THE GROWTH RESPONSES OF ALFALFA AND SUDAN GRASS IN RELATION TO CUTTING PRACTICES AND SOIL MOISTURE

By

Robert E. Dennis

A THESIS

Submitted to the School for Advanced Graduate Studies
of Michigan State University of Agriculture and
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Department of Farm Crops

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Approved C M Harrison

ABSTRACT

Alfalfa, (Medicago sativa) and Sudan Grass, (Sorghum vulgare) were arranged in a double randomized Latin square, and were cut weekly, bi-weekly, monthly and at six week intervals.

Yields were found to be associated directly with cutting interval--the oftener the plants were cut the less productive they became. However, the plants cut at the four week interval produced more crude protein than did those cut at the six week interval.

Root production and winter survival were curtailed by frequent cutting. Regrowth was stimulated by frequent cutting for a short period after which any new growth was definitely curtailed. Two thirds of the alfalfa top growth was produced by early July and nearly all Sudan grass top growth developed after July 1st.

Comprehensive studies of soil moisture were made to a depth of three feet using Bouyoucous blocks and gravimetric methods. Water consumed, per unit of forage produced, decreased as length of cutting interval increased. Alfalfa cut frequently used slightly less water than alfalfa cut at four or six week intervals, and less was used from the deeper soil horizons. The zone of most active water absorption by alfalfa plants cut at four and six week intervals shifted to a greater depth with time when rainfall was inadequate.

Most of the soil moisture used by Sudan grass was moisture which had been stored prior to July, and came from the upper 1 foot of soil. Differences in moisture use between the four cutting treatments were very slight.

Sudan grass used water more efficiently than did alfalfa during the period extending from early June to September. During the period of active plant growth, consumptive use of water per day was closely associated with rainfall.

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INTRODUCTION

Forage crops available for use during the summer grazing season are frequently arranged in a pasture calendar in order to use the various species most effectively. Alfalfa and Sudan grass fit together, the alfalfa being used during the first part of the grazing season and the Sudan grass during the latter part, when the alfalfa is less productive.

In Michigan, it would appear that water supply, stored soil moisture and rainfall during the growing season, is the key to production of both alfalfa and Sudan grass. When moisture becomes limiting, alfalfa production is limited, whereas Sudan grass culture may allow moisture conservation in the early growing season, and its consequent use later in the growing season.

With "green chopping," and "strip grazing" becoming more and more prevalent, questions arise as to the relationship of moisture supply to the production of different species of forage. Will frequent cutting or grazing result in less moisture use than cutting at less frequent intervals? From what part of the soil profile does the moisture come for alfalfa and Sudan grass? If irrigation is feasible, when should water be applied? To answer these and similar questions an experiment was set up on the Experiment Station farm, of Michigan State University, at East Lansing, Michigan to study the relationships between soil

moisture and production of alfalfa and Sudan grass under four different cutting treatments.

REVIEW OF LITERATURE

The effect of clipping frequency on root and top growth has been studied by many investigators. Hildebrand in 1938 (5) showed that frequent cutting of alfalfa resulted in food reserve depletion and a large decrease in yield and plant vigor. Kuhn and Kemp (7) found that increasing the severity of defoliation of bluegrass resulted in large significant decreases in root and top production. Harrison and Hodgson (4) found that frequent close cutting stimulated recovery growth for a short time, but severely reduced root and top production ultimately. Gernert (2) pointed out that the most frequently clipped grasses produced the smallest total quantity of roots and tops.

Studies have been made on the effect of cutting frequency on moisture ultilization at different soil levels. Duley (1) of Kansas reported that alfalfa grown continuously for four years depleted the deep subsoil moisture to a low point which remained almost constant thereafter. Hobbs in Kansas (6) reported that the soil was dry to only four feet following four years of brome grass. Alfalfa depleted the moisture to 18 feet after four years.

Toenjes, Higdon, and Kenworthy (10) obtained results which indicated that cutting treatments applied to Michigan grass and legume sods caused these sods to vary in the amount of water withdrawn from the soil.

Erickson and Willits (12) of the Michigan station studied the moisture used by two grasses and two legumes using Bouyoucos blocks.

They concluded that stage of crop development had more effect than weather on water use. Water use reached a maximum about July 1st, with a consumption of 0.13 inches per day. The top 9 inches of soil supplied most of the water used by the crops studied. When grasses were clipped frequently, less total water was used but a greater percentage was taken from the surface layer. The correlation between water used from a horizon and the amount initially present in the horizon was high. This correlation decreased with depth. Water appeared to be used from the horizon where it was most abundant.

Schofield (9) of the Rothamsted experiment station found that evaporation was governed by atmospheric conditions when a water table of 18 inches existed. Irrigation needs in this instance might be governed by atmospheric conditions. Northern humid regions rarely experience 18 inch water tables and an attempt to maintain field capacity at all times in these areas was impractical.

Hagan and Peterson of California (3) studied soil moisture extraction by irrigated pasture mixtures and observed nearly equal consumptive use for forages under several clipping frequencies. Large differences in yield therefore gave large differences in forage production per unit of water consumed. Then also concluded that consumptive use rates were little affected by botanical composition.

Van Horn (11) of Tennessee, using a mixture of orchard grass-Ladino clover, found a water requirement of two inches for each 10 day period during the April to October season. When the rainfall dropped below two inches in two weeks in the summer, McKibben (8) working in

Illinois found that additional water was needed to maintain maximum growth of a grass-legume mixture.

PART I

FORAGE PRODUCTION

Procedure

Vernal alfalfa, (Medicago sativa) and Piper Sudan grass, (Sorghum vulgare) were used in pure species for this experiment. The soil was a moderately heavy Conover clay loam. Alfalfa was seeded August 1, 1955 at 11 pounds and fertilized with 400 pounds of 4-12-12 per acre. Plots to be sown to Sudan grass were plowed May 29, and seeded May 30, 1956. Sudan grass was sown at 25 pounds of seed per acre and 400 pounds of 12-12-12 fertilizer were applied. An alfalfa stand approximately 16 inches tall was plowed under for the Sudan grass.

The area used for the intensive trials of 1956 was divided into 32 plots, each 32 feet wide and 45 feet long. There were eight rows of plots, four of the rows being seeded to Sudan grass, and four to alfalfa, the two species being adjacent to each other in all cases. Alfalfa and Sudan grass plots were cut weekly, bi-weekly, monthly or every six weeks and each row of plots contained all four cutting treatments. The plots were arranged in a double randomized Latin square.

Forage yields were determined by mowing a strip 30 inches wide and 39 feet long through the center of each plot. Forage samples for moisture and crude protein were taken from all four replications, from all cutting treatments, on all harvest dates.

Alfalfa plots to be cut weekly were harvested on May 20, 1956, when the plants were 8 inches tall and these plots were cut 15 times. The first cutting for the two week treatment was made on May 28, 1956, and the plots receiving this treatment were cut bi-weekly a total of 8 times. Plots to be cut monthly were harvested for the first time on June 9, 1956, and a total of four harvests were made. Plots subjected to cutting at six week intervals were cut three times with the first cutting being made on June 23, 1956. Final cutting in 1956 for all alfalfa plots was August 27th.

The Sudan grass plots in this experiment were placed on an area which had been seeded to alfalfa on August 1st, the preceding year. Sudan grass plots were planted May 30, 1956. The first cuttings of Sudan grass were made June 30, 1956, when the plants were 16 inches tall. Those plots cut weekly were harvested 11 times, bi-weekly, 6 times monthly, 3 times, and plots cut every six weeks were harvested twice.

The alfalfa plots in the 1956 trials were left and harvested four times during the 1957 growing season, at 1/10 bloom.

A second alfalfa seeding was made on August 1, 1956, similar to that of 1955. The layout was identical with that used for the 1956 trial except that the plot width was reduced from 30 feet to 14 feet.

Sudan grass was seeded May 29, 1957, using 27 pounds of seed per acre, and 400 pounds of 12-12-12 fertilizer per acre. The alfalfa and Sudan grass were subjected to the same treatments used in 1956.

Roots were dug October 1st, in two systematically selected locations, in each alfalfa plot. A sample area 14 inches square and 18 inches deep

was used and all alfalfa roots were removed, counted, washed, dried, and weighed. These determinations were made on the alfalfa after one growing season in 1956, and again in 1957 on the second group of plots. The alfalfa plots used for the intensive trials of 1956 were harvested again in 1957, and root samples were taken from these plots October 2, 1957.

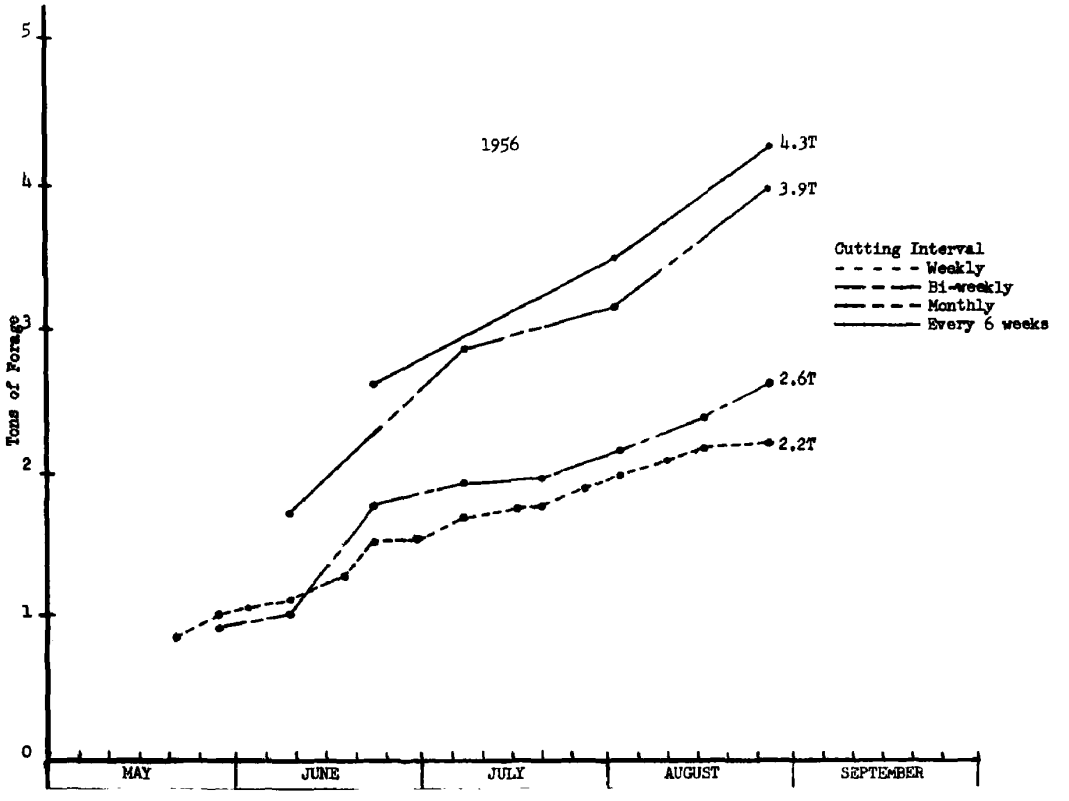
Samples obtained June 12, 1957, from the plots seeded August 1, 1955, were divided into alfalfa and non-alfalfa portions. Oven dry weights were taken and percentages determined. Detailed information on plant counts was obtained at the time the root weight determinations were made.

Results

Alfalfa

Yield of Forage. Alfalfa stands at the beginning of the season were excellent both years. The first cutting accounted for a substantial percentage of the total yield of the one and two week cutting frequencies in both 1956 and 1957, being 34.7% in 1956 and 33.4% in 1957. Plots cut frequently produced new growth, but as the season advanced most of the alfalfa was replaced by weeds.

The cumulative yield of alfalfa undergoing different cutting treatments is shown in Figure 1. Under the two week cutting treatment the plants did not reach the bud stage. The four week interval was approximately equivalent to cutting at the 1/10 bloom. Yields for each cutting are shown in Table 1.



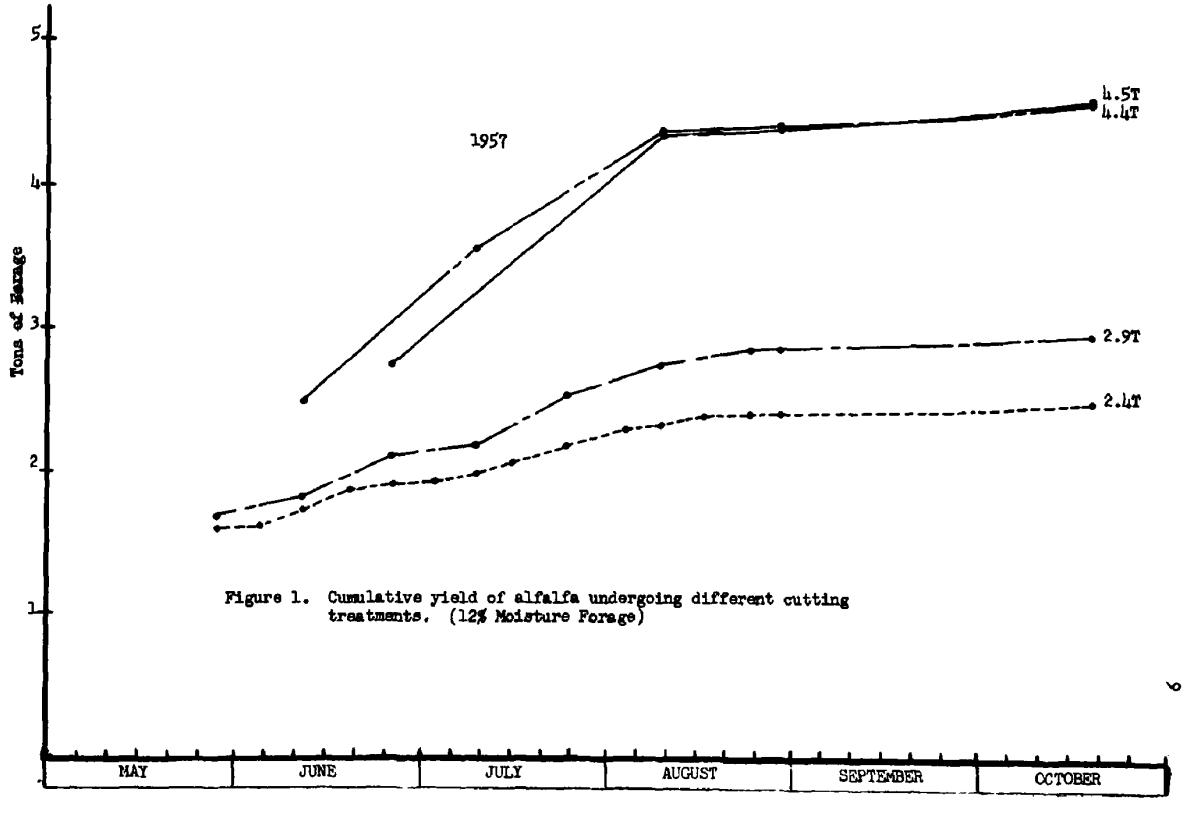


Figure 1. Cumulative yield of alfalfa undergoing different cutting treatments. (12% Moisture Forage)

TABLE I

THE PRODUCTION OF FORAGE BY ALFALFA
(12% Moisture)
Tons

Cutting Interval	Date of Cutting--1956															
	5/21	5/28	6/2	6/9	6/18	6/23	6/30	7/7	7/16	7/20	7/27	8/2	8/10	8/16	8/27	Total Tons
Weekly	.84	.19	.04	.05	.19	.23	.02	.14	.07	.02	.11	.09	.12	.08	.02	2.207
Bi-weekly		.93		.09		.76		.17		.05		.17		.24	.23	2.615
Monthly				1.72				1.14				.33			.74	3.923
Six weeks						2.61						.92			.74	4.263

	Date of Cutting--1957														
	5/28	6/4	6/11	6/19	6/26	7/2	7/9	7/15	7/24	8/2	8/9	8/16	8/24	8/29	Total Tons
Weekly	1.60	.004	.11	.15	.04	.03	.05	.07	.12	.13	.04	.04	.02	.01	2.402
Bi-weekly	1.68		.14		.28		.08		.33		.22		.12	.02	2.900
Monthly			2.48				1.05				.83			.09	4.462
Six weeks					2.73						1.60			.13	4.411

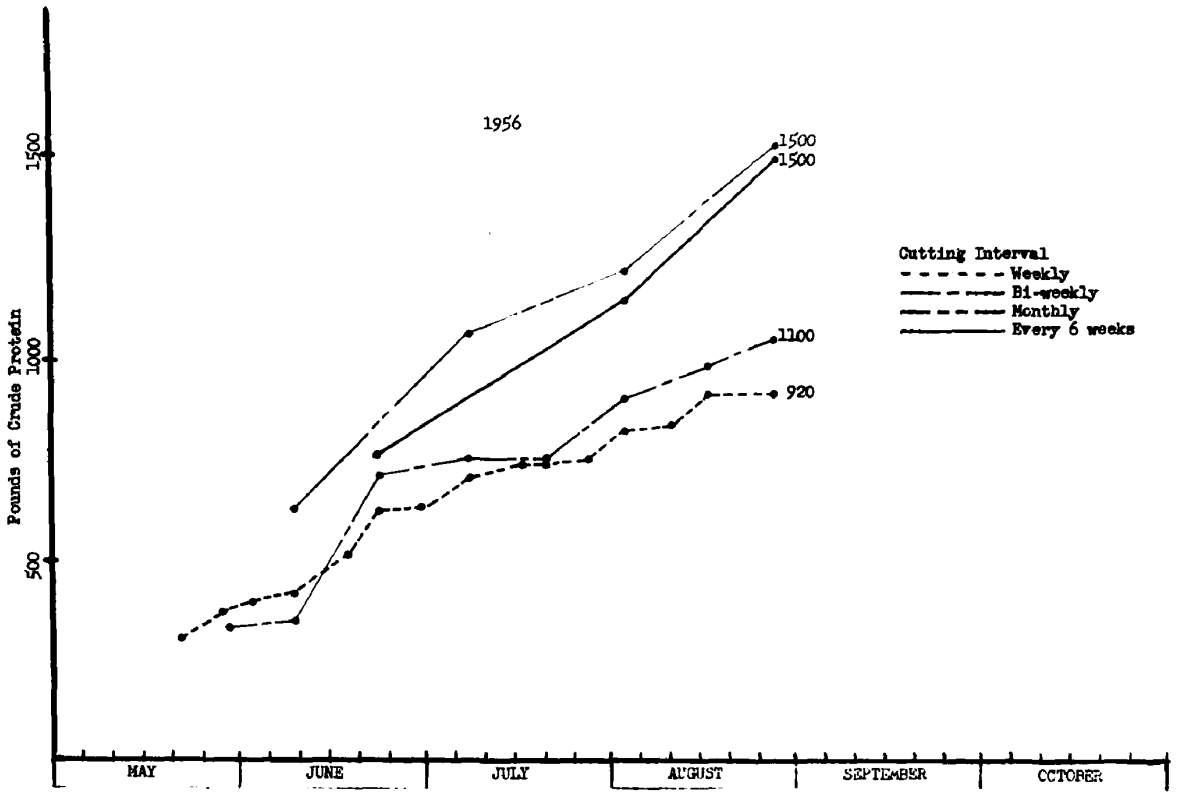
The two most frequent cutting treatments resulted in a vigorous growth of alfalfa in late June, 1956. The initial yield for these cutting treatments was higher in 1957 than in 1956, but the late June response was less pronounced in 1957. Late August yields for the plots cut bi-weekly were greater in 1956 than in 1957.

An analysis of variance and Studentized range test showed yields obtained from four and six week cutting interval plots were significantly larger than those obtained from one and two week cutting treatment plots. The least significant difference was found to be 0.34 tons. The first cutting provided the largest yield in all cutting treatments in both years.

Yield of Protein. Forage samples were taken from all replications, from all cutting treatments, on all harvest dates. These samples were dried immediately for moisture determination. The samples from the four replications were bulked for crude protein analysis in 1956, but determinations were made on each individual replicate sample in 1957.

Cumulative protein production is shown in Figure 2. Alfalfa cut weekly averaged 945, bi-weekly 1200, monthly 1550, and every six weeks 1650 pounds of crude protein per acre. Over 50% of the total protein yield was obtained from the first cutting of the plots cut at the four and six week intervals.

Reference to Figure 2 shows that the cumulative yield of crude protein followed the same pattern for both 1956 and 1957. The alfalfa cut at the four week interval in 1956 produced 98%, and in 1957, 83% as



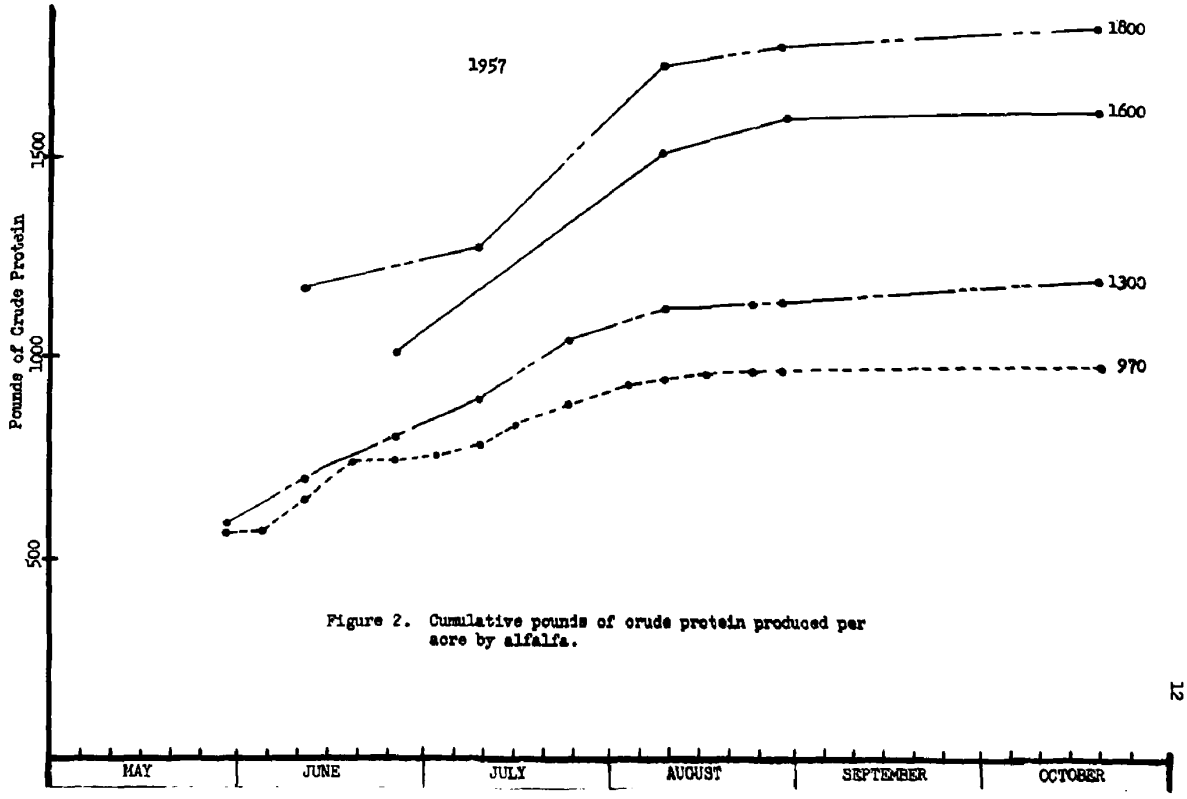


Figure 2. Cumulative pounds of crude protein produced per acre by alfalfa.

much protein as that cut at the six week interval. The percent of protein in alfalfa harvested under the different cutting treatments followed about the same pattern in the two years. The crude protein determinations for July 2, 1956, averaged 23.76% for the alfalfa cut at one and two week intervals. The percent of protein in the forage cut monthly dropped after August 2, 1956, and August 27, 1957, but increased in the last cutting at the six week interval.

Alfalfa cut frequently increased in percent protein after the first cutting had been removed, but then declined to a relatively constant level. Plots subjected to weekly and bi-weekly cutting treatments declined in percent of protein as the season advanced, probably due to the high percent of weed plants present in the stand. The average percent of crude protein in the alfalfa forage is shown in Table 2.

TABLE 2

THE AVERAGE PERCENT OF CRUDE PROTEIN IN ALFALFA FORAGE

	1956	1957
Weekly	23.30	22.39
Bi-weekly	22.54	22.44
Monthly	21.90	22.27
Every 6 weeks	19.75	19.63

Root Production. Sample areas 14 inches square and 18 inches deep were systematically located and the alfalfa removed in each to show the

top and root production (Tables 3 and 4). Analysis of Variance and Studentized range test on root production indicated significant differences between all cutting interval treatments except between those cut weekly and bi-weekly.

Alfalfa plots previously harvested at different frequencies in 1956 were harvested four times in 1957 at 1/10 bloom. Alfalfa roots dug from plots cut weekly weighed 51.5% as much as those removed from plots cut at six week intervals.

Dry matter per plant root was significantly less, on the plots cut frequently, at the end of the first growing season. Alfalfa cut more frequently had roots which penetrated only short distances. The alfalfa plots seeded August 1, 1955, were harvested in both 1956 and in 1957. Root weight averaged for all treatments was 67.8% greater in 1957 than in 1956. Differences for root production between treatments were large and were significant at the 0.01 percent level. Depth of root penetration was also greater during the second growing season.

Performance of Alfalfa in Year Following Varied Cutting Treatments. The 1957 root and top production of alfalfa following four different cutting treatments in 1956 and identical treatments in 1957 is shown in Table 5. Total yield for the weekly cut plots was significantly less than yield from the plots cut monthly and every six weeks. The least significant difference was found to be 0.58 tons.

Differences in total yield as a result of the previous cutting treatments in 1956 were small. However, plots cut every four weeks in

TABLE 3

THE ALFALFA ROOT PRODUCTION FOLLOWING VARIOUS CUTTING TREATMENTS IN 1956 AND IDENTICAL CUTTING TREATMENTS IN 1957

Plots Seeded August 1, 1955

Cutting Interval:	Weekly		Bi-weekly		Monthly		Every 6 Weeks	
Date of Sampling:	Oct. 1 1956	Oct. 1 1957	Oct. 1 1956	Oct. 1 1957	Oct. 1 1956	Oct. 1 1957	Oct. 1 1956	Oct. 1 1957
O.D.W. (Grams)	10.41	14.55	10.34	19.05	17.26	26.13	25.10	33.30
Number alfalfa plants	18.9	12.8	17.9	19.3	25.3	16.5	27.4	25.8
Dry matter per plant root (grams)	.55	1.14	.58	.99	.68	1.58	.92	1.29

TABLE 4

THE ALFALFA ROOT PRODUCTION ON PLOTS FOLLOWING VARIOUS CUTTING TREATMENTS IN 1957

Plots Seeded August 1, 1957

Cutting Interval:	Weekly	Bi-weekly	Monthly	Every 6 Weeks
Date of Sampling:	Oct. 1, 1957	Oct. 1, 1957	Oct. 1, 1957	Oct. 1, 1957
O.D.W. (Grams	7.29	8.30	19.25	26.98
Number alfalfa plants	14.4	15.9	25.9	25.9
Dry matter per plant root (grams)	.51	.52	.74	1.04

TABLE 5

THE 1957 PERFORMANCE OF ALFALFA PLOTS FOLLOWING FOUR DIFFERENT CUTTING TREATMENTS IN 1956

	1956 Cutting Interval			
	Weekly	Bi-weekly	Monthly	Every 6 Weeks
Total yield (tons/acre)	4.0	4.1	4.6	4.8
Percent alfalfa in yield obtained	32.2	35.7	77.1	97.0
Yield of alfalfa (tons/acre)	1.30	1.45	3.51	4.67
Oven dry weight of roots (grams) October 1, 1957	14.55	19.05	26.13	33.30
Dry matter per root (grams)	1.1	1.0	1.6	1.3

1956 yielded about 0.5 ton more in 1957 than did those cut more frequently in 1956. Alfalfa harvested at six week cutting intervals in 1956, produced in 1957 about 0.75 ton more total forage per acre than did the plots cut weekly in 1956. Most of the 1957 yield difference came in the third cutting.

Plots cut weekly and bi-weekly in 1956 had little alfalfa, but had excellent stands of self seeded red clover in 1957. There was some red clover in the plots cut at the four week interval, but almost none in the plots cut every six weeks in 1956.

The first cutting was sampled to determine the percentage of the total forage consisting of alfalfa. A yield of alfalfa only was

obtained by multiplying total yield by this percentage. Plots cut weekly in 1956 produced 1.30 tons of alfalfa in 1957, whereas plots cut every six weeks in 1956 produced 4.67 tons in 1957. On October 1, 1957 there were over twice as many alfalfa roots in the plots harvested at six week intervals in 1956 as there were in the plots harvested weekly in 1956. The least significant difference was found to be 4.61 grams.

Sudan Grass

Yield of Forage. Sudan grass seeded May 30, 1956, emerged more rapidly than did the Sudan grass seeded on May 29, 1957. Plants attained a height of 16 inches by July 1, 1956. The stand was not as uniform on July 1, 1957 as it had been in the previous year. Some plants were 16 inches tall on July 1, 1957 but half of the plants were only 8 to 10 inches tall.

Sudan grass yields are graphically presented in Figure 3. Total forage production decreased as cutting frequency increased.

The Sudan grass cut frequently seemed to produce more vigorous shoots and regrowth during the first part of the 1956 growing season than it did in July 1957. Table 6 and Figure 3 show that the yields for frequent cutting were larger in 1956 than in 1957. The 1957 yields for Sudan grass cut weekly and bi-weekly were only 54.3 percent as great as those obtained in 1956. An analysis of variance and Studentized range test showed yields obtained from four and six week cutting interval plots were significantly larger than those obtained from one and two week cutting treatment plots. The least significant difference for adjacent yields was 0.43 tons.

TABLE 6

THE PRODUCTION OF FORAGE BY SUDAN GRASS
(12% Moisture)
Tons

Cutting Interval	Date of Cutting--1956											Total Tons
	6/30	7/7	7/16	7/20	7/27	8/2	8/10	8/16	8/27	9/6	9/15	
Weekly	.31	.23	.28	.15	.19	.14	.23	.12	.15	.16	.05	1.984
Bi-weekly		.65		.27		.44		.34		.29	.08	2.063
Monthly				1.82				.94			.45	3.217
Six weeks						3.03					1.34	4.368

	Date of Cutting--1957												
	7/2	7/9	7/15	7/24	8/2	8/9	8/16	8/24	8/29	9/3	9/13	9/18	
Weekly	.09	.07	.08	.17	.21	.03	.07	.06	.02	.05	.02	.04	.906
Bi-weekly		.39		.31		.27		.13		.15		.05	1.292
Monthly				2.59				.52				.13	3.237
Six weeks						4.28						.49	4.771

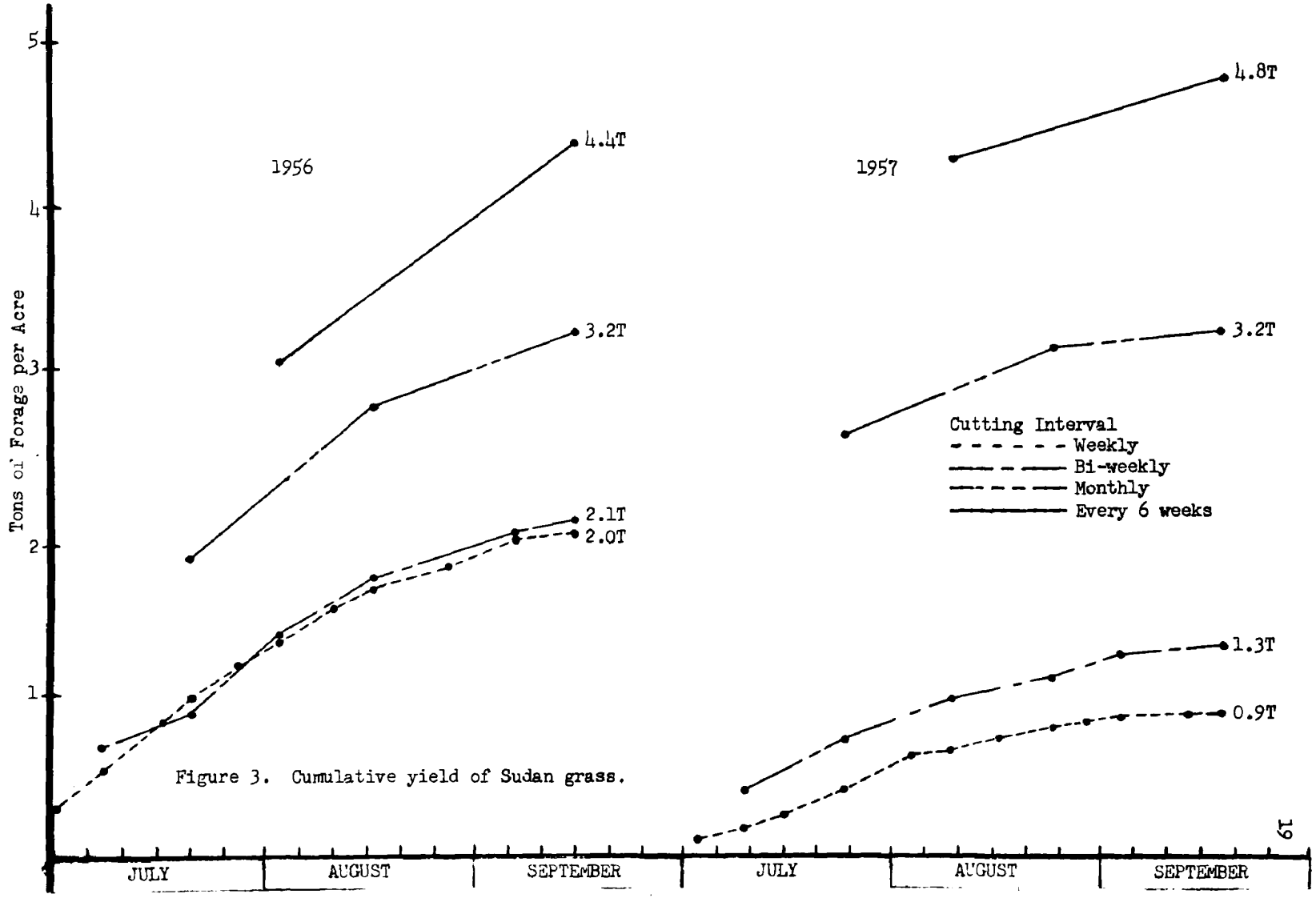


Figure 3. Cumulative yield of Sudan grass.

Sudan grass plots cut for the first time during the first week of August had headed out and were approximately 7 feet tall (Table 7). Plots cut both weekly and bi-weekly became very weedy by August 1st. The final cutting for both four and six week treatments produced a lower yield in 1957 than in 1956.

TABLE 7

THE AVERAGE HEIGHT OF SUDAN GRASS PLANTS IN INCHES

Cutting Interval	Date of Cutting										
	6/30	7/7	7/16	7/20	7/27	8/2	8/10	8/16	8/27	9/6	9/15
Weekly	16	7	6	5	3	4	5	4	3	2	4
Bi-weekly		24		10		14		12		4	3
Monthly				54				32			12
Six weeks						84					36

Table 7 shows that the plants at first made a quick recovery after being cut but regrowth declines as the season advances.

Yield of Protein. The percentage of crude protein in Sudan grass plants declined with the advance of the season in the plots cut weekly and bi-weekly but increased late in August 1957. This trend was not evident in 1956. The percent of crude protein in the plots cut at the four week interval remained almost constant for the three cuttings in 1956, but increased nearly 8 percent during the period August 24th to September 18th in 1957. The percent of protein in the forage taken

from the plots cut at the six week interval was 6.5 percent greater for the second cutting than for the first.

Figure 4 shows the cumulative yield of protein for the Sudan grass. All treatments produced nearly the same amount of crude protein in 1956. The plots subjected to cutting at four and six week intervals produced nearly twice as much protein per acre in 1957 as did those cut weekly and bi-weekly. The average percent of crude protein in Sudan grass forage is shown in Table 8.

TABLE 8

THE AVERAGE PERCENT OF CRUDE PROTEIN IN SUDAN GRASS FORAGE

	1956	1957
Weekly	22.29	22.40
Bi-weekly	21.33	18.77
Monthly	13.19	12.07
Every six weeks	9.47	8.46

Seasonal Production of Alfalfa and Sudan Grass

Table 9 shows the seasonal production of alfalfa and Sudan grass. Alfalfa made an early start in the spring, producing nearly two-thirds of its growth before the second week of July. Sudan grass made nearly all of its growth gain after this date.

The period of most vigorous growth for alfalfa was in May and June. The period of maximum growth for Sudan grass was in July and early August.

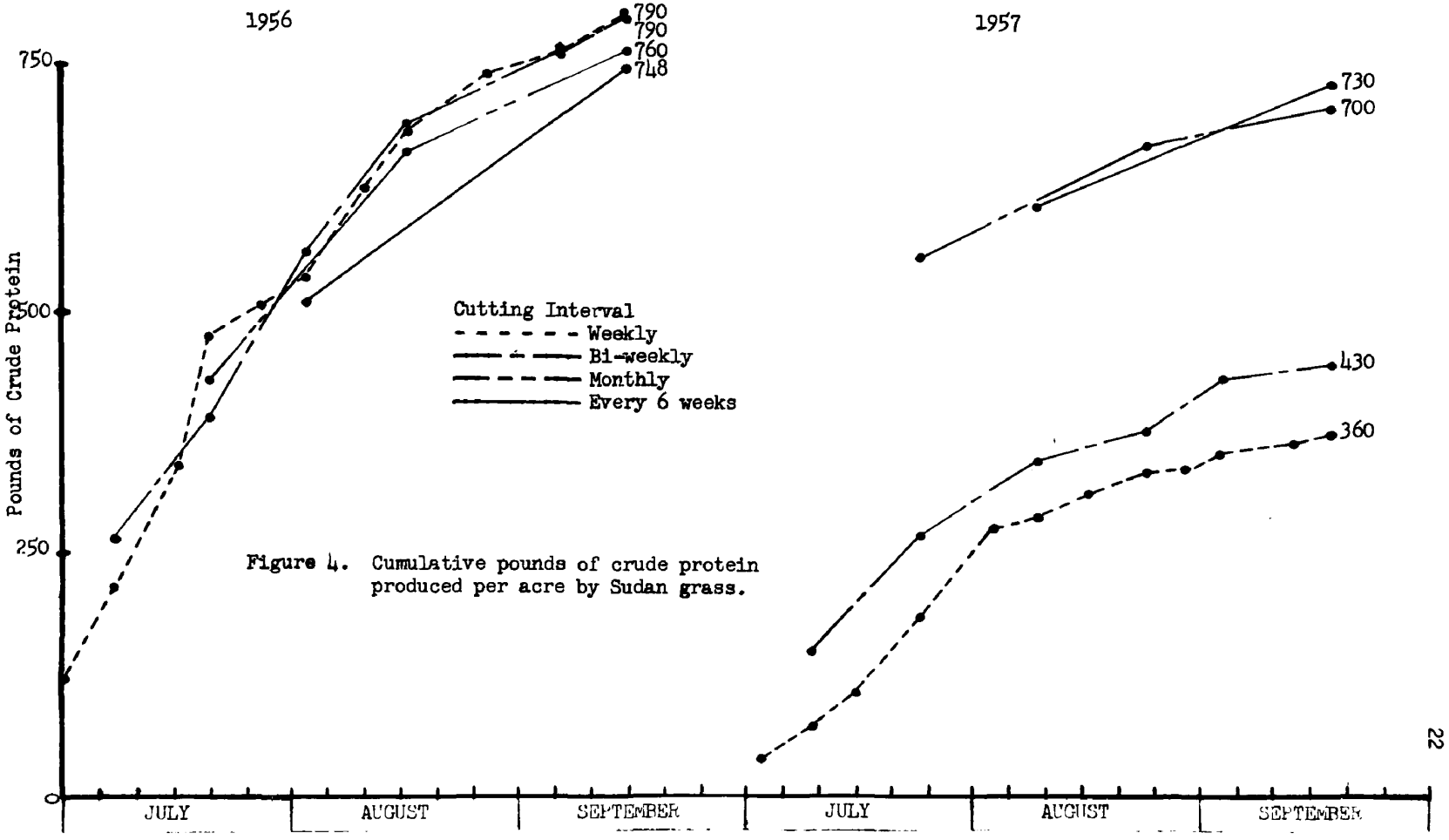


Figure 4. Cumulative pounds of crude protein produced per acre by Sudan grass.

TABLE 9

SEASONAL PRODUCTION OF ALFALFA AND SUDAN GRASS

(Tons of Forage)

Cutting Treatments	1956		1957	
	Before July 7	After July 7	Before July 9	After July 9
Alfalfa				
Weekly	1.70	.51	1.98	.43
Bi-weekly	1.95	.69	2.18	.69
Monthly	2.86	1.07	3.53	.92
Every six weeks	2.61	1.66	2.73	1.73
Sudan Grass				
Weekly	.54	1.47	.16	.75
Bi-weekly	.65	1.42	.39	.86
Monthly		3.22		3.24
Every six weeks		4.37		4.77

Discussion

The first evidences of alfalfa growth occurred about April 1st. By the middle of May the plants were about six inches tall, and a height of 16 to 18 inches was attained by June 1st.

July growth of alfalfa was greater in 1957 than in 1956. The August growth of alfalfa in 1956 was far greater than in 1957. It is interesting to note that 5.20 inches of rain fell in August 1956, with 2.54 inches coming in July. The situation was somewhat reversed in

1957 with 7.22 inches in July and only 1.55 inches in August. Growth was closely associated with current rainfall.

Alfalfa plants cut every week made a regrowth but soon the plots became very weedy as the regrowth of alfalfa after cutting became less and less. The plots cut at the bi-weekly interval fared but little better than did those cut once per week. Cutting the plots at four week intervals approximated cutting at 1/10 bloom. Practically no weeds were evident in the plots which were cut every four or every six weeks.

The plots receiving differential cutting treatments in 1956 were all cut at 1/10 bloom in 1957. Table 5 shows the alfalfa yield from these plots, after removal of the non-alfalfa portion from the total yield. Plots cut every four weeks in 1956 produced 2.69 times as much alfalfa in 1957, as did the plots cut weekly in 1956.

The six week cutting interval produced only slightly more alfalfa than did that from the four week interval and the latter produced the greatest amount of crude protein in both seasons.

Weekly and bi-weekly cutting treatments reduced the stand of alfalfa, and caused the plants to go into the winter season in a weakened condition. Most of the alfalfa plants remaining in the plots cut frequently in 1956 "heaved" one to two inches or more by the spring of 1957. There was practically no heaving of alfalfa cut at the four and six week intervals. In the spring of 1957, the vegetation on the plots cut frequently in 1956 was predominantly red clover which had volunteered.

Plant counts in 1957 disclosed only a trace of plants other than alfalfa, in the alfalfa subjected to the six week cutting interval in 1956. Reference to Table 5 shows that 77.1% of the vegetation in the plots cut at monthly intervals in 1956 was alfalfa at the time of first cutting on June 12, 1957.

Alfalfa plots cut in 1956 were not harvested after August 27th, in order to give the plants a greater chance for winter survival. However, growth during the late fall was very limited due to the fall drought.

Crude protein determinations using standard Kjeldahl procedure showed the superiority of four and six week cutting treatments in producing protein. The frequently cut alfalfa tended to be high in protein early in the season, but soon tapered off. Pounds of dry matter produced by frequently cut alfalfa were very small and even though the forage was high in crude protein, the total production was limited.

The first cutting produced 40.68% of the total protein in 1956 and 44.89% in 1957. Growth from early April until early June, therefore, represented a substantial portion of the total seasonal growth.

Frequent cutting of alfalfa reduced weight of roots produced as shown in Tables 2 and 3. Depth of root penetration was also reduced as cutting interval decreased. The influence of the 1956 cutting treatment on root development of alfalfa was again evident on October 1, 1957, although all plots had received identical treatment during the 1957 season.

The Sudan grass of 1956 withstood frequent cutting better than did that of 1957. Sudan grass was slow to emerge in 1957 and was not as vigorous at the time of the initial cutting as it was in 1956. Cutting the plots at heading time was a severe treatment, for several days passed before new growth from the crowns was visible. The plots cut at the four week interval were also slow to recover after the first cutting which was made July 20th in 1956 and July 24th in 1957. However, they did recover more quickly than plants allowed to grow two weeks longer before being harvested.

Alfalfa had begun bud and leaf formation by April 1st, and two-thirds of the top growth was produced by the early part of July. Soil moisture was at or above field capacity during most of this period. Top growth of alfalfa following early July was succulent and high in crude protein but total production was relatively small even when moisture conditions were favorable.

Growth of Sudan grass during the germination and seedling period was active but maximum rate of top growth did not take place until July. There was a phenomenal growth during this June and July period in the life cycle of the developing Sudan grass plant.

Growth during late August and September, as measured by leaf and shoot production, was small for both crops. Rain which fell during August stimulated Sudan grass growth, but this increase was small, the period of most active growth having passed.

Summary and Conclusions

A study was made of the effect of four cutting treatments on the performance of alfalfa and Sudan grass.

1. The yield of both alfalfa and Sudan grass was associated directly with cutting interval--the oftener the plants were cut the less productive they became.
2. Sudan grass, in both years, headed out prior to removal of the first cutting at the six week interval. As a consequence, the forage was coarse and lower in percentage of protein than those cuttings made at more frequent intervals.
3. Alfalfa and Sudan grass cut every six weeks was significantly lower in crude protein percentage than when cut monthly.
4. Competitive weeds were present in considerable amount at the close of the growing season in all plots cut frequently.
5. Root production and winter survival were curtailed by frequent cutting.
6. Regrowth was stimulated by frequent cutting for a short period after which any new growth was definitely curtailed.

PART II

MOISTURE UTILIZATION

Procedure

The plots used to study the effect of cutting frequency were also used to determine the effect of cutting treatment and crop on the use of soil moisture.

The soil of the experimental area was a moderately heavy Conover loam. The Ap layer consisted of a dark greyish-brown mellow loam about 8 inches thick. Beneath this was a grey or yellowish-grey friable gritty somewhat mottled loam. At about 15 inches this fraction graded into a more compact yet penetrable clay with nut-like structure. Soil below the 36 inch sampling depth consisted of clay loam calcareous glacial drift to a depth of several feet. The top soil was slightly acid before the investigation started and was treated with ground limestone. The plot area was nearly level.

An analysis of a composite sample of soil from the plow layer gave a hygroscopic coefficient of 0.60, and a moisture equivalent of 13.51 percent. Mechanical analysis of the top soil indicated 46.76 percent particles smaller than 0.05 mm. with almost 40 percent of the remainder fine sand and very fine sand. About 10 percent of the total weight was made up of particles less than 2 microns in diameter.

A comprehensive study of soil density was made by sampling the plot area in 8 locations to a depth of 3 feet. The soil was sampled at 6 inch

intervals by driving a 3 inch core into the undisturbed earth. Each density determination shown in Table 6 is an average of 10 replications except the 6-9 inch and 9-12 inch which each are an average of 5 replications. Thus a total of 480 cores were taken. The core containing the undisturbed soil was dried at 105 degrees Centigrade for 48 hours. The density of the dried soil was then determined. The results of these density determinations are shown in Table 10. The figures designated as average were used in water utilization computations.

The site selected was not tiled and this prevented a differential in soil moisture as a result of drainage.

Soil samples for gravimetric moisture determinations were taken at weekly intervals throughout the growing season during 1956 and 1957. These samples were taken at 6 inch intervals to a depth of three feet. Locations at which samples were taken was predetermined by chance, and the same sampling pattern was followed in both the 1956 and 1957 growing season. Soil samples were not taken from the strip harvested for yield determinations and were never taken nearer than four feet from one another.

Soil samples for gravimetric determinations were obtained by the soil sampling tube shown in Figure 5. Cores 3/4 inch in diameter were removed from each six inch depth to 36 inches and moisture determinations made.

Precipitation data was obtained from the United States Department of Agriculture Hydrologic Research Station located less than one-half

TABLE 10

THE BULK DENSITY OF SOIL USED FOR WATER UTILIZATION STUDY*

Depth in Inches	1957 Plots				
	1	2	3	4	Average
0-6	1.53	1.51	1.59	1.51	1.53
6-9	1.56	1.47	1.51	1.56	1.53
9-12	1.66	1.60	1.64	1.65	1.64
12-18	1.72	1.64	1.58	1.62	1.64
18-24	1.82	1.68	1.66	1.79	1.74
24-30	1.81	1.83	1.79	1.83	1.82
30-36	1.82	1.83	1.87	1.91	1.86
	1956 Plots				
	5	6	7	8	Average
0-6	1.50	1.46	1.42	1.45	1.46
6-9	1.53	1.46	1.45	1.52	1.49
9-12	1.58	1.46	1.54	1.52	1.53
12-18	1.69	1.64	1.66	1.61	1.65
18-24	1.65	1.63	1.69	1.67	1.66
24-30	1.78	1.70	1.74	1.72	1.74
30-36	1.84	1.74	1.80	1.75	1.78

*The 6-9 inch and 9-12 inch determinations are average of 5 replications. All other determinations represent averages of 10 replications.

mile from the plot area. Tables 11 and 12 give a record of the total precipitation for 1956 and 1957.

Bouyoucos blocks were carefully placed in the alfalfa plots at depths of 12, 24 and 36 inches and placement was completed in

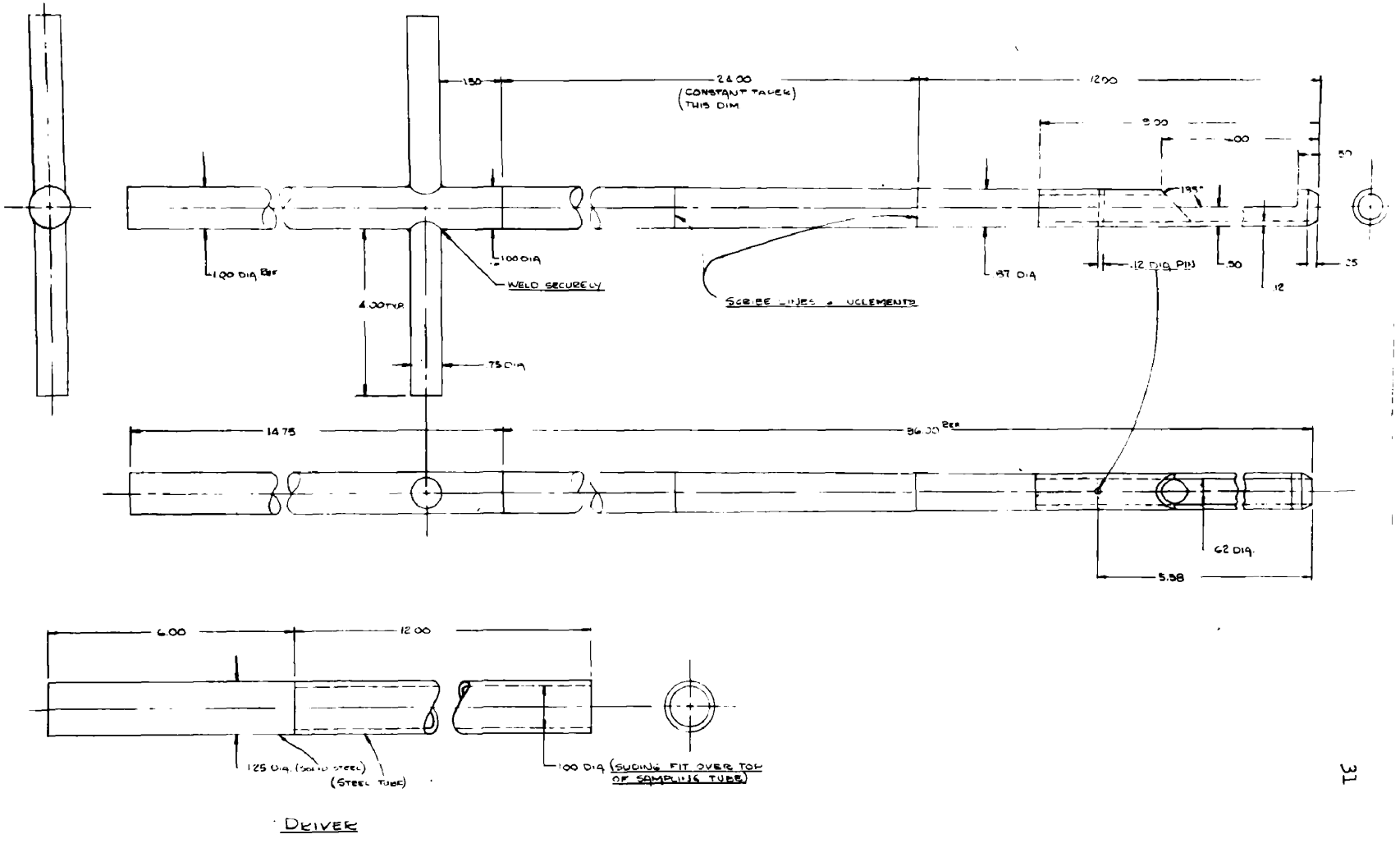


Figure 5. Tool used for gravimetric sampling.

TABLE 11

THE PRECIPITATION RECORD FOR 1956 OBTAINED USING STANDARD RAIN GAUGE*

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1			.10	.05			.09		.06		T	
2	.08	.10		.06	.09					.08		
3	.06			.35	.09	.06	.02				T	
4	.02				.57		.03	1.10				
5			.18		.13		.06	.88				.10
6		T	.62		.80					.05	.08	T
7		.14	.08	.23			.02	.04				T
8			T			.03	.04		.03		.01	.05
9		.26			1.86			.97				
10					.22		.14		.02			
11	.05		.02		.05		.11	.32		T		
12		.20			1.24							T
13					.12			.01			T	.04
14				.02								
15			.04	T	.43	.09		.03	.02		.08	.11
16		.30		T	.03	.77	.31	.03	.04		.26	
17		.57		T	.18	.44						
18			.09		.02	.06		.20				
19	T						.01		.02			
20	.06						.04			.04	.10	.13
21					.01				.03		.46	
22					.30	.15	.03		.30		.02	.52
23	T							.64				.21
24		.08	.40			.81					.05	.10
25		.27		.05			1.08				.03	
26				.80	.10	.39				.09	.04	
27				1.36			T	.08				
28			.60	1.07				.85			.01	
29	.06	T	.01		.02						T	T
30	.15							.05	.11		.01	T
31							.56					
Total	.48	1.92	2.14	3.99	6.26	2.80	2.54	5.20	.63	.26	1.15	1.26

Total for Year 28.63

*Data furnished by the Michigan Hydrologic Research Station (ARS).

TABLE 12

THE PRECIPITATION RECORD FOR 1957 OBTAINED USING STANDARD RAIN GAUGE**

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1			T	.33		.46						
2			.02	.01					.13			
3	T		T						T			
4	T			.33			1.34		.17			
5	T			.49								T
6							.02					.21
7	.02					.01						.50
8		.19					1.30				.58	
9	.16	.36		.02	.19		T		.11		T	
10	.02	T			1.29				.12			.08
11			.70	.09	.69	.18	2.96					.07
12	.03	.07			.13		.26		.21			
13		.13			.11	.28					.30	
14		.03	.22		.94	.07					1.05	
15	T		T			.04			.16		.01	.02
16	T	.01	T							1.31		
17	.01			.01						.18	*	.02
18			.08	.01	.60					T	.21	.34
19			.48		1.80	.19				T	.09	.03
20			.02		T				.01		.02	.59
21									.34		.05	.08
22	.78			.01		.51	1.34		T	.19	T	
23		T		.66	.17				.03	1.80		
24	.01	.11		.61		T		.77		.24		
25	.11	.10	.09	.38	.20						.01	.35
26		.10	T	.21				T				
27				.70	T	.09				.06		
28	.09			T		.59		.32			.13	.14
29	.08		.18					.03		.04		T
30			.02					.19		.02	T	.07
31								.24				.36
Total	1.31	1.10	1.81	3.86	6.12	2.42	7.22	1.55	1.28	3.84	2.43	2.86

Total for Year 35.80

*Discontinued using standard rain gauge. Measurements taken directly from pail.

**Data furnished by the Michigan Hydrologic Research Station (ARS).

November 1956. The first readings were made April 22, 1957 and a total of 47 readings were taken during the 1957 growing season. Blocks were placed in the Sudan grass plots sown in 1957 immediately after seeding in the same manner as described above. The first readings for these plots were taken on June 4, 1957. A separate hole was dug for every block.

Results

Bouyoucos Blocks

Alfalfa. Figures 6-9 show the available water at various levels according to Bouyoucos blocks. The first readings were taken on April 22, 1957, and soil moisture remained at near field capacity until the middle of May. Blocks at all depths showed 95% or more available moisture until June 5, 1957.

On June 25th the percent of available moisture at the 12 inch depth was reduced to 21% in the plots (6 week interval) which had not been cut, whereas there was 34% available moisture in plots cut at the four week interval which had previously been harvested on June 11th. The percent moisture in the plots cut at the two week interval was 44 and in those cut weekly 70.

Frequent cutting and reduction of top growth saved soil moisture noticeably. On July 2nd moisture at the 24 inch depth was reduced to 57% in the plots cut at the six week interval; and to 64% in the plots cut at the four week interval. Moisture at the 24 and 36 inch levels

stayed at nearly 100% available moisture in the plots cut bi-weekly and weekly until August 10th.

Rainfall on July 4, 8, and 11th totaled 5.60 inches and on July 15th the available moisture percentage at all levels in all plots was at 100%.

There was only 2.83 inches of rain from July 22nd until August 16th. Distinct differences in soil moisture between cutting treatments may be observed in Figures 6 through 8. The cutting treatment was closely related to the reduction of soil moisture. All plots reduced the moisture at the 12 inch level to approximately 12% by October 15, 1957. Moisture at all depths in the six week cutting interval was reduced to below 10% on October 15th. Only the blocks at 36 inches showed more than 10% moisture in the four week cutting interval. These blocks averaged 32% available soil moisture on October 15th. There was but little difference between the four and two week cutting interval treatments. Blocks at 36 inches in the plots cut at one week intervals showed 84% available soil moisture on October 15, 1957.

There was a total of 1.49 inches of rainfall on October 16 and 17, 1957. An additional 2.23 inches of rainfall fell on October 22, 23 and 24th. The block readings were taken 30 hours after the completion of the October 24th rain. The moisture at the 12 inch depth on October 26th was above 75% in all plots for all treatments. Available moisture at 24 inches ranged between 80 and 85 percent in the plots receiving the weekly, bi-weekly and monthly cutting treatment. Available moisture at 24 inches in the six week cutting treatment plots was 65%.

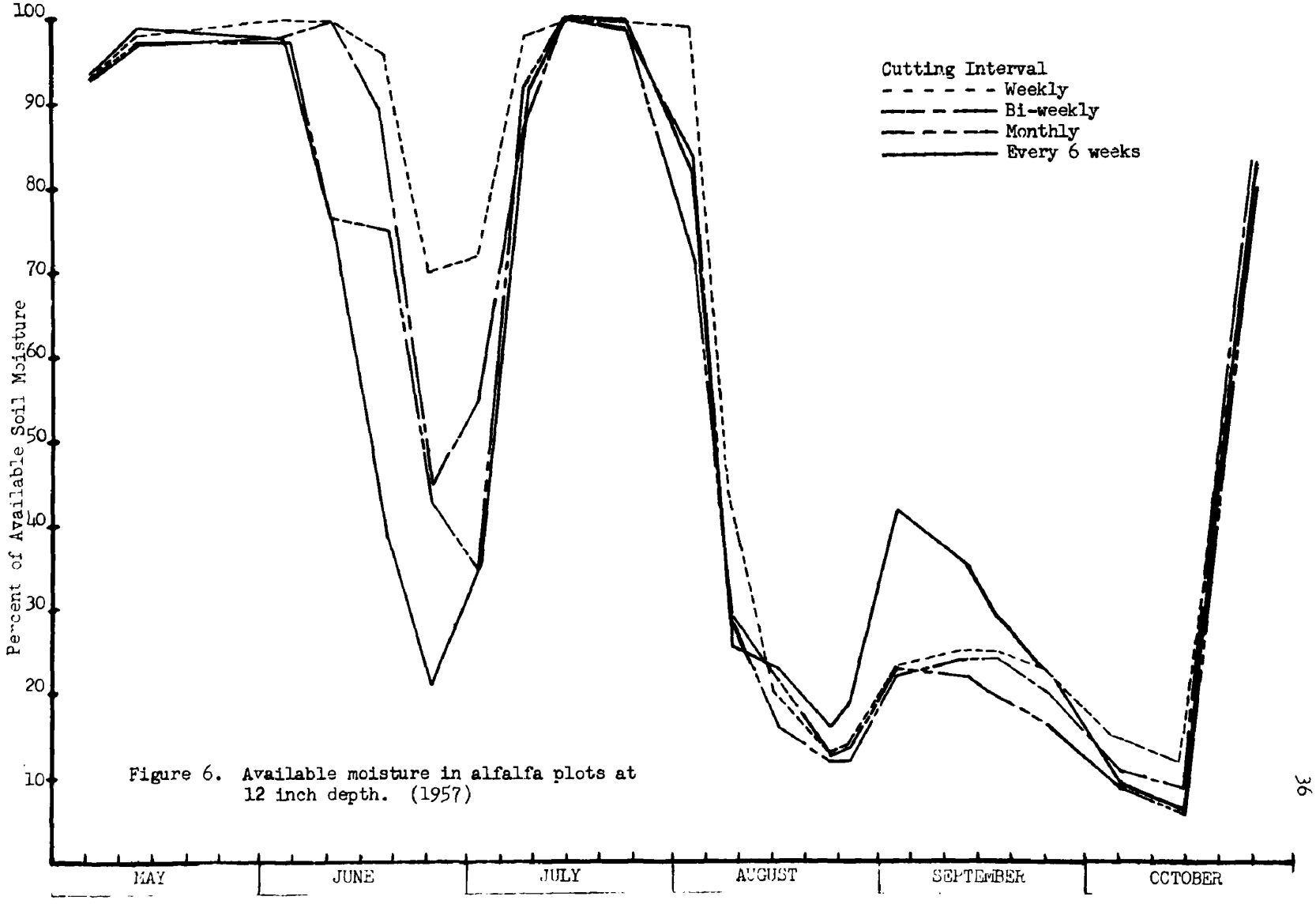


Figure 6. Available moisture in alfalfa plots at 12 inch depth. (1957)

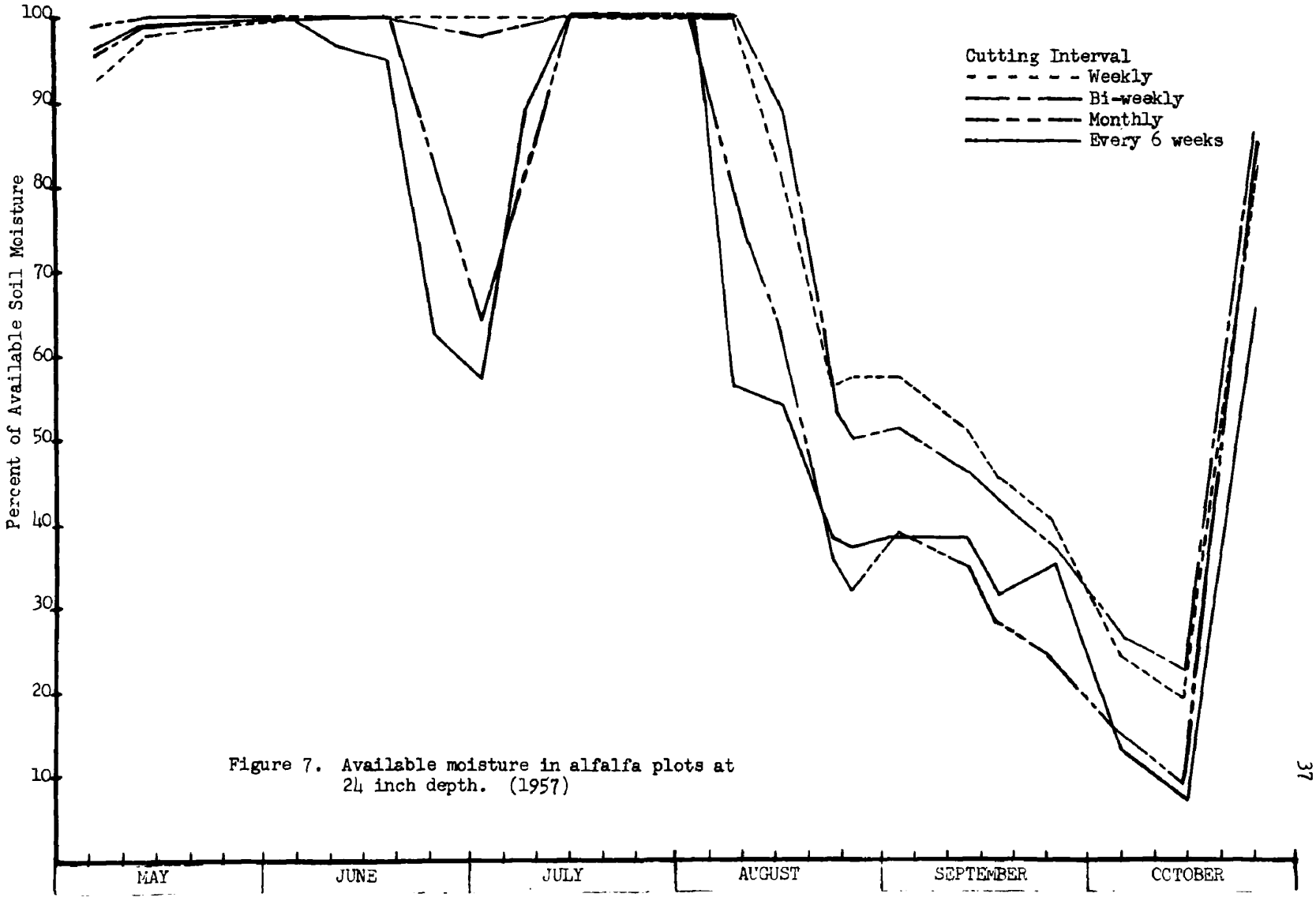


Figure 7. Available moisture in alfalfa plots at 24 inch depth. (1957)

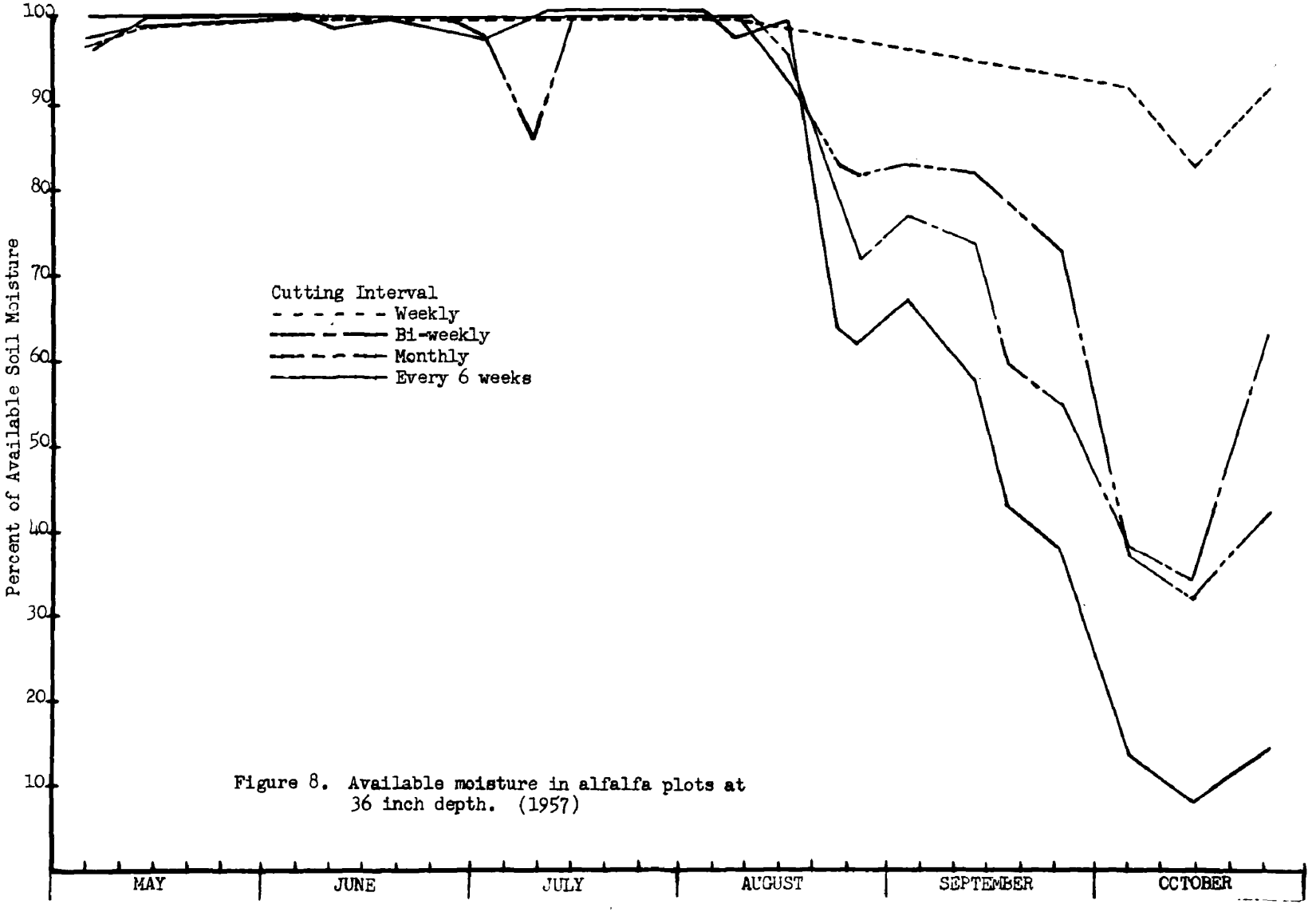


Figure 8. Available moisture in alfalfa plots at 36 inch depth. (1957)

Differences between alfalfa treatments were most clearly evident at the 36 inch depth on October 26th. Available moisture at 3 feet was 82% for plots cut weekly, 64% for plots cut bi-weekly, 42% for plots cut every month, and only 14% for the plots which were harvested every six weeks.

Sudan Grass. Bouyoucos blocks were also placed in Sudan grass plots, immediately after seeding. Readings from these moisture blocks are given in Figures 9 through 11. The first readings were taken on June 4, 1957. There was .46 inches of rain on June 1, 1957, and no additional rain until June 11, 1957, when 0.18 inches fell. The second block readings were taken on June 11, 1957, just before the rain came. Block readings were 96 percent or above for all cutting treatments.

Moisture as recorded by Bouyoucos blocks stayed at approximately 100 percent in all plots at the 36 inch depth for the entire growing season, Figure 11. The moisture extraction pattern at 24 inches for all four Sudan grass cutting treatments was nearly identical from June 4, 1957, remaining at 100 percent until July 16, 1957.

The same pattern of moisture utilization with minor variations was observed in all plots, at the 12 inch depth, Figure 10.

The available moisture at the 12 inch level in the plots cut every six weeks stayed at 100 percent until July 24, 1957. Moisture then declined to 21 percent on September 9th.

The rain which fell during the period October 15, 1957 to October 24, 1957 caused the percent of available moisture at the 12 inch depth

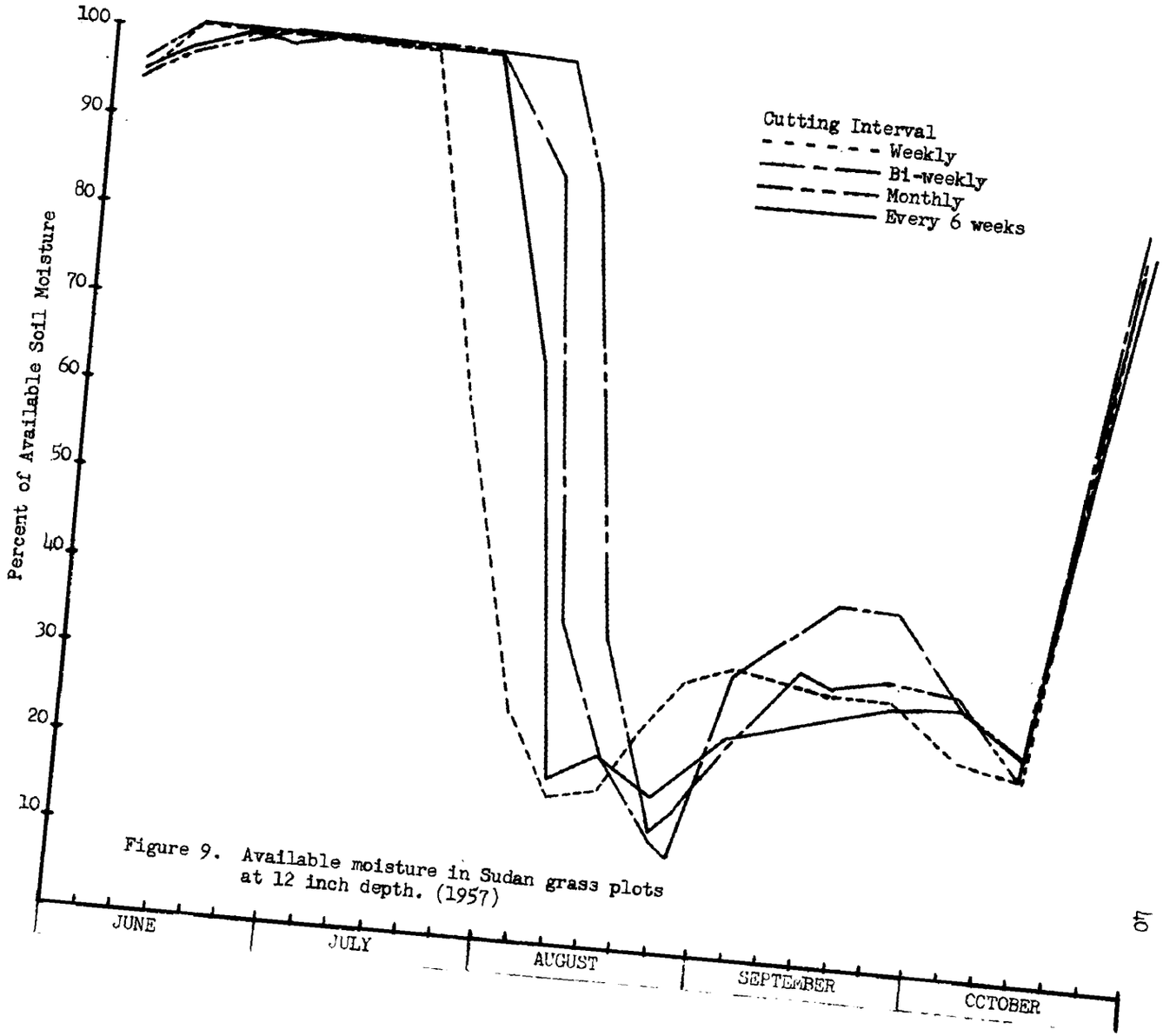


Figure 9. Available moisture in Sudan grass plots at 12 inch depth. (1957)

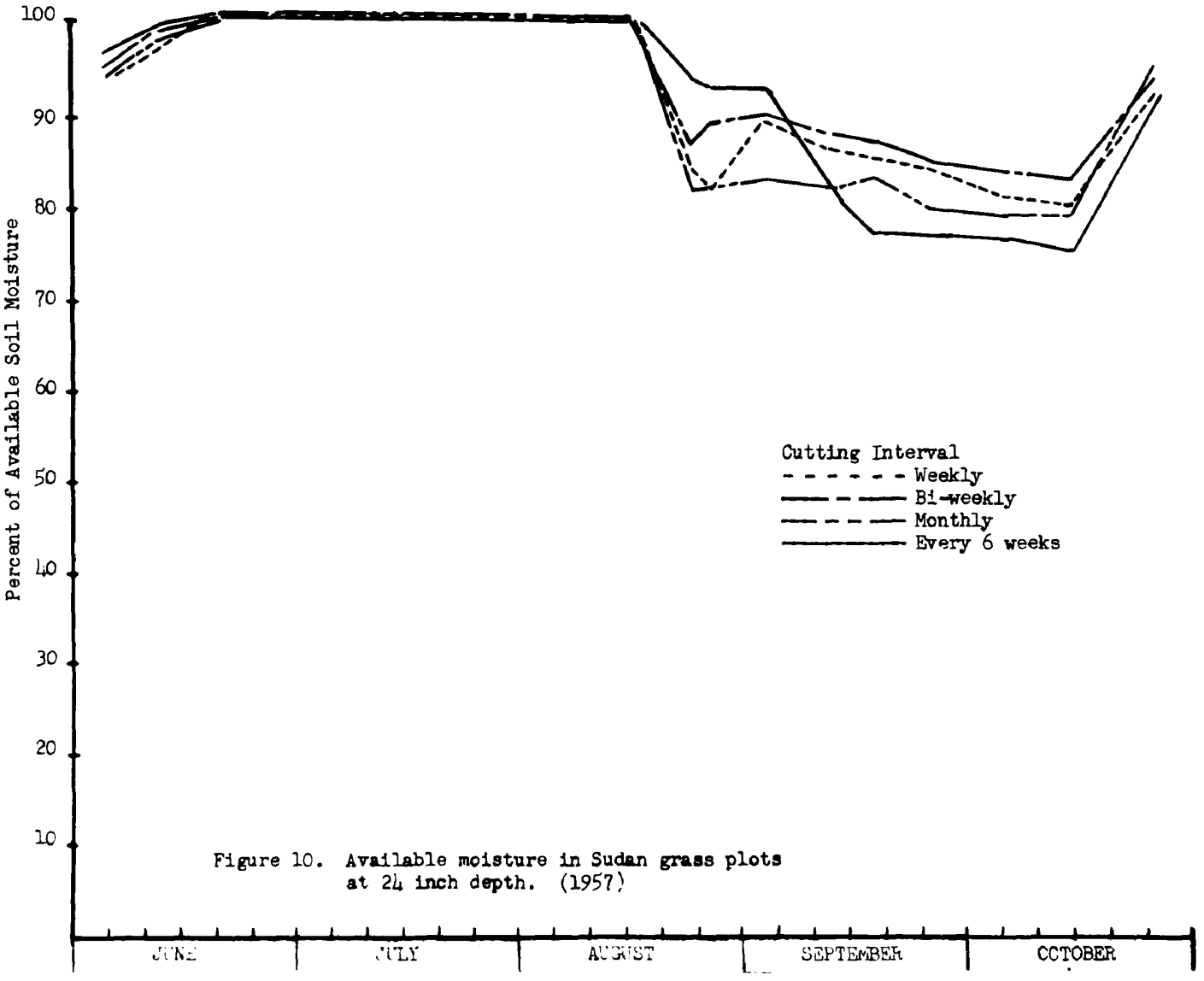


Figure 10. Available moisture in Sudan grass plots at 24 inch depth. (1957)

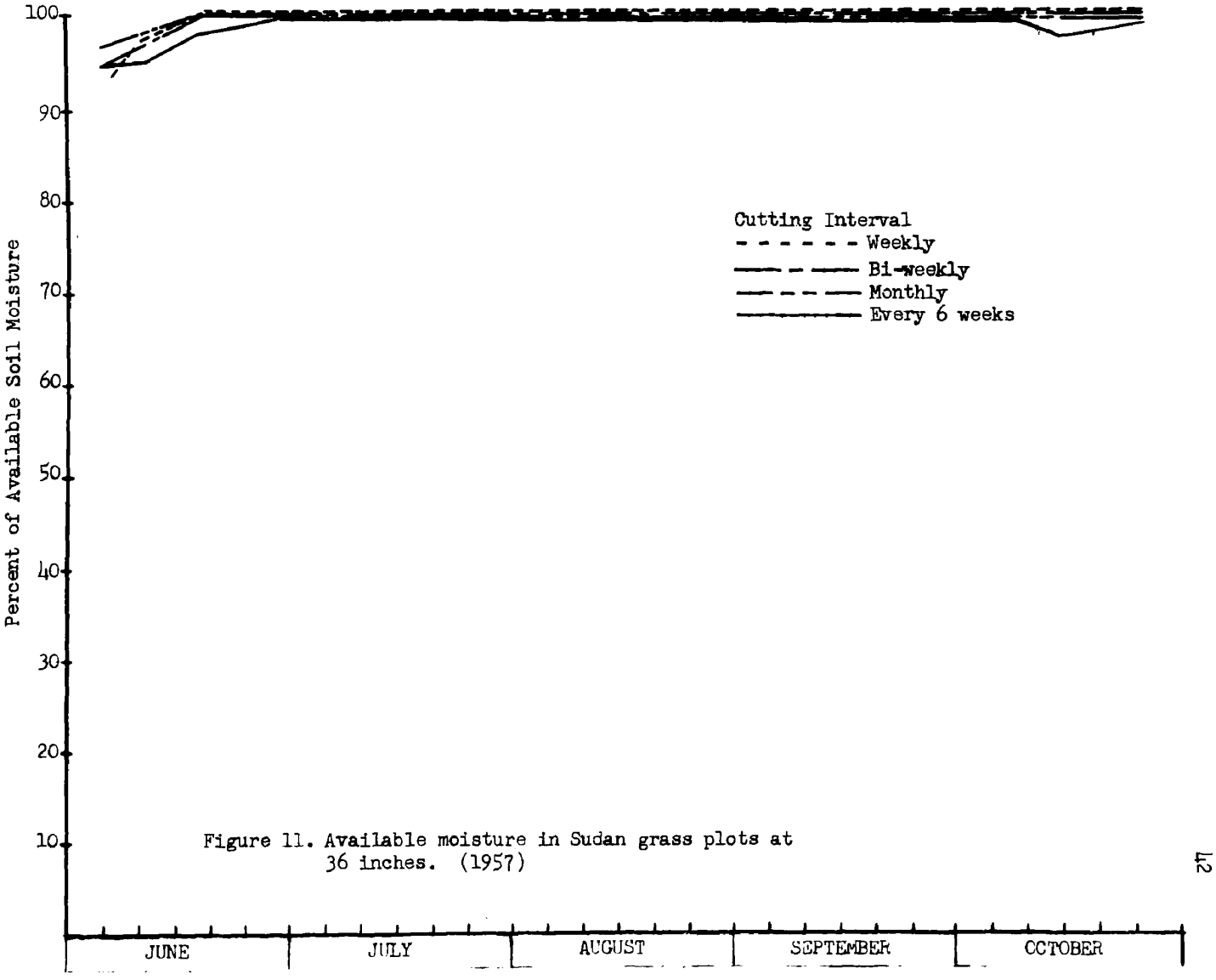


Figure 11. Available moisture in Sudan grass plots at 36 inches. (1957)

to rise uniformly in all plots to an average final reading of 81 percent available soil moisture.

Gravimetric Determinations

Percent of Soil Moisture by Six Inch Intervals. The percent of soil moisture by six inch intervals is shown in Figures 12 through 35. The first six figures 12 to 18 pertain to alfalfa harvested in 1956. The alfalfa plots started the 1956 season with the soil at field capacity, the moisture supply being replenished in August and depleted by the drought which followed. The soil near the surface varied more in moisture percentage than that at greater depths, particularly following rainfall.

The Sudan grass was seeded May 30, 1956 when the soil was at or above field capacity. Percent of soil moisture in these plots is shown in Figures 18 through 23. The 2.80 inches of rain which fell in June caused soil moisture to increase above field capacity. On July 20th, the plots cut every six weeks had lower percentages of water at all six depths than did the plots cut weekly. The 5.20 inches of rain which fell in August 1956, brought the soil moisture back to above field capacity. Soil at the 0-6 inch level averaged 24.5 percent and at the 30-36 inch depth 17.0 percent moisture for all cutting treatments.

Soil samples were taken from the alfalfa plots which were seeded August 1, 1956, and harvested during 1957, in the same manner as described earlier for the plots sampled during 1956. The percentages of moisture contained are graphically presented in Figures 24 through 29.

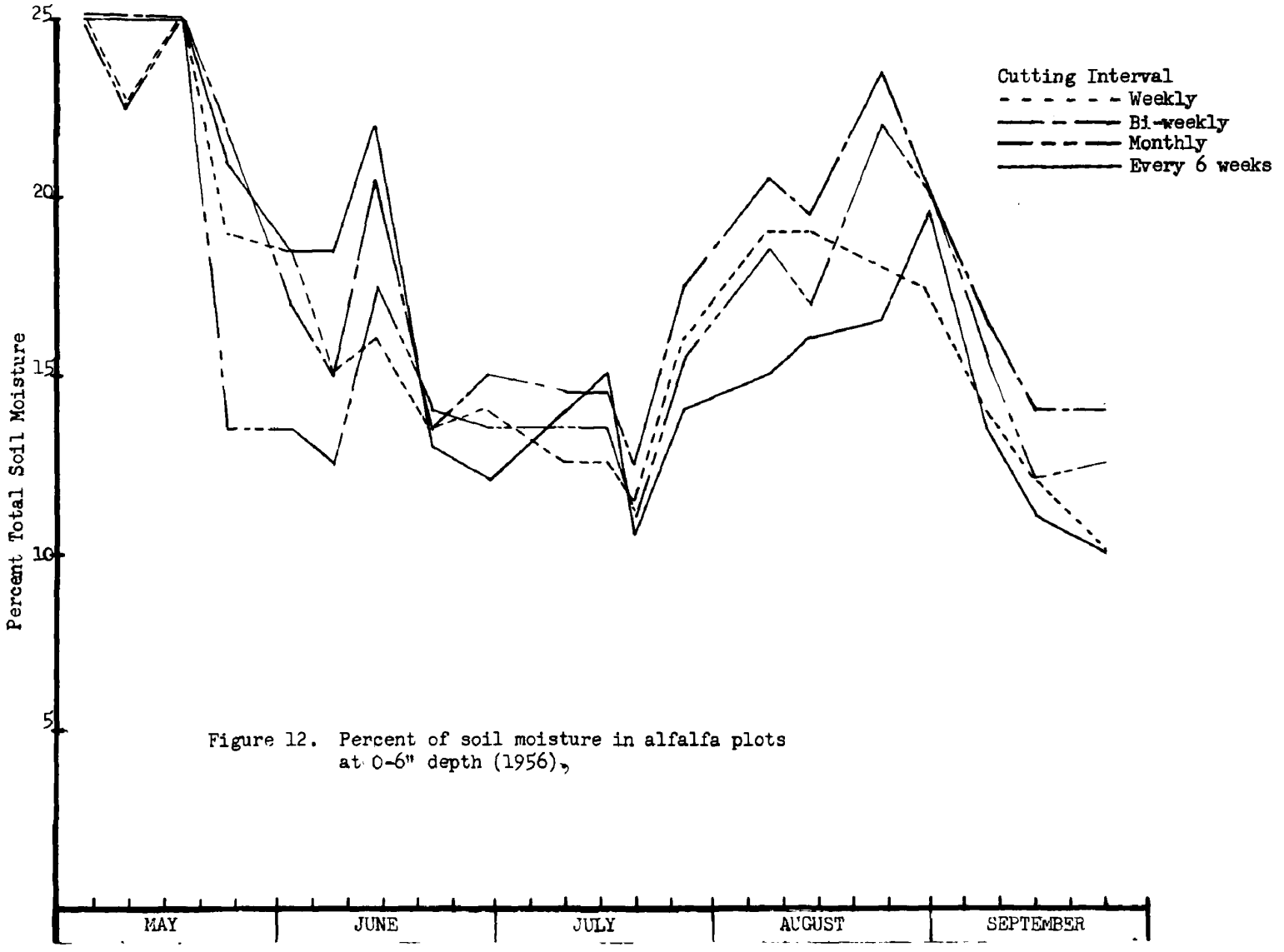


Figure 12. Percent of soil moisture in alfalfa plots at 0-6" depth (1956).

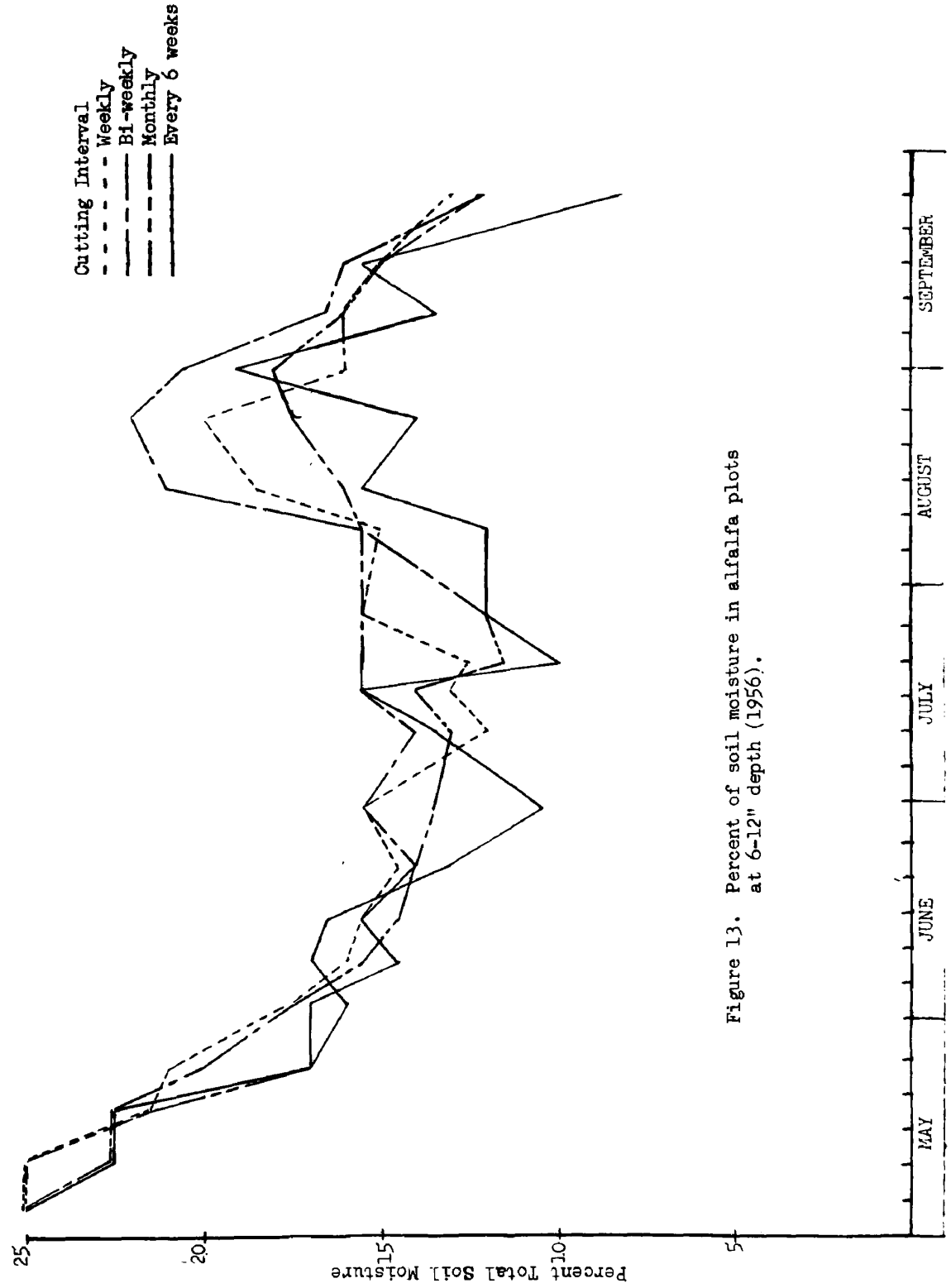


Figure 13. Percent of soil moisture in alfalfa plots at 6-12" depth (1956).

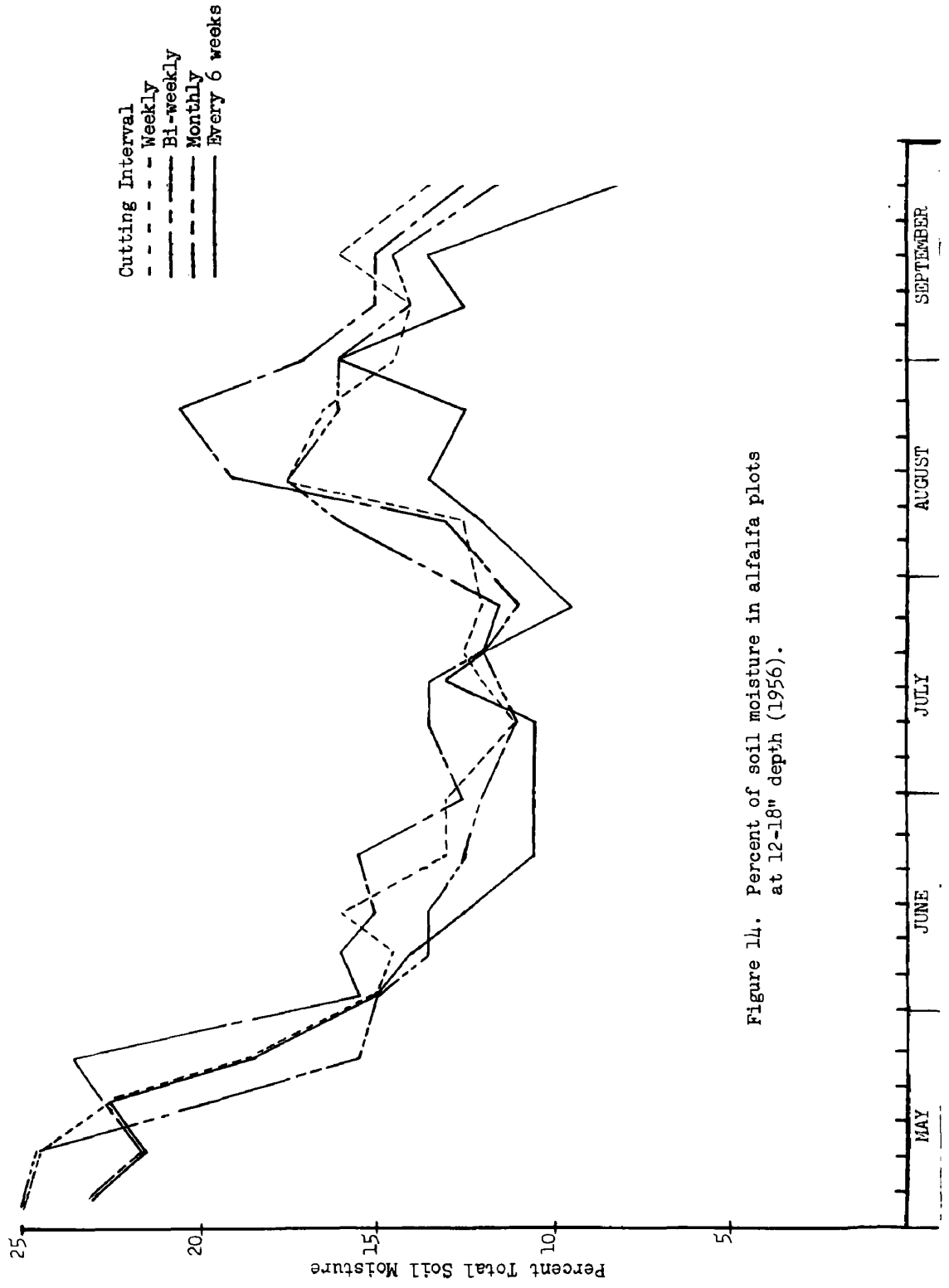


Figure 14. Percent of soil moisture in alfalfa plots at 12-18" depth (1956).

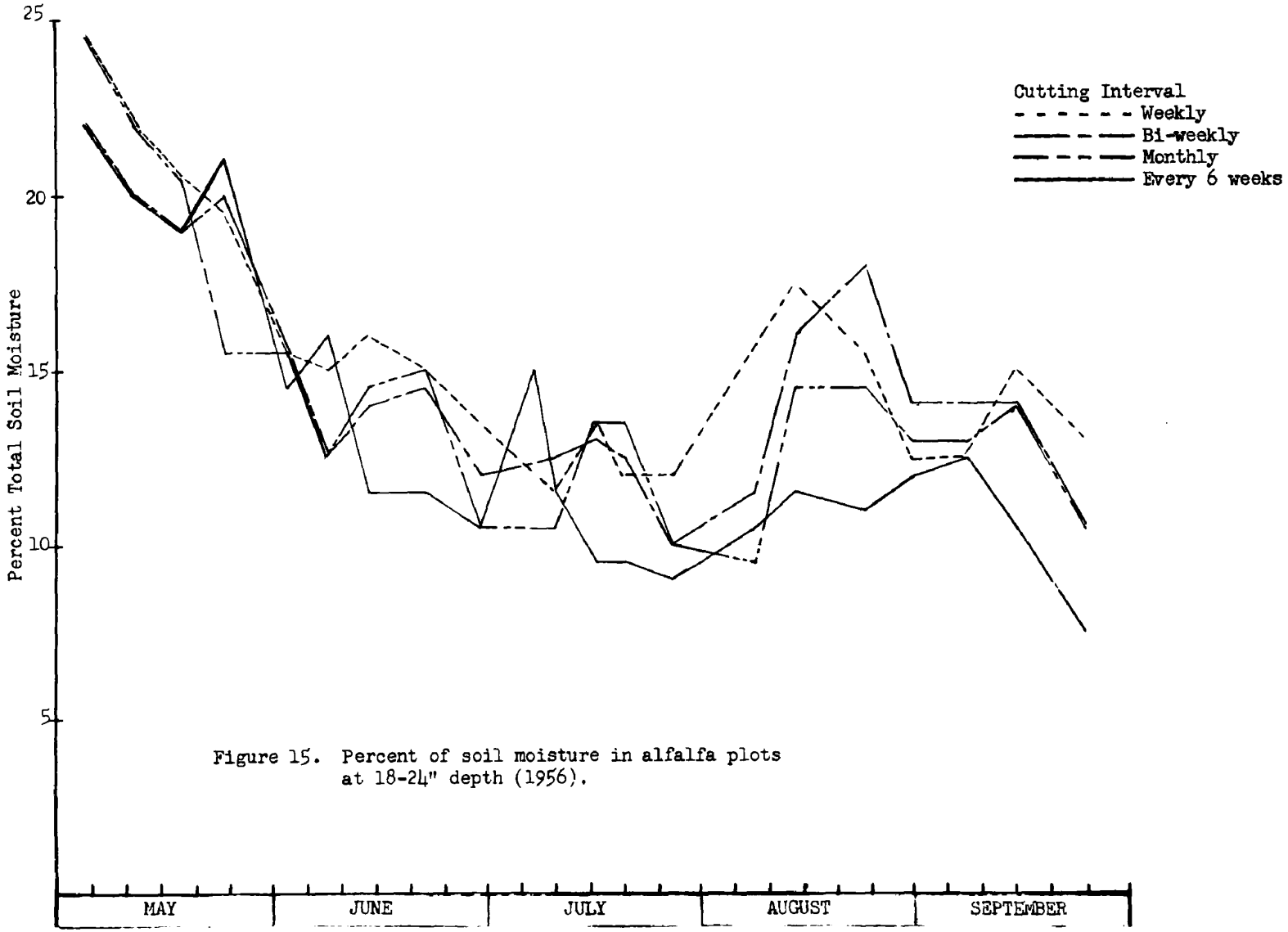


Figure 15. Percent of soil moisture in alfalfa plots at 18-24" depth (1956).

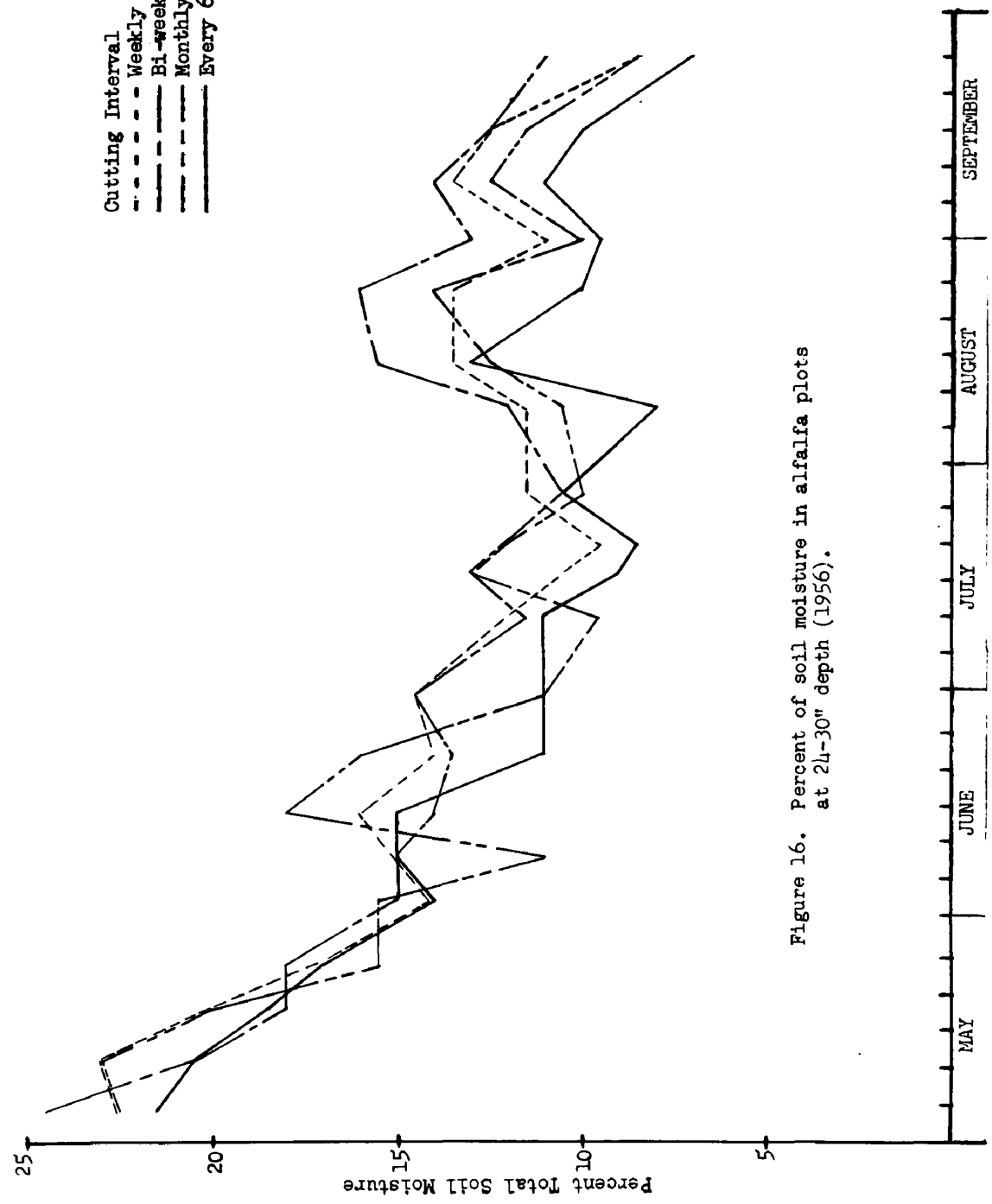


Figure 16. Percent of soil moisture in alfalfa plots at 24-30" depth (1956).

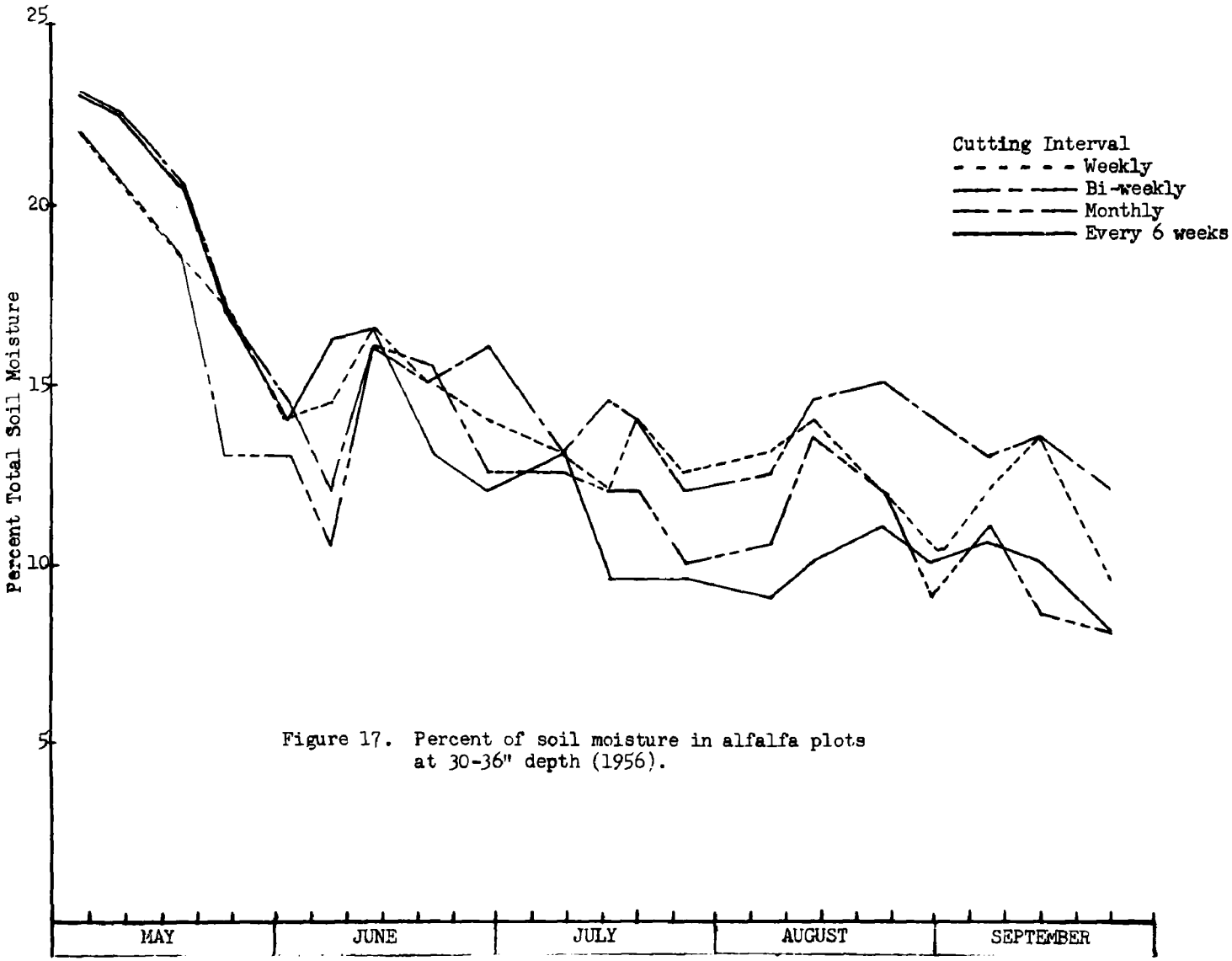


Figure 17. Percent of soil moisture in alfalfa plots at 30-36" depth (1956).

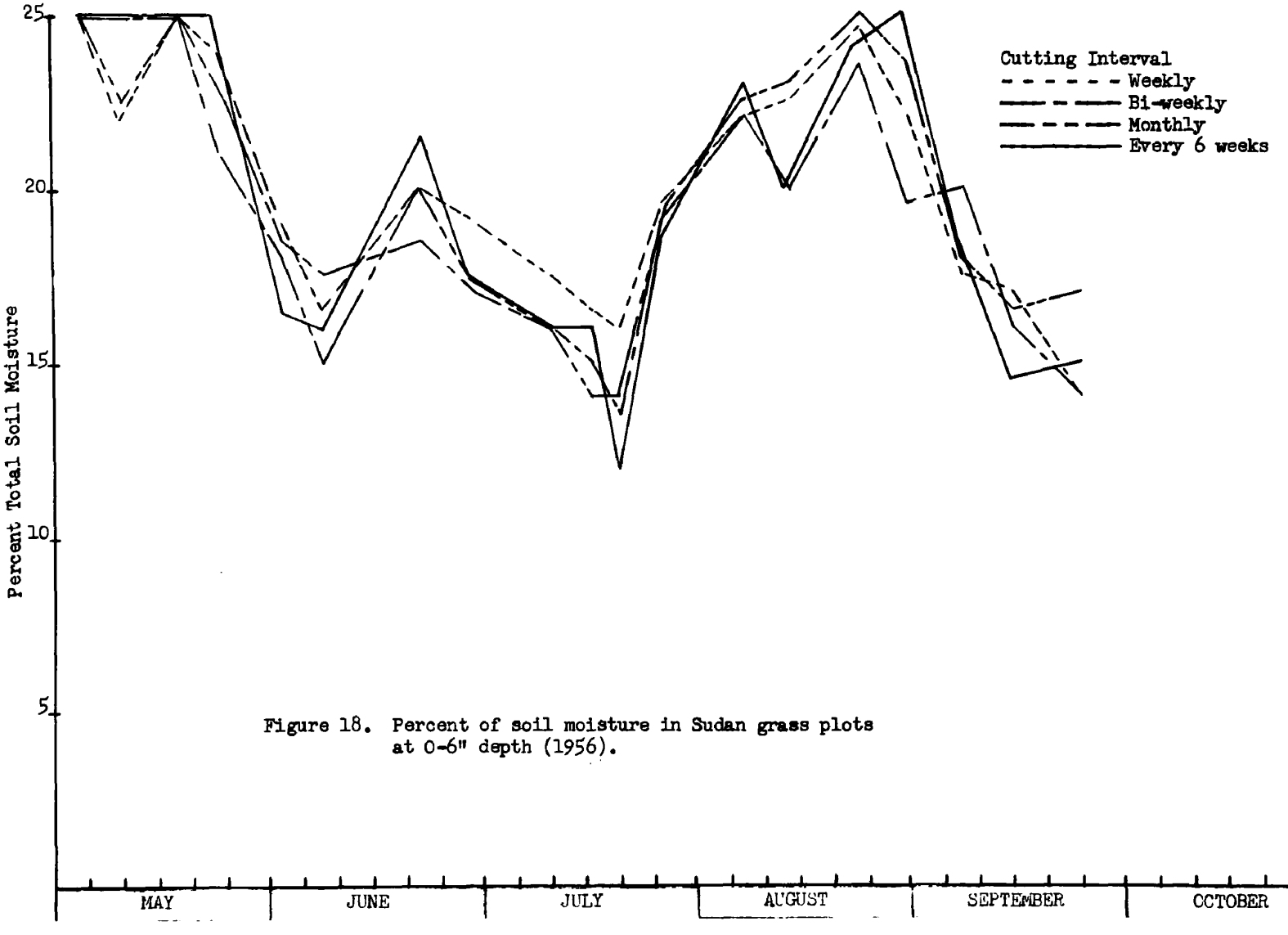


Figure 18. Percent of soil moisture in Sudan grass plots at 0-6" depth (1956).

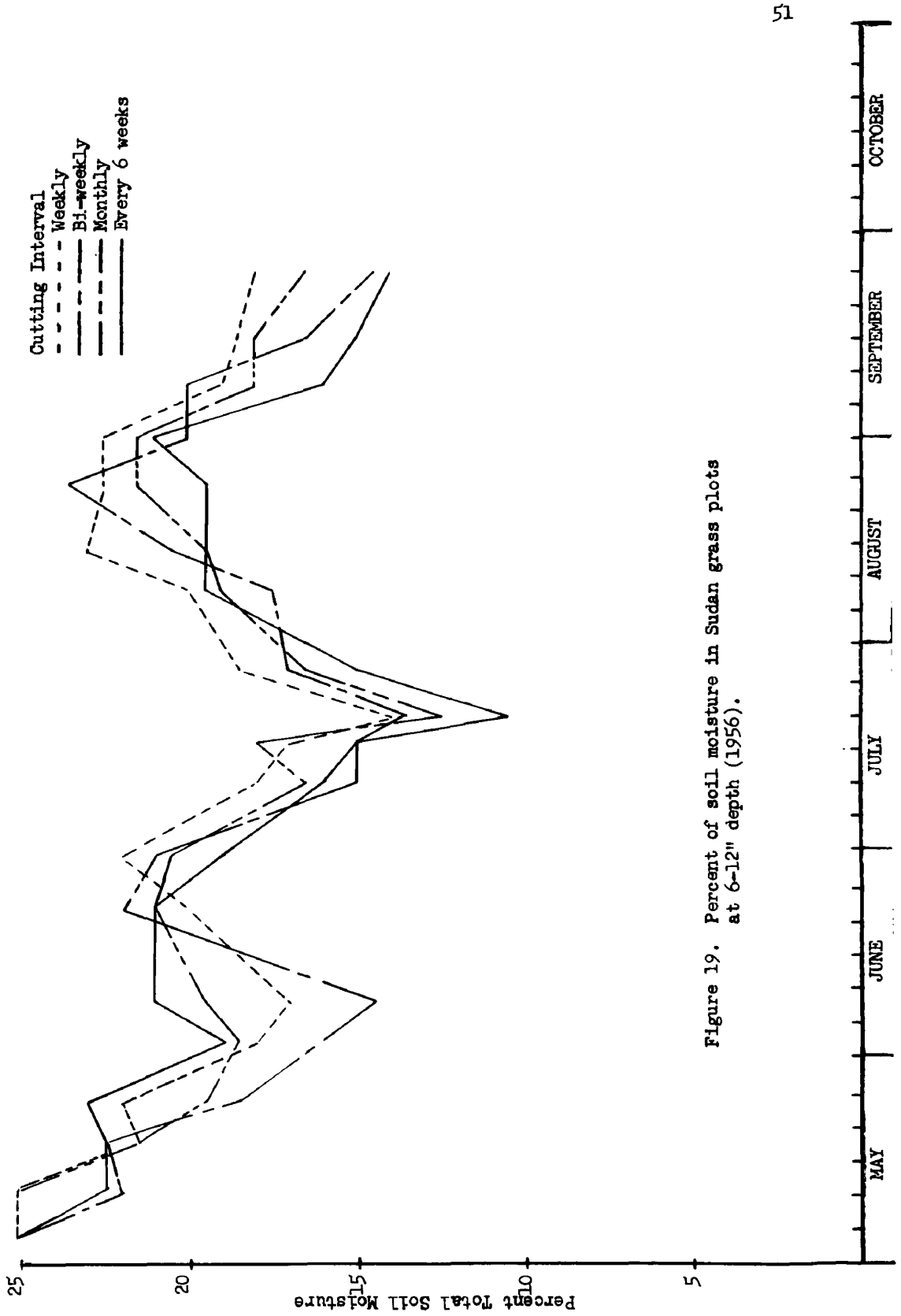


Figure 19. Percent of soil moisture in Sudan grass plots at 6-12" depth (1956).

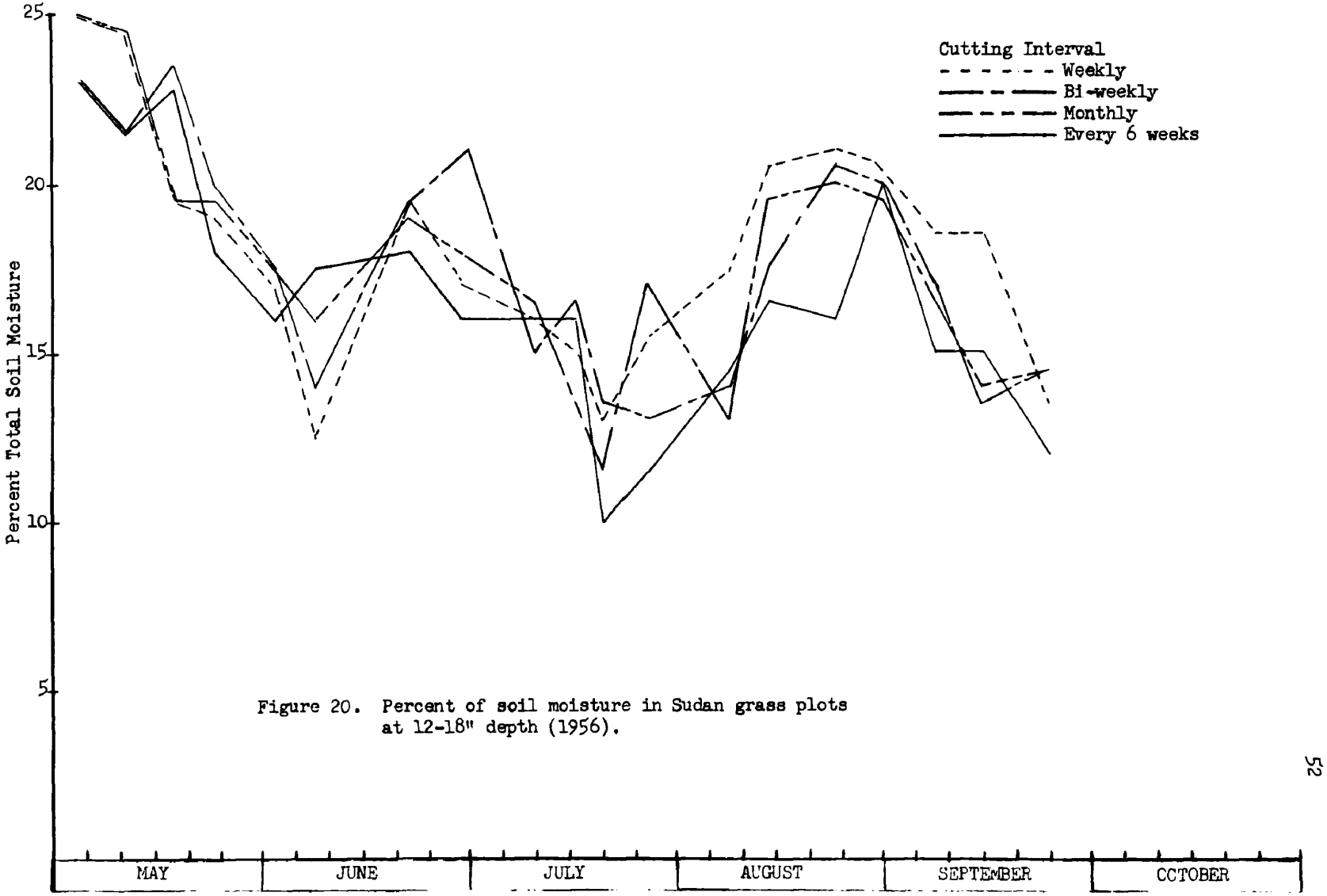


Figure 20. Percent of soil moisture in Sudan grass plots at 12-18" depth (1956).

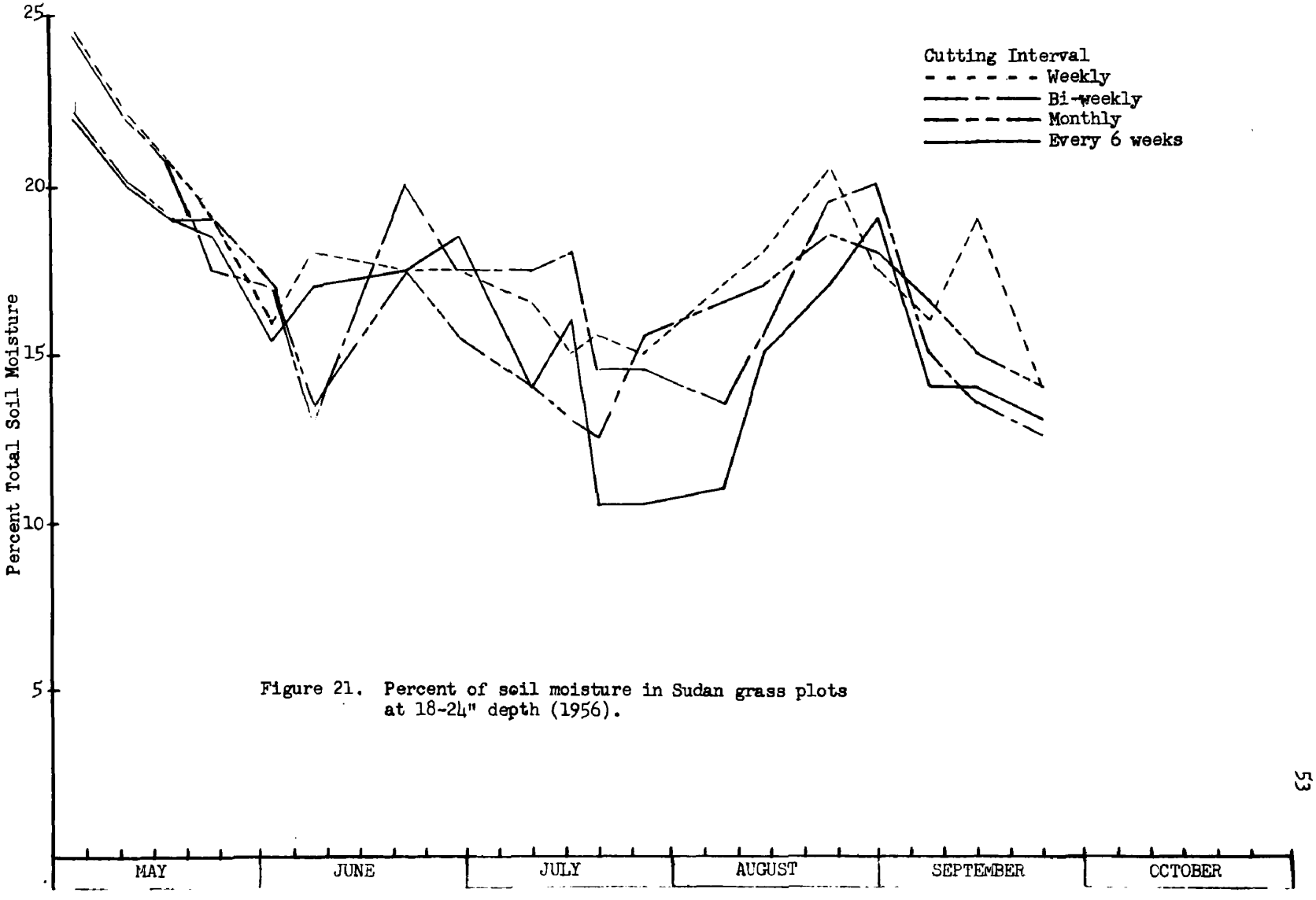


Figure 21. Percent of soil moisture in Sudan grass plots at 18-24" depth (1956).

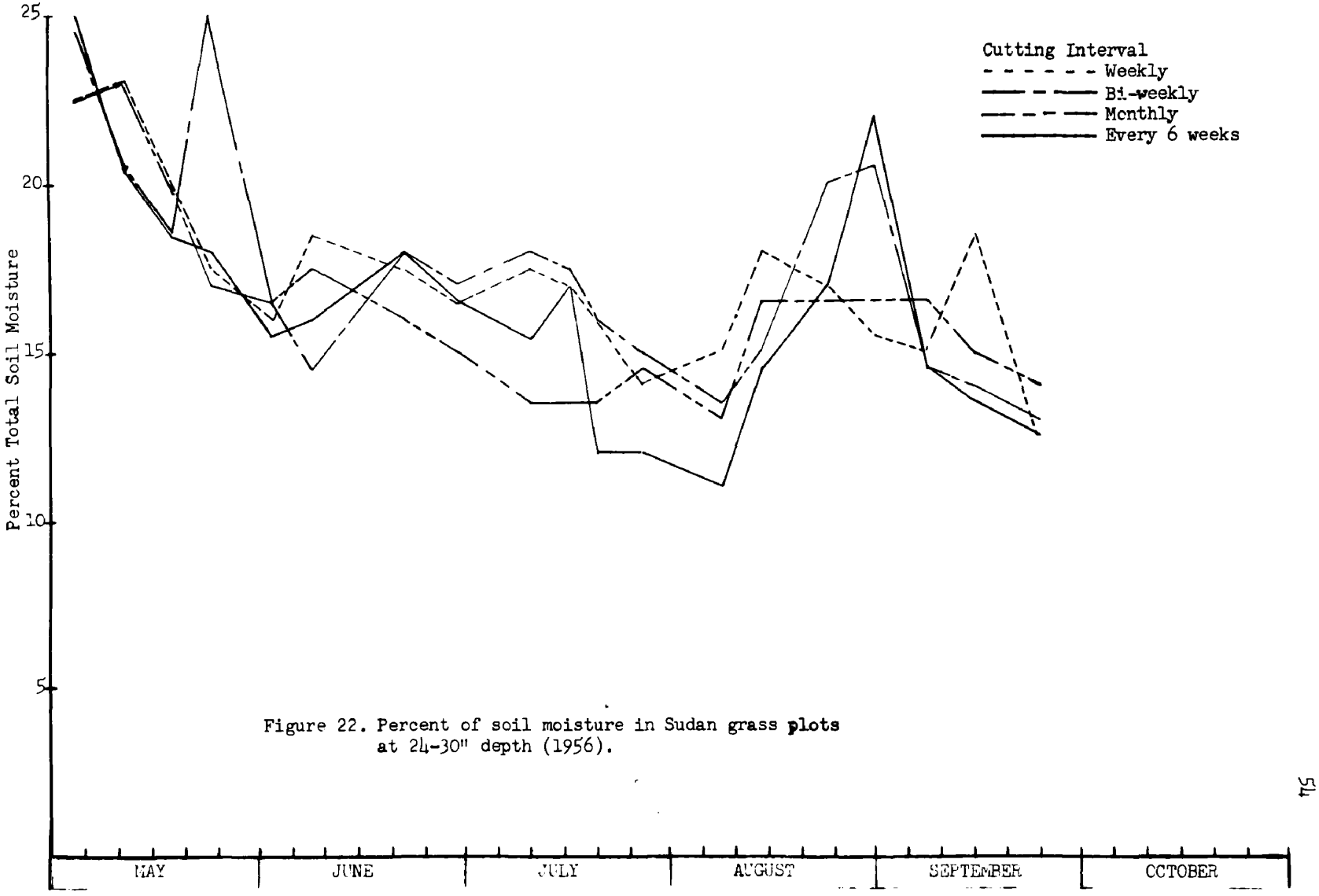


Figure 22. Percent of soil moisture in Sudan grass plots at 24-30" depth (1956).

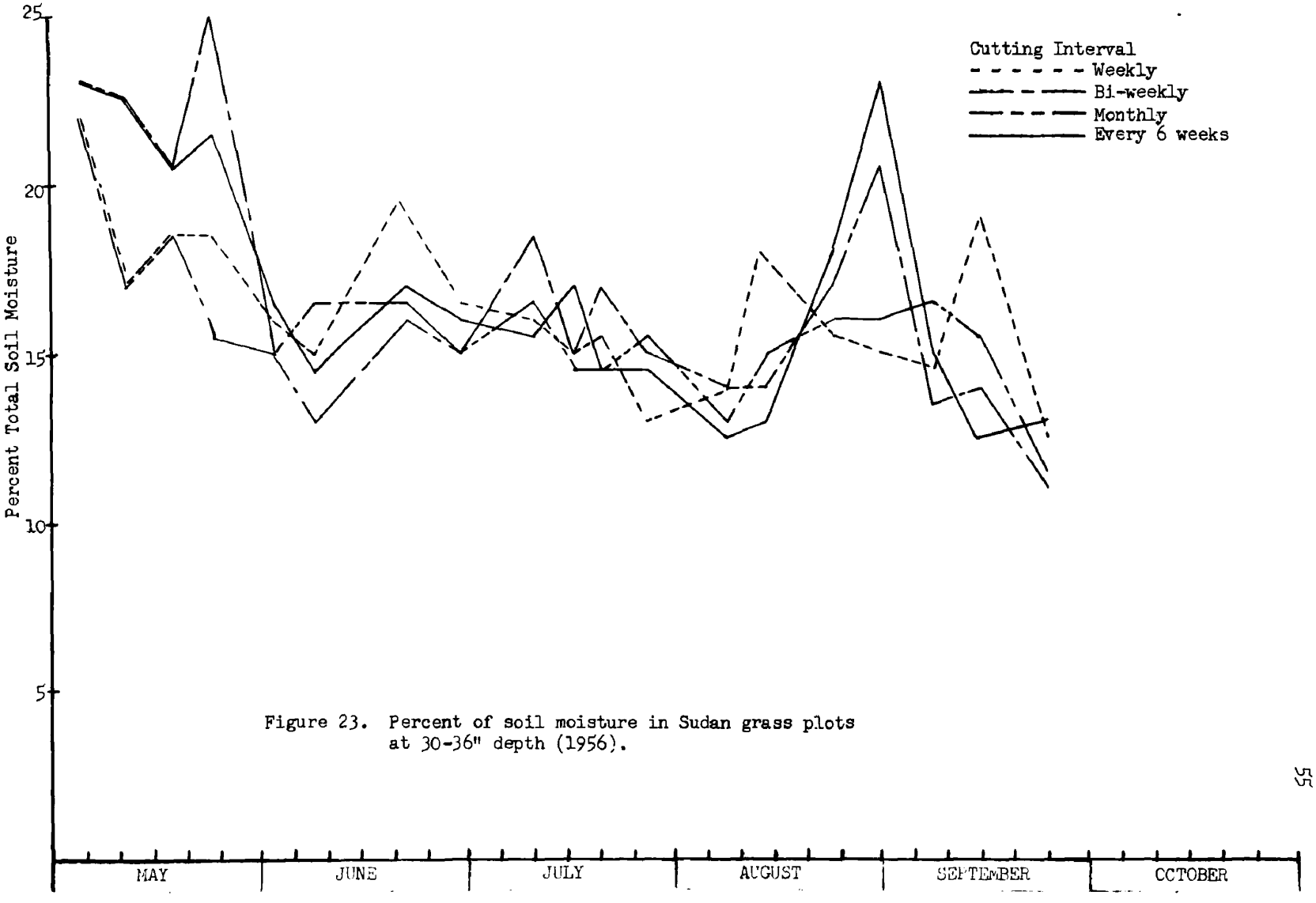


Figure 23. Percent of soil moisture in Sudan grass plots at 30-36" depth (1956).

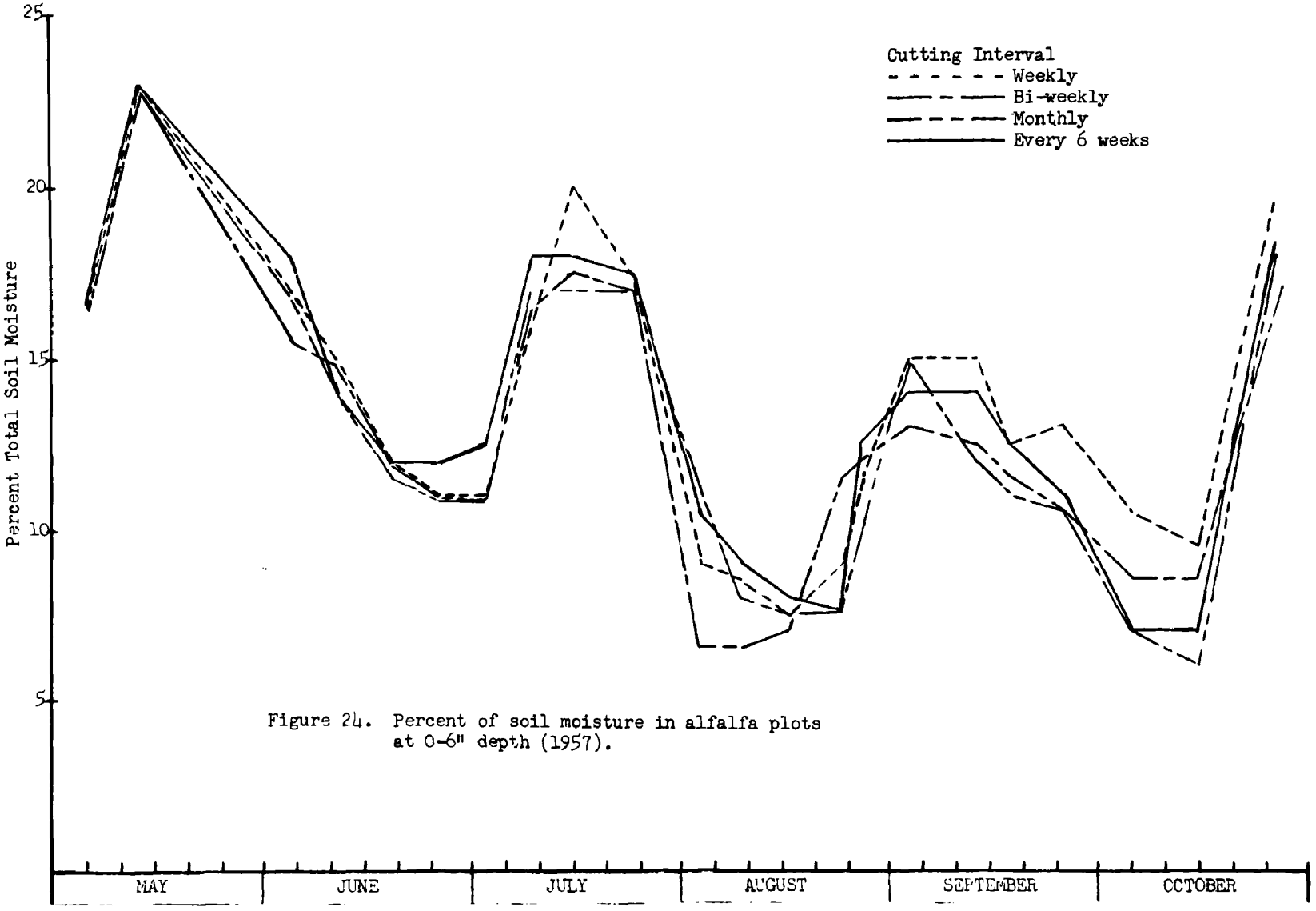


Figure 24. Percent of soil moisture in alfalfa plots at 0-6" depth (1957).

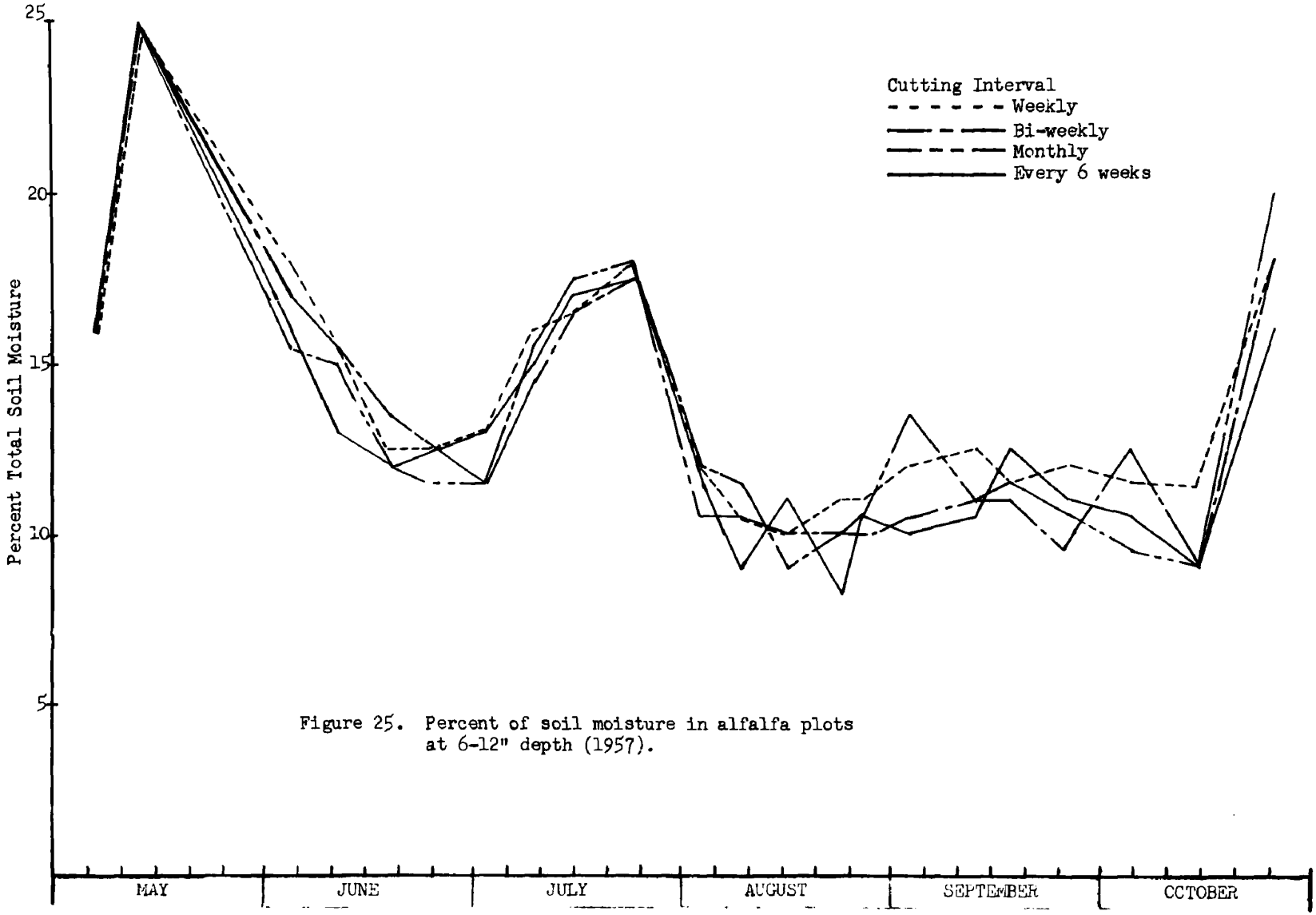


Figure 25. Percent of soil moisture in alfalfa plots at 6-12" depth (1957).

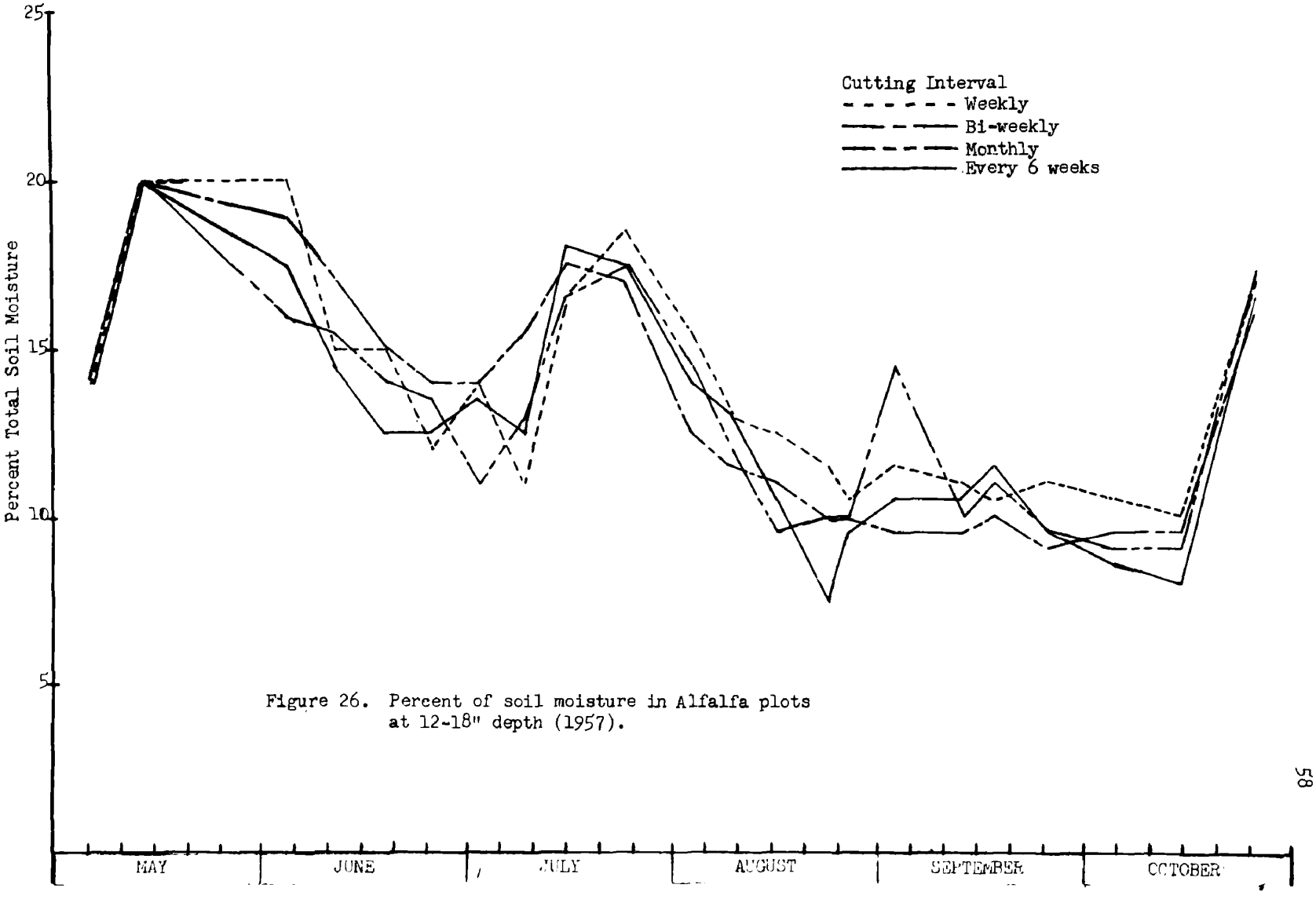


Figure 26. Percent of soil moisture in Alfalfa plots at 12-18" depth (1957).

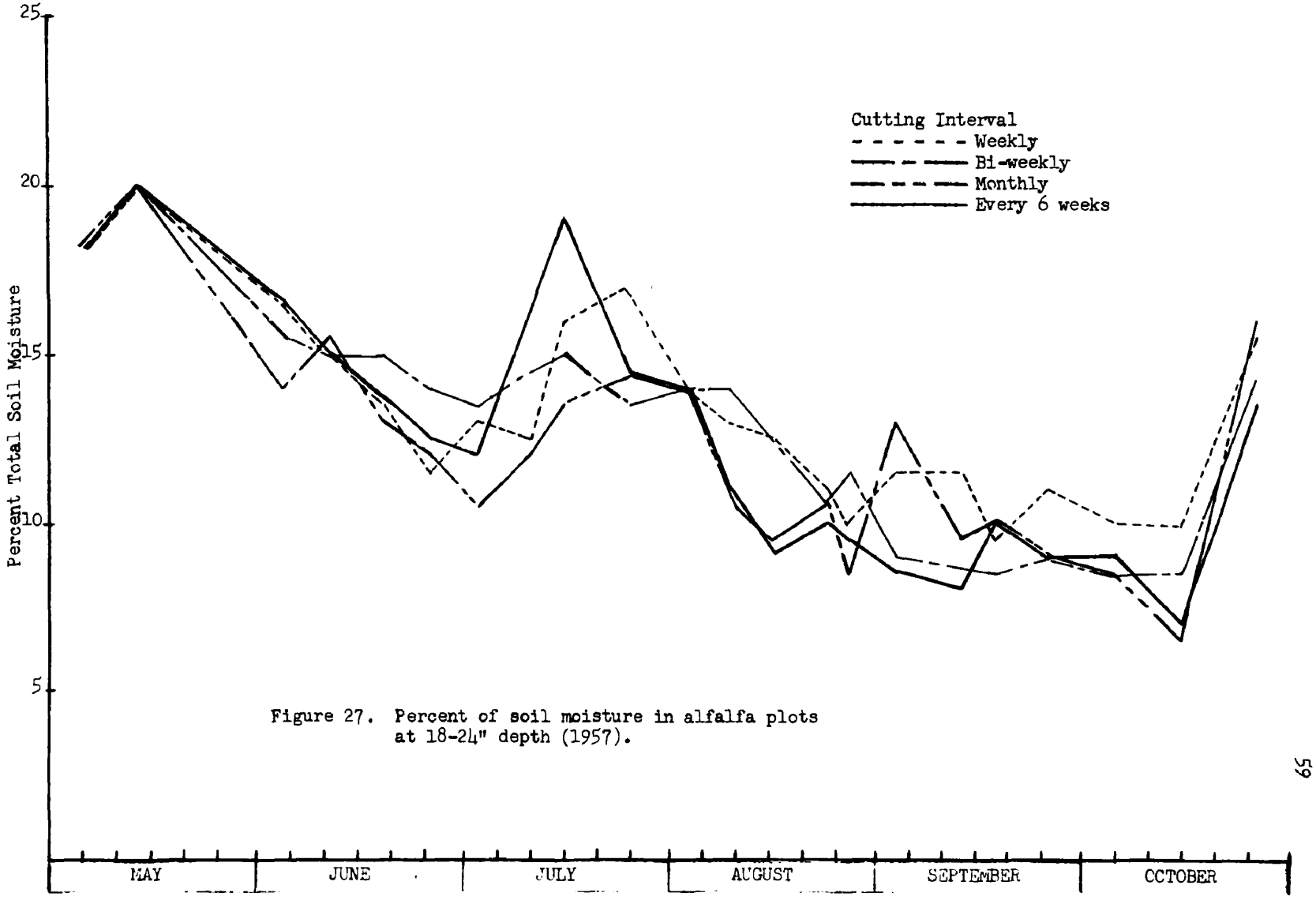


Figure 27. Percent of soil moisture in alfalfa plots at 18-24" depth (1957).

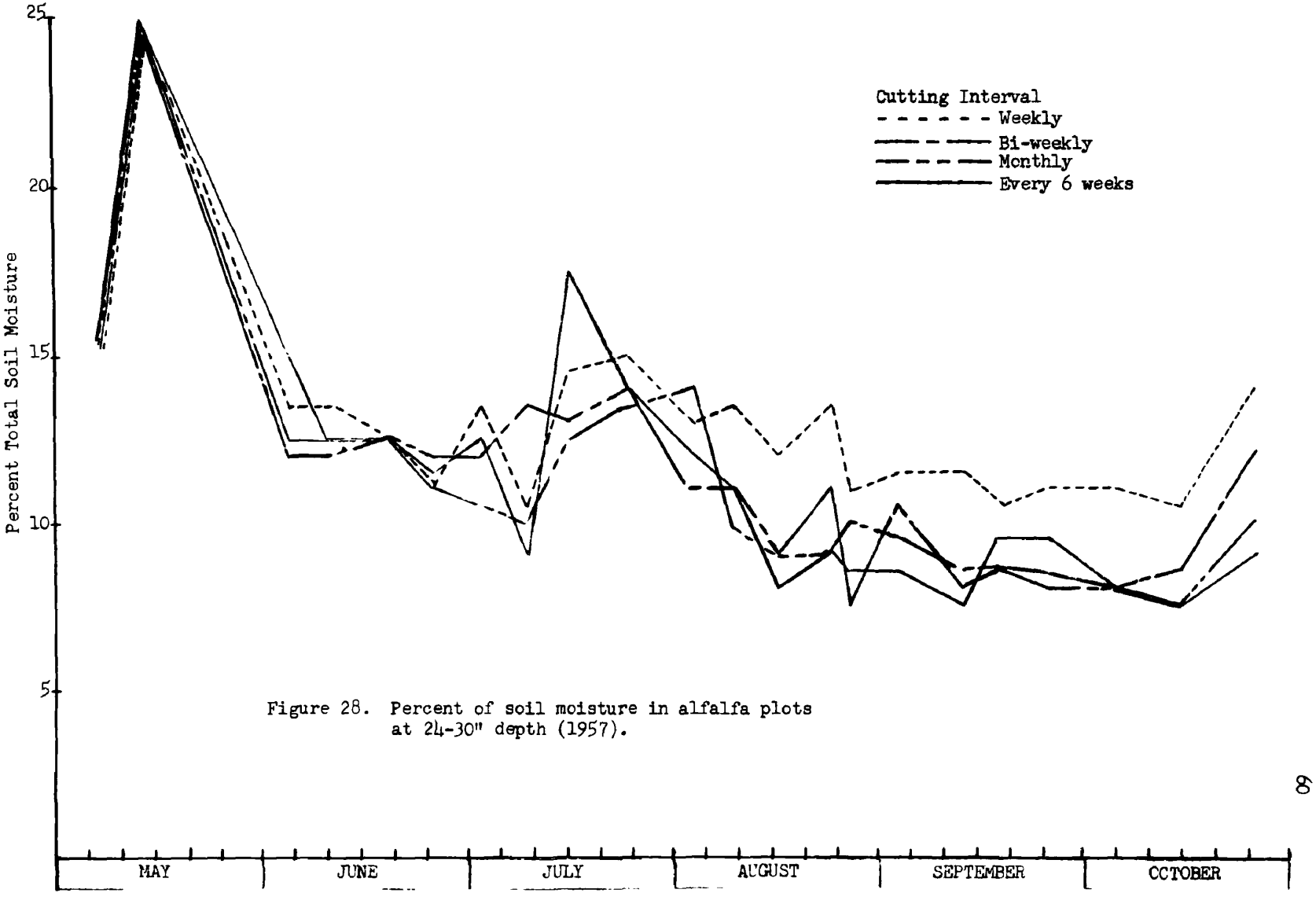


Figure 28. Percent of soil moisture in alfalfa plots at 24-30" depth (1957).

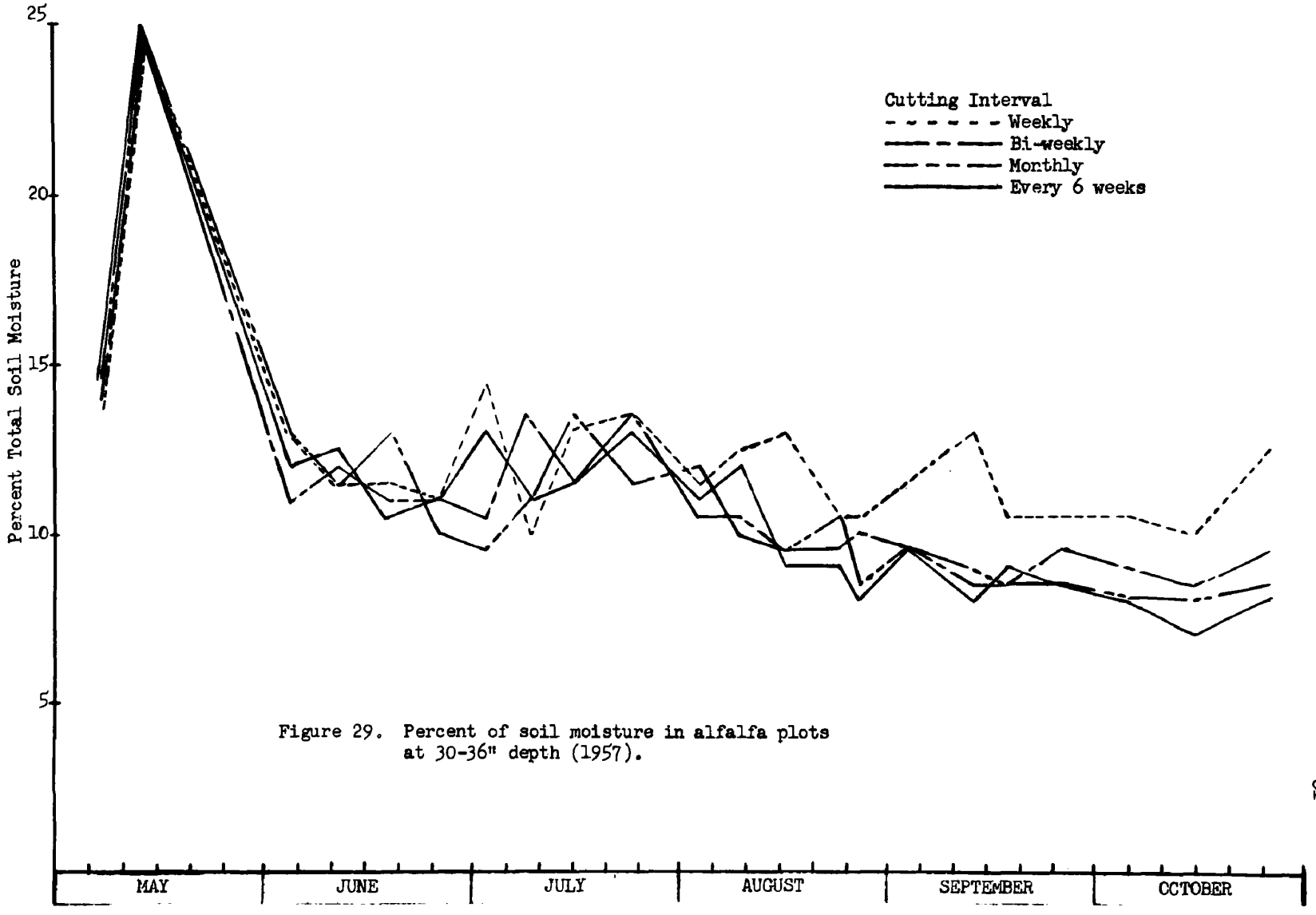


Figure 29. Percent of soil moisture in alfalfa plots at 30-36" depth (1957).

The fall drought in 1956 caused soil moisture in early May 1957 to be below field capacity. There was 6.12 inches of rainfall from May 9th to 25th bringing the soil moisture above field capacity in all plots. There was a decline in moisture during June and then the heavy rains of July returned the soil to field capacity. Depletion of soil moisture followed until August when 1.55 inches of rain fell between the 24th and the 31st, which raised the percent of moisture in the upper six inch horizons but not at the lower levels. The percent of moisture at 30-36 inches was approximately the same during the 1956 and 1957 seasons, during August and September. However, during October the percent moisture increased slightly in 1957, at 30-36 inches, but declined considerably in 1956.

Sudan grass which was seeded May 29, 1957, started the growing season with the soil near field capacity. Figures 30 through 35. July rains in 1957 increased the moisture in all levels above field capacity. Soil moisture in the upper six inch horizon, was depleted by August 16th to 7.7 percent (average of all four cutting treatments). The six week cutting treatment reduced soil moisture at six inches to 6.6 percent, and the weekly cutting to 8.3 percent. Moisture below 12 inches remained nearly constant in the Sudan grass plots, after August 10, 1957.

Inches of Water in Top 36 Inches of Soil. The amount of water per inch of soil was calculated by multiplying density of the horizon being considered by the percent of moisture in the soil. These values were

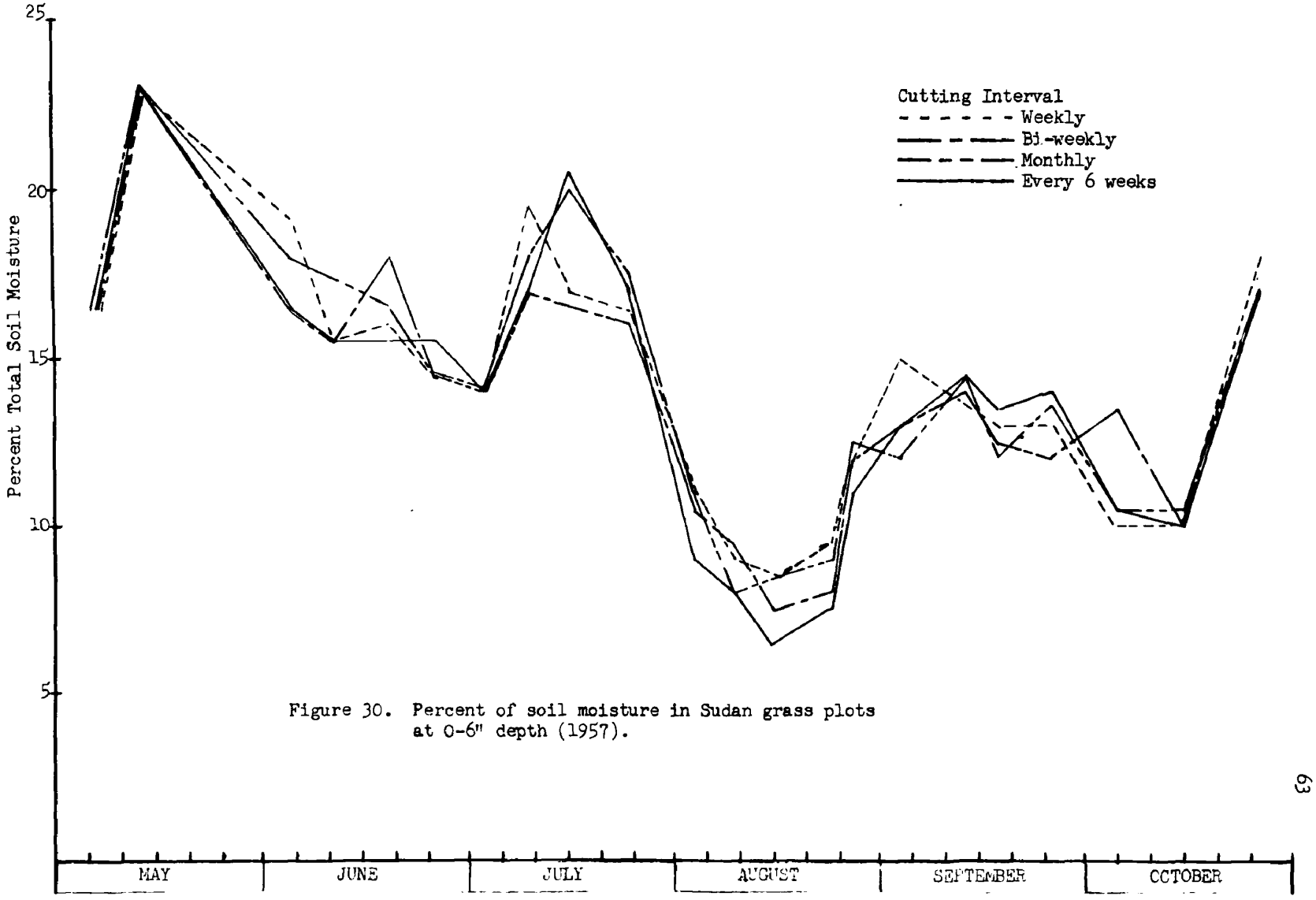


Figure 30. Percent of soil moisture in Sudan grass plots at 0-6" depth (1957).

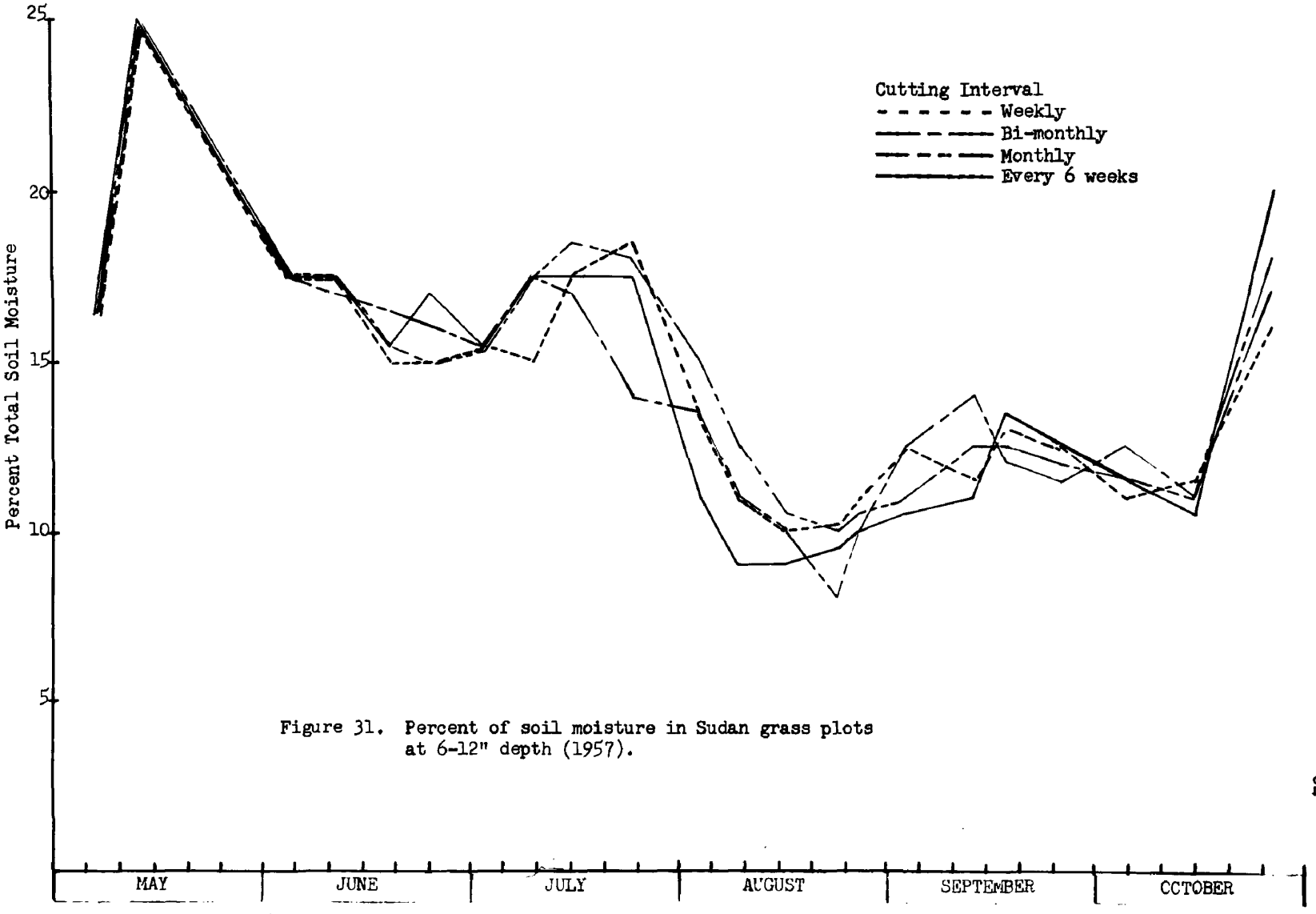


Figure 31. Percent of soil moisture in Sudan grass plots at 6-12" depth (1957).

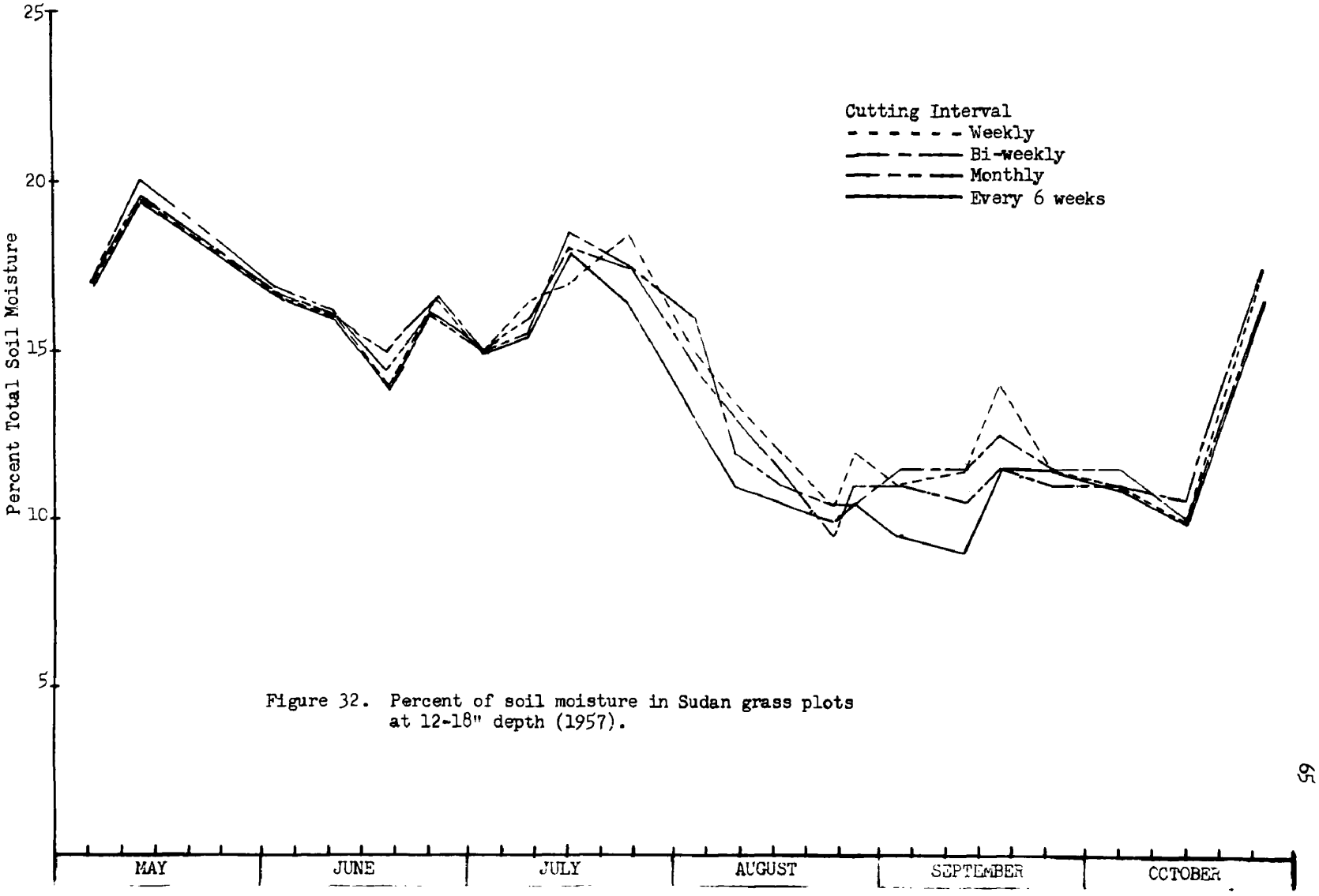


Figure 32. Percent of soil moisture in Sudan grass plots at 12-18" depth (1957).

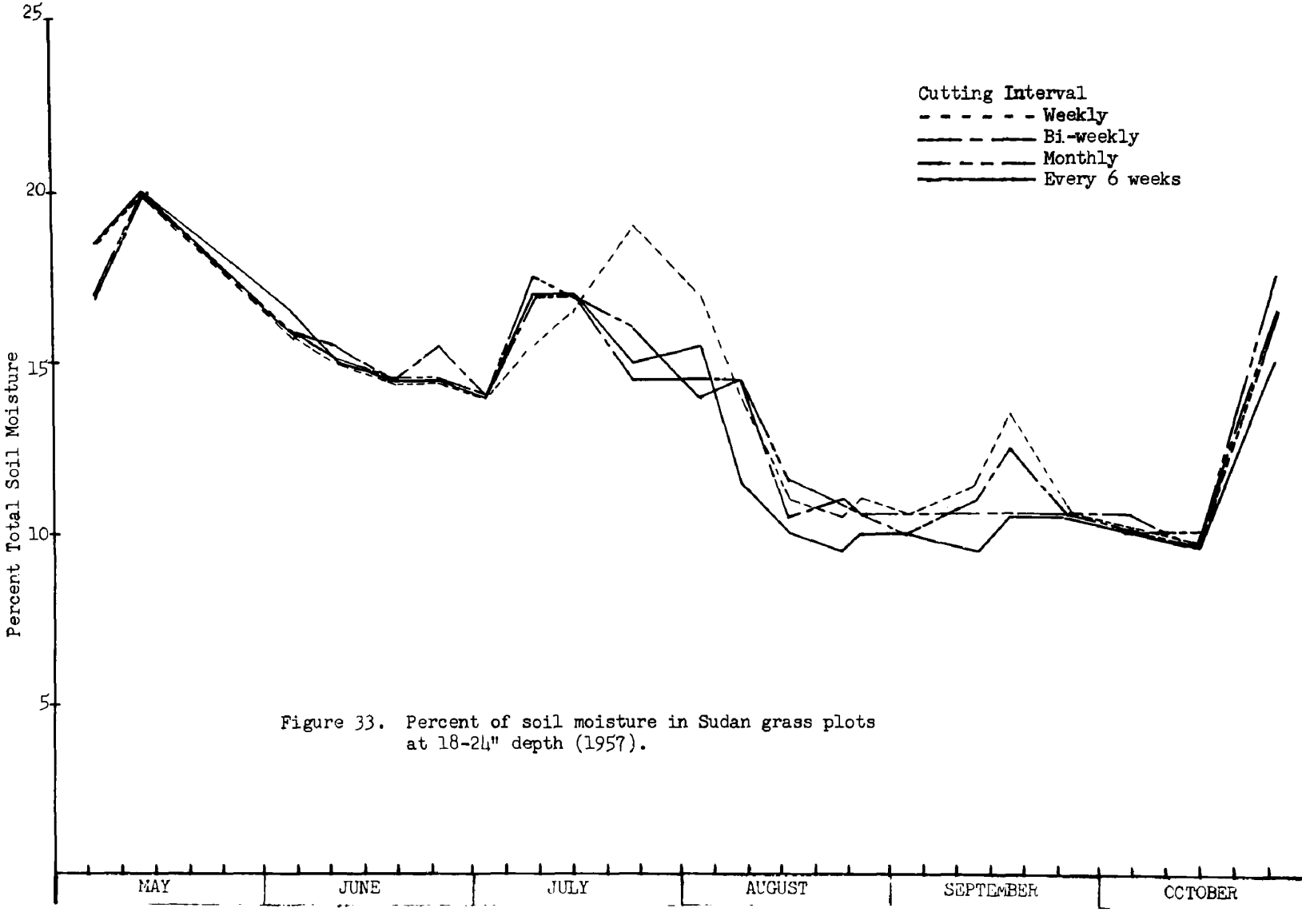


Figure 33. Percent of soil moisture in Sudan grass plots at 18-24" depth (1957).

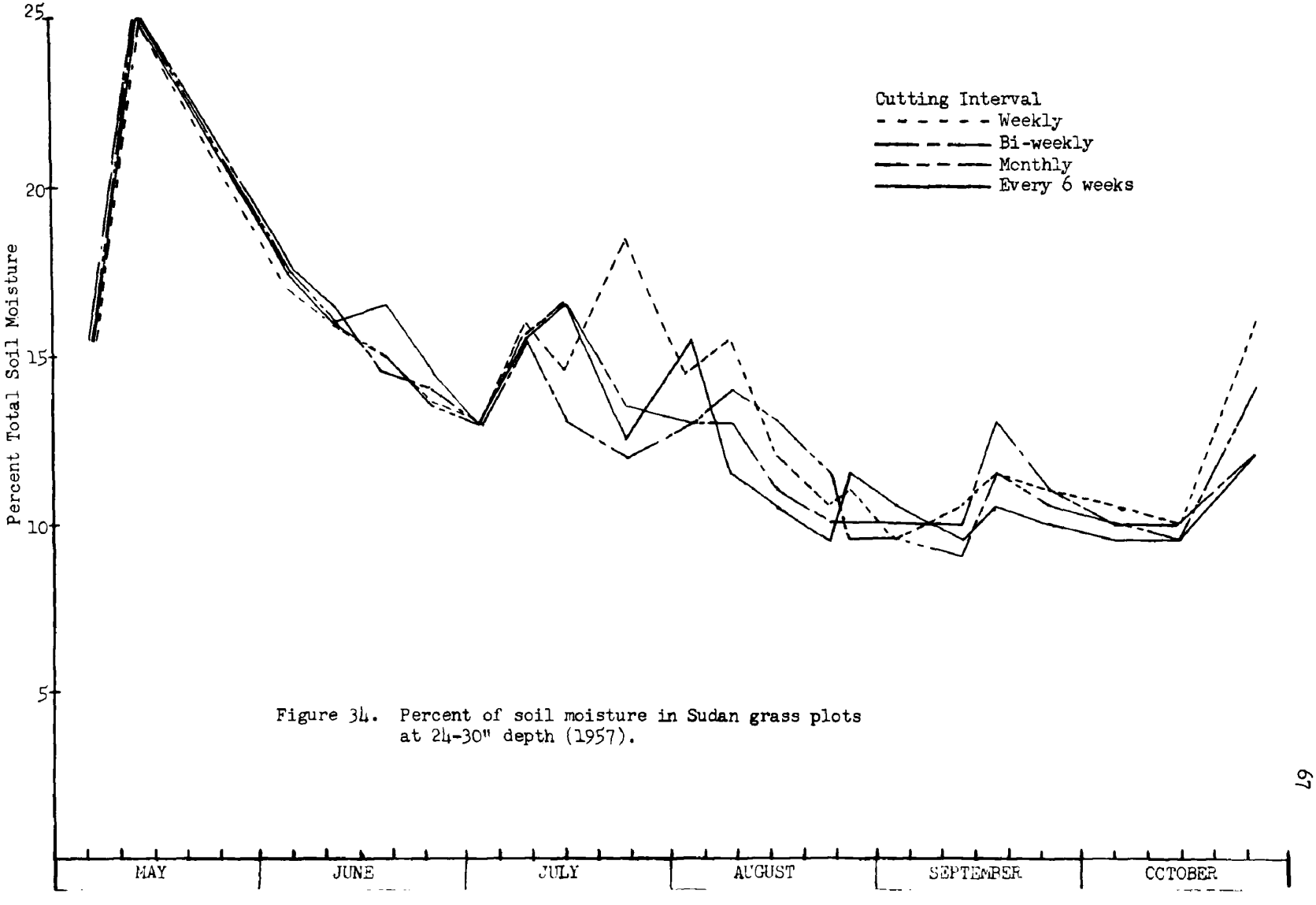


Figure 34. Percent of soil moisture in Sudan grass plots at 24-30" depth (1957).

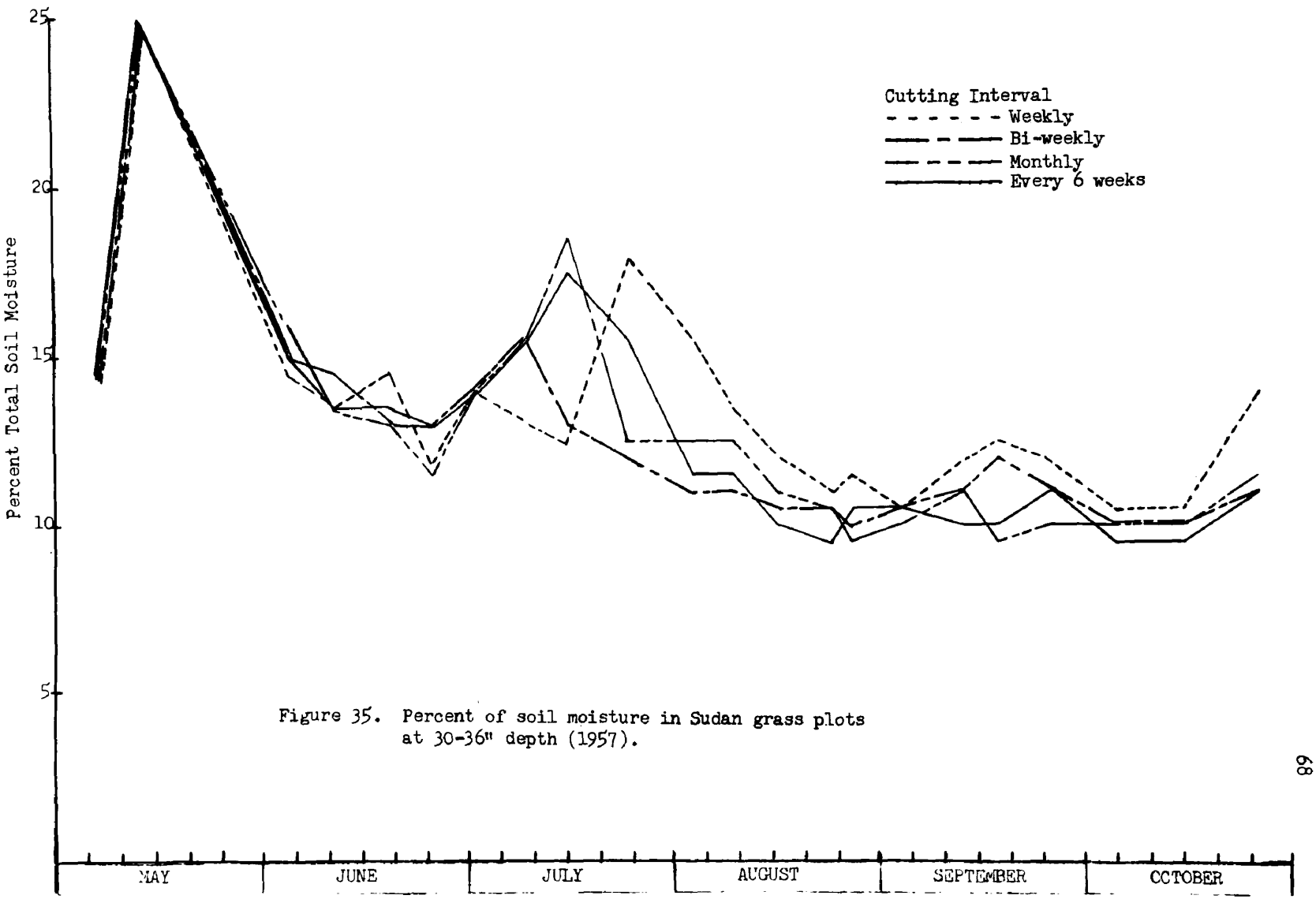


Figure 35. Percent of soil moisture in Sudan grass plots at 30-36" depth (1957).

summed and multiplied by 6 to give the inches of water in the top 36 inches of soil, Figures 36 through 39.

Field capacity for the top 36 inches of soil for 1956 was 11.4 inches and for 1957 10.2 inches of water. These values represent the inches of water found in the soil 48 hours after the soil had been wetted to a depth of at least 3 feet. All plots in 1956 were above field capacity until June 2nd. After June 2nd, total inches of water in the upper 36 inches of the soil profile declined throughout June and July. The plots most frequently cut generally had more water in the upper 36 inches of soil than did those cut monthly and at six weeks.

There was 5.20 inches of rain in August 1956 and on August 14th the alfalfa plots cut at the six week interval had 7.81 inches, the plots cut monthly 8.99 inches, those cut bi-weekly 10.42 inches, and cut every week 9.86 inches of water in the top 36 inches of soil. There was 1.28 inches of rain in September 1956, and by September 25th the water in the top 36 inches of soil had dropped to 4.74 inches in the plots being cut every six weeks, those cut monthly 6.22 inches, bi-weekly 7.18 and weekly 6.74 inches. There was only 0.37 inches of rain from September 25th until October 31, 1956. During this period all plots declined to less than 3 inches of water in the upper 36 inches of soil.

The Sudan grass plots were at field capacity when the Sudan grass was seeded May 30, 1956. There was an increase in the total inches of water in the soil during June, while the plants were small. The amount of water in the upper 36 inches of soil then decreased in July 1956.

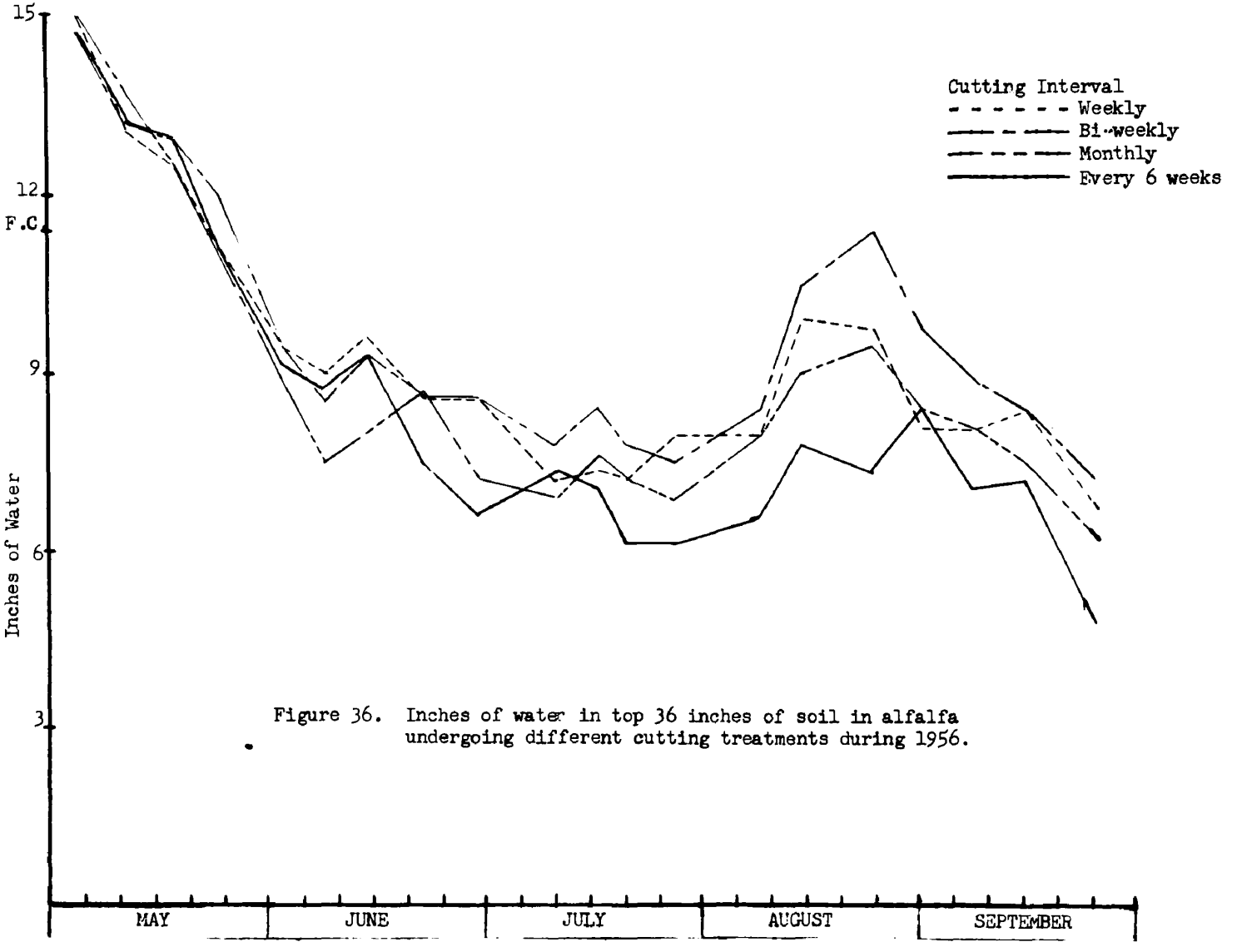


Figure 36. Inches of water in top 36 inches of soil in alfalfa undergoing different cutting treatments during 1956.

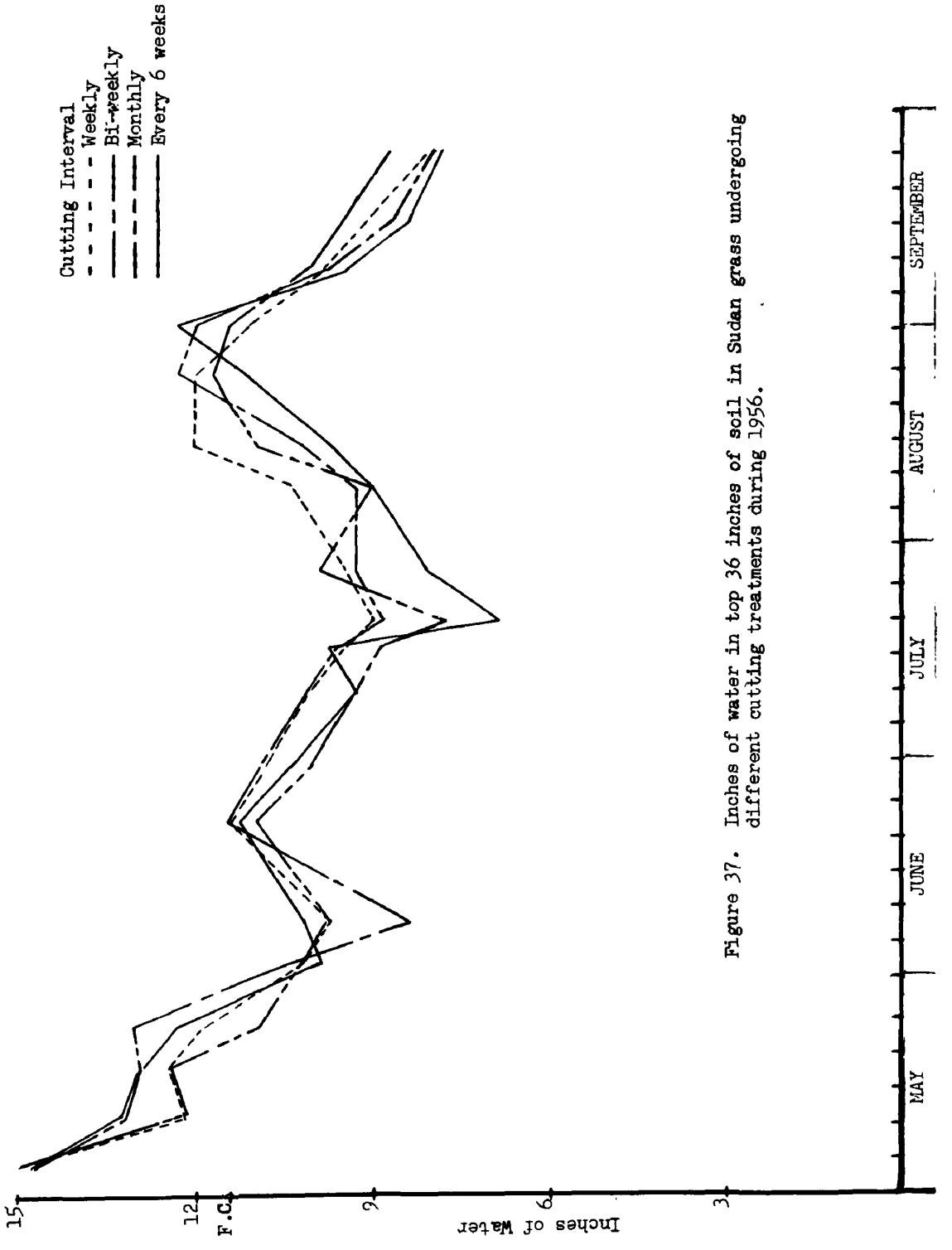


Figure 37. Inches of water in top 36 inches of soil in Sudan grass undergoing different cutting treatments during 1956.

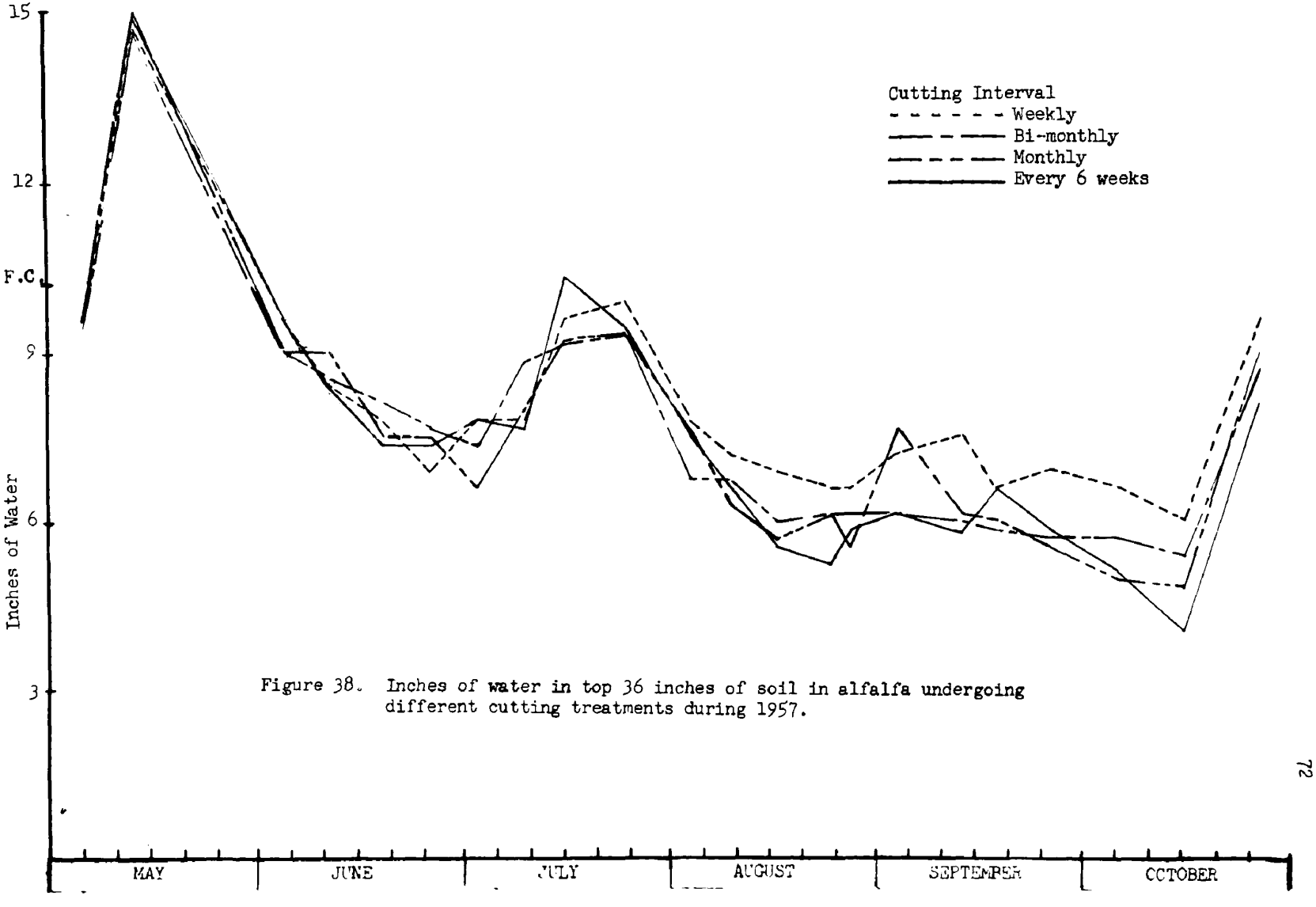


Figure 38. Inches of water in top 36 inches of soil in alfalfa undergoing different cutting treatments during 1957.

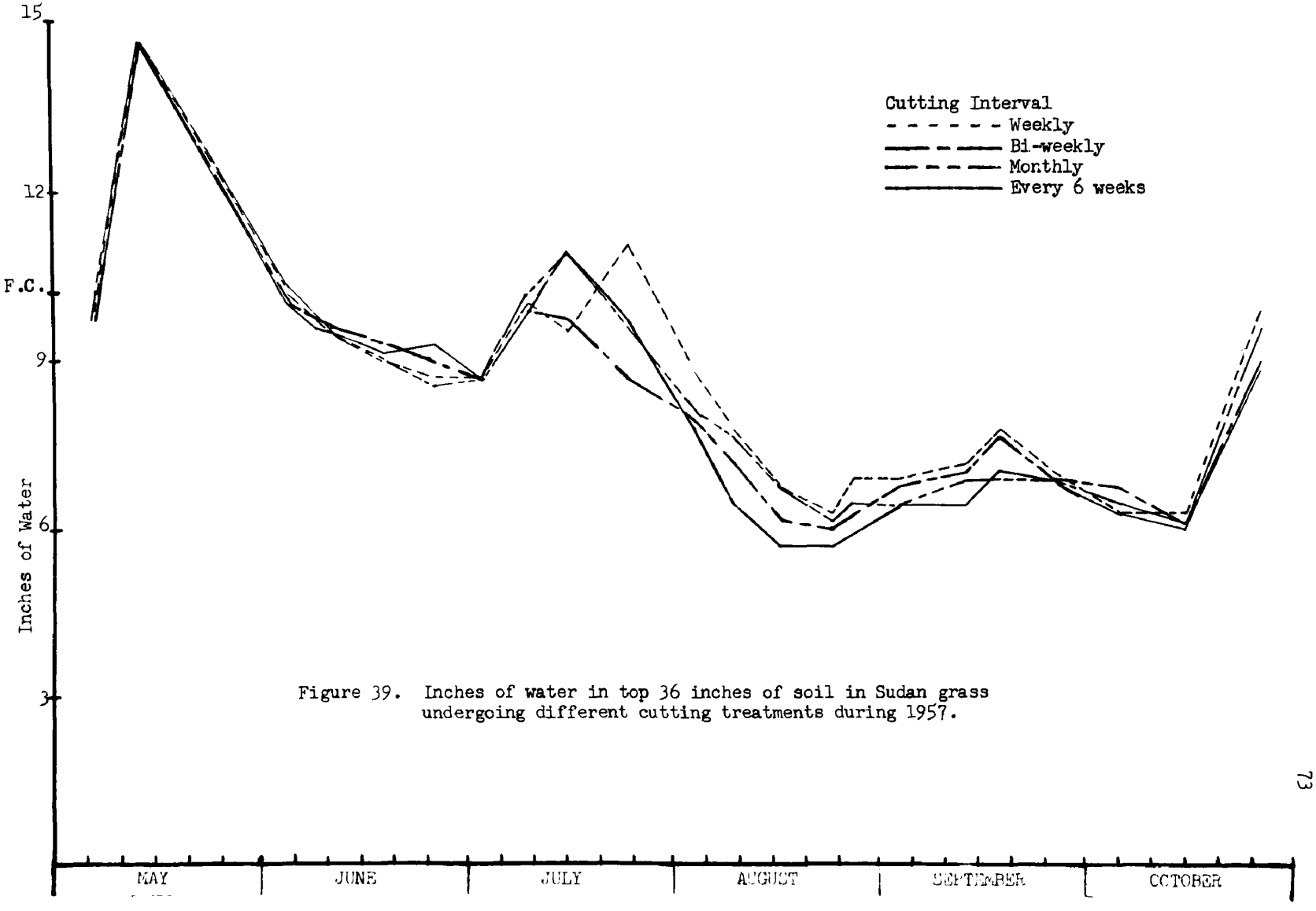


Figure 39. Inches of water in top 36 inches of soil in Sudan grass undergoing different cutting treatments during 1957.

On July 20, 1956, Sudan grass which was to be cut every six weeks (first harvest 1956 was August 2nd) had reached a low of 6.94 inches of water in the top 36 inches of soil. Plots cut monthly had 7.85 inches in the upper 3 feet of soil on July 20th, and there was 8.85 inches and 9.02 inches respectively in the plots cut bi-weekly and weekly.

The 1.98 inches of rainfall which fell on August 4th, and 5th, and the 0.97 inch on August 9th, increased soil moisture in all Sudan grass plots to near field capacity.

Figure 37 shows that there was very little difference between cutting treatments in the total amount of moisture in the top 36 inches of soil on September 15th when the final samples of Sudan grass were taken in 1956.

The 1956 late fall drought resulted in the moisture in the upper 36 inches in the alfalfa plots seeded August 1, 1956 being 1.78 inches below field capacity when the first 1957 soil samples were taken on April 8th. There was 3.86 inches of rain in April 1957, and the soil in all plots approached field capacity by late April 1957. All the determinations made on May 11, 1957 exceeded field capacity.

Soil moisture declined rapidly from May 13, 1957 until July 2, 1957. Cutting treatments started on May 28th. There were slight differences between treatments from May 28th to July 2nd. On July 2nd the soil in the plots cut weekly contained 7.95 inches of water and those cut at the six week interval 7.75 inches of water. There was 7.22 inches of rainfall between July 4 and July 22, 1957. Moisture in all

plots was near field capacity on July 24th, but field capacity was not reached.

During the interval July 23rd to October 26th there was only 6.55 inches of rainfall. All plots declined in moisture during the period until October 15, 1957. There was 3.72 inches of rain from October 16 to October 24, 1957. On October 26th moisture approached but did not reach field capacity. Differences in soil moisture as a result of differences in cutting treatments were small. On October 15th, however, before the 3.72 inches of rainfall, there were clearly defined differences. The total inches of water in the top 36 inches of soil were; plots cut weekly 6.25 inches, cut bi-weekly 5.41 inches, cut monthly 4.73 inches and every six weeks 4.00 inches. These differences were reflected in the soil moisture percentages obtained on October 26, 30 hours after the rainfall between October 16th and 24th.

The rains of July 1957 caused an upsweep in soil moisture curves for both alfalfa and Sudan grass as shown in Figures 38 and 39. The dry months which followed caused a decline of water in the top 36 inches of soil. From July 24, 1957 until the end of the growing season there was always more total water in the plots being cut weekly than in those cut every six weeks.

The Sudan grass harvested in 1957 only slightly reduced soil moisture, Figure 39, and only slight differences between cutting treatments were observed.

Consumptive Use of Water

Consumptive use, or evapotranspiration includes loss of soil moisture by evaporation and by absorption through the plant roots. Consumptive use was determined for the period May 18 to September 25, 1956 and May 13 to September 26, 1957, Tables 13 and 14. The total inches of water used by alfalfa during both of the above periods increased as frequency of cutting decreased. The difference between weekly interval cutting water used and the six week cutting interval water used was 0.98 inches in 1956 and 0.89 inches in 1957.

The greatest daily consumptive use for alfalfa was in May in both 1956 and 1957. The lowest consumptive use was in July 1956, with 0.093 inches per day and in August and September 1957 when an average of 0.077 inches per day was recorded, Table 15.

The average consumptive use of water by Sudan grass, as shown in Table 16, increased with the decrease in cutting frequency, except that in 1956 Sudan grass cut monthly used 0.23 inch less water during the season than did Sudan grass cut bi-weekly. The consumptive use averaged for all treatments of Sudan grass in 1956 increased for each month from June through September reaching a maximum of 0.16 inch per day for September. Maximum use in 1957 was 0.23 inch per day in July, and use per day then declined to 0.03 inch for September.

Alfalfa and Sudan grass which was cut frequently required more inches of water to produce a ton of forage than did alfalfa and Sudan grass cut at either the four or six week intervals, with but one exception.

TABLE 13

THE INCHES OF WATER USED PER TON OF ALFALFA FORAGE PRODUCED

Cutting Frequency	Time Interval--1956			
	6/9 to 7/7	7/7 to 8/2	8/2 to 8/27	Average
Weekly	7.21	9.97	16.18	9.75
Bi-weekly	4.83	13.59	5.70	6.27
Monthly	3.96	7.79	4.22	4.62
Every six weeks	4.18	4.12	3.65	4.01
Average	5.04	8.87	7.44	6.16
	Time Interval--1957			
	6/11 to 7/9	7/9 to 8/9	8/9 to 8/29	Average
Weekly	21.48	14.08	24.43	17.97
Bi-weekly	14.97	9.45	13.71	11.91
Monthly	5.61	5.02	18.67	5.96
Every six weeks	7.47	4.90	17.69	6.73
Average	12.38	8.36	18.63	10.64

TABLE 14

THE INCHES OF WATER USED PER TON OF SUDAN GRASS FORAGE PRODUCED

Cutting Frequency	Time Interval--1956		Average
	7/7 to 8/2	8/2 to 8/15	
Weekly	4.65	8.28	6.58
Bi-weekly	4.21	8.49	6.35
Monthly	1.76	5.62	3.42
Every six weeks	1.04	5.37	2.60
Average	2.92	6.94	4.73
	Time Interval--1957		
	7/9 to 8/9	8/9 to 9/18	
Weekly	9.45	9.00	9.29
Bi-weekly	10.07	7.42	9.11
Monthly	2.29	6.41	3.02
Every six weeks	1.60	8.08	2.32
Average	5.85	7.73	5.94

TABLE 15

THE CONSUMPTIVE USE OF WATER BY ALFALFA

(Inches per Day)

Cutting Frequency	1956 June	July	August	September	Average
Weekly	0.14	0.09	0.14	0.07	0.11
Bi-weekly	0.14	0.11	0.10	0.12	0.12
Monthly	0.17	0.08	0.12	0.10	0.12
Every six weeks	0.20	0.08	0.10	0.16	0.13
Average	0.16	0.09	0.12	0.11	0.12
	1957				
	June	July	August	September	Average
Weekly	0.14	0.23	0.07	0.06	0.13
Bi-weekly	0.13	0.23	0.08	0.07	0.13
Monthly	0.15	0.19	0.06	0.13	0.13
Every six weeks	0.14	0.23	0.10	0.06	0.14
Average	0.14	0.22	0.07	0.08	0.13

TABLE 16

THE CONSUMPTIVE USE OF WATER BY SUDAN GRASS

(Inches per Day)

Cutting Frequency	1956 June	July	August	September	Average
Weekly	0.07	0.12	0.10	0.09	0.09
Bi-weekly	0.07	0.13	0.08	0.19	0.11
Monthly	0.09	0.08	0.11	0.15	0.10
Every six weeks	0.10	0.15	0.07	0.21	0.12
Average	0.08	0.12	0.09	0.16	0.11
	1957 June	July	August	September	
Weekly	0.12	0.19	0.08	0.01	0.12
Bi-weekly	0.12	0.24	0.09	0.01	0.13
Monthly	0.13	0.22	0.10	0.03	0.14
Every six weeks	0.13	0.26	0.10	0.06	0.15
Average	0.12	0.23	0.10	0.03	0.14

The total inches of water required by alfalfa per ton of forage during the period June 9 to August 27, 1956 decreased as the cutting frequency decreased. The average inches required per ton for the season for all alfalfa cutting treatments was 5.52 inches in 1956 and 8.78 inches in 1957. The inches used per ton by Sudan grass during the 1956 and 1957 periods studied were 4.01 inches and 3.83 inches respectively. Consumptive use was closely associated with rainfall during the periods of active plant growth.

Relationship of Yield to Soil Moisture

The total inches of water in the top 36 inches of soil and yield of forage is shown graphically for each crop and for each cutting treatment in Figures 40 through 43.

The second cutting from the plots subjected to the six week cutting treatment had a yield of 0.92 ton per acre in 1956 as contrasted to 1.60 tons per acre in 1957. The situation in the two years was reversed in August.

The third cutting of the six week cutting interval produced 0.61 ton per acre more forage in 1956 than in 1957, Figure 43. Similar differences in yield during the two years for the other alfalfa cutting treatments were evident and are shown in Figures 40 through 42.

The first cutting of Sudan grass which was taken on August 2, 1956 (Figure 44) was 1.25 tons per acre less than the first cutting taken on August 9, 1957. The Sudan seeded in 1957 was slow to emerge and was

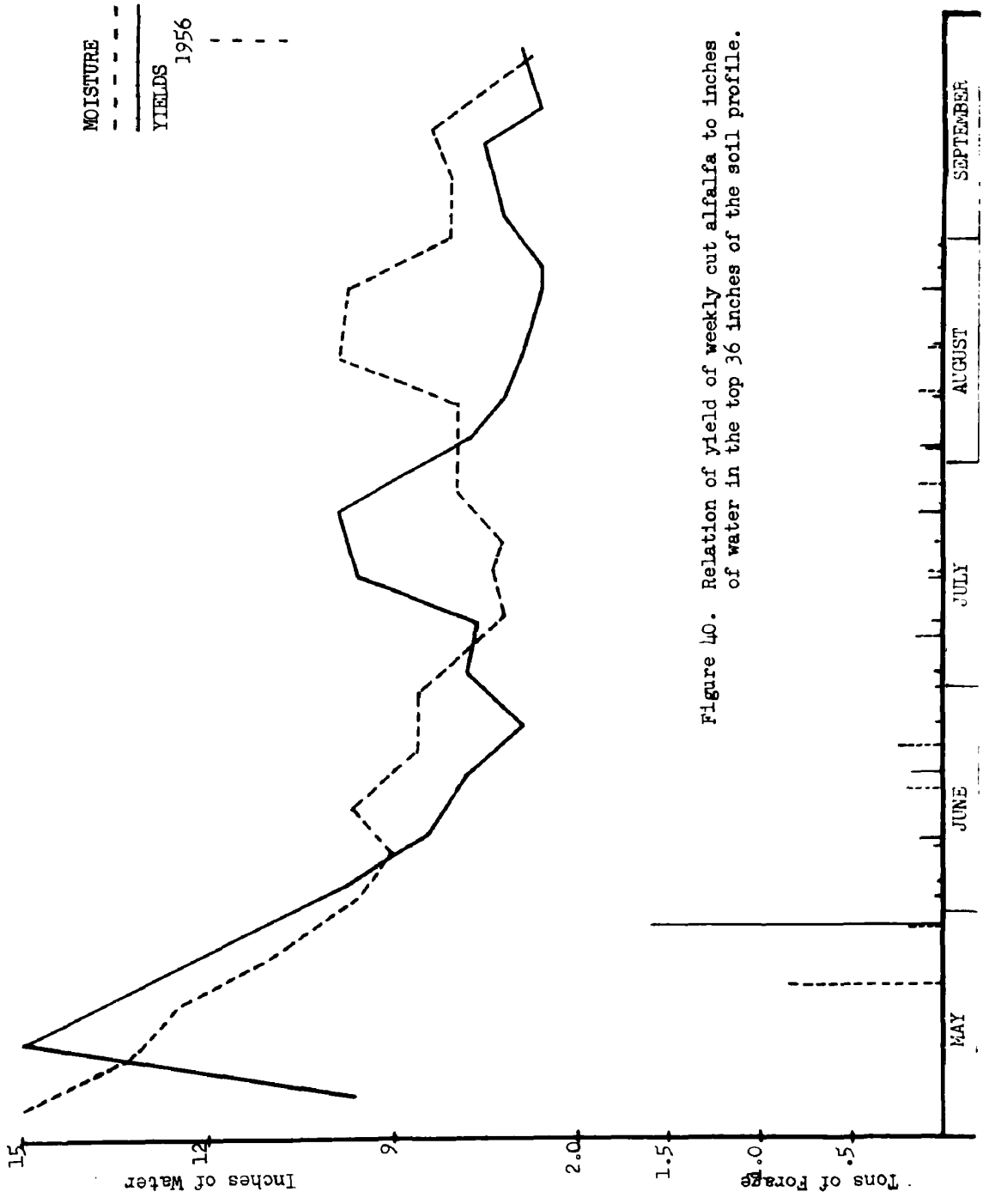


Figure 40. Relation of yield of weekly cut alfalfa to inches of water in the top 36 inches of the soil profile.

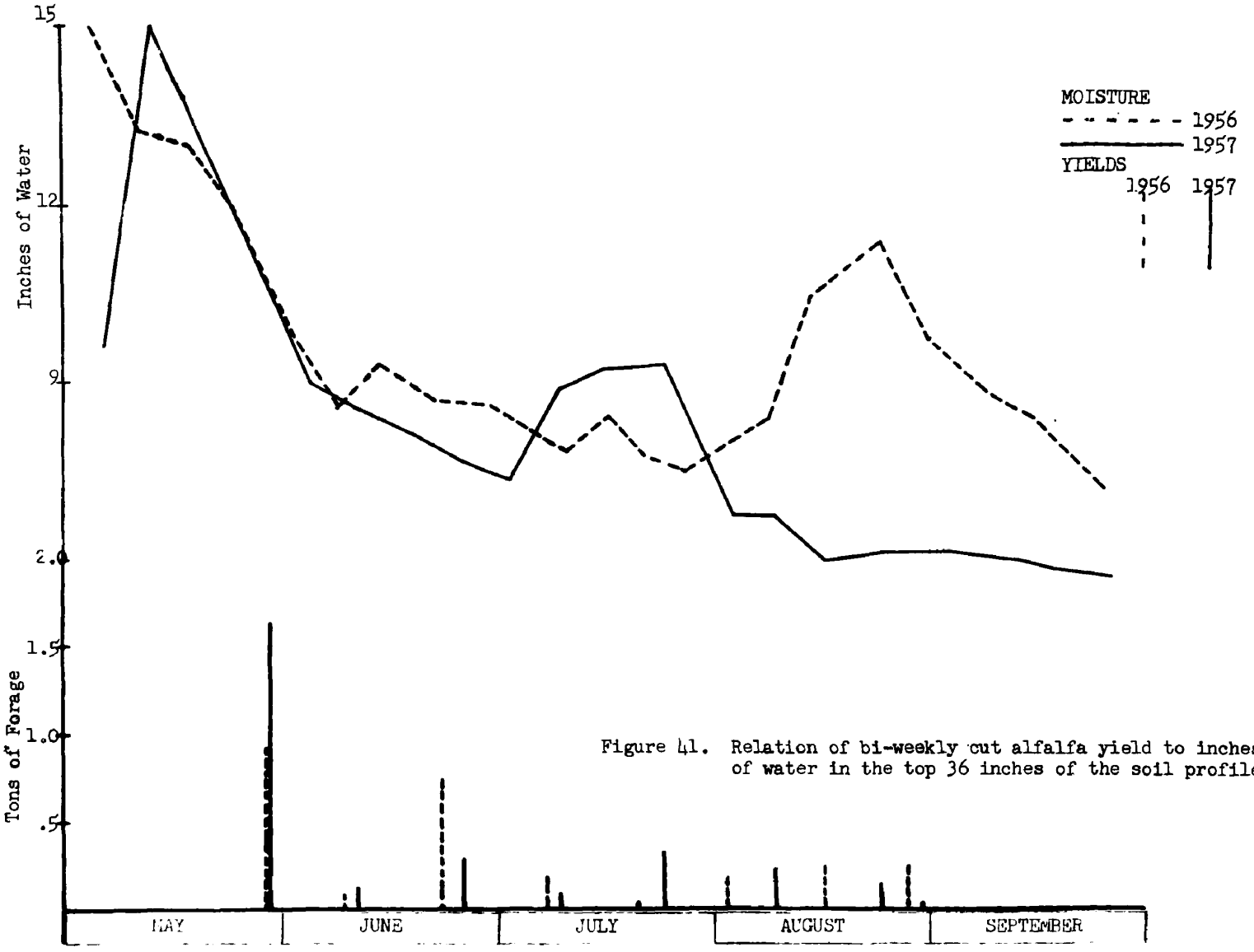


Figure 41. Relation of bi-weekly cut alfalfa yield to inches of water in the top 36 inches of the soil profile.

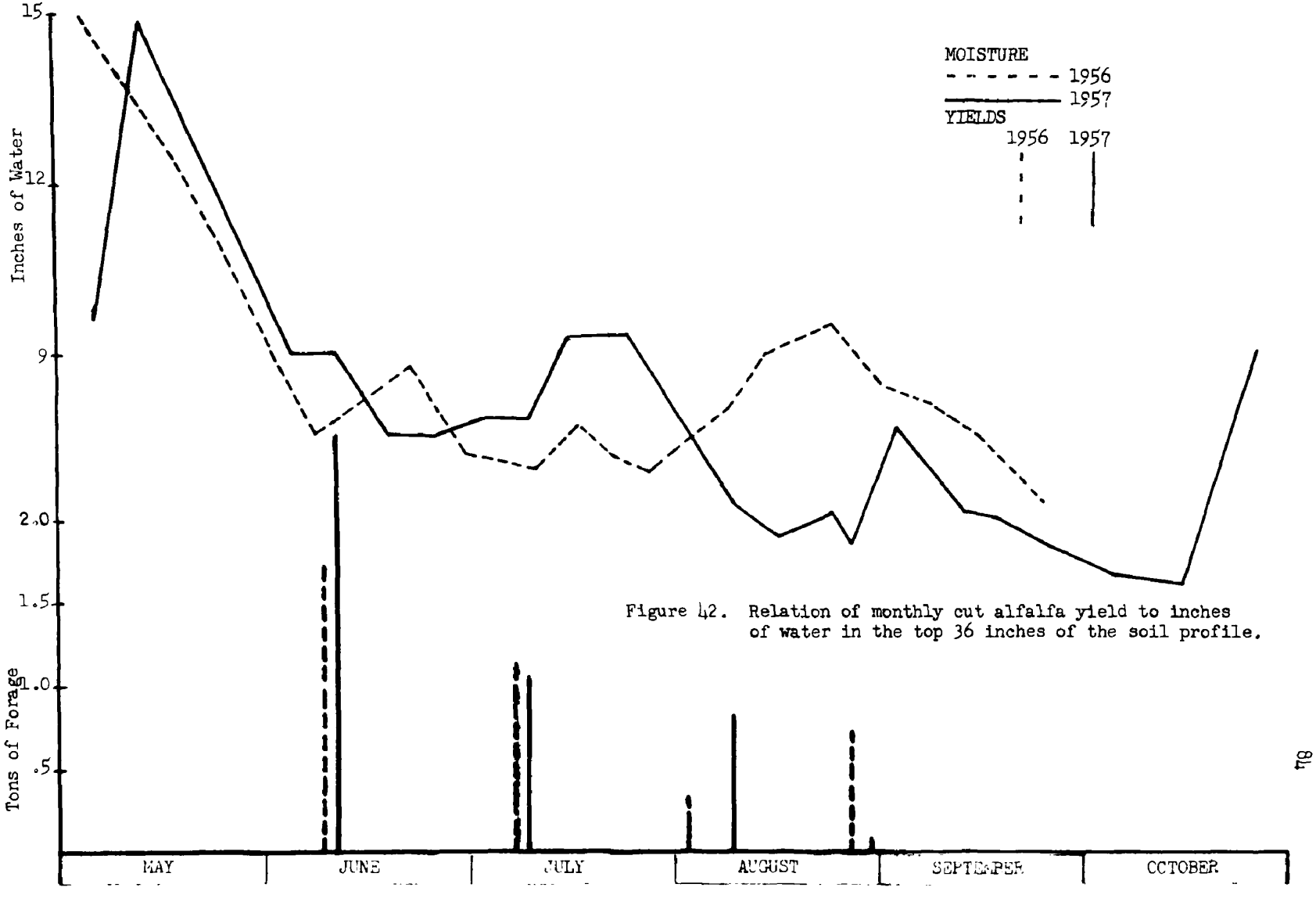


Figure 42. Relation of monthly cut alfalfa yield to inches of water in the top 36 inches of the soil profile.

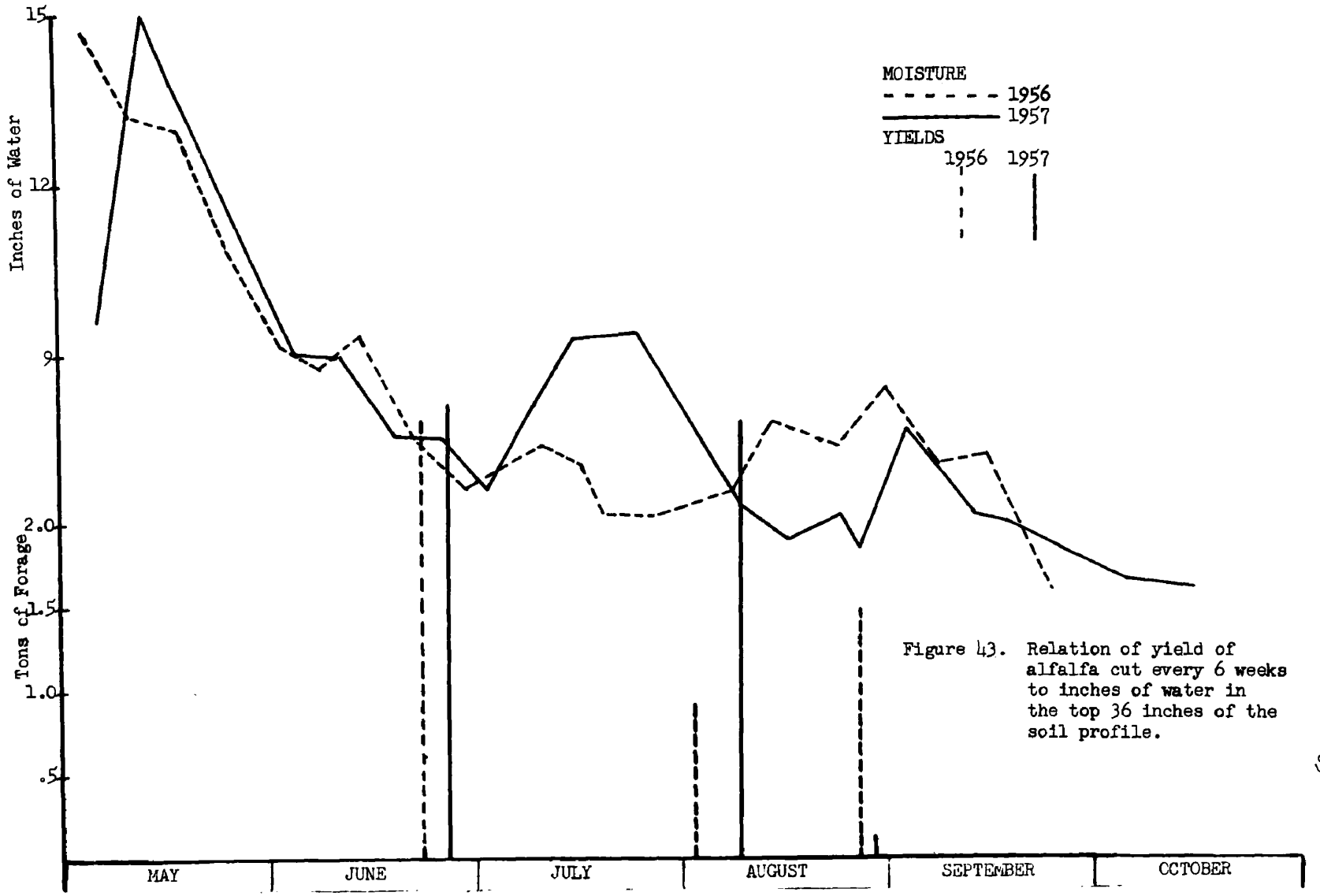


Figure 43. Relation of yield of alfalfa cut every 6 weeks to inches of water in the top 36 inches of the soil profile.

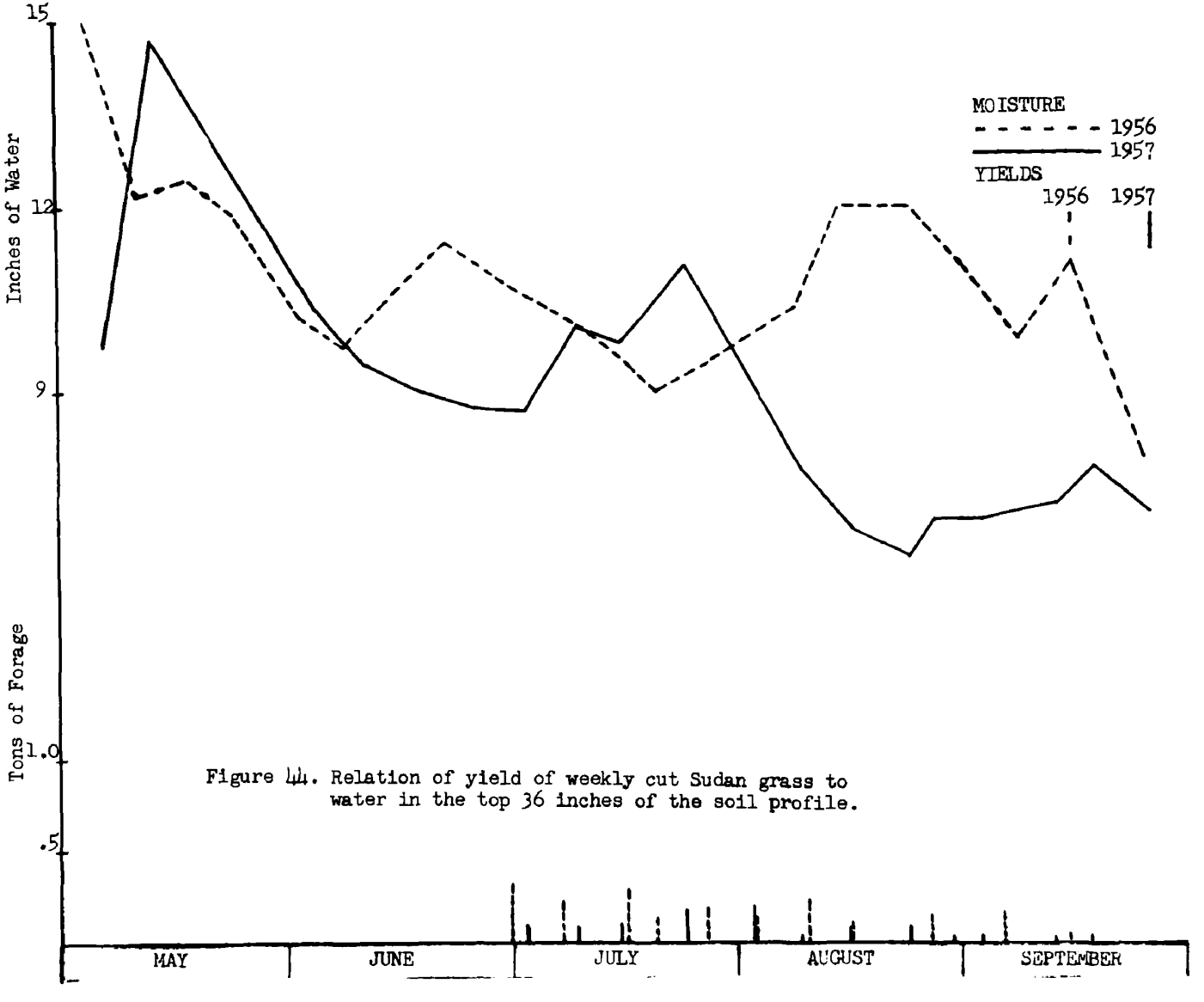


Figure 44. Relation of yield of weekly cut Sudan grass to water in the top 36 inches of the soil profile.

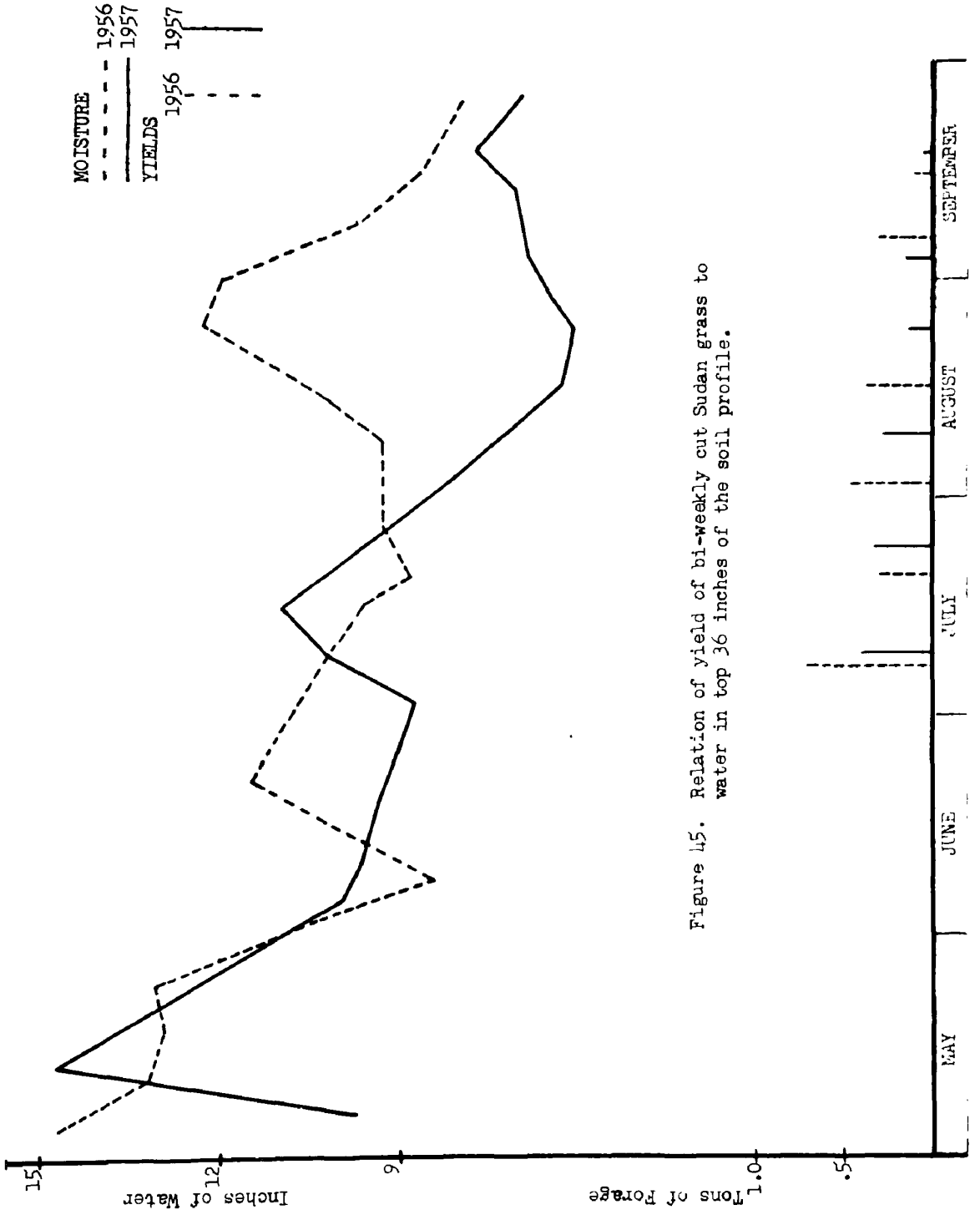


Figure 45. Relation of yield of bi-weekly cut Sudan grass to water in top 36 inches of the soil profile.

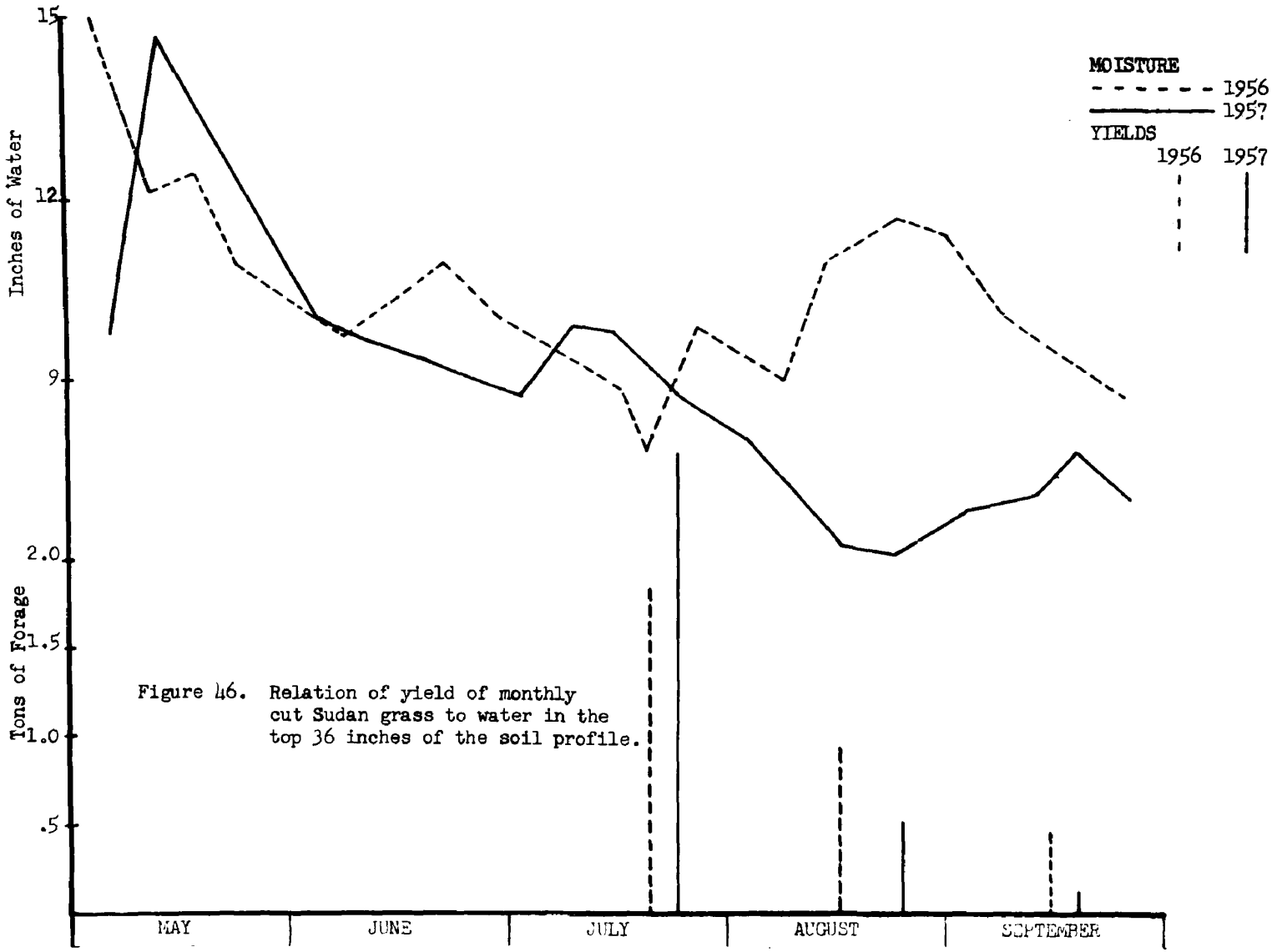


Figure 46. Relation of yield of monthly cut Sudan grass to water in the top 36 inches of the soil profile.

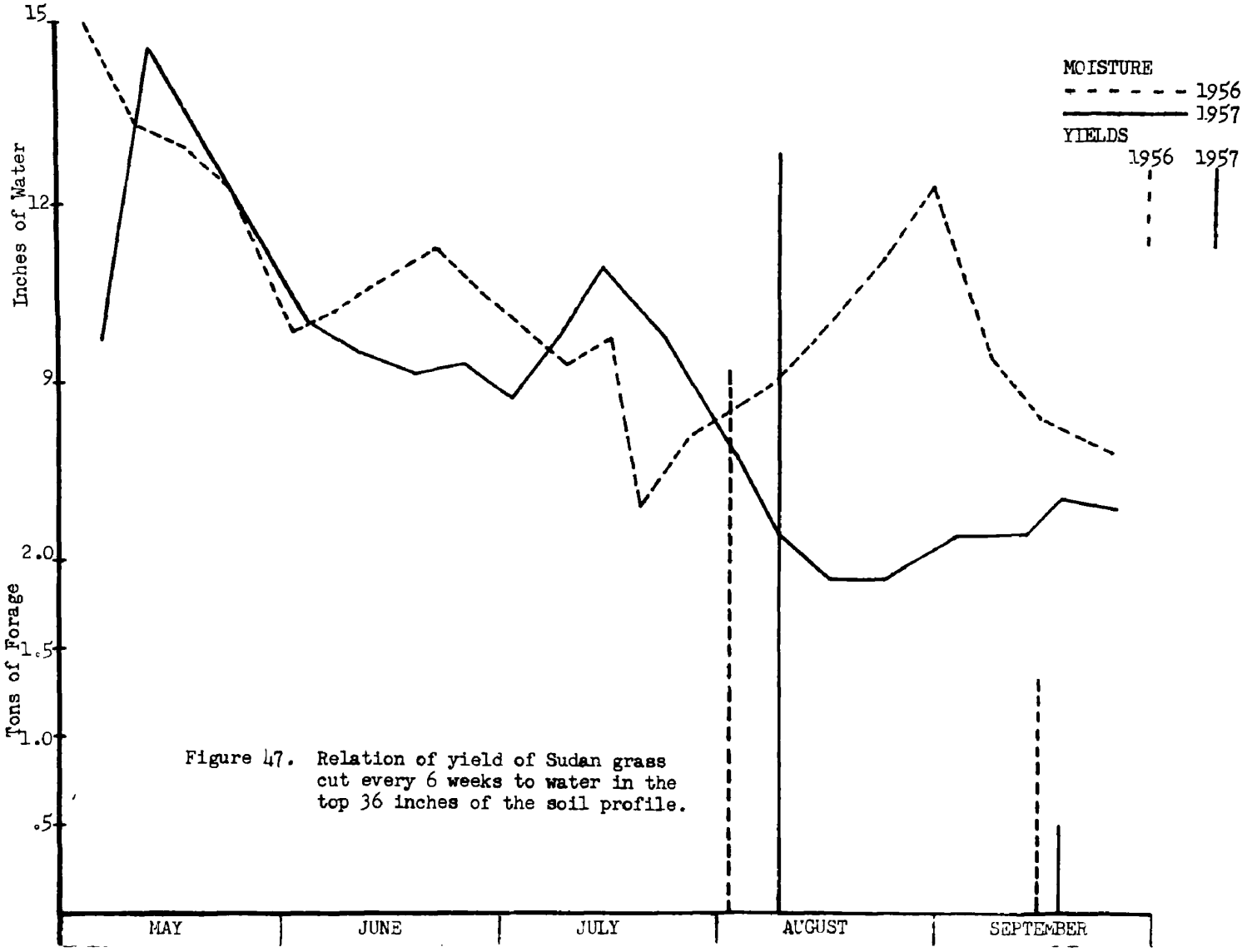


Figure 47. Relation of yield of Sudan grass cut every 6 weeks to water in the top 36 inches of the soil profile.

much less vigorous than the 1956 Sudan grass up until July 15th. The yields obtained show this clearly, Table 6.

The second cutting of the plots cut at the six week interval was 0.85 ton greater in 1956 than 1957. Very favorable moisture conditions existed during the period between the first and second cuttings taken in 1956. Yields obtained from the other cutting treatments were similarly affected by the moisture relations existing during the 1956 and 1957 growing seasons (Figures 45, 46, and 47).

Discussion

Moisture supplies for alfalfa were adequate during April and May while the plants were growing vigorously. During the months which followed, when moisture supplies were limited, a clear pattern in soil moisture depletion as related to cutting frequency was observed at all depths.

Frequent defoliation saved water, and abundant top growth, as in the four and six week cutting intervals, reduced soil moisture notably. The pattern of moisture depletion was temporarily disturbed by abundant rain.

Soil moisture depletion in the upper soil layers was only slightly affected by virtual killing of alfalfa and replacement by weeds in plots cut weekly and bi-weekly. Soil moisture depletion in the lower soil layers was less when cutting was frequent.

Water consumed per unit of forage produced decreased as the length of cutting interval increased. Alfalfa used water more efficiently in

1956 than in 1957, even though 1957 yields were higher. The difference in efficiency may have been caused by the slight difference in soil or by the variation in the period of the time of heavy rainfall. Top growth varied directly with water added to the soil by rainfall but both alfalfa and Sudan grass were more responsive to favorable moisture relations in July than in August. Soil moisture measurements for the complete life cycle were possible for Sudan grass, and results obtained on the efficiency of water use in 1956 and 1957 were very similar.

Soil moisture stresses for Sudan grass were slight during these two growing seasons, however, Sudan grass did appear to use water efficiently even though the inches of water within the 36 inch zone were always within a few percent of field capacity.

Forage production by both alfalfa and Sudan grass was increased by rainfall whenever it came in adequate amounts.

Alfalfa used water for a 7 to 8 month period, whereas Sudan grass used moisture for a shorter time, 4 months or less. Sudan grass used stored soil moisture and rainfall during its short yet productive life cycle. Five tons of forage per acre at 12% moisture would account for about 10% of the total water used during the growth period assuming a use rate of 0.13 inch per day (the average use by all cutting treatments for alfalfa and Sudan). Therefore, much of the water taken from the soil was probably used in transpiration by the plants and evaporation from the soil surface.

Summary and Conclusions

Alfalfa and Sudan grass were subjected to four cutting treatments and soil moisture depletion was studied using gravimetric determinations in 1956 and 1957, and Bouyoucos blocks in 1957.

1. Water consumed, per unit of forage produced, decreased as length of cutting interval increased.
2. Periods of maximum forage production by alfalfa and Sudan grass appear to be directly related to the time of greatest water consumption.
3. Alfalfa cut frequently used slightly less water than alfalfa cut at four or six week intervals, and a greater percentage was used from the surface layers.
4. The zone of most active water absorption by alfalfa plants cut at 4 and 6 week intervals shifts to a greater depth with time when rainfall is inadequate.
5. Sudan grass depleted moisture at 12, 24, and 36 inches in the same manner in all cutting treatments and most of the moisture used was removed from the upper 1 foot of soil.
6. Sudan grass demands upon soil moisture did not come until July and August. Thus much of the water used by Sudan grass was that which had been stored in the soil prior to the period of most intense use.
7. Sudan grass used water more efficiently than did alfalfa during the period extending from early June to September.

During the period of active plant growth, consumptive use of water per day was closely associated with rainfall.

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