REGROWTH ANALYSIS OF ALFALFA (*Medicago sativa*, L.) DURING THREE SEASONS IN 1966

by

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Thesis submitted to the Graduate Faculty of the
Virginia Polytechnic Institute
in candidacy for the degree of
MASTER OF SCIENCE
in
Agronomy

APPROVED:

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June, 1967

Blacksburg, Virginia

ACKNOWLEDGMENTS

The author wishes to express his appreciation to for his patience and guidance throughout this study and in the preparation of this thesis.

Appreciation is due to Head of the Agronomy Department, and Dairy Science Department, for serving on his graduate committee.

Appreciation is also expressed to . and for their suggestions and assistance in setting up experiments and certain methods of procedure.

The author is especially grateful to the Rockefeller Foundation and to the Colombian Agricultural Institute (I.C.A.) for the opportunity given for his graduate studies.

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INTRODUCTION

Regrowth rates of perennial grasses and legumes under favorable environments are attributable to many factors, but it appears that food reserves and leaf area are most important. After defoliation, the formation of a new leaf area is apparently positively associated with level of carbohydrate reserves and residual leaf area. Later, growth rates are associated primarily with leaf area.

Specific information is needed on the regrowth potential of alfalfa at various seasons of the year. In addition, specific data are needed on dry matter production at various morphological and physiological stages of plant development to ascertain the optimum time for defoliation. It is quite possible that the magnitude of dry weight, height, green weight, and leaf area may serve as indicies for the optimum date of defoliation. Interrelationships between these factors and herbage quality were investigated.

REVIEW OF LITERATURE

Carbohydrate Reserves

Sugars as products of photosynthesis play key roles in plant metabolism, respiration, and synthesis of various organic compounds during plant growth. Knowledge of their relative concentration should be useful in considering growth rates (3).

Graber et al. (15) defined reserves as "those carbohydrate and nitrogen compounds, elaborated, stored, and utilized by the plant itself as food for maintenance and for development of future top and root growth."

The principal carbohydrate reserves in grasses are sugars, fructosans, and starch. Grasses adapted to cool temperate climates usually contain fructosan; whereas the primary reserve of grasses adapted to the warmer climates is generally starch (18, 21). Legumes generally contain starch reserves (8, 24, 27). Cellulose and pentosan are not considered reserves because they do not fluctuate in concentration during growth processes as is characteristic of sugars, fructosan and starch. Hemicellulose may or may not be used as an energy reserve (3, 18). McCarty (19) concluded "..... the seasonal march of the carbohydrates, as shown by the sum total of the sugars and starch, was found to be in inverse ratio of the rate of growth of the herbage." It is generally accepted that initial regrowth of defoliated alfalfa occurs at the expense of previously accumulated energy reserves in the roots and rhizomes (30). It is also reported that practices which tend to limit carbohydrate reserves in basal portions of plants may jeopardize the longevity of plants (8, 23).

Any one or combination of environmental factors that stimulate growth relatively more than net photosynthesis cause respective decreases in carbohydrates in plant tissue. Conversely any factor which restricts growth relatively more than photosynthesis would cause a carbohydrate buildup in plant tissue (4, 8). For example, during the summer months, Blaser et al. (4) found that carbohydrates in orchardgrass stubble were much higher for slow growing grass without irrigation as compared with the rapid growth with irrigation. The carbohydrate accumulation under moisture stress indicates that growth was retarded relatively more than photosynthesis. The authors pointed out that it was rather surprising that carbohydrates buildup under moisture stress since closed stomates would seem to inhibit CO_2 intake and photosynthesis. These researchers also found that carbohydrates accumulated in plant tissues with low temperatures, low nitrogen or by slowing up growth with M.H. 30.

Barnes (2) found that at any temperature carbohydrates varied inversely with moisture, and at any moisture level the per cent reserves also varied inversely with temperature.

Other investigators believe that carbohydrates are not very important in regrowth. Davidson and Milthorpe (10) state that defoliation by grazing or cutting reduces leaf surface and thereby photosynthesis. The reserve carbohydrates then provide one pool and other labile substances another pool which may serve as possible sources of substrates for growth and respiration. They conclude that reserve carbohydrates form part of a labile pool used for synthesis of new compounds and respiration when photosynthesis is restricted. However, the carbohydrates form only a part of this pool and other substances must be regarded as being quantitatively of equal significance. Furthermore, with plants having an appreciable leaf area, these same workers found that high concentration of reserves is likely to reflect a situation where the growth potential was not realized. In such a situation, reserves represent growth not being made rather than contributing to growth.

Leaf Area Index (L.A.I.)

This term is the ratio of leaf area to soil area (31) and expresses the leaf area for the whole crop rather than for individual plants.

Many workers have reported an "optimum" L.A.I., that coincides with the maximum rate of dry matter production. With subterranean clover, Davidson and Donald (9) found the optimum L.A.I. to be 4.5; and as L.A.I. rose above this value, the lower leaves had less photosynthesis than respiration and became parasitic. Thus, the growth rate of the sward declined. Brougham (6), working with a mixture, found an increase in growth rate up to an L.A.I. of 5.0 remaining at the maximum even when the L.A.I. increased to 9.0. Brougham associated maximum growth rate with 95% or more light interception and called this the "critical" L.A.I. Watson (32) found an increase in growth rate up to an L.A.I. of 6.0, with sugar beets.

Smith et al. (27) reported as follows for alfalfa: (a) L.A.I. was the most important single independent variable that accounted for variation in dry matter yield; and (b) correlations were r = +0.896 between L.A.I. and yield and r = +0.776 between L.A.I. and growth rate.

The importance of L.A.I. in growth as related to light interception and utilization is expressed in what Donald and Black (11) postulated: "..... the ultimate capacity of a species to produce dry matter depends on the degree to which a community of such plants can exploit the light falling on it. This level of production will depend on the stature and habit of the species." The magnitude of a critical L.A.I. is affected by leaf position, orientation, shape, and species (22). Thus, a critical L.A.I. will have different values with different species. For example, work done by Brougham (7) showed that 95% of the sunlight was intercepted at an L.A.I. of 7.0 for ryegrass and 4.0 for white clover. As Ward and Blaser (30) point out, accumulation of an L.A.I. beyond that needed to intercept 95 to 100% of the light may result in sufficient self-shading to reduce dry matter accumulation per unit of time. Bonner and Galston (5) report: "..... as higher and higher intensities fall on the plant, more and more of its leaves attain light saturation". Donald and Black (11) working with individual leaves, found maximum photosynthetic rates at low light intensities, sometimes below 1,000 foot-candles, but the photosynthetic rate of whole plant canopies was maximal at much higher light intensities.

The decline in the rate of dry matter production as L.A.I. reaches high values, has clear significance in grazing practices, and clearly stresses the undesirability of accumulating "overgrown pasture". However, grazing such pastures back to optimum L.A.I. or less, can give substantial stimulus to production. It is known that maximum leaf production will not necessarily give maximum economic returns for some crops. However, with pastures, leaf production directly governs sward quality for livestock and at least in legumes, an increase in leaf production gives a direct increase in protein production (11).

Defoliation intensity

Graber et al. (15) advanced the following hypothesis: "..... that organic reserves are essential to normal top and root development; that their quantity and availability sharply limits the amount of both top and root growth that will occur; and that progressive exhaustion of such reserves by early, frequent, and complete removal of top growth results ultimately in the death of the plant regardless of the most favorable climatic and soil environment".

Wolf et al. (35) found that forage yields and food reserves of alfalfa vary with frequency of clipping but not with height of stubble unless frequent defoliation is practiced. Feltner and Massengale (14) reported that differences in total available carbohydrates caused by cutting schedules were not large during cool temperature periods, but were greatest during warm summer months. Work by Weinmann (33) shows that defoliation has a more lasting effect on reserve carbohydrates during autumn than at other times of the year. However, rest during autumn may enable plants to replenish reserves, to overcome low carbohydrates from previous defoliation treatments. Kust and Smith (17) found a close relationship between the amount of available carbohydrates present in the storage organs of alfalfa in the fall and the yield of hay obtained in the subsequent year.

Dotzenko and Ahlgren (12) indicate that cutting earlier than at 1/10 bloom markedly reduces the yield of alfalfa in an alfalfa-bromegrass mixture and that this reduction is related to root weight and the percentage of polysaccharides in them.

MATERIALS AND METHODS

A two-year old stand of Williamsburg alfalfa at the Virginia Polytechnic Institute Agronomy Farm near Blacksburg, was divided into three sections to study regrowth during three seasons: (a) spring, April 19-May 31; (b) early summer, May 28-July 9; and (c) late summer, August 14-September 25, 1966. Each of the three areas was divided into four uniform blocks with eight treatments randomized per block. The randomized treatments consisted of eight cuttings to study dry matter production as associated with various factors. Cuttings were made at six-day intervals during a 42-day period. The first cutting, designated 0-day, was made when there was a meager leaf area and the plants were 11 cm high and growing rapidly, (April 19 for the spring season). At 0-day for the early summer experiment, May 28, all plots were cut when alfalfa was in about 10% bloom. For the late summer experiment, the alfalfa was cut on May 28, on July 11 in 50% bloom, and finally on 0-day, August 14, when in early bloom. On early and late summer experiments, yields were not taken on day-six because of insufficient growth.

The following data were obtained at each sampling date for all three seasons: (a) green and dry matter yield; (b) leaf area index; (c) light interception; (d) carbohydrate reserves in roots; (e) approximate analysis of the herbage; (f) "in-vitro" digestibility of dry matter; (g) leaf stem ratios; and (h) height and stage of maturity when cut.

Yield samples (2 m^2) were taken by cutting strips lengthwise through the center of each plot. During the spring and early summer, the first three harvests were taken with a rotary mower with a grass catcher. Later harvests were taken with a cycle bar mower. The rotary mower left approximately 1 cm as compared with 3 cm stubble heights for the cycle bar mower. The total sample was weighed green, dried, and reweighed.

Two sub-samples of about 20 stems with leaves were used for leaf stem ratios. Approximately 15 to 20 leaves were taken at random from each sub-sample to determine leaf area with a photoplanimeter. The following regression equation was used: $Y = 87.10 - 5.707\ X$, where Y corresponds to leaf area in cm^2 and X corresponds to the reading in the photoplanimeter. The leaf samples were dried to calculate dry weight per cm^2 which made it possible to compute leaf area from leaf weights in botanical fractions.

Light interception was determined with a Weston Illuminator Meter by measuring light intensity above and at the base of the stand.

The approximate analysis of the herbage was made according to A.O.A.C. (1) methods for crude protein, N.F.E., ether extract, and ash, on a per cent dry basis. Crude fiber was determined using the method described by Whitehouse _et al_. (34).

Immediately after cutting, root samples were taken from each plot, washed, and dried at 80°C for about 24 hours. Root sections below the crown, 10 cm long, were used. The dry material was ground with a Willey mill through a 60-mesh screen and stored for starch analysis. Duplicate 0.1 gram samples were placed in 100 ml centrifuge tubes; 10 ml of 0.2N H_2SO_4 were added and the samples were hydrolyzed for one hour in a boiling water bath. The hot solution was filtered through Whatman filter paper #31. The filtrate was cooled and 25% NaOH was added until phenolphthalein changed color. A few drops of 25% HCl were added to remove the color. The filtrate was diluted to 100 ml with destilated water. A 0.4 ml aliquot was analyzed for glucose by the Somogyi (28)-Nelson (20) method, to determine the per cent of total available carbohydrates as glucose.

The "in-vitro" digestion of herbage was carried out in duplicate on each plot sample. The method used was similar to that reported by Tilley and Terry (29) with some modifications. The procedure involves 48-hours digestion of a dry 1-gram sample in the artificial rumen using the "Ohio" fermentation media (16), followed by 24-hours Pepsin digestion in order to remove microbial protein and remaining plant protein.

Data on dry matter, L.A.I., root carbohydrate reserves and some chemical results, were subjected to an analysis of variance. Means were compared by Duncan's multiple range method (13). Correlations were made for some of the data.

During the spring growth, insecticides were applied to control the alfalfa leaf weevil, which was considered a serious problem and could have affected the results for this season. Insects were also controlled by spraying during late summer.

An endeavor was made to obtain optimum growth rates at all three seasons. Irrigation was provided when soil moisture restricted growth. Two, nine, and two irrigations were made during the spring, early summer, and late summer experiments, respectively.

RESULTS

Spring Regrowth

The unusual weather conditions during this season affected the results. The daily minimum temperatures were under 10°C during most of the experiment, and temperatures were especially low with severe frosts and one freeze during the 12 to 24-day period of regrowth, Figure 1. The light intensity expressed in ly/day as shown in Figure 1, was probably quite normal for this season. Alfalfa leaf weevil (Hypera postica) reduced yields and leaves during spring as its control was difficult because of the rain and cool temperatures. Irrigation was applied only two times during the last two weeks of the experiment; at other times there was enough soil moisture for normal growth.

Herbage Growth

Dry matter data (kg/ha) are considered very important because they influence economy of production. The accumulative yields generally show increases in dry matter for the successive six-day periods, but because of low temperatures and weevil injury, the differences for periods were not always statistically significant, Figure 2. The maximum growth rate, 1,000 kg/ha of dry matter, was obtained during 6 to 12 days; the values were low during 24 to 30 days, and during the last six days the yield was less than 100 kg/ha.

The low growth rate for the last period was attributed to maturity and diseased leaves, but the low value during 24 to 30 days is attributed to frost and weevil injury.

The L.A.I. was affected by weevil attack and by low temperatures; but the values generally increased with dry matter for 30 days, Figure 2. The L.A.I. decline between 12 to 18 days was caused by weevil and frost damage. The decline after the 30 days is associated with dying leaves, because of diseases and age. The highest L.A.I. of 6.5, reached by 30 days, differed from other values at the 1% level. There was a significant correlation ($r = +0.91$) between L.A.I. and dry matter.

For all growth periods, height was highly correlated ($r = +0.90$) with dry matter, Figure 2.

Figure 3 shows that 95% of the light was intercepted by alfalfa foliage by day-12, at an L.A.I. of 5.0. Between 18 to 24 days, there was a decrease in light interception (statistically different); this was caused by weevil attack that destroyed many leaves and by frost damage that caused alfalfa apex stems to bend over. The gradual decline in light interception after 30 days is due to a lower L.A.I. The correlation between % light interception and height ($r = +0.82$) was significant at 5% level, but correlations between % light interception and rate of dry matter accumulation were low.

Carbohydrate reserves, expressed as per cent glucose (dry basis) in roots, show a gradual (non-significant) decrease from 34.1 to 31.6% for the first twelve days, Figure 2. For the next six days a slight buildup of the reserves was observed, and after 18 days there was a progressive slow decrease in the carbohydrate reserves. Statistically there were no differences between 0 through 24 days; 12, 30, and 36 days; and the last two 6-day periods.

By using the accumulative herbage yields, net assimilation rates (N.A.R.) were calculated for the six-day periods, Figure 3. The N.A.R. values show usual overall sharp declines as L.A.I. increased, but there was much variance among the six-day periods because of leaf injury from frosts, diseases, weevil, and variable growth rates because of sub-optimum temperatures.

Herbage Value

During spring regrowth, leaf stem ratio declined from its maximum value of 1.19 on day-6 to 0.68 on day-42, Table 4. Leafiness was positively associated to nutritive value of the alfalfa herbage.

The highest protein content, 31.4% obtained on day-6, was statistically significant from other values; thereafter protein content declined through 36 days, Table 1. The per cent crude fiber generally increased as plants advanced in stage of maturity, but the values for 12 to 24-day periods were not statistically significant, Table 1.

The calculated total digestible nutrients (T.D.N.) in kg/ha, Table 4, increased through 24 days; thereafter the values were erratic, a minor decline and then increasing again. The T.D.N. values were directly

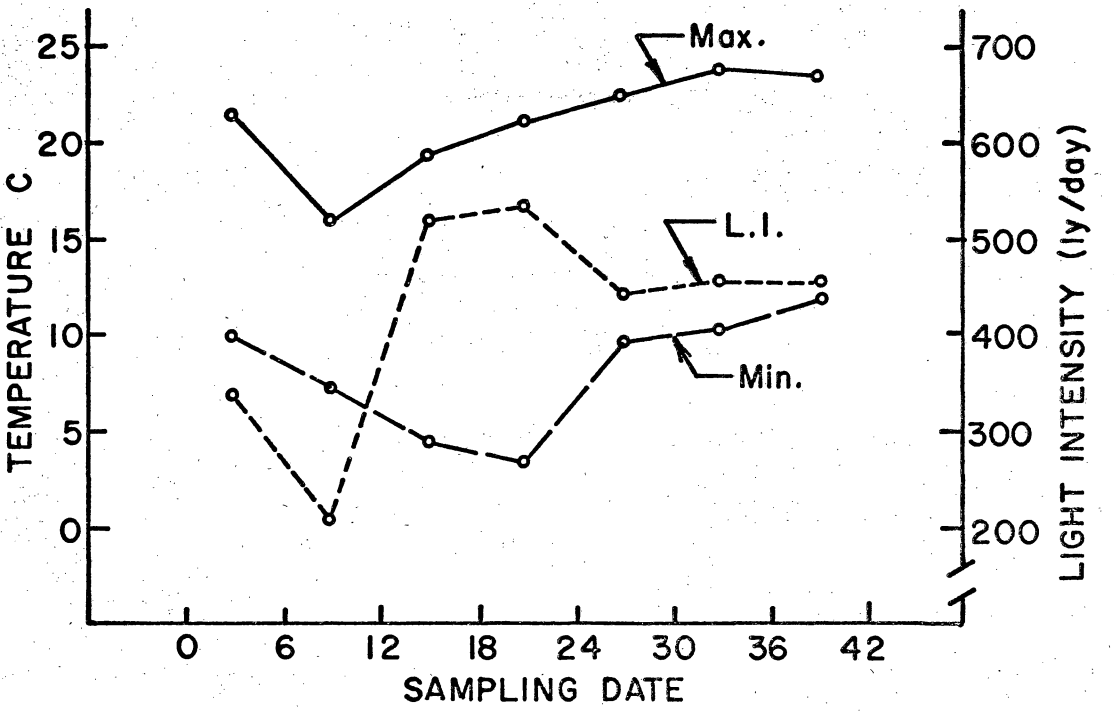

FIGURE I. RELATIONSHIP BETWEEN TEMPERATURE (MAXIMUM AND MINIMUM) AND LIGHT INTENSITY DURING SPRING, 1966.

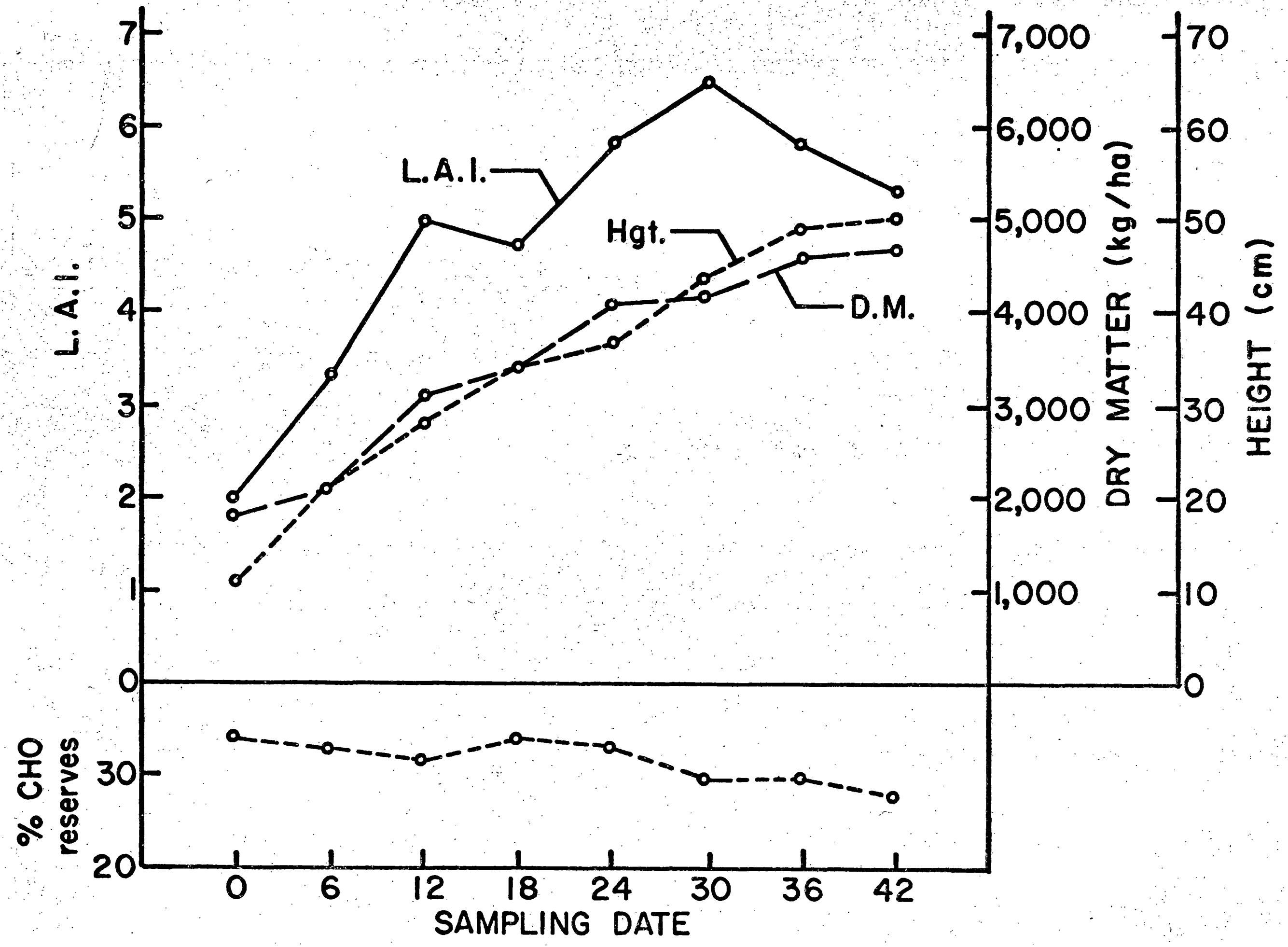

FIGURE 2. RELATIONSHIPS BETWEEN L.A.I., DRY MATTER, HEIGHT AND CARBOHYDRATE RESERVES IN ALFALFA SAMPLED AT 6-DAY PERIODS DURING SPRING, 1966.

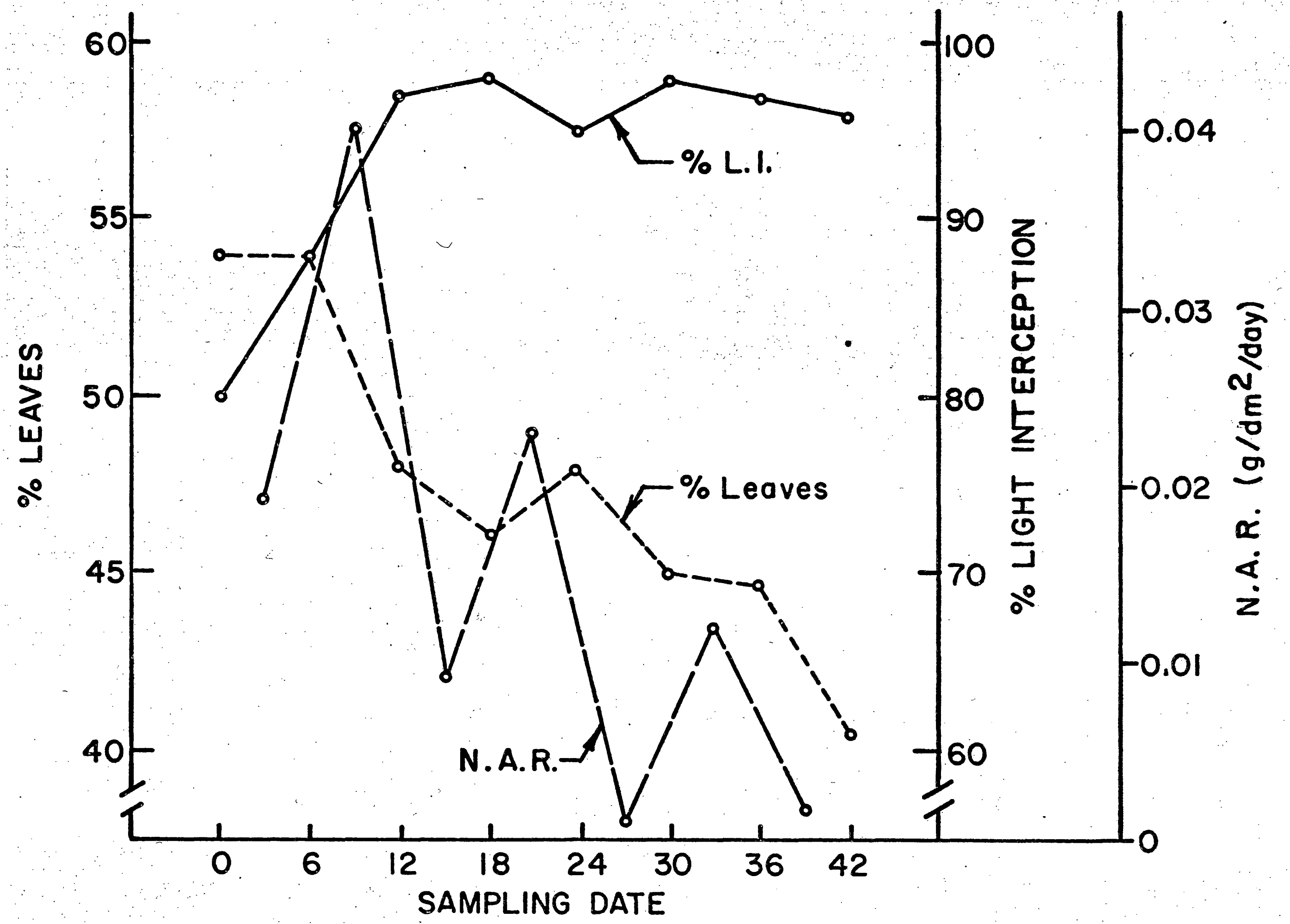

FIGURE 3. RELATIONSHIPS BETWEEN % LEAVES, % LIGHT INTERCEPTION AND N.A.R IN ALFALFA SAMPLED AT 6-DAY PERIODS DURING SPRING, 1966.

associated with protein content but there was an inverse relationship with crude fiber. A highly significant correlation was found between kg/ha of T.D.N. and height (r = +0.97); also the correlation (r = +0.91) was highly significant between kg/ha of T.D.N. and L.A.I. The highest amount of digestible protein and fiber (kg/ha) was obtained on day-18 and day-42, respectively, Table 2. There was a non-significant correlation (r = +0.74) between digestible protein and L.A.I.

The "in-vitro" per cent dry matter digestibility was quite erratic for the first four periods, reaching the highest value of 67.5% on day-18; thereafter values declined with increases in stage of maturity, Table 3. However, the maximum value in digestible dry matter (D.D.M.), 2,706 kg/ha, was reached after 36 days, decreasing for the last six-day period as seen in Table 3. Highly significant correlations were found between D.D.M. and height (r = +0.96), and between D.D.M. and L.A.I. (r = +0.93).

The use of a rotary mower affected the results for the first two six-day periods because it picked up dead material, decreasing the % crude protein and % "in-vitro" digestibility.

Early Summer Regrowth

In general, temperatures for this period were quite high and generally increased, Figure 4. Light intensity (ly/day) increased to a maximum of 650 during the period 12 to 18 days, and then decreased sharply as shown in Figure 4. Rainfall was a limiting factor (1.55 cm during the experiment), so nine irrigations were made to provide an adequate soil moisture. Insects and diseases were not a problem during the experiment.

Herbage Growth

The accumulative yields show successive significant increases in dry matter by six-day periods, except between 36 and 42 days, Figure 5. The maximum growth rate of 1,000 kg/ha of dry matter was obtained by 30 days. After this, the growth rate decreased to a minimum of 500 kg/ha mainly because of leaf loss and less solar energy.

The L.A.I. generally increased and paralleled dry matter for 30 days of regrowth, and then leveled off at a value of 4.5, Figure 5. There were no statistically significant differences between 24 and 30 days; and between 30, 36, and 42 days. There was a highly significant correlation ($r = +0.93$) between L.A.I. and dry matter.

For all growth periods, height was highly correlated ($r = +0.99$) with dry matter, Figure 5.

Approximately 95% of the light was intercepted by day-18, at an L.A.I. of 2.6, Figure 6. The correlations between % light interception and height, and % light interception and rate of dry matter accumulation were low.

The carbohydrate reserves in roots, show a sharp decrease after six days as rapid growth began, Figure 5. The carbohydrates then fluctuated at around 10-15% of the dry weight for the next 18 days. For the last twelve days, the reserves accumulated rapidly, reaching almost 26.0% as for 0-day.

By using the accumulative herbage yields, N.A.R. was calculated for the six-day periods, Figure 6. The N.A.R. values generally declined sharply throughout the season, but the differences between 18, 24, and 30 days were not significant. The L.A.I. did not differ during the last 12 days, but N.A.R. declined very sharply.

Herbage Value

During this season the leaf stem ratio decreased from 1.29 on day-12 to 0.69 on day-42, as shown in Table 4.

Crude protein declined with advanced stages of maturity, except for the growth on 12 and 18 days which did not differ significantly, Table 1. The highest value was 27.4% on day-18 and the lowest on day-42. The crude fiber values between the first three periods were not statistically different but were lower than for the last three periods.

The calculated T.D.N. in kg/ha, Table 4, increased from about 550 on day-12 to 2,680 on day-42; but the highest calculated value of 63% T.D.N. was obtained after 24 days of regrowth. The lowest value of 56% occurred during the last six-day period. Highly significant correlations were found between kg/ha of T.D.N. and height ($r = +0.99$), and also between kg/ha of T.D.N. and L.A.I. ($r = +0.95$). On day-36 the digestible protein yield was the highest for the season; however, the maximum digestible fiber in kg/ha occurred on day-42, Table 2. There was a highly significant correlation ($r = +0.96$) between total digestible protein and L.A.I.

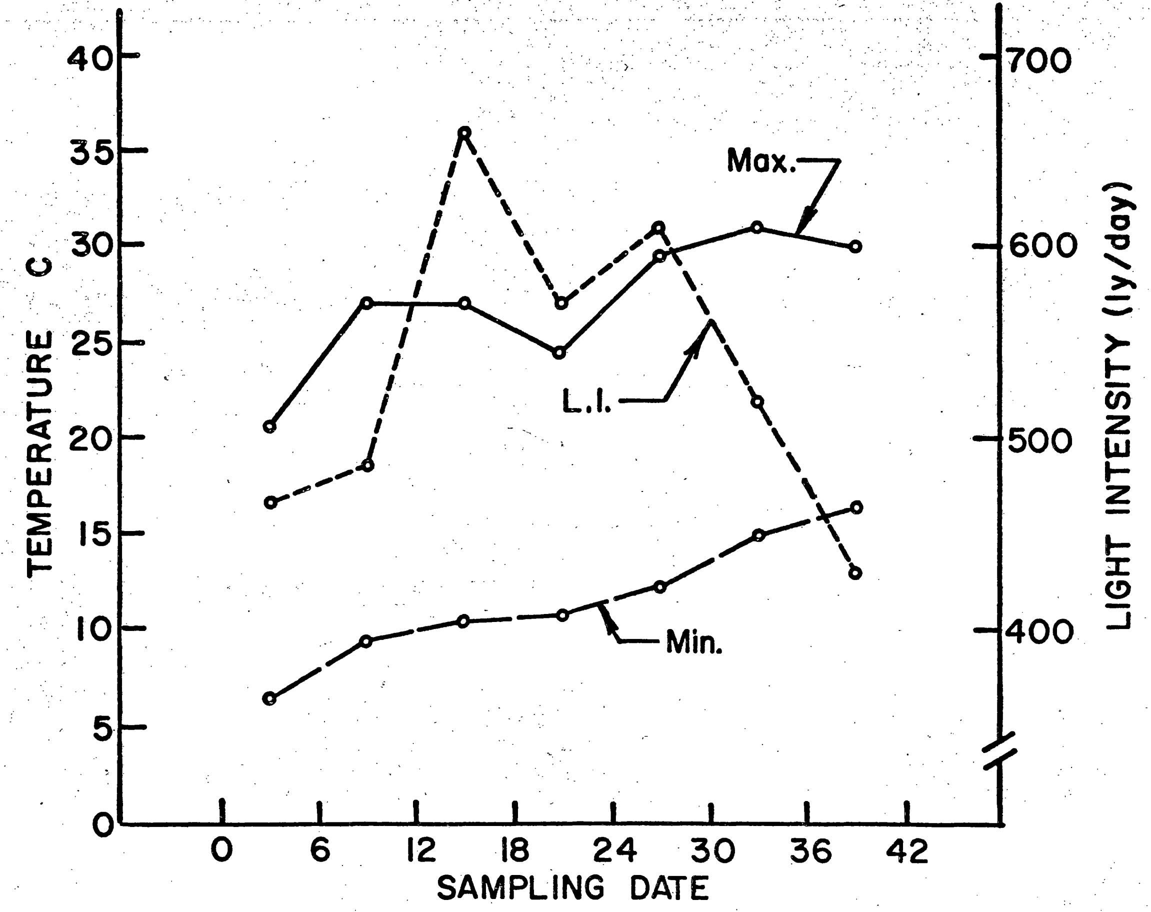

FIGURE 4. RELATIONSHIP BETWEEN TEMPERATURE (MAXIMUM AND MINIMUM) AND LIGHT INTENSITY DURING EARLY SUMMER, 1966.

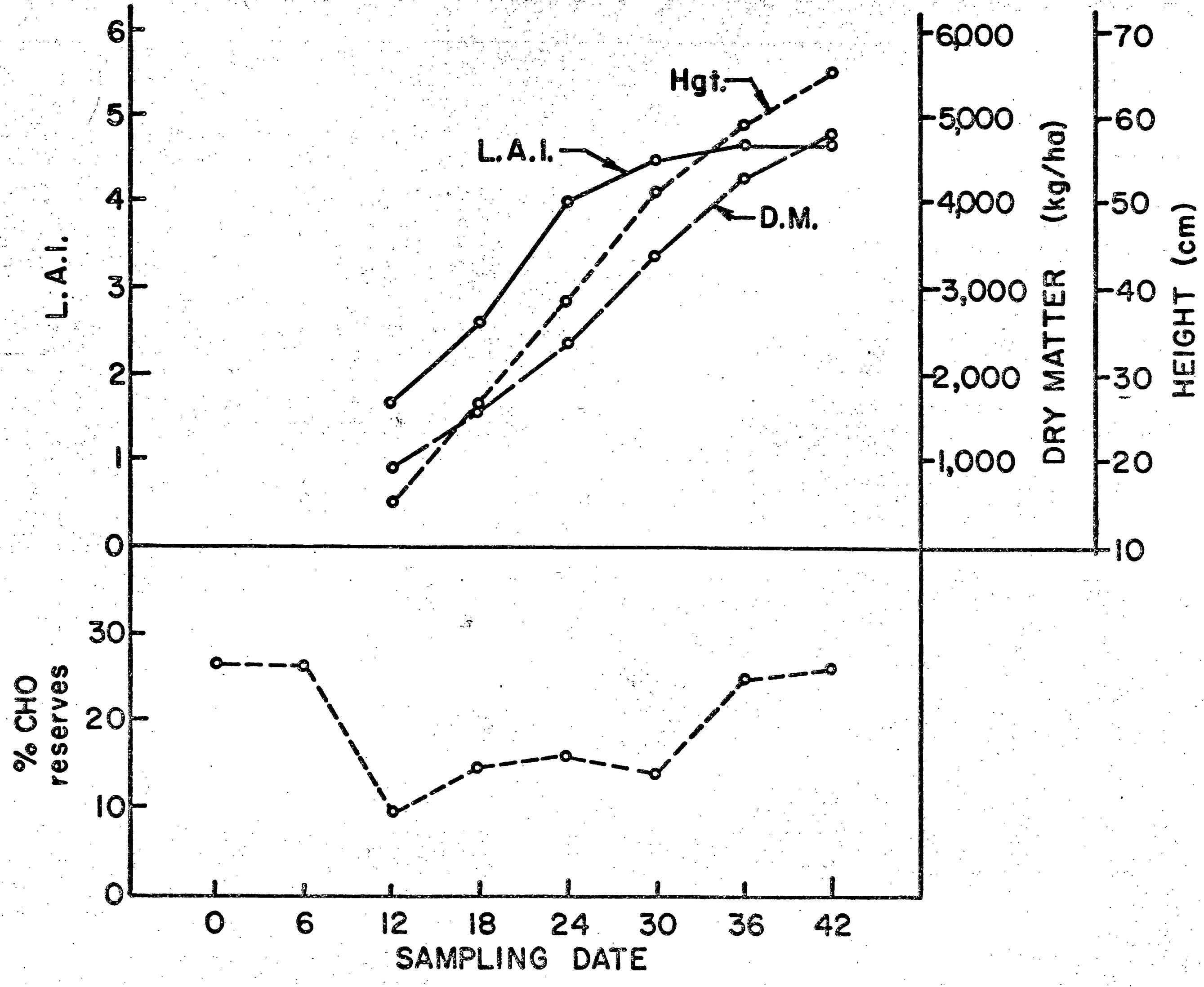

FIGURE 5. RELATIONSHIPS BETWEEN L.A.I., DRY MATTER, HEIGHT AND CARBOHYDRATE RESERVES IN ALFÁLFA SAMPLED AT 6-DAY PERIODS DURING EARLY SUMMER, 1966.

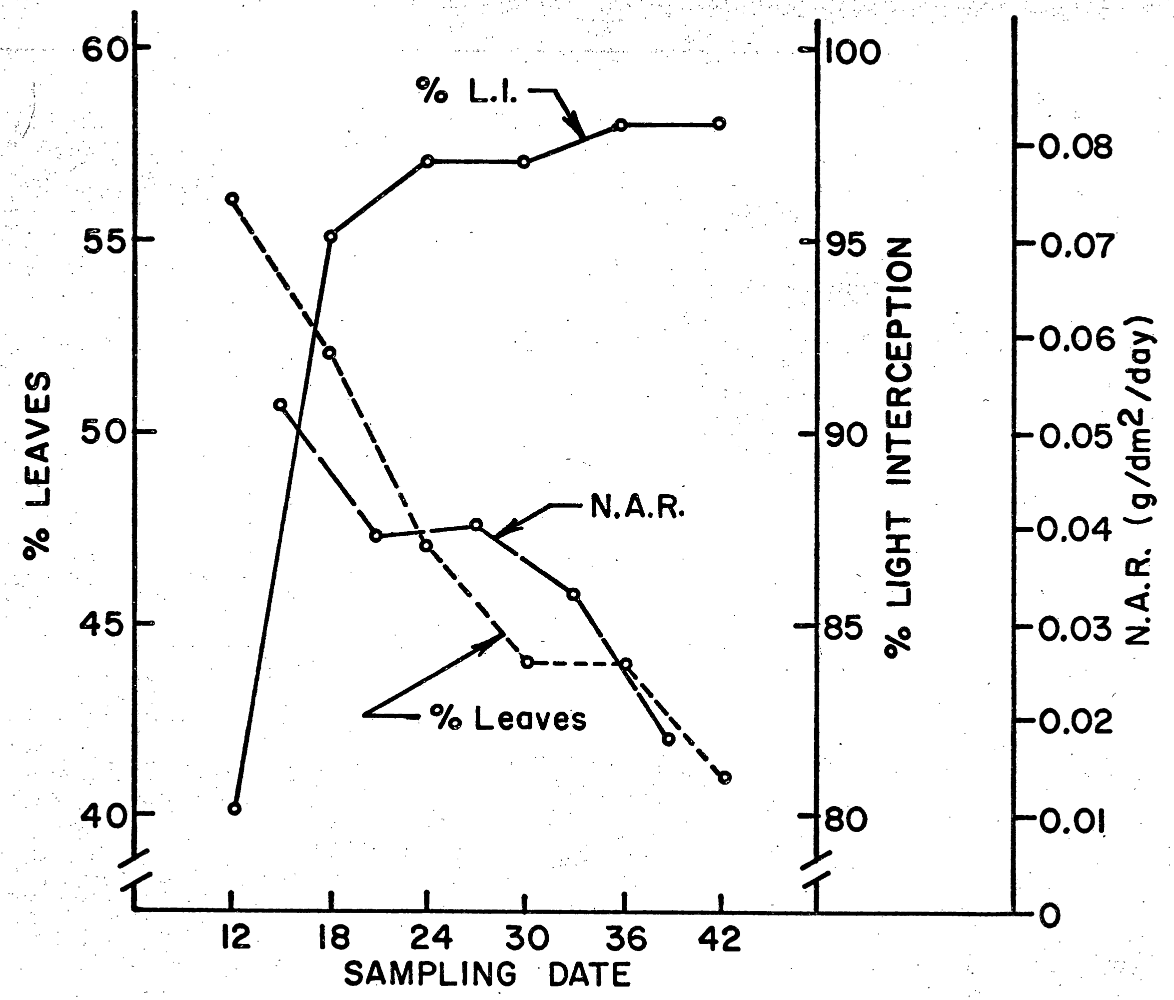

FIGURE 6. RELATIONSHIPS BETWEEN % LEAVES, % LIGHT INTERCEPTION AND N.A.R. IN ALFALFA SAMPLED AT 6-DAY PERIODS DURING EARLY SUMMER, 1966.

The "in-vitro" dry matter digestibility was lowest (45.4%) on day-12 and statistically significant from other values. The next four periods did not differ statistically and then there was a decrease for the last two periods, Table 3. The D.D.M. in kg/ha increased with advanced maturity for all periods reaching a maximum of 2,554 on day-42 when alfalfa was in 50% bloom. Total D.D.M. and height were highly correlated (r = +0.99); also, a highly significant correlation was found between total D.D.M. and L.A.I. (r = +0.95).

The results for the 12-day harvest were affected by the use of a rotary mower; decreasing the % crude protein and % "in-vitro" dry matter digestibility, and increasing the % crude fiber due to the dead material picked up by the mower.

Late Summer Regrowth

During late summer the maximum temperature generally declined with season as is normal for this time of the year, Figure 7. Light intensity declined very sharply for the last 12 days and averaged only about 200 ly/day for the last six days. There was some injury from "Japanese beetle" (Popillia japonica) which was controlled by spraying insecticides two times. Irrigation was applied four times during summer before the 0-day, and three times during the trial to provide adequate soil moisture for normal growth. Even by the end of the experiment no flowers had developed because of short days, cool temperatures, and low light intensities.

Herbage Growth

The accumulative dry matter production shows sharp increases during early regrowth and no increases after 30 days, Figure 8. Statistically significant differences were found between 12 and 18 days, but not for other six-day periods. The maximum growth rate, 900 kg/ha of dry matter, was obtained during 12 to 18 days; the values decreased for the next two periods and were negative for the last 12 days of regrowth. The negative values in growth rates may be attributed to low solar energy, sub-optimum temperatures for growth and dying leaves due to maturity and insects.

The L.A.I. increased sharply for 24 days to a maximum value of 3.5, leveled off for the next 12 days, and finally declined, Figure 8. The decline after 24 days of regrowth is attributed to maturity, possibly leaf diseases, and insect damage. A correlation (r = +0.82) between L.A.I. and dry matter was not significant at 5% level.

For all growth periods, height was highly correlated (r = +0.96) with dry matter, Figure 8.

Figure 9 shows that 95% of the light was intercepted by 24 days, at an L.A.I. of 3.5. From 24 to 36 days there was no change in light interception, but it decreased very rapidly for the last period as a consequence of the decline in L.A.I. Correlations between % light interception and height, and % light interception and rate of dry matter accumulation were very low.

Carbohydrate reserves in roots gradually increased for 18 days, decreased for 12 days, and again increased for the last 12 days of regrowth, Figure 8. The values were not statistically significant between the following: 0, 6, 12, and 30 days; 24, 30, 36, and 42 days; 6, 12, 24, and 30 days; and 18, 24, 36, and 42 days.

The N.A.R. decreased very rapidly for 30 days; the negative values for the last two six-day periods were due to negative growth rates.

Herbage Value

The leaf stem ratio decreased from 1.17 on day-12 to 0.67 on day-42, Table 4.

During this season, the rotary mower was not used. Thus, per cent crude protein generally decreased for all six-day periods as alfalfa advanced in stage of maturity, Table 1. The differences were not significant between 30 and 36 days, and the last two harvests. There were increases in per cent crude fiber with advances in maturity, but the differences between successive harvests were not generally statistically significant, Table 1.

In calculating digestible protein (kg/ha), there was poor agreement between cattle and sheep factors given by Schneider *et al*. (25, 26). For cattle factors the highest value was obtained on day-24, and for the sheep factors on day-30, Table 2. For digestible fiber the maximum value after 36 days of regrowth, was about 300 kg/ha, Table 2. There was no correlation between digestible protein and L.A.I.

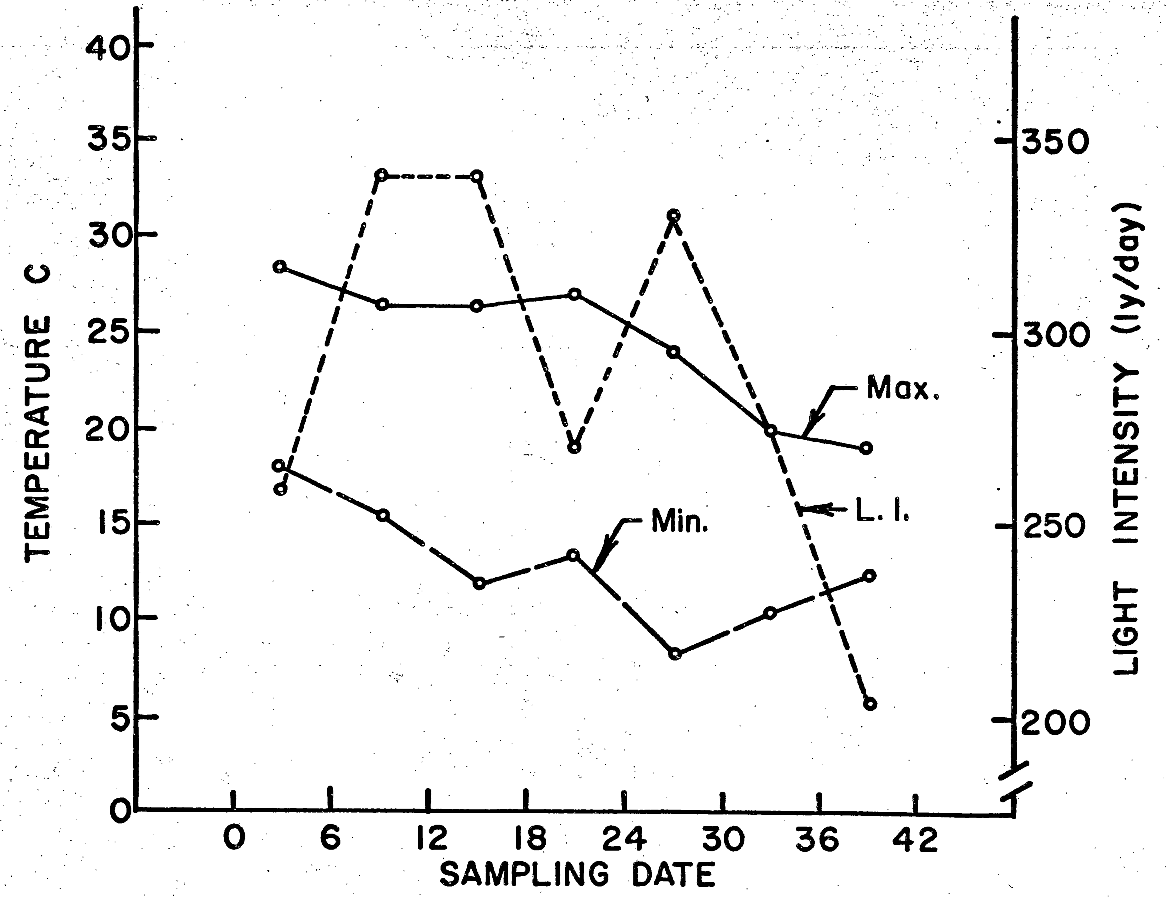

FIGURE 7. RELATIONSHIP BETWEEN TEMPERATURE (MAXIMUM AND MINIMUM) AND LIGHT INTENSITY DURING LATE SUMMER, 1966.

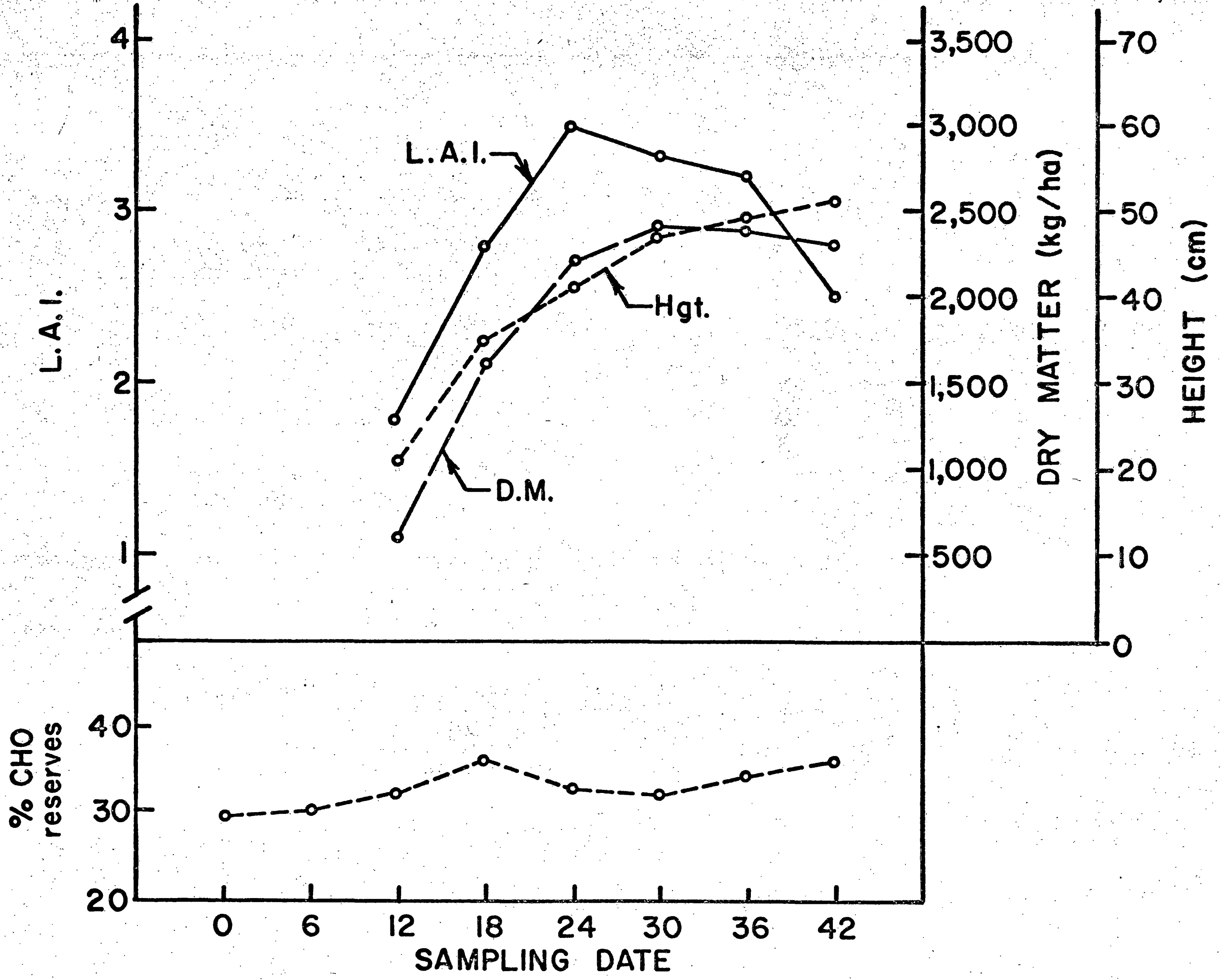

FIGURE 8. RELATIONSHIPS BETWEEN L.A.I., DRY MATTER, HEIGHT AND CARBOHYDRATE RESERVES IN ALFALFA SAMPLED AT 6—DAY PERIODS DURING LATE SUMMER, 1966.

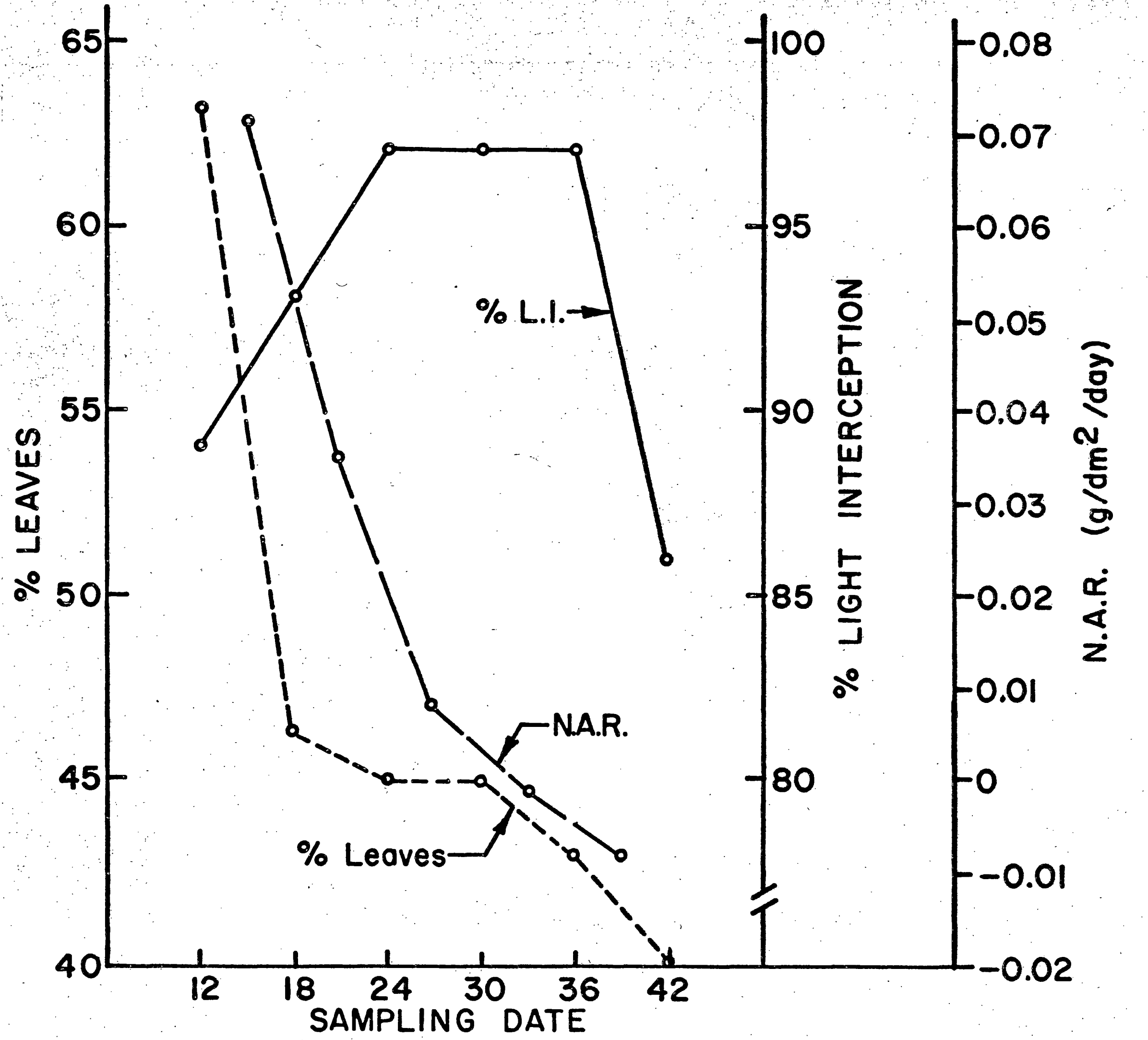

FIGURE 9. RELATIONSHIPS BETWEEN % LEAVES, % LIGHT INTERCEPTION AND N.A.R. IN ALFALFA SAMPLED AT 6—DAY PERIODS DURING LATE SUMMER, 1966.

The T.D.N. yield increased up to 1,400 kg/ha on day-36, and then decreased due to a sharp decline in leaf stem ratios, Table 4. Generally, there was a progressive decrease in per cent T.D.N. for successive six-day periods as alfalfa advanced in maturity. The correlations were highly significant between T.D.N. yield and height ($r = +0.94$), and also significant between T.D.N. yield and L.A.I. ($r = +0.86$).

No statistically significant differences were found between six-day periods in per cent dry matter digestibility; but the digestible dry matter (D.D.M.) increased up to 1,451 kg/ha on day-36, and decreased for the last period due to the negative growth rate of alfalfa, Table 3. There were highly significant correlations between D.D.M. and height ($r = +0.97$), and D.D.M. and L.A.I. ($r = +0.84$).

Table 1. Chemical composition of the dry matter in alfalfa sampled at six-day periods during three seasons in 1966.

Day	% Crude Protein	% Ether Extract	% Crude Fiber	% Ash	% N.F.E.
Spring Season, April 19 - May 31					
0	27.8 a	2.4 a	16.6 f	12.4 a	40.3 ab
6	31.4 f	2.7 a	19.3 e	10.5 b	36.1 c
12	29.3 b	3.0 d	21.2 a	14.4 c	32.2 d
18	28.4 ab	3.2 cd	22.7 ab	11.9 ab	33.9 d
24	24.7 e	3.6 b	21.8 a	10.6 b	39.3 b
30	23.3 d	3.4 bcd	24.3 bc	11.8 ab	37.3 c
36	20.3 c	3.5 bc	25.5 cd	10.2 b	40.5 ab
42	20.9 c	3.1 d	26.3 d	8.3 d	41.5 a
Early Summer, May 28 - July 9					
12	26.5 a	1.7 c	21.6 b	16.9 d	33.2 a
18	27.4 a	2.7 a	20.2 b	14.2 c	36.1 ab
24	23.9 b	2.6 a	20.6 b	10.0 a	42.8 d
30	21.9 c	3.1 b	28.4 a	8.3 ab	38.3 bc
36	19.6 d	2.8 ab	28.7 a	7.6 ab	41.3 cd
42	17.1 e	2.4 a	30.2 a	7.2 b	43.1 d
Late Summer, August 14 - September 25					
12	33.4 e	1.9 d	18.3 d	16.6 c	29.7 d
18	29.8 d	2.9 ab	23.7 a	11.0 a	32.7 c
24	24.6 c	2.7 ac	23.9 a	10.7 a	38.1 ab
30	23.4 a	2.6 c	24.6 ab	13.9 b	35.6 a
36	22.8 ab	3.1 b	27.8 c	9.7 a	36.8 a
42	21.7 b	2.5 c	26.2 bc	10.1 a	39.6 b

Within a column in each season the values followed by the same letter do not differ significantly (5% level).

Table 2. Digestible protein and fiber (kg/ha) in alfalfa sampled at six-day periods during three seasons in 1966.

	Cattle Factors*		Sheep Factors*	
Day	Protein	Fiber	Protein	Fiber
	Spring Season, April 19 - May 31			
0	433	140	447	147
6	633	227	612	218
12	823	315	877	357
18	851	381	880	407
24	825	404	867	437
30	752	426	824	493
36	671	467	742	540
42	713	536	747	565
	Early Summer, May 28 - July 9			
12	210	86	235	106
18	385	151	409	169
24	464	227	474	233
30	560	442	585	467
36	598	540	628	568
42	536	595	573	635
	Late Summer, August 14 - September 25			
12	207	59	204	65
18	438	202	439	207
24	451	250	470	267
30	440	242	494	295
36	420	301	446	328
42	368	259	393	282

*Digestibility coefficients were calculated according to Schneider *et al*. (25, 26).

Table 3. Total and per cent digestible dry matter at different stages of maturity in alfalfa sampled at six-day periods during three seasons in 1966.

Day	Digestible Dry Matter %	Digestible Dry Matter kg/ha	Stages of Maturity
	Spring Season, April 19 - May 31		
0	60.3 cd	1,064	54.0% leaves
6	64.9 abc	1,353	54.3% "
12	61.3 bcd	1,904	48.3% "
18	67.5 a	2,267	46.4% "
24	65.3 ab	2,672	48.4% "
30	62.2 bcd	2,577	45.2% "
36	58.9 d	2,706	2 % flowers
42	58.1 d	2,701	5 % "
	Early Summer, May 28 - July 9		
12	45.4 c	427	56.3% leaves
18	58.3 a	943	52.2% "
24	59.8 a	1,432	47.0% "
30	59.0 a	2,008	5 % flowers
36	56.8 ab	2,450	20 % "
42	53.2 b	2,554	50 % "
	Late Summer, August 14 - September 25		
12	59.4 a	369	63.5% leaves
18	61.7 a	983	45.9% "
24	58.3 a	1,312	44.6% "
30	58.5 a	1,411	45.0% "
36	60.5 a	1,451	43.3% "
42	59.3 a	1,347	40.0% "

Within a column in each season the values followed by the same letter do not differ significantly (5% level).

Table 4. Leaf stem ratios and kg/ha of T.D.N. in alfalfa sampled at six-day periods during spring (April 19 - May 31); early summer (May 28 - July 9); and late summer (August 14 - September 25), 1966.

	Spring Season		Early Summer		Late Summer	
Day	leaf/stem	T.D.N.	leaf/stem	T.D.N.	leaf/stem	T.D.N.
0	1.17	1,152	----	----	----	----
6	1.19	1,425	----	----	----	----
12	0.93	1,928	1.29	552	1.17	407
18	0.87	2,110	1.09	1,005	0.85	1,025
24	0.94	2,513	0.89	1,508	0.81	1,374
30	0.82	2,415	0.79	1,991	0.82	1,377
36	0.81	2,615	0.80	2,488	0.76	1,398
42	0.68	2,741	0.69	2,680	0.67	1,312

Factors used to calculate per cent T.D.N. were for cattle (25, 26).

DISCUSSION

Environmental conditions such as low to freezing temperatures during spring regrowth, low solar energy, and declining temperatures during late summer caused some inconsistencies in the results during the three seasons. Also, leaf weevils were serious during spring, and there was some insect damage during late summer. Moisture was kept favorable to study yield potentials, thus, the results are applicable to farm conditions when moisture is favorable.

Because of the arrangement of the field experiment, statistical comparisons can be made within each season and not between the three seasons. This arrangement was chosen because of convenience of irrigation and minimized variance within each season by using small blocks was thought to be more important than between season comparisons.

Day-0 for spring should be taken only as a reference point, since slow growth started earlier. Thus, day-36 means 36 days of regrowth after 0-day. For the other two seasons, regrowth started on 0-day as all the plots were defoliated.

Even with the adverse factors in spring, the total dry matter production was as high as for early summer. However, a higher L.A.I. was necessary to produce a given amount of dry matter in spring than in early summer. When considering only top growth in calculating N.A.R., efficiency per unit L.A.I. was higher during early summer than for spring. The lower efficiency in spring may have been influenced by damaged leaves from weevils and frost. Shorter days and lower solar energy in spring as compared with early summer may also have influenced N.A.R. In late summer the efficiency per unit L.A.I. was relatively low as compared with the other two seasons because of insufficient solar energy and sub-optimum temperatures for growth.

At the end of spring and early summer, the accumulative dry matter production continued to increase, but for late summer it decreased because of negative growth rates. If dry matter alone is used to determine cutting date, an exact date cannot be given for spring and early summer because the dry matter production was still increasing at the final cutting date. For late summer, cutting after 30 days of regrowth seems to be best under these specific conditions. However, a recommendation for cutting date should consider nutritional value and other factors as well as dry matter production and stage of maturity.

Reserve carbohydrates showed different trends between seasons. For spring regrowth some of the decrease in reserves for the first three periods may be attributed to the formation of new herbage. The decrease for the last four periods may be attributed to the formation of new leaves to replace damaged ones and to root growth. Photosynthesis was probably very low due to freezing and weevil damage; thus, some of the energy for new growth and leaves may have come from carbohydrate reserves. For early summer the reserves decreased sharply for the 6 to 12-day period of regrowth due to rapid formation of herbage. After that date, the reserves were restored rapidly; apparently photosynthesis exceeded repiration for the rest of the season. The decline observed on day-30 was not statistically significant. In general the reserves increased during regrowth in late summer. This may be explained by slow growth and comparatively high photosynthesis under the low temperatures (4). The trend of reserves in late summer may be associated with pre-dormancy physiological responses.

Variations in carbohydrate reserves within each season, associated with days of regrowth, dry matter, or stage of maturity do not establish a best time for cutting. Table 3 and Figures 2 and 5 clearly show that the reserves made up 28% of the dry matter in roots during spring at 5% bloom and approximately 42 days of regrowth. However, during early summer the reserves were 14% at 5% bloom and 30 days of regrowth. No flowers formed during 42 days of late summer regrowth, yet the reserves reached 36%. However, reserves appear to be important during the first days of regrowth as alfalfa is nearly completely defoliated after harvesting.

Because of differences of leaf orientation, plant height, position of the sun and environmental conditions during the three seasons, light interception of 95% required different L.A.I. values. Also, L.A.I. values at 95% light interception were reached at different dates of regrowth and different stages of maturity. Critical L.A.I. values where maximum growth rates are associated with 95% light interception did not occur in any of the experiments.

Height of alfalfa was highly correlated with dry matter and D.D.M. production for all seasons. Height, when harvesting under these conditions, was the best criteria for cutting date. The optimum height during spring and late summer was about 50 cm and about 65 cm during early summer. However, heights varied with days of regrowth.

Maximum production of D.D.M. (kg/ha) is considered a very important parameter. The best time of cutting must be a compromise between dry matter production, stage of maturity, nutritive value and D.D.M. yield. Thus, under these environmental conditions alfalfa may be cut on about day-36, 42, and 36 for spring, early summer, and late summer regrowths, respectively.

Attempts to associate approximate cutting dates with T.D.N. and production of digestible protein were not made because these values were calculated from coefficients, and the regressions may not apply to these experiments (25 and 26).

Because of the short duration of this research and many biological interactions it is not possible to give absolute conclusions. To help farmers produce better yields and quality of alfalfa, other similar experiments must be conducted to associate time of cutting with subsequent regrowths and the parameters studied here.

SUMMARY

The rate of alfalfa regrowth during three seasons was associated with different parameters with the objective of finding a most suitable date of cutting. The rate and total dry matter produced was higher during spring and early summer seasons than in late summer. Factors limiting growth rates during spring were sub-optimum temperatures and alfalfa leaf weevil; and sub-optimum temperatures, low solar energy and some insect damage during late summer. Water was kept favorable by irrigation.

The higher leaf area index (L.A.I.) during spring than for the other two seasons may be attributed to the production of new leaves because of weevil and frost damage. When associating L.A.I. with dry matter production, the greatest efficiency occurred during early summer and the lowest in late summer. Net assimilation rate (N.A.R.) calculated from rate of top growth production was highest during early summer regrowth, lowest for late summer, and the spring regrowth showed large variations due to different growth rates because of leaf damage.

Interception of 95% of the light required different L.A.I. values during the three seasons. Also, such L.A.I. values were reached at different dates of regrowth and with different stages of maturity. Critical L.A.I. values were not found, because maximum growth rates were not associated with 95% light interception.

Height, when harvesting under these conditions, was the best criteria for cutting date. However, the optimum heights are not related to days of regrowth.

The status of carbohydrate reserves differed within each of the three seasons. These reserves generally declined immediately after defoliation indicating that they furnish energy for regrowth.

The nutritive value of the forage generally declined as stage of maturity advanced. The use of a rotary mower as compared with a cycle bar mower during initial harvests in spring and early summer affected these trends.

Because of the short duration of this research and biological interactions the conclusions are not final. Many complex interrelated factors must be studied to make wise compromises for establishing a more definite date of cutting within a season.

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Regrowth Analysis of Alfalfa (*Medicago sativa*, L.)
During Three Seasons in 1966

by

Vicente Davila Suarez

ABSTRACT

The rate of alfalfa regrowth during three seasons was associated with different parameters with the objective of finding a most suitable date of cutting in each season.

The rate and total dry matter produced was higher during spring and early summer seasons than in late summer.

The higher L.A.I. during spring than for the other two seasons may be attributed to production of new leaves because of weevil and frost damage. The greatest efficiency in L.A.I. occurred during early summer and the lowest in late summer; the same trend was observed in N.A.R.

Interception of 95% of the light required different L.A.I. values during the three seasons, and these values were reached at different dates of regrowth and stages of maturity. Maximum growth rates were not associated with 95% light interception.

Height was the best criteria for cutting date. However, the optimum heights were not related to days of regrowth.

The status of carbohydrate reserves differed within each season. These reserves generally declined immediately after defoliation, indicating that they furnish energy for regrowth.

The nutritive value of the forage generally declined as stage of maturity advanced.