May 16	May 22	June 1	June 8
3	June 8	June 18	29	July 13
4	29	July 13	July 30	Aug. 16
5	July 20	Aug. 6	Aug. 29	Sept. 21
6	Aug. 13	Sept. 4	Oct. 3	
7	Sept. 4	Oct. 5		
8	Oct. 9			
1957				
1	Mar. 25	Mar. 25	Mar. 25	Mar. 25
2	Apr. 22	Apr. 29	May 6	May 13
3	May 13	May 27	June 10	June 17
4	June 6	June 21	July 5	July 15
5	27	July 15	Aug. 6	Aug. 15
6	July 19	Aug. 9	Sept. 6	Sept. 20
7	Aug. 12	Sept. 3	Oct. 12	Oct. 17[b]
8	Sept 3	Oct. 7		
9	Oct. 3			
1958	All cut at approximately 1/10 bloom			
1	Apr. 16	Apr. 16	Apr. 16	Apr. 16
2	May 26	May 26	May 26	May 26
3	June 26	June 26	June 26	June 26
4	July 25	July 25	July 25	July 25
5	Aug. 19	Aug. 19	Aug. 19	Aug 19
6	Oct. 2	Oct. 2	Oct. 2	Oct. 2

[a] No bloom.
[b] Early bloom

both with and without the first cutting for 1956 and 1957. Using the method described above for determining stages of maturity, each plot was harvested as it reached the appropriate stage. The dates and numbers of cuttings at each stage are shown in table 3. At cutting time green weight was obtained and a representative sample from each replication of the forage was taken for the determination of dry matter and protein. This treatment of all plots was continued for three years (1955, 1956 and 1957). To test the effect of this differential cutting on stand survival and plant vigor, all plots were harvested at the same stage of maturity (approximately 1/10 bloom) during the 1958 growing season.

Results

Cutting Interval Study (Calendar Basis—1954). Yield and composition of the alfalfa cut at 3-, 4-, 5- and 6-week intervals are shown in table 4.

TABLE 4. YIELD AND AVERAGE COMPOSITION OF ALFALFA PRODUCED BY CUTTING AT THREE-, FOUR-, FIVE- AND SIX-WEEK INTERVALS

No. of cuttings	Yield per acre, lb.		Composition, dry basis		
	Dry matter	Protein	Protein, %	Carotene, p.p.m.	Crude fiber, %
	Three-week cutting interval				
8	10,512	2,603	25.3	260	22.2
	Four-week cutting interval				
6	15,750	3,153	20.5	229	26.1
	Five-week cutting interval				
5	18,566	3,188	17.4	208	28.9
	Six-week cutting interval				
4	18,782	2,881	16.3	167	30.2

Harvesting at three-week intervals markedly reduced the yield of dry matter with a very sharp drop in production late in the season. Although protein and carotene in this harvested material were high, the protein yield was the lowest for this treatment. The four-week cutting interval also resulted in some reduction in yield late in the season but the effect was less marked than with the three-week interval. The dry matter yield per acre at the five-week interval approached that of the six-week interval and produced the highest yield of protein per acre. It should be noted that the growing period for the five-week interval was 25 weeks as compared to 24 for all other treatments.

The composition of the composite hay is shown in table 5. The decrease in lignin in the six-week cutting interval compared to the five-week cutting interval may be explained by larger amounts of recurrent growth in this

TABLE 5. COMPOSITION OF HAY FED IN 1954 DIGESTION TRIALS (DRY BASIS)

Cutting interval	Crude protein	Crude fiber	Lignin	Nitrogen-free extract	Ether extract	Ash	Carotene
	%	%	%	%	%	%	p.p.m.
3 weeks	27.8	21.8	7.1	37.8	1.4	11.2	17
4 weeks	22.1	27.2	8.0	38.9	1.2	10.6	14
5 weeks	18.2	31.1	9.5	40.3	1.0	9.4	19
6 weeks	17.6	31.1	9.3	41.0	1.3	9.0	12

sample. The recurrent or new growth was observed to be 6 to 8 inches in height at cutting time for the six-week interval.

The digestibility and total digestible nutrient content of the four types of hays are reported in table 6. The digestibility of the organic matter, protein and the nitrogen-free extract and the total digestible nutrient content decreased with each increase in the cutting interval. There was little if any difference in fiber digestibility at the four- and five-week cutting intervals, but the fiber of the six-week cutting interval was markedly less digestible than that from the three-week cutting interval. The true digestibility of the protein showed no difference.

The net result in terms of digestible protein and total digestible nutrient yield per acre for the season (less the first cutting) is given in table 7. The greatest yield of digestible protein came from the four-week cutting interval, while the largest yield of total digestible nutrients came from the five-week cutting interval. Unless high protein forage demands a particu-

TABLE 6. DIGESTION COEFFICIENTS AND TOTAL DIGESTIBLE NUTRIENTS OF ALFALFA CUT AT VARIOUS INTERVALS 1954

Cutting interval	Organic matter	Crude protein: Apparent digestibility	Crude protein: True digestibility	Crude fiber	Nitrogen-free extract	Total digestible nutrients (dry basis)
3 weeks	71.1 (1.3)[a]	84.3 (.7)	94.4 (1.3)	51.4 (2.8)	76.1 (1.3)	63.4 (1.0)
4 weeks	65.6 (1.9)	81.3 (.5)	94.0 (1.1)	45.5 (3.7)	73.4 (2.0)	58.9 (1.0)
5 weeks	64.0 (1.0)	78.3 (.5)	93.9 (.9)	48.0 (2.0)	72.0 (2.0)	58.1 (1.0)
6 weeks	61.0 (2.3)	76.4 (1.9)	92.3 (3.0)	40.7 (4.7)	71.8 (2.0)	55.6 (2.0)
LSD (.05)	3.1	1.5	N.S.	6.0	2.0	2.1
(.01)	4.7	2.3	....	9.1	3:0	3.2

[a] Standard deviation.

TABLE 7. YIELD OF DIGESTIBLE PROTEIN AND TOTAL DIGESTIBLE NUTRIENTS PER ACRE 1954

Cutting interval	Digestible protein, lb.	Total digestible nutrients, lb.
3 weeks	2,194	6,665
4 weeks	2,563	9,277
5 weeks	2,496	10,787
6 weeks	2,201	10,443

lar premium, it appears that under the conditions of this experiment the five-week interval would be the most economical basis to use in planning a cutting interval.

The effect of the varying cutting intervals on plant vigor is shown in the root and crown size, in the dry matter production and in the ability of stands to compete with weeds (figure 2). The root and crown weights, expressed as percentage of plants by treatments in December, 1954, following the cutting interval program, were in the order of 100% for the 42-day interval, 82% for the 35-, 62% for the 28-, and 45% for the 21-day cutting interval. The dry matter yield for the first cutting in 1955 for the six-week interval plots was 3,000 lb.; the five, 2,760; the four, 2,220; and for the three-week interval plots, 2,100 lb. per acre. Weeds accounted for 1.0% of the yield of the 35- and 42-day cutting interval, while 23% and 36% of the yield of the 28- and 21-day interval, respectively, consisted of weeds.

Cutting Interval Based on Stage of Maturity (1955)—Digestibility Study. The composition and yield of alfalfa cut according to stage of

Figure 2.

Left: Crown and tap root following various cutting intervals, A—3-week; B—4-week; C—5-week; D—6-week.

Right: Adjoining plots first cutting alfalfa in the spring of 1955. At left, plot cut at 6-week interval; at right, plot cut at 3-week interval during 1954 growing season.

TABLE 8. COMPOSITION OF ALFALFA CUT ACCORDING TO STAGE OR MATURITY SECOND CUTTING (1955)

Vegetative stage	Composition, dry basis		
	Protein	Crude fiber	Lignin
	%	%	%
Pre-bud	30.9	15.2	5.3
1% bud	26.9	20.9	6.4
62% bud	25.2	21.7	6.6
11% bloom	21.3	27.3	8.2
46% bloom	19.1	28.5	8.2
96% bloom	16.9	31.4	8.3

maturity are shown in table 8. The pre-bud stage produced high-protein and low-fiber hay, the protein decreasing and the fiber and lignin increasing as the plants matured.

The digestion coefficients for organic matter, protein, the true digestibility of the protein (corrected for metabolic protein in the feces) and the total digestible nutrients of the alfalfa cut at the six stages are given in table 9. The digestibility of the organic matter decreased rapidly until the 11% bloom stage and then leveled out. The apparent digestibility of

TABLE 9. PROTEIN DIGESTIBILITY AND TOTAL DIGESTIBLE NUTRIENTS OF SECOND CUTTING ALFALFA HARVESTED AT SIX STAGES OF MATURITY—1955

Vegetative stage	Organic matter digestion coefficient	Crude protein		Total digestible nutrients (dry basis)
		Apparent digestion coefficient	True digestion coefficient	
Pre-bud	73.1 (2.4)[a]	78.8 (2.0)	87.9 (2.0)	66.1 (2.4)
1% bud	68.7 (1.7)	75.8 (1.0)	85.9 (.8)	61.9 (1.8)
62% bud	64.2 (5.1)	73.4 (3.4)	84.4 (3.4)	58.9 (5.1)
11% bloom	61.9 (3.8)	72.8 (2.7)	85.4 (2.7)	57.2 (3.9)
46% bloom	60.1 (2.7)	70.3 (2.2)	84.8 (2.2)	54.7 (2.7)
96% bloom	60.2 (3.8)	69.2 (3.0)	84.4 (3.0)	55.7 (3.9)
LSD (.05)	3.3	3.2	N.S.	3.0
(.01)	4.5	4.3	....	4.1

[a] Standard deviation.

the protein decreased from pre-bud to 62% bud and then leveled out. As in the previous year's results there was no difference in true digestibility of protein. The TDN was significantly lower in the bud stage than in the pre-bud stage with no significant difference in the bloom stages.

TABLE 10. YIELD OF ALFALFA CUT AT FOUR STAGES OF MATURITY FOR THREE GROWING SEASONS

Stage of maturity and year	No. of cuttings	Seasonal yield, lb. per acre: Including 1st cutting	Seasonal yield, lb. per acre: Without 1st cuttings (1956 and 1957)	Protein yield, lb. per acre: Including 1st cutting	Protein yield, lb. per acre: Without 1st cuttings (1956 and 1957)
1955					
Pre-bud	6	11,289	11,289	2,918	2,918
Bud	5	12,988	12,988	3,086	3,086
1/10-bloom	4	14,716	14.716	2,948	2,948
1/2-bloom	4	14,796	14,796	2,795	2,795
1956					
Pre-bud	8	17,373	12,277	4,291	3,347
Bud	7	19,892	15,130	4,436	3,543
1/10-bloom	6	22,731	17,881	4,755	3,645
1/2-bloom	5	21,867	16,785	4,240	3,107
1957					
Pre-bud	9	14,796	11,921	3,964	3,216
Bud	8	18,920	15,863	4,654	3,833
1/10-bloom	7	21,686	18,593	4,806	3,971
1/2-bloom	7	23,551	19,950	4,795	3,873
Total for 3 years					
Pre-bud	23	43,458	35,487	11,173	9,481
Bud	20	51,800	43,981	12,176	10,462
1/10-bloom	17	59,133	51,190	12,509	10,564
1/2-bloom	16	60,214	51,531	11,830	9,775
LSD	.05	3,652	3,710	806	711
	.01	4,458	9,953	1,127	869

Four-year Study on Yield, Composition and Stand Vigor. The seasonal yield of dry hay and protein produced during the three seasons when the plots were cut at the assigned stages of maturity is shown in table 10. All cuttings were made according to plan except that the last cutting to be cut at the half-bloom stage failed to flower in October, so it was harvested without proper flowering in 1955 and 1957. The data showing all cuttings give the total forage produced from May 26, 1955 to early October 1957. The next column which omits the first cutting in 1956 and 1957 represents the total forage cut at the specified stages of maturity.

Analysis of variance on the yield data for the total dry matter for the three seasons showed highly significant differences for treatment and replications. Analysis of variance by season showed highly significant treatment and season effects with a highly significant interaction for season by treatment. When the interaction value was used as the denominator, treatment was highly significant both with and without the first cuttings included; season was highly significant with the first cuttings included but significant ($P<.05$) without the first cuttings included. Clearly, the alfalfa cut at the bloom stages produced more dry matter than that cut at the bud stage, and that cut at the pre-bud stage produced the least. Analysis of the protein yield data showed highly significant differences by treatments on the three-year total. When analyzed by season, highly significant values were obtained for treatment, season, replications and treatment x season interaction. When tested with the interaction value as denominator, only season was significant. The alfalfa cut at 1/10-bloom produced the most protein after the first season and that cut in the bud stage produced well in the first season but less in the second and third seasons. The pre-bud cut alfalfa produced almost as much as that cut at 1/10-bloom in the first season but dropped to the lowest protein production by the third season.

TABLE 11. YIELD OF ALFALFA DURING FOURTH SEASON AFTER BEING CUT AT FOUR STAGES OF MATURITY THE THREE PREVIOUS SEASONS

Previous treatment	No. of cuttings	Seasonal yield, lb. per acre	Protein yield, lb. per acre
Pre-bud	6	17,380	3,884
Bud	6	17,860	3,993
1/10-bloom	6	18,237	3,978
1/2-bloom	6	18,361	4,015
		N.S.	N.S.

The yield during the fourth season when all the alfalfa was cut at approximately 1/10 bloom is shown in table 11. Although the data appear to show a slight trend toward the plots cut previously at the more mature stages, analysis of variance showed the differences to be nonsignificant; that is, despite three seasons of differential cutting, the alfalfa produced at the same rate during the fourth season when all plots were cut at the same time. Stand counts made during the four years of this study showed no difference in plant density due to cutting treatments. The reduced yield of the more frequently cut plots resulted from fewer culms per plant and slower recovery after cutting.

Table 12 shows the average seasonal yield for the three years. To calculate the production of total digestible nutrients and digestible protein per acre, the digestibility data obtained earlier (table 9) for the various stages of maturity were used as the best available estimate. When the total yield is multiplied by the TDN content per pound, the greatest production of TDN is clearly by the alfalfa cut at the 1/10 bloom stage of maturity. The slightly greater dry matter yield of the 1/2 bloom alfalfa is more than offset by the reduced digestibility. The largest production of digestible protein came from the alfalfa cut at bud stage, followed closely by that cut at 1/10 bloom. With the pre-bud stage material, the high digestion coefficient could not overcome the low production, and with the 1/2 bloom hay the lower digestibility of the protein further depressed the amount of digestible protein available.

TABLE 12. CALCULATED YIELD OF TOTAL DIGESTIBLE NUTRIENTS AND DIGESTIBLE PROTEIN FROM ALFALFA CUT AT FOUR STAGES OF MATURITY

Stage of maturity	Pre-bud	Bud	1/10-bloom	1/2-bloom
Average seasonal yield, lb. per acre [a]	11,829	14,660	17,063	17,177
TDN per lb.	0.661	0.604 [b]	0.572	0.547
TDN yield, lb. per acre	7,819	8,855	9,760	9,396
Average protein yield, lb. per acre	3,160	3,487	3,521	3,258
Protein digestion coefficient	78.8	74.6 [b]	72.8	70.3
Digestible protein, lb. per acre	2,490	2,601	2,563	2,290

[a] Without the first cutting 1956 and 1957.
[b] Average of values for 1% bud and 62% bud.

Discussion

Although the results reported here are most applicable to irrigated alfalfa produced in an area with a long growing season, they demonstrate further the desirability of harvesting forage before it is so mature that decreased digestibility offsets the increased dry matter obtained as the forage matures. At the other extreme, forage cut at too immature stages, while highly digestible, will not continue to yield enough total forage to make the production of this product practical. The increased number of haying operations per season, coupled with the greater difficulty in drying the immature forage, further increase the cost and labor involved with the short cutting interval. The hay producer interested only in total hay yield will usually cut at the more mature stages—1/2 bloom or later—because he knows from experience that his total yield is high and the hay is easily cured. To produce the maximum feed value as indicated by TDN and digestible protein per acre, the hay should be cut in the late bud to early bloom stages. If hay purchasers buy on the basis of protein analyses or preferably lignin or crude fiber content as suggested by Meyer *et al.* (1959), hay producers will become more conscious of producing a quality product by harvesting at earlier stages of maturity.