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Harvest Practices On the Performance Of Alfalfa

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HUGO O. GRAUMANN, J. E. WEBSTER,

C. L. CANODE and H. F. MURPHY

Agricultural Experiment Station

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The Effect Of Harvest Practices On The Performance Of Alfalfa

By HUGO O. GRAUMANN,[1] J. E. WEBSTER,[2]
C. L. CANODE[3], and H. F. MURPHY[4]

It is common practice in north central and western Oklahoma, as in many states of the Great Plains Region, to harvest the first one to three cuttings of alfalfa for hay, followed by a seed crop whenever conditions are favorable for seed setting. Little thought is given to meadow management practices that are conducive to high seed yields and failure of the seed crop is commonly attributed to unfavorable weather or insect damage, or both. Because of the frequency of seed crop failures even under reasonable weather conditions, other important factors seem to be involved.

The investigations reported herein were undertaken to obtain specific information on the relation of cutting practices to forage and seed yield, hay quality, root reserves, and stand longevity. The studies were designed to establish a physiological explanation of these relationships.

REVIEW OF LITERATURE

Many investigators have reported on the effect of cutting practices on the performance and stand longevity of perennial forage species. The conclusions of the more important papers are presented on a classified subject matter basis.

[1] Formerly, Associate Professor of Agronomy, Oklahoma Agricultural and Mechanical College, Stillwater, Oklahoma; now, Research Agronomist, Agricultural Research Service, Section of Forage Crops and Diseases, United States Department of Agriculture.

[2] Professor and Research Chemist, Oklahoma Agricultural and Mechanical College.

[3] Formerly Assistant Professor of Agronomy, Oklahoma Agricultural and Mechanical College; now, Assistant Professor of Agronomy, University of Idaho, Moscow, Idaho.

[4] Head, Department of Agronomy, Oklahoma Agricultural and Mechanical College.

Yield.—The important role of the rate of photosynthetic activity in the leaves of plants by way of determining crop yields has been recognized since the days of Sachs; however, the application of this principle in actual meadow management practice is of relatively recent origin.

Numerous investigators working with alfalfa (7, 9, 14, 16, 19, 20, 24, 28, 37, 38*), grasses (3, 5, 9, 15, 31, 34), and red clover (36) have shown that frequent and consistent removal of excessively immature top growth generally results in drastic reduction of forage yield. The lower yields were frequently associated with limited root development and severe stand losses.

Willard (35) of Ohio reported that repeated cutting of alfalfa at the bud and early bloom stages, as compared with full bloom and seed stages, did not reduce forage yields in the first season, but caused sharp declines during the succeeding three years. On the contrary, Woodman *et al.* (38) noted in England that first season yields were only 84.4 and 52.5 percent as great, respectively, when harvested at the bud and "prebudding" stages as when in full bloom. Kiesselbach and Anderson (20) in Nebraska and Salmon *et al.* (28) at the Kansas station reported a decrease in the proportion of leaves with increasing maturity of any given cutting.

Improper late summer management of alfalfa meadows frequently results in decreased plant vigor, stand losses and lowered forage yield. This was demonstrated by findings of Sylven (32) in Sweden; Silkett, Megee, and Rather (30), and Rather and Harrison (26) in Michigan; and Brown and Munsell (4) in Connecticut. These workers reported that mowing in September gave marked reductions both in the winter survival of plants and in the forage yields of the following season as compared with either no late summer harvest or delay until October. Similarly, 6-year results from Arkansas reported by Nelson (23) show that omission of a fall harvest enhanced the yields the following year.

Hildebrand and Harrison (16), working under greenhouse conditions for a 12-week period, studied the effects of cutting Hardigan alfalfa at the respective stubble heights of 1, 3, 6, 9, and 12 inches at weekly, bi-weekly, and monthly intervals. The 1-inch height gave significantly lower yields than the other heights. Within each harvest frequency the researchers noted a direct relationship between forage and root yields, and the height of clipping, except that plants clipped to 6-inch and 9-inch heights at monthly intervals produced more than those

* Numbers refer to Literature Cited, page 35.

cut to a 12-inch height every 30 days. Furthermore, clipping at 7-day intervals gave lowest total forage production, whereas highest yields resulted from monthly harvests.

Under greenhouse conditions Grandfield (13) studied the effect of soil moisture and organic root reserves on the seed production of alfalfa. High-reserve plants produced 226 and 109 percent more seed at high and low moisture levels, respectively, than did low-reserve plants. Wilsie and Hollowell (36) reported that mammoth red clover and medium red clover grown in Iowa gave higher yields of forage and protein when cut at the early to full bloom stages than at either earlier or later maturity. Sturkie (31), working with Johnson grass in Alabama, concluded that the amount of root development was in inverse relation to the frequency of forage harvest, and increased directly with the age and height of plant at the time of clipping. Frequent cutting at immature stages as compared with one annual harvest, was reported by Graber *et al.* (9) to reduce the forage yields of both bluegrass and redtop, and the amount of rhizome and root growth of bluegrass. Carter and Law (5), working with six species of grasses, obtained a highly significant correlation coefficient of 0.82 between dry weights of roots and tops.

Plant Vigor and Stand.—Although average forage yields of alfalfa harvested at various stages of maturity give a satisfactory measure of the gross response to such cutting practices, they do not supply the information needed to determine changes in physiological behavior of the plant that are coincident with the cutting systems employed. This was recognized by Graber *et al.* (9), who reported that although frequent harvesting of top growth ultimately reduced the yield and vigor of alfalfa, there was an apparent immediate increase in the number of new shoots and stems per plant following premature cutting early in the growing season. Rather and Harrison (26) and Silkett *et al.* (30) observed that alfalfa plants cut at critical fall dates developed fewer and less vigorous crown buds than those not clipped or those cut in late October. Many workers including Kiesselbach and Anderson (20), Nelson (23), Dawson *et al.* (7), Salmon *et al.* (28), and Garver (8) have noted a relationship between cutting alfalfa at immature stages and stand loss, especially during the winter. Tysdal and Kiesselbach (33) also noted a differential varietal response. Salmon *et al.* (28) observed that repeated clipping of the new shoots coincident with cutting at the more advanced stages of growth caused no apparent injury to the crop. Late fall harvest of an additional cutting, over-grazing in the fall, cutting at the bud stage and allowing little time for fall growth all have been noted (1, 4, 10, 21, 26, 27, 30) as reducing stand and plant vigor.

Chemical Composition of Hay.—In general, there is a gradual decrease in the percentages of ash and protein and an increase of crude fiber in alfalfa forage as its maturity advances beyond the pre-bloom stage (4, 7, 20, and 28).

Salmon *et al.* (28) noted little relationship between percentage of fat and maturity of alfalfa. Kiesselbach and Anderson (20) reported a lower proportion of this contituent in hay cut at the seed stage than at six earlier stages of growth. Brown and Munsell (4) also observed that delayed mowing decreased the fat content of the resulting forage.

Dawson and co-workers (7) harvested alfalfa regularly for three years at initial bloom, one-half bloom, and full bloom. Little difference in chemical composition of hay cut at the two earlier maturities was noted; however, full bloom hay was decidedly lower in crude protein and higher in crude fiber. For cuttings made at uniform stages of development, crude protein, calcium, and phosphorus tended to increase and crude fiber to decrease in each successive harvest during any given season.

Comstock and Law (6) subjected pure stands of alfalfa and mixed plantings of alfalfa and grass to three years of differential cutting treatments. Forage clipped frequently to simulate grazing contained a higher percentage of protein than did either more mature hay, or forage from deferred clippings simulating deferred rotational grazing.

Kiesselback and Anderson (20) reported average protein contents of 21.98, 20.02, 19.24, 18.84, 18.38, 18.13, and 14.06 percent in alfalfa cut regularly during four years at the respective stages of pre-bloom, initial bloom, one-tenth bloom, one-half bloom, new growth, full bloom, and seed. Nitrogen-free extract ranged around 40 percent with variations being inconsistent in relation to stage of growth.

Root Reserves.—Graber *et al.* (9) reported that the amount of top and root growth and the vigor and vitality of alfalfa plants were generally correlated with carbohydrate and nitrogen reserves in the roots. Nelson (24) noted that, "Chemical analyses of alfalfa roots and physiological observations show that stored organic foods in the roots of certain plants such as alfalfa have an important influence on their productivity." Root reserves studies have been made on sand sagebrush by Savage and Costello (29) and on Kudzu by Pierre and Bertram (25).

Many workers, including Nelson (23), Janssen (17), Brown and Munsell (4), Comstock and Law (6), and Harrison (14) have reported lower energy reserves in roots of alfalfa plants cut frequently at excessively immature stages than in those from plants harvested later. Harrison (14) noted a 50 percent loss in the dry weight of roots for plants grown in a greenhouse and clipped to a 1-inch height at weekly intervals for eight successive weeks. Histological studies of these roots indicated that no starch had been stored, whereas plants clipped to 6-inch heights or not clipped at all stored appreciable amounts of starch in the roots. Based on determinations made at time of cutting, Brown and Munsell (4) reported a gradual lowering of root reserves throughout the season under Connecticut conditions when plants were cut regularly at unduly immature stages (less than 40 days growth).

Using stained microtome sections of alfalfa roots collected periodically during the growing season in Michigan, Rather and Harrison (27) showed that as active top growth was initiated and progressed, starch reserves decreased in the roots for a period of two to three weeks and then gradually increased. Once starch storage in the roots began, it was far more pronounced in alfalfa grown alone than when grown in association with grasses. Fall storage of starch reached a maximum about October 1, after which there was a gradual depletion because of short intermittent growth periods between killing freezes. Under Kansas conditions, Grandfield (12) noted that maximum concentration of carbohydrates in alfalfa roots occurred in late October. Thereafter total sugars increased at the expense of starch, with peak percentages of sugars being reached during December.

Mark (21) analyzed roots obtained from a 2-year-old field of Grimm alfalfa in Iowa and found that reducing sugars constituted a progressively smaller proportion of the energy reserves as the fall season advanced. The non-reducing sugar (sucrose) increased during the fall and remained constant in winter except for a slight increase toward spring. Janssen (18), working at the Arkansas station, noted a decided reduction of starch and a marked increase of total sugars during the winter in the roots of Grimm and Hairy Peruvian alfalfa, the changes being greatest in Grimm.

Brown and Munsell (4) of Connecticut reported on various chemical constituents found in roots dug 0, 9, 20, 31, 41, 52, and 62 days after cutting alfalfa on August 10, and also in roots obtained at 2-week intervals between October 19 and December 3. Nitrogen and carbohydrates decreased during the first 20 days after harvest. Beginning approximately 30 days after removal of tops, the roots showed a progressive increase of carbohydrates and nitrogen as the interval after mowing lengthened. By the 52nd day the nitrogen supply had surpassed the 0-day level, whereas the replenishment of carbohydrates was only 74.4 percent of the original amount. At 2-week intervals throughout late October and November considerable decreases were noted in starch. During this time sucrose increased 25 percent and then decreased to its original level.

Cutting alfalfa at critical periods during late summer or early fall has been observed by Silkett *et al.* (30), and by Grandfield (11) to lower the energy reserves of the roots to such an extent that the plants were more susceptible to winter injury. Grandfield found that maximum storage of root reserves during the fall was attained when the aftermath reached a height of 8 to 10 inches before fall growth ceased.

EXPERIMENTAL PROCEDURE

These investigations extended over the 5-year period 1946-1950 and involved a number of cutting treatments which were grouped according to general use of the meadow as cuttings for hay only, and cuttings for hay and seed. Five distinct tests were completed, two for the first and three for the second group of meadow use. Harmful insects (especially webworms, grasshoppers, and lygus bugs), when present in sizable populations, were controlled by spraying the test fields and surrounding alfalfa with appropriate insecticides.

Location and Size of Experimental Plots.—The five test areas used were located in 2- and 4-year-old fields of Oklahoma Common alfalfa (previous management was careful and uniform for a given field of alfalfa) grown on Yahola fine sandy loam, bottom land soil on the Experiment Station Farm at Stillwater, Oklahoma. Selection of specific test areas was made on the basis of uniform stand and plant performance as shown by completeness of soil cover and general plant development during the preceding year. Plots were laid out on these areas during the winter before the various cutting treatments were imposed.

All field observations and results were for either 3-, 4-, or 6-replicate plots in randomized block designs. Two sizes of plots were used for yield determinations; 1/80 acre for the hay production studies, and 1/100 acre for the cutting combinations involving both hay and seed production. Smaller areas, one adjoining each yield plot and receiving the same cutting treatment, served as a source of roots for the energy reserve studies.

Cutting Treatments.—Harvests for hay production were either at the bud, one-tenth bloom, or full bloom stages with successive cuttings of any given plot being at the same maturity. Studies concerning both forage and seed were designed to provide annually several cuttings of hay and a crop of seed. The hay harvests of these involved a variable sequence of maturity stages with the different combinations so planned that the last cutting, prior to the seed crop, fell on either of two days approximately three weeks apart. The two periods of seed production provided minimized risk of complete seed failure in all plots because of unfavorable seasonal conditions, and they also provided a means of comparing early summer with late summer seed-set. Within each of these seed-set periods different harvest practices were comparable because the total growth period was under the same weather conditions for any given year.

Yield Determinations.—Plot weights of uncured forage were determined to the nearest one-tenth pound shortly after cutting. Samples were collected from each plot for moisture determination at the time of weighing. These were dried at 105°C. to a moisture-free basis. The forage yields are reported as pounds of moisture-free hay per acre.

In the case of seed crops the partially wilted alfalfa was bunched soon after cutting for further curing in the field. Threshing was done with a nursery-type small grain thresher. All handling of the cured crop, both in the field and during threshing, was over a canvas in order that losses of seed by shattering could be minimized. Yields of total seed recovered are reported as pounds per acre on a recleaned basis.

Rate of recovery following cutting, number of shoots per unit area at harvest time, and comparative plant losses were determined to afford added measure of growth and yield in relation to the cutting practices used.

Plant Vigor and Stand Losses.—During 1946 average plant heights were determined for three measurements in each plot at intervals of 5, 10, 15, 20, and 25 days after the previous harvest, and at time of cutting.

The average number of alfalfa stems per unit area as influenced by previous treatment was determined at harvest time for all cutting treatments of 1946. The numbers reported are based on the actual counts of stems in each of two randomly selected square meter quadrats for each plot.

Stand losses resulting from various cutting treatments in 1946 are reported as percentages of dead plants contained in two 1.2-×11-foot strips of alfalfa sod plowed out of each plot in late November. Stand counts were made for the various cuttings at the end of the 1948-50 period on each of the 1/100 acre plots.

Feed Constituents in Hay.—A 5-pound sample of freshly cut forage was collected for chemical analysis from each plot at the time of cutting and immediately dried at 105° C. The moisture-free weights were included with those of the corresponding plots as a part of the hay yields.

The dried samples were ground through a screen of medium mesh in a Wiley cutting mill. Representative portions of each sample of ground hay were preserved in stoppered bottles and later analyzed for ash, crude protein, ether extract, crude fiber, and nitrogen-free extract, according to the *Official and Tentative Methods of Analysis* of the A.O.A.C. (2).

Chemical Composition of Roots.—Fifty alfalfa plants were dug from representative root-sampling areas adjacent to each plot within one day of the time of cutting for hay. Additional root samples obtained during the fall and winter months and at intervals between cuttings were composites from 50 plants tracing to the several replicated plots of a particular treatment. In all cases the freshly dug plants were trimmed, leaving only a 10-inch segment including the crown (perennial underground portion of the stem) and an attached portion of the root. For brevity this segment will be called the "root."

The samples of 50 trimmed roots were tightly enclosed in double-walled wax paper bags and immediately placed in cold storage for quick freezing at a temperature of —17° C. They were kept at this temperature for approximately four to six weeks. Upon removal from cold storage and after several hours of thawing at room temperature, the roots were thoroughly washed in a stream of running tap water. Excess surface water was blotted from the washed roots. All dead and partially decomposed stems, crown shoots and root tissue (representing portions that were dead before the plants were dug) were cut out. Each segment was closely trimmed, saving only the upper eight inches. These cleaned roots were run through a power meat grinder and then thoroughly mixed.

Of this mixed material, duplicate 50-gram samples were preserved in 80 percent alcohol and later analyzed for starch, sugars, and soluble nitrogen; triplicate 10-gram samples were used for total nitrogen determinations; and 40 grams were used to determine total solids and ash. Total solids were determined by drying the samples at 105° C., and ash was determined by burning the samples at a maximum temperature of 650° C. Both of these reductions were completed in platinum dishes. All nitrogen analyses were made according to the Kjeldahl-Gunning (2) procedure. Samples of ground root material were extracted with 80 percent alcohol for 24 to 36 hours in large Soxhlets. Reducing sugars were determined on the ethanol-free and neutral lead acetate cleared alcoholic root extracts according to the Shaffer-Hartmann (22) method. Total sugars were determined by the Shaffer-Hartmann (22) method on the previously cleared extracts after inversion with hydrochloric acid. Sucrose was calculated by substracting the value for reducing sugars from total sugars and multiplying the difference by 0.95, which is standard procedure.

Starch was determined on the dried alcohol-extracted residues ground to 100-mesh by use of the diastase method described in the *Official and Tentative Methods of Analysis* of the A.O.A.C. (2). Taka-diastase was substituted for malt diastase.

Insoluble nitrogen was calculated by difference from actual determinations of soluble and total nitrogen. The three carbohydrates (reducing sugars, sucrose, and starch) were grouped and are herein collectively termed "total carbohydrates."

Of these analyses, those of greatest interest were soluble nitrogen, insoluble nitrogen, reducing sugars, sucrose, and starch. Insoluble nitrogen, and starch are most important because they represent the principal metabolite storage in roots. The other three materials, classified as soluble metabolites, are stressed because of their usual occurrence in all living plant tissue and their immediate availability for metabolic processes within the plant.

EXPERIMENTAL RESULTS

There is a complex inter-dependency existing between forage yields, composition of hay, seed yields, root reserves, plant vigor and stand longevity in relation to stage of harvest; therefore, the detailed results are presented as specific topics.

Effect of Successive Cuttings At Uniform Maturity Stages on the Yield and Composition of Hay

Various uniform cutting treatments of one season's duration were imposed on vigorous 4-year-old stands of alfalfa during 1946 and 1947. The consecutive harvests in the various practices were either at the bud, one-tenth bloom, or full bloom stages. The yield and composition data both calculated to an oven dry basis are shown in Tables 1 and 2.

The relative yields of moisture-free hay as averaged for the two tests were 100, 116 and 123 percent for the bud, one-tenth bloom, and full bloom harvests, respectively. Cutting in the bud stage reduced the yield of hay compared with harvesting at the later stages of growth. The reduction was greater in 1947 than in 1946. A combination of exceptional drought and localized damage by crown disease may have contributed to the smaller differences in 1946. The general effect of bud or prebud harvest on hay yield compared with harvesting at one-tenth bloom for the five years 1946-1950 is summarized in Table 11.

There was a considerable range in crude protein percentage in the hay harvested during 1946. The seasonal averages for hay cut at the bud, one-tenth bloom and full bloom stages were 21.6, 20.2, and 18.3 percent, respectively, while the highest crude protein was 23.7 percent in the second cutting at the bud stage and the lowest was 17.5 percent in the third cutting at full bloom.

Crude fiber increased with maturity, the respective average percentages being 22.9, 24.6, and 26.8 for hay harvested at bud, one-tenth bloom, and full bloom stages. The percentage of ash increased to early bloom but decreased thereafter as the dry matter increased without the corresponding uptake of inorganic salt from the soil.

Data calculated from those given in Table 2 would indicate a slightly higher total crude protein yield for bud stage harvesting over harvesting at later stages of growth. However, in view of data from other experiments (Table 9), the general effect is a reduction in annual crude protein yield with excessive early harvesting.

Effect of Successive Cuttings At Variable Maturity Stages On Yield and Composition Of Hay and On Seed Yield

These studies involved two 1-year tests and one of three years duration, each designed to provide annually two to four cuttings of hay and a seed crop. The hay harvests, although varying some for each of the three tests, involved various maturity combinations so planned as to have harvest management practices which allowed for early summer and late summer seed set. The seed crops of any given year for the treatments in either seed set group are comparable because they were produced under the same weather conditions. The 1-year test in 1946 and the other in 1947 were each set up in uniform vigorous 4-year-old alfalfa meadows. The 3-year test (1948-1950), was established in a meadow planted in the late summer of 1946 and cut uniformly during 1947. Data on these tests are shown in Tables 3, 4, 5, 6, 7, 8, and 9. In addition, the 1947 test plots were harvested for hay twice during 1948 at uniform stages of growth to determine the carry-over effect of the various cutting treatments of the previous year. These data are shown in Table 10.

Forage Yields.—The removal of the first cutting in 1946 at one-fourth bloom, as compared with prebud, increased the succeeding prebud cutting by 75 percent. While the dates of the second cuttings (May 14 and 28) differed, it seems unlikely that the 75 percent greater yield can be attributed to the more favorable seasonal conditions caused by delay in view of the fact that this growth was produced in 28 days as compared with 33 days for the lower yielding harvest (Table 3). The substitution of a first cutting at one-fourth bloom for the prebud stage increased the total yield of hay in 1946 by one-third over prebud harvesting only. There was a decided trend for yields of successive harvests when cut at the same stage of maturity during a given season to decrease (Tables 3, 4, 5 and 6).

With equal growth periods where all the harvests for a particular season preceding the seed harvest were made at the prebud stage, the hay yield was decreased 7 out of 8 trials with an over-all average decrease of 572 pounds per acre compared with yields from seasonal harvests which included wholly or in part later stages of plant development preceding the seed harvest (Table 7). This was nearly 15 percent less hay than where more mature growth was involved throughout a part or the entire harvest season.

The mean daily increase in hay yield for alfalfa harvested consecutively at the prebud stage was approximately 41 pounds per acre while the corresponding daily gains where more mature harvests were involved, wholly or in part, averaged about 14 percent higher.

Meadow management designed for a relatively early seed crop resulted in nearly a 20 percent decrease in annual hay yield (Table 8). This management was distinctly more favorable to seed production; however, the average annual sacrifice in order to secure 60 pounds of seed per acre was slightly over 900 pounds of hay during the four years seed was harvested in these experiments.

Feed Constituents.—Alfalfa cut uniformly in the prebud stage produced hay higher in ash and crude protein than when harvested at later stages of growth (Tables 3, 4, and 5). Crude fiber increased with increasing maturity. There was a trend toward a slightly higher ether extract content in the early cut hay. The nitrogen-free extract showed no definite trend in relation to maturity at harvest. While the prebud harvests produced hay higher in ash and crude protein than later maturity harvests, the annual yield of all feed constituents, as well as hay itself, was higher where later maturity stages were involved wholly or partly in the season's harvest procedure (Tables 7 and 9). This applied to meadows managed either for early or late summer seed set. Naturally meadows managed for late summer seed set produced more total forage and total feed constituents than those managed for early summer seed set. (See Table 8 for hay and seed yields.)

Seed Yields.—These data are given in Tables 3, 4, and 5, and summarized in Tables 6 and 8. As an average for the years 1946-1949 inclusive, early summer seed set and late summer seed set harvests have produced 63.6 and 3.5 pounds of seed per acre, respectively. The lower yields for the late seed set do not necessarily indicate that the preceding maturity stages of hay harvest were detrimental to profitable seed production. For the most part, this lower seed yield was due to unfavorable climatic and soil factors occurring during late July and August at the time of seed set. However, the effect of prebud harvesting for hay on seed production was quite evident since the average annual yield of seed where this system of harvest was used in the early summer seed set for 1946-1949 was approximately 33 pounds while for later growth stages of hay harvest for the same early summer seed set, the average was about 88 pounds per acre. At the same time the later stages of growth harvests averaged 3954 pounds compared with 3468 pounds of hay per acre for the prebud stage of hay harvest. Thus, there was an average annual difference in favor of cutting hay at the later stages of development over uniform prebud cutting in the early summer seed set type of meadow management of approximately 55 pounds of seed and nearly one-quarter of a ton of hay per acre for the 4-year period.

Yields of Hay in Subsequent Season.—The effects of various harvest practices in 1947 on 1948 forage yields are reported in Table 10. Each 1947 treatment included two to three cuttings for hay of either uniform or variable maturity stages, plus a seed crop, whereas all plots were harvested uniformly for hay the following season.

Delaying the harvest in the preceding year until at least one-half bloom had a distinctly beneficial effect. The relative yields in 1948 for the uniform prebud and one-tenth bloom stages of harvest in 1947 were 100 and 102, respectively, while for the more mature harvest stages the range was from 119 to 129 in 1948. On the basis of this test, there is some question whether cutting hay even as early as one-tenth bloom, which is the conventional procedure in Oklahoma, provides a type of management which is conducive to maximum vigor and production of alfalfa hay during subsequent seasons.

Leaf Data.—The proportion of leaves to stems in hay is shown in Tables 4 and 5. The leaf-stem ratio was highest in hay cut at the prebud stage. The percentage of leaves in hay at prebud, one-tenth bloom, and one-half bloom or later ranged from 61 to 65, 50 to 61, and 46 to 54, respectively, for the seasons of 1947 and 1948.

Leaves from the 1948 prebud hay harvests were analyzed for various feed constituents. The amounts of ash, crude protein, ether extract, crude fiber, and nitrogen-free extract contained in the leaves were 72, 80, 77, 43, and 64 percent, respectively, of the total of these several constituents in the hay. It is evident that hay making procedures which are conducive to the maximum retention of leaves without otherwise impairing quality are requisite to the production of nutritious forage, since up to approximately 80 percent of the crude protein, and only about 43 percent of the crude fiber of the hay are contained in the leaves.

Carotene Content.—In 1950, samples of the second cutting of hay were analyzed for their carotene content. The average carotene content on a dry weight basis was 308, 158, and 110 ppm for the prebud, one-tenth bloom, and one-fourth bloom hays, respectively.

Effect of Consecutive Cuttings At Uniform and at Variable Maturity Stages on Root Reserves

Consecutive Cuttings at Uniform Maturity Stages.—Roots dug at the time of cutting from plots harvested uniformly for one season (1946) at the bud, one-tenth bloom, and full bloom stages of plant development, as well as roots dug at more frequent intervals from the full bloom plots, were analyzed for their food reserve constituents. The results are reported in Table 12 and in Appendix Table 1. Some of the pertinent data are plotted in Figures 1 and 2.

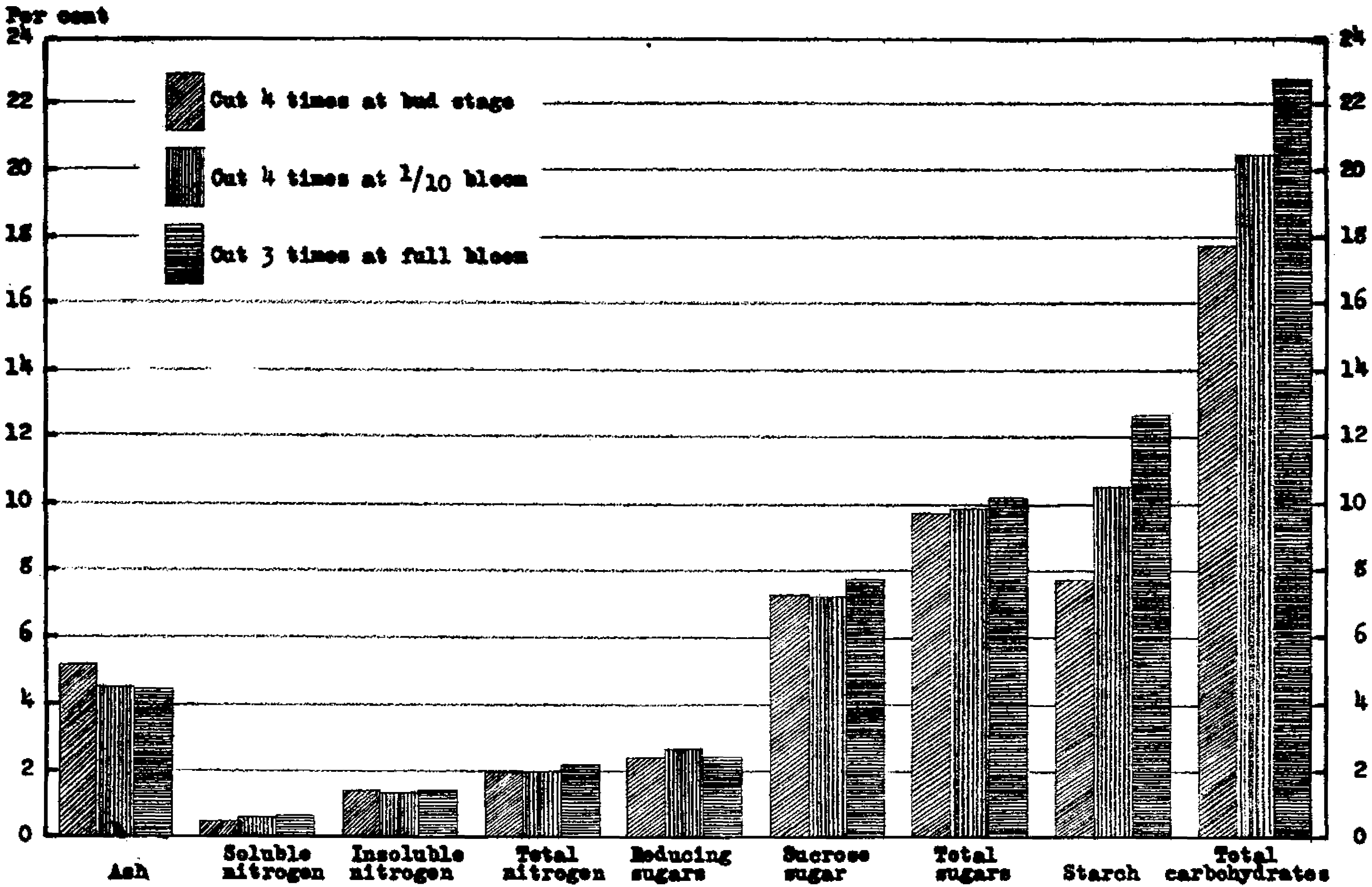

Fig. 1.—Chemical composition of alfalfa roots at time of harvesting the forage at various maturity stages, 1946. Based on data reported in Appendix Table I.

The roots from the plots cut at bud stage at harvest time were somewhat higher in ash and had about the same percent of insoluble nitrogen as the roots from the one-tenth or full bloom plots. There was a progressive increase in the percentage of soluble nitrogen, total nitrogen, total sugars, starch, and total carbohydrates and a decrease in the percentage of ash in the roots at harvest with advancing maturity. With bud stage harvesting, the soluble nitrogen, starch, and total carbohydrates were particularly low at time of cutting. The sucrose content of the roots at harvest time was highest for the full bloom stage.

The seasonal trend in total carbohydrates in the root reserves starting in the fall of 1945 on the meadow which for that season had been cut

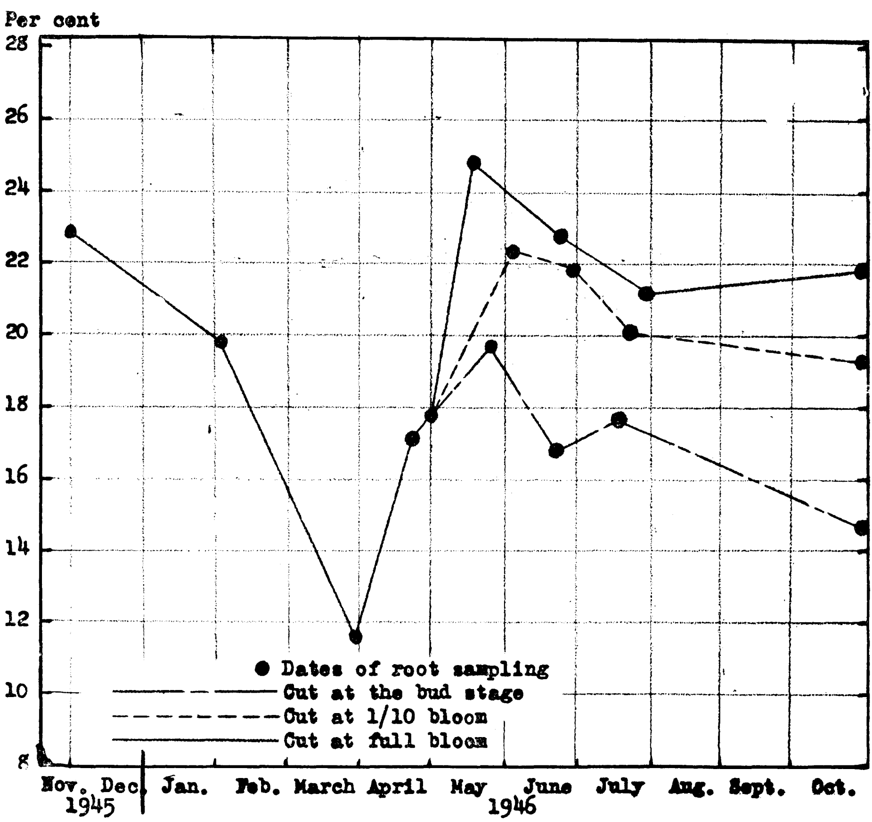

Fig. 2.—Total carbohydrates in the roots of alfalfa plants during the winter, and during the growing season as related to harvesting the forage at various maturity stages, 1946. The dates of root sampling and cutting for hay were identical during the months of April, May, June, and July. Data taken from Appendix Table I.

uniformly at full bloom and continuing through the 1946 season with respective uniform harvests at bud, one-tenth and full bloom stages is shown in Figure 2.

It will be observed that the total carbohydrates decreased from 22.9 percent in November to 19.8 percent on February 1. This decrease was mostly at the expense of starch. During February and March, the decline was accelerated. New growth started the first part of March, and by the latter part of that month the carbohydrates were at the lowest level. A rapid increase during April or by May 1 occurred, attributed chiefly to the translocation of newly synthesized carbohydrates and protein.

At the end of the season the effect of the three different stages of growth harvests on root constituents was quite pronounced. The roots from the plants harvested in the bud stage were lowest in nitrogen and reserve carbohydrates, followed in order by those harvested at the one-tenth bloom and at full bloom stages. The percent of ash was in the inverse order. It is clear that the two earlier harvest stages interfered with the elaboration of organic constituents; the effect was much more pronounced with bud than with one-tenth bloom harvesting. The roots dug at the end of the season of plants harvested at the bud stage contained 124, 70, 82, 70, 95 and 37 percent as much ash, soluble nitrogen, insoluble nitrogen, reducing sugars, sucrose, and starch, respectively, as was present in the roots of plants harvested uniformly at full bloom.

Consecutive Cuttings at Variable Maturity Stages.—Roots were dug at 7-to 14-day intervals throughout one year, and at harvest time for the various cutting practices over a 3-year period. They were analyzed and the results are recorded in Appendix Tables II, III, and IV. Fluctuations during the year of soluble nitrogen, insoluble nitrogen, reducing sugars, sucrose and starch in the roots are shown in Figure 3, whereas seasonal trends in carbohydrates as affected by cutting practices are shown in Figures 4 and 5. Root weights are shown in Figure 6.

Both sucrose and starch were low in the roots during March and April. The starch content increased rapidly about the first of May and continued on a relatively high fluctuating level until December. During the winter months the starch content declined.

Unlike starch, the sucrose level did not start to decline until in March. It tended to remain on a more or less low level during the whole of the growing season, being lowest the latter part of May or first part of June. It increased the latter part of October or in November and remained on a high level until about the first of March. The re-

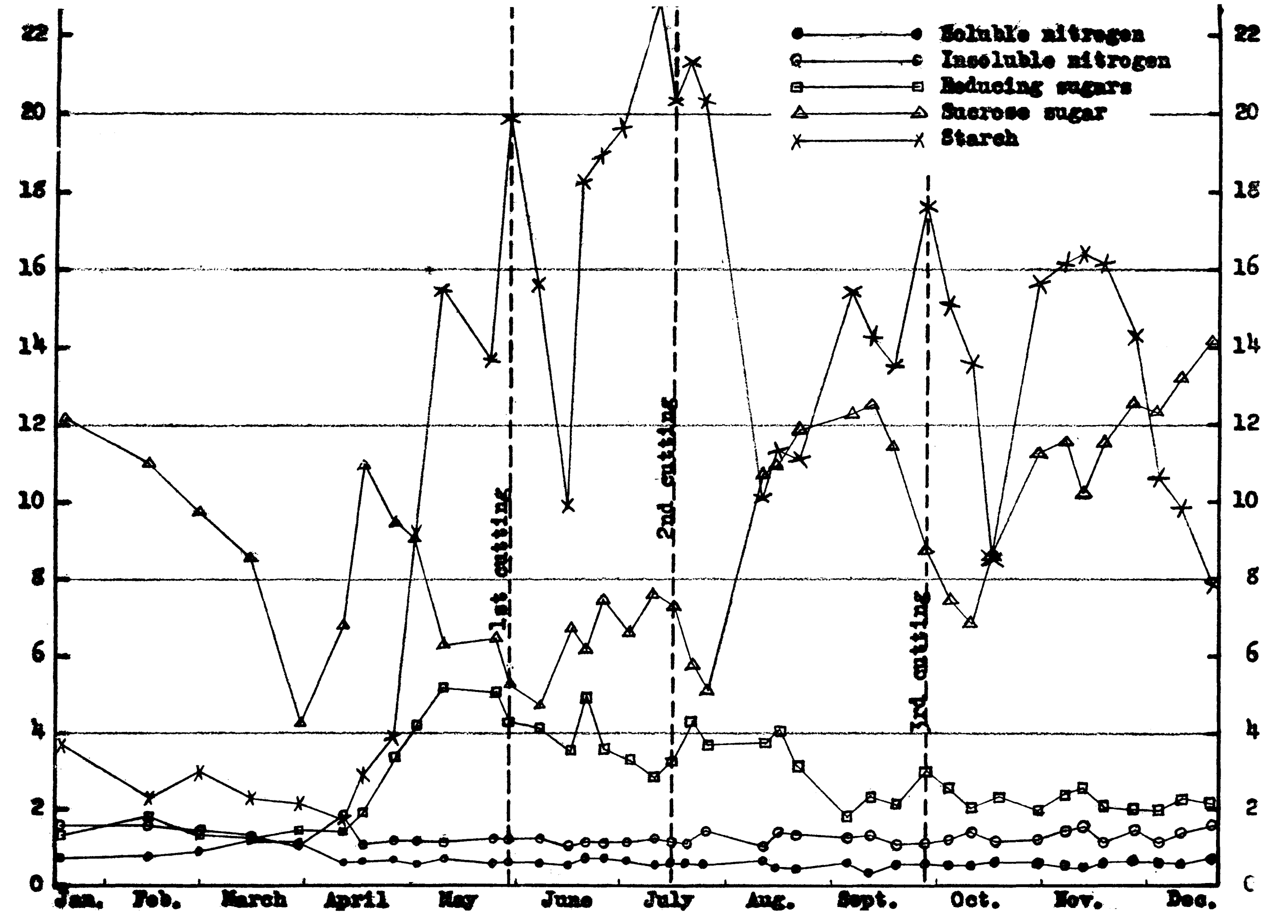

Fig. 3.—Principal constituents in the roots obtained from a productive alfalfa meadow during the winter, and during the following growing season. The successive cuttings were at the full bloom, early seed, and seed stages. Data taken from Appendix Table III.

ducing sugars were low during the late fall and winter months. During spring growth this constituent followed closely the trend of starch except that the magnitude was not nearly so great. The starch loss during the winter was, no doubt, due to its conversion to reducing sugars with a rapid synthesis to sucrose. The sucrose was apparently the usable carbohydrate, and its content remained fairly constant during this period of greatest demand as long as starch was available or until photosynthesis took care of the situation.

The late fall and winter losses of starch and total carbohydrates from roots of alfalfa plants subjected to different cutting treatments during the preceding growing seasons for the winters of 1945-46 and 1947-48 are shown in Table 13.

At the advent of early spring growth the starch and total carbohydrates in the roots had dropped to their lowest levels during their yearly cycle. These data are shown in Table 14. It will be noted that nitrogen generally decreased in the roots to the low level slightly *later* than did the total carbohydrates. Apparently the plant started using the energy materials in the roots at a rapid rate upon the initiation of spring growth, and as this continued it started using nitrogen more rapidly. This reduced the total nitrogen in the roots to a low level before the soil organisms or nitrogen-fixing organisms became active enough to supply the needed nitrogen.

The seasonal trend of available carbohydrates is shown in Figure 4. The percentages of carbohydrates in the roots indicate that an excessively immature (prebud) first cutting prevents adequate replenishment of root reserves exhausted during the winter and early spring to support satisfactory growth throughout the remainder of the year. Continued harvesting at such immature stages tends to hold root reserves at relatively low levels. Even when carbohydrates in the roots approximated 23.5 percent as a result of delaying the first cutting until the one-fourth bloom stage, decided reductions in carbohydrates resulted from two subsequent prebud harvests. Contrasted with this, when the first cutting at one-fourth bloom was followed by a second at full bloom, carbohydrates increased to approximately 25 percent. The percentage of total carbohydrates was increased in all tests by including a seed crop in the cutting sequence, the greatest increase of 6.1 percent occurring in alfalfa previously harvested at the prebud stage. However, prior cutting of such excessively immature growth had lowered root reserves sufficiently as to preclude satisfactory flowering and seed set. Consequently, the need of carbohydrates for the development of the limited seed produced was negligible, and therefore the replenishment and storage of carbohydrates in the roots increased.

A careful study of the root reserves during the growth of the third cutting (full bloom, early seed, seed harvest plan), which was permitted to mature seed reveals some striking relationships. (See Figure 3 and Appendix Table III.)

In the first place, during the major stage of vegetative development starch decreased, but by the end of about 50 days, the vegetative growth was completed, and the starch content reached a high point. It decreased some for about two weeks during seed development, but at the time of seed maturity (harvest) it had reached another high. Presumably

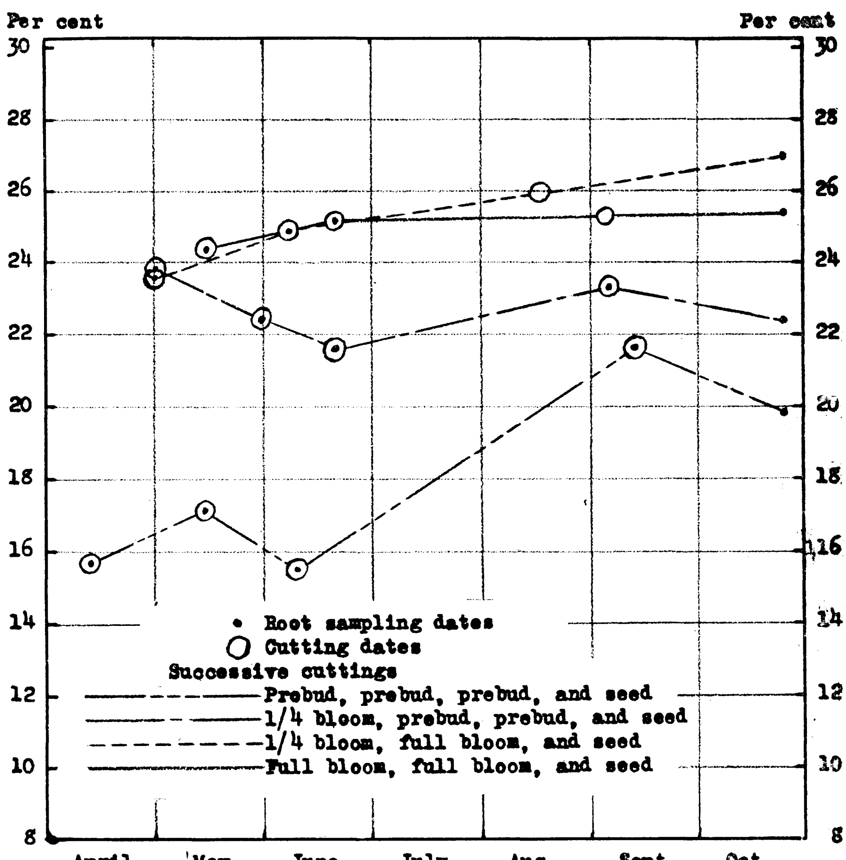

Fig. 4.—Total carbohydrates in the roots of alfalfa during the growing season as related to harvesting at variable maturity stages, 1946. Data taken from Appendix Table II.

more energy was needed during the early stage of seed development than was in the photosynthate being manufactured.

Secondly, the sucrose content remained at an unusually high level during the later stages of maturing vegetative growth and early seed development. At seed maturity the sucrose content waned, and as stated above, the starch reached a high level, thus indicating the utilization of sucrose in plant growth and development and the deposition of photosynthates as starch in the roots as growth and seed development ceases.

In late October 1946, roots taken from alfalfa that had been harvested three times at prebud and once for seed contained 19.8 percent carbohydrates as contrasted with 27.0 percent where two hay cuttings, one at one-fourth and the other at full bloom, and a seed crop had been harvested. (Appendix Table II). Accompanying this difference in root reserves, the first cutting sequence yielded only 83 and 29 percent as much forage and seed, respectively, as did the second (Table 3).

The decline of carbohydrates in the roots during the winter and early spring of 1947 is shown in Figure 5. Near maximum quantities (29.4 and 30.8 percent) of total carbohydrates were stored at harvest time when the harvest of the first two cuttings was delayed until the full bloom, and early seed stages, respectively. Lowest proportions of total carbohydrates resulted from three consecutive mowings at prebud. The respective amounts stored at successive cutting dates were 21.7, 18.5 and 17.3 percent (Appendix Table III).

The percentages of carbohydrate tended toward similar levels during growth of the seed crop irrespective of prior cutting treatment, and except for small deviations showed a more or less uniform decline during the following winter and early spring, and almost parallel variations under uniform treatment in the summer of 1948. However, differences in root weight continued throughout the fall and winter, with roots of plants harvested at more mature stages being heaviest (Figure 6). Those roots that excelled in weight and stored food provided more stimulus for abundant, vigorous growth during early spring of 1948. This resulted in an earlier use and depletion of root reserves in the spring, and likewise in an earlier elaboration and storage of food in underground portions of the plant. Consequently, the proportion of total carbohydrates in roots of alfalfa harvested three times during the previous year at full bloom, early seed, and mature seed, respectively, was lower in mid-March to mid-April and higher in early May than that following any other combination of cutting treatments.

The average dry weight of roots in winter and at the succeeding first and last harvest dates of the season, and in the following February are plotted in Figure 6 for various cutting treatments. At time of the first harvest in 1947, the relative weights of roots, considering that of the preceding winter as 100, were 74, 84, and 102 for alfalfa cut at the pre-bud, one-tenth bloom, and full bloom stages, respectively. Corresponding weights at the time of the last harvest in September (following three pre-bud cuttings plus a seed crop; three harvests at one-tenth bloom plus a seed crop, and two consecutive cuttings for hay at the full bloom and

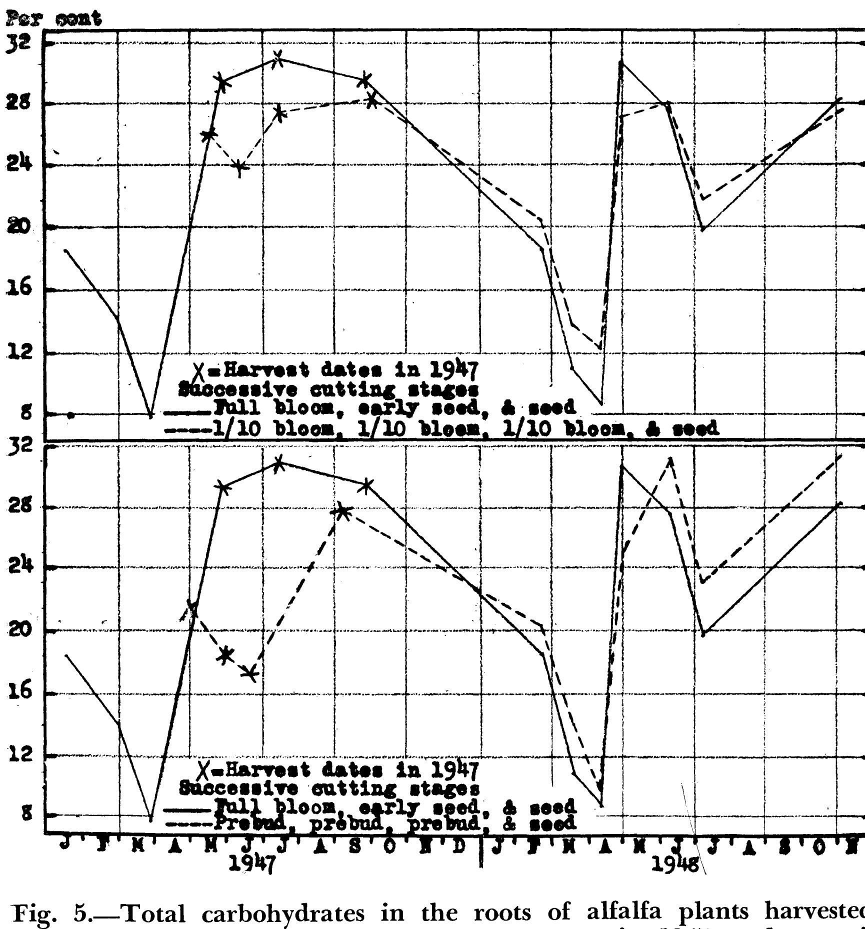

Fig. 5.—Total carbohydrates in the roots of alfalfa plants harvested at six combinations of variable maturity stages in 1947, and at uniform maturity in 1948. The six cutting treatments may be compared indirectly through a common treatment shown in all sections of the graph. Based on data reported in Appendix Table III.

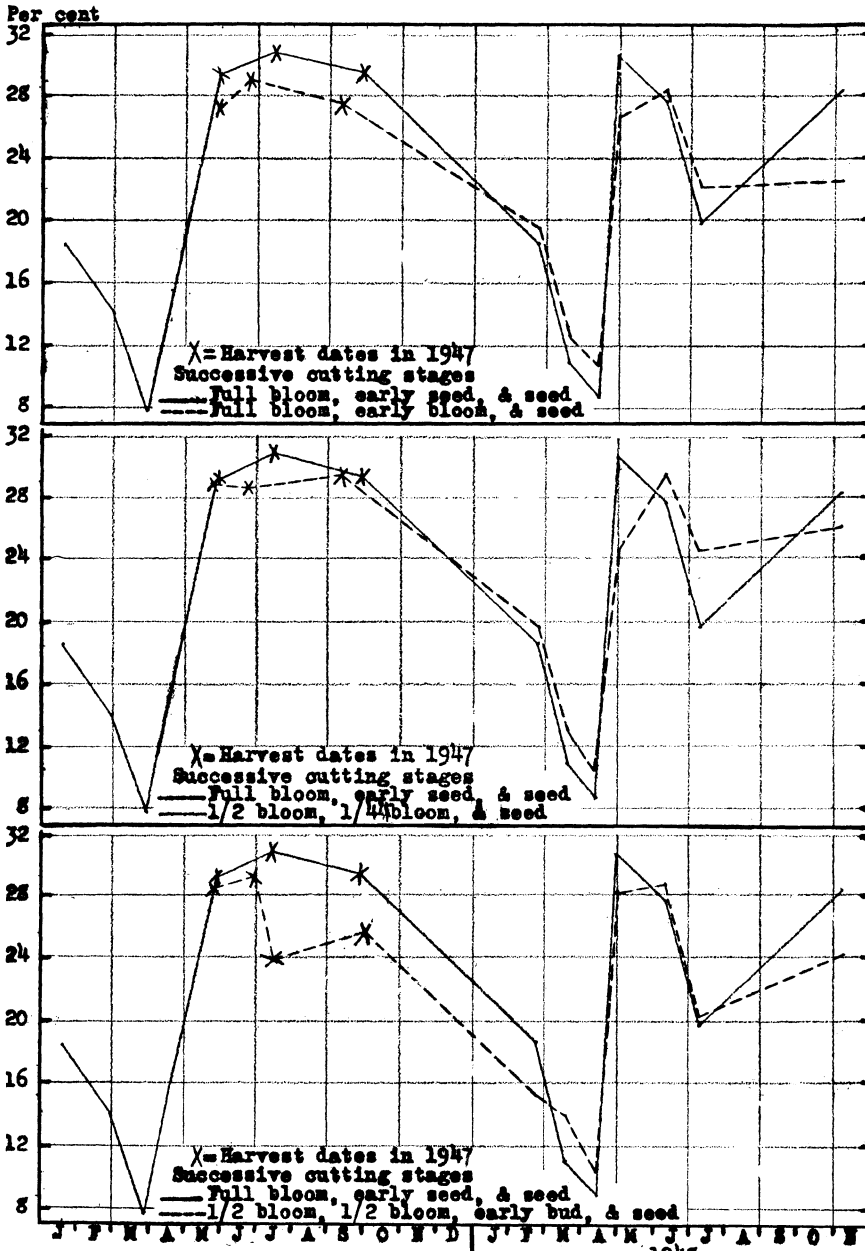

Fig. 5.—Concluded (legend on preceding page).

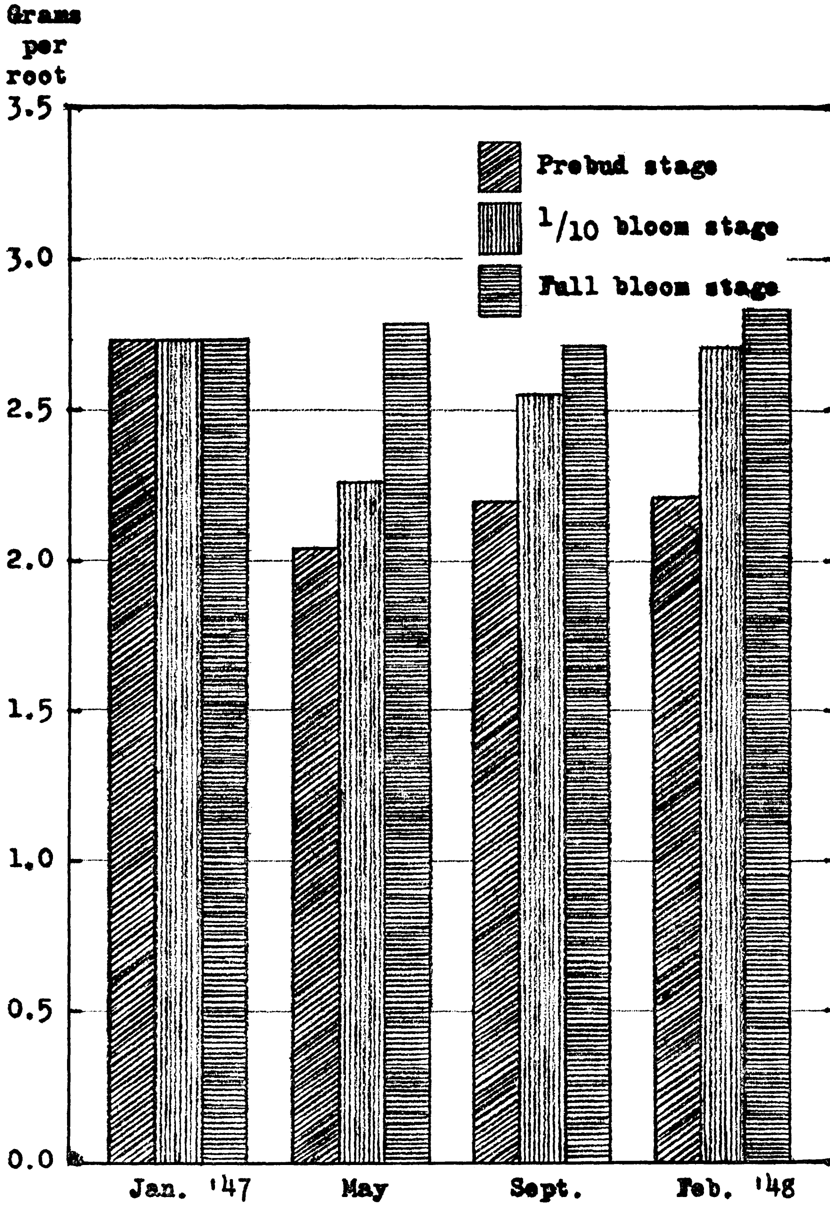

Fig. 6.—Periodic moisture-free weights of individual roots (top 8-inch segments) for alfalfa harvested at various maturity stages in 1947. The January weights are alike because the different cutting treatments were not started until May.

early seed stages plus a seed crop) were 79, 93, and 100, respectively, and those for February were 80, 99, and 103. Thus, even with conservative treatment during late summer and fall, root size was reduced 20 percent by removal of three premature (prebud) cuttings of hay in 1947. By delay of harvest until the one-tenth bloom stage, root size was decreased at first but later increased, with no appreciable loss for the year. Harvesting at full bloom or later resulted in a slight increase of root weight.

Effect of Cutting at Different Maturity Stages on Plant Vigor

The relative vigor of alfalfa in response to various cutting practices was determined in 1946 by measuring the growth rates of the forage at 5-day intervals after harvest, by counting the number of shoots per unit area at the end of each growth period, and by stand-loss counts at the end of the season. Also a stand count was made on the 5-year-old alfalfa meadow which had two seasons (1946-1947) of uniform and careful management, followed by three seasons (1948-1950 inclusive) of harvesting at variable maturity stages. These data are shown in Tables 15 and 16.

Rate of Top Growth.—It has been pointed out that the storage of food reserves increased with maturity of the forage. Likewise, the daily increment of top growth was increased through delayed harvest of the previous crop (Figure 7). The initiation of new growth was retarded by harvesting at pre-bloom and its vigor was reduced. At any given time after harvest the height of plants cut at full bloom exceeded that of plants cut at the bud stage by 37 to 100 percent, the greatest advantage being in the early part of the growth period (Table 15). Hence, it may be concluded that rate of shoot elongation was directly related to maturity at which the previous crop was harvested which in turn affected root reserves. The second growth of plants on the 10th day and at three successive 5-day intervals thereafter following harvest at one-fourth bloom was 250, 120, 67, and 64 percent, respectively, taller than that of plants cut previously at the prebud stage. However, the third growth following second-cutting prebud harvests in both cases, progressed at a uniform but retarded rate.

Number of Stems per Unit Area.—For successive cuttings at uniform stages of maturity, the number of stems per unit area at harvest varied directly with the maturity of the previous cutting up to the one-tenth bloom stage, beyond which the relation reversed. Actual counts showed 335, 404, 420, and 362 alfalfa stems per square meter as averages for two, three, three, and two cuttings of hay harvested at the prebud, bud,

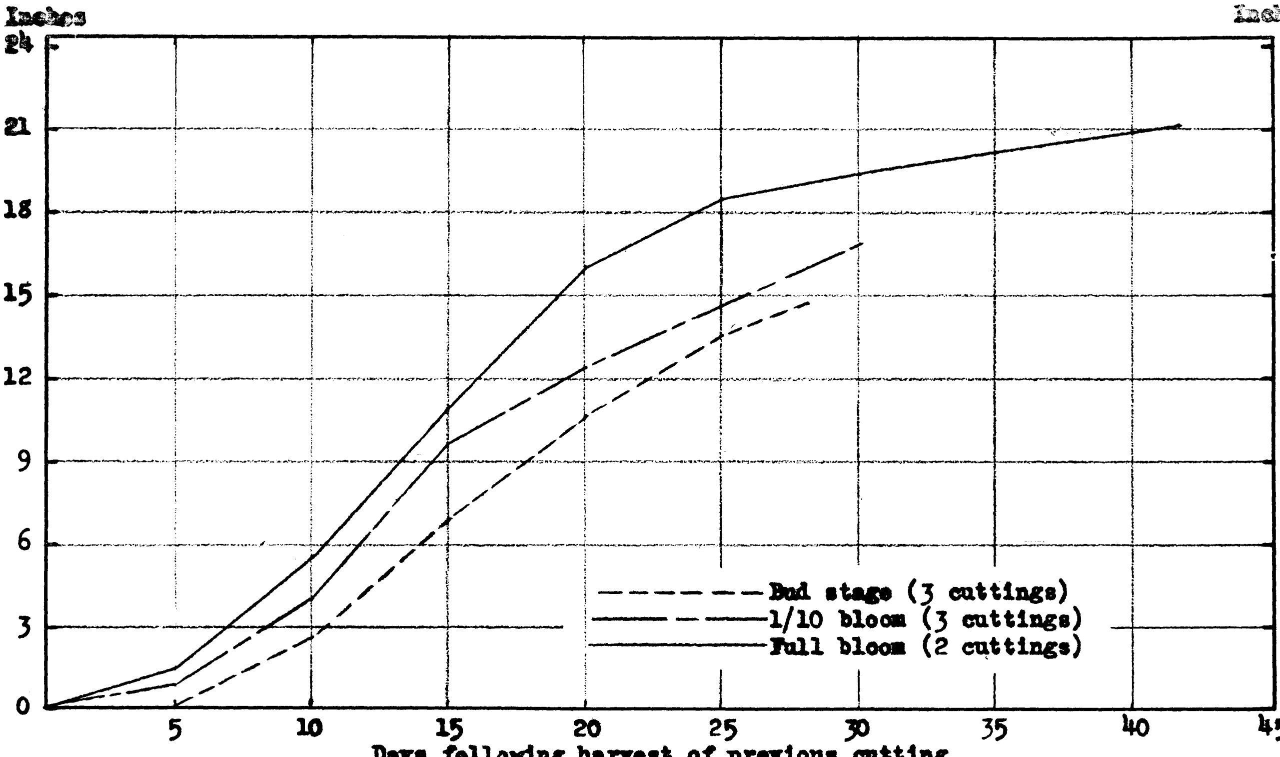

Fig. 7.—Height of alfalfa at successive 5-day intervals after harvest at three stages of maturity, 1946.

one-tenth bloom, and full bloom stages, respectively. The number of shoots for two succeeding prebud harvests was increased 25 percent by delay of the first cutting until the plants reached one-fourth bloom.

Stand Losses.—If it is assumed that the lowest plant loss observed in 1946—namely 9.5 percent from consecutive full-bloom harvests—represents the normal mortality expected in the meadow, greater losses may be attributed to less favorable cutting practices (Table 16). Compared with this loss, four consecutive harvests at the bud stage showed a stand loss of 24.8 percent, the greatest loss of any cutting treatment used; while three consecutive cuttings at the prebud stage followed by a seed crop showed a stand loss of 16.9 percent. This latter loss would no doubt have been greater had it not been for recovery during the growth of the seed crop. Cutting four times during the season at one-tenth bloom showed a stand loss of 12.1 percent, indicating that this is a fairly satisfactory cutting stage.

Considering the data on Meadow 2 (Table 16), stand counts from plots cut consecutively in the prebud stages substantiates the undesirability of harvesting at this stage of maturity.

DISCUSSION

The top growth on established alfalfa plants was rather closely correlated with the amount of food reserves stored in the roots and crowns. Tardiness in the appearance of new shoots and decreased vigor of growth during the regular growing season under favorable moisture conditions were in general associated with low energy storage in the roots.

The total amount of root reserves at any given time depends largely on the cutting treatment to which the crop has been subjected. The more immature the growth at time of cutting, or the more frequent the harvests, the lower will be the quantity of energy materials in the roots, and in the end, the lower will be the total annual yield. Low energy reserves resulting from several consecutive premature harvests were partially but inadequately replenished by permitting the mid- or later summer growth to advance to the mature seed stage. Less reduction and even greater replenishment were noted when harvesting of both the initial and last growth of the season was delayed until it reached or exceeded one-fourth bloom, and aftermath development was sufficient to provide for adequate fall storage.

When alfalfa was allowed to reach the full bloom stage before being cut, the total carbohydrate reserves dropped between harvests; but by harvest time they were usually near their peak. The roots of plants cut at earlier stages of growth were not able to attain their full storage capacity. In 1946 the total carbohydrate reserves for full bloom, one-tenth bloom, and bud stages at harvest were 21.9, 20.2 and 17.9 percent, respectively; in 1947 hay harvests at one-half to full bloom, early to one-tenth bloom, and prebud to bud stages averaged 29.0, 26.6 and 20.3 percent, respectively. The yield data likewise were favorable to harvesting at the more mature stages of development.

Where hay was cut consecutively at the bud stage throughout the entire season, the plants went into the winter with 14.6 percent total reserve carbohydrate in the roots; but where three cuttings were made at the prebud stage and a seed crop allowed to develop, the carbohydrate reserves were up to 19.8 percent. Hence, allowing the plants which had been cut at these excessively premature stages sufficient time to develop a seed crop was helpful in building root reserves for winter. Yet these reserves were generally considerably less than when the hay harvests were made at more mature stages.

The total root storage was reflected both in percentage of the stored constituents in the roots and the weight of the roots. Not only was the percentage of stored energy in the roots lower for the prebud harvests, but the actual weight of the roots was also considerably lower than when the harvests were made at the more mature stages. It is apparent that successive harvesting at the early stages of growth was not conducive to plant vigor, longevity, and yield.

Fall storage of root reserves has been shown by Graber *et al* (9), Mark (21), and others to be extremely important to winter survival of alfalfa. The data presented here confirmed these conclusions. The winter season in Oklahoma is extremely hard on alfalfa due to intermittent periods of mild weather favorable for growth activity. This means that the alfalfa at the start of spring has a lowered root reserve of starch and total carbohydrates and the plants are in a weakened condition. Early spring growth further reduces these reserves to an extremely low figure. If a system of harvesting, prebud or bud, is superimposed upon this, the plants are further weakened to where the results are reflected in stand, vigor and yield losses. In order that plants so weakened by winter and early spring growth may recuperate and continue vigorous growth and high yields, it is especially important that harvest of the first cutting be delayed until the one-fourth to one-half bloom stage or until new shoots appear at the crown.

It would appear that prebud or bud harvesting might be less severe on the alfalfa crop where the winters are more uniformly cold than in

Oklahoma. There should be less winter loss of root reserves under such circumstances, and the plants should be in a more favorable condition for early spring growth.

The data showed conclusively that early summer seed set was essential for seed production in Oklahoma. While consecutive prebud harvesting may be employed previous to the early seed set, it will materially reduce the seed yield. The seed yields under these circumstances are usually so low that seed harvesting is not profitable. When high production of both good quality forage and seed is desired, without impairment of subsequent vigor and yield, a conservative system such as two successive cuttings at one-fourth and one-tenth bloom followed by a seed crop is recommended. In years of delayed opening of spring weather coupled with early summer drought, a combination of only one cutting for hay followed by a seed crop would appear desirable. In this case the alfalfa should be allowed to advance at least to one-half bloom or until new growth starts at the crown before being cut for hay so as to assure replenishment of food reserves depleted during the winter and early spring.

Delaying consecutive harvests for hay until growth reaches one-tenth to one-half bloom usually results in a slightly poorer quality forage than is obtained by cutting at earlier stages. On the other hand, these more mature cuttings produce more forage and higher total yields of protein and other feed constituents. Of greater importance is the fact that this delay in harvest more nearly provides the physiological relationships within the plant that are conducive to continued vigorous growth and stand maintenance. More photosynthetic activity, and storage of food reserves in the roots are physiological functions of prime consideration. The net result is increased root reserves for initiation of more vigorous new top growth, larger production of weed-free hay and seed, greater extension of the root system, and healthier longer-lived plants. Common shortcomings associated with premature harvesting of alfalfa to obtain high protein forage are decreased vigor, lowering of hay and protein yields, early deterioration of stand, rapid ingress of weeds and grass, and subsequent failures of profitable seed production.

SUMMARY AND CONCLUSIONS

The vigor, yield, composition, and root reserves of alfalfa as affected by harvesting at various maturity stages are reported.

1. When grown for hay only and harvested uniformly at various stages of development, annual forage production was increased as

maturity advanced to the full bloom stage. Relative yields of moisture-free hay from two 1-year tests cut regularly at the bud, one-tenth bloom, or full bloom stages averaged 100, 116, and 123 percent, respectively.

2. While prebud to bud stage harvesting produced hay higher in ash and protein than later maturity harvests, the annual yield of feed constituents per acre was usually lower because of lower hay yields.

3. Early summer seed set is essential for seed production in Oklahoma. Late summer seed set was a failure each of the years 1946 to 1949, inclusive.

4. Prebud harvesting is not recommended either for maximum hay or seed production. As an average of four years data, (1946-49 inclusive) consecutive harvests at the prebud stage so as to allow for an early summer seed set produced only 37.6 and 87.3 percent as much seed and hay, respectively, as compared with harvesting at more mature stages.

5. While late summer seed set has meant seed failure, the extra length of hay season increased the forage yield by more than 24 percent over the shorter hay season.

6. When the same area was cut four times at the prebud stage each of two seasons, the meadow became very weedy and stand showed excessive thinning. The plants were weak and recovered very slowly after cutting. Meadows cut at later stages of growth were still holding good stands and were practically weed free.

7. Cutting alfalfa prematurely gradually decreased both the food reserves and the weight of the roots; the greatest reduction resulting from consecutive harvests at the prebud to bud stage. At the end of the hay harvesting season, the total carbohydrates in the roots of alfalfa cut at full bloom and at the bud stages were 21.9 and 14.6 percent, respectively.

8. Oklahoma winters are extremely hard on the root reserves of alfalfa. Data collected during three winters showed a loss of 48 to 86 percent of the starch, and 14 to 41 percent of the total root-stored carbohydrates.

9. The maximum depletion of food materials in the roots occurred shortly after the advent of spring growth. This is a critical period, and with a first harvest at prebud the plants are weakened and are subject to the ill effects of adverse factors which may occur.

10. The rate of recovery after cutting and the total vegetative growth, were closely associated with root reserves. With the late maturity harvests there was a build-up of starch in the roots by harvest time, and these plots made the quickest recovery after cutting.

11. Cutting at one-tenth bloom or later stages was materially better than harvesting at earlier stages in holding a stand of alfalfa.

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Table 1.—Effect of Cutting at Various Maturity Stages on the Total Yield of Alfalfa During 1946 and 1947.[1]

	Number of Cuttings		Yields lbs/A		Average	
Stage of Maturity	1946	1947	1946	1947	lbs.	percent
Bud	4	5	4998	4741	4869	100
1/10 bloom	4	4	5353	5906	5630	116
Full bloom	3	4	5293	6648	5971	123

[1] Different experimental fields were used for the respective years.

Table 2.—Forage Yields and Composition of Alfalfa Hay Cut at Various Stages of Maturity for the 1946 Season.

			Constituents of the forage				
Date of cutting[1] 1946	Growth period (days)	Hay yield (lbs.)	Ash (percent)	Crude protein (percent)	Ether extract (percent)	Crude fiber (percent)	Nitrogen-free extract (percent)
			Bud Stage				
April 18	30	1746	8.68	20.50	4.38	23.72	42.71
May 20	32	1542	8.57	23.71	3.10	23.09	41.52
June 17	28	994[2]	8.95	21.54	3.47	22.87	43.06
July 11	24	716[2]	9.28	20.67	3.37	21.89	44.80
Total or averages		4998	8.87	21.61	3.58	22.89	43.02
			One-tenth Bloom Stage				
April 25	37	1514	8.62	19.74	3.97	24.76	42.91
May 31	36	2202	9.96	20.39	3.08	25.83	40.74
June 24	24	927	10.00	20.38	2.96	23.05	43.60
July 18[3]	24	710					
Total or averages		5353	9.53	20.17	3.34	24.55	42.42
			Full Bloom Stage				
May 14[4]	56	2028	8.97	19.55	3.29	25.80	42.39
June 20	37	2119	7.54	17.79	3.13	28.05	43.50
July 24	34	1146	8.69	17.47	3.90	26.40	43.53
Total or averages		5293	8.40	18.27	3.44	26.75	43.14

[1] Due to depleted soil moisture, growth was insufficient for harvest after the July cuttings.
[2] The third and fourth cuttings at bud stage contained 2 and 19 percent grass respectively; however, the yields recorded are for grass-weed free hay. At the more mature stages, sufficient vigor was maintained so as to practically prevent weed and grass encroachment.
[3] The samples of hay collected for analytical purposes from this cutting were lost.
[4] Includes new shoots which were 7 inches tall when this cutting was made.

Table 3.—Forage and Seed Yields and Composition of Alfalfa Hay Cut at Variable Stages of Maturity, 1946.

Stage of maturity	Date of cutting 1946	Growth period (days)	Yield of hay per acre (lbs.)	Yield of seed per acre (lbs.)	Feed constituents of the forage (moisture-free basis)				
					Ash (percent)	Crude protein (percent)	Ether extract (percent)	Crude fiber (percent)	N-free extract (percent)
Prebud	April 11	25	1567		9.02	21.66	4.47	23.77	41.08
Prebud	May 14	33	1099		8.50	25.08	3.00	20.15	42.61
Prebud	June 7	24	616		9.51	25.30	2.75	20.07	42.38
Seed	Aug. 16	70		39.2					
Total or averages			3282	39.2	9.01	24.01	3.41	21.33	42.02
¼ bloom[1]	April 30	44	1799		8.93	19.44	3.26	26.12	42.24
Full bloom	June 7	38	2176		8.48	19.53	3.10	26.85	42.04
Seed	Aug. 16	70		133.7					
Total or averages			3975	133.7	8.71	19.49	3.18	26.49	42.14
¼ bloom[1]	April 30	44	1834		8.85	19.40	3.45	25.84	42.47
Prebud	May 28	28	1923		8.68	20.96	3.29	23.33	43.73
Prebud	June 20	23	635		8.68	22.15	3.54	20.48	45.15
Seed	Sept. 4	76		3.2					
Total or averages			4392	3.2	8.74	20.84	3.43	23.22	43.78
Full bloom[2]	May 14	58	2130		8.99	20.97	3.23	25.22	41.60
Full bloom	June 20	37	1772		7.58	17.82	3.14	26.94	44.52
Seed	Sept. 4	76		8.8					
Total or averages			3902	8.8	8.29	19.40	3.19	26.08	43.06

[1] Includes new shoots which were 3 inches tall when this cutting was made.
[2] Includes new shoots which were 7 inches tall when this cutting was made.

Table 4.—Forage and Seed Yields and Composition of Alfalfa Hay Cut at Various Stages of Maturity, 1947.

Stage of maturity	Date of cutting	Growth period (days)	Proportion of leaves (percent)	Yield of hay (lbs.)	Yield of seed per acre (lbs.)	Feed constituents of the forage (moisture-free basis)				
						Ash (percent)	Crude protein (percent)	Ether extract (percent)	Crude fiber (percent)	N-free extract (percent)
Prebud	May 1	27	61	1279		10.81	22.77	3.03	22.89	40.50
Prebud	May 29	28	64	929		8.04	23.81	3.57	24.05	40.53
Prebud	June 20	22	61	338		9.45	20.63	2.38	26.18	41.36
Seed	Sept. 8	80			28.8					
Total or averages				2546	28.8	9.43	22.47	2.99	24.37	40.80
½ bloom[1]	May 22	48	46	2513		7.97	18.04	3.22	31.20	39.57
½ bloom	June 20	29	54	1643		7.96	17.99	2.33	33.06	38.67
Seed	Sept. 8	80			89.3					
Total or averages				4156	89.3	7.97	18.02	2.78	32.13	39.12
Full bloom[2]	May 28	54	47	2415		8.16	16.89	2.76	30.28	41.91
Early bloom	June 20	23	57	1195		8.17	19.22	2.17	30.42	40.02
Seed	Sept. 8	80			78.9					
Total or averages				3610	78.9	8.17	18.06	2.47	30.35	40.97
1/10 bloom	May 13	39	50	1925		9.21	19.31	2.87	26.93	41.70
1/10 bloom	June 12	30	56	1447		8.14	19.72	2.72	28.91	40.51
1/10 bloom	July 15	33	56	791		8.62	21.15	3.97	23.97	42.28
Seed	Sept. 27	74			4.8					
Total or averages				4163	4.8	8.66	20.06	3.19	26.60	41.50
½ bloom[1]	May 22	48	48	2636		8.05	18.74	3.10	29.60	40.50
½ bloom	June 26	35	51	1722		7.45	17.38	3.08	29.21	42.89
Initial bud	July 15	19	56	634		9.17	26.66	3.88	22.24	38.06
Seed	Sept. 27	74			6.8					
Total or averages				4991	6.8	8.22	20.93	3.35	27.02	40.48
Full bloom[2]	May 27	48	47	2511		7.54	18.52	3.43	27.78	42.72
Early seed[3]	July 15	54	51	2468		7.66	20.64	3.82	31.36	36.52
Seed	Sept. 27	74			13.0					
Total or averages				4979	13.0	7.60	19.58	3.63	29.57	39.62

[1] Includes new shoots which were 2 to 3 inches tall when this cutting was made.
[2] Includes new shoots which were 6 inches tall when this cutting was made.
[3] Includes new shoots which were 10 inches tall when this cutting was made.

Table 5.—Forage and Seed Yields and Composition of Alfalfa Hay Cut at Various Stages of Maturity, 1948.

						Feed constituents of the forage (moisture-free basis)				
Stage of maturity	Date of cutting	Growth period (days)	Proportion of leaves (percent)	Yield of hay (lbs.)	Yield of seed per acre (lbs.)	Ash (percent)	Crude protein (percent)	Ether extract (percent)	Crude fiber (percent)	N-free extract (percent)
Prebud	April 16	24	65	1493		10.21	22.81	3.44	20.36	43.18
Prebud	May 22	36	64	961		10.96	23.13	4.09	23.57	38.07
Prebud	June 18	27	64	723		9.86	21.14	3.38	24.65	40.96
Seed	Sept. 7				53.1					
Total or averages				3177	53.1	10.34	22.36	3.64	22.86	40.74
¼ bloom	May 13	51	57	1893		9.69	18.89	2.92	23.53	44.97
1/10 bloom	June 18	36	61	1435		11.05	25.68	3.26	24.96	32.91
Seed	Sept. 7				55.1					
Total or averages				3328	55.1	10.37	22.29	3.09	24.25	38.94
Prebud	April 16	24	65	1426		10.26	23.46	3.21	20.43	42.63
Prebud	May 22	36	64	946		10.84	23.35	3.18	24.47	38.17
Prebud	June 18	27	65	762		10.68	21.76	3.45	24.60	39.13
Prebud	July 8	20	65	730		9.86	25.45	4.47	20.81	39.40
Seed[1]	Sept. 7				0					
Total or averages				3864	0	10.41	23.51	3.58	22.58	39.83
1/10 bloom	May 8	46	59	1819		9.84	19.57	2.88	23.64	44.07
1/10 bloom	June 5	28	60	1436		10.29	23.91	3.23	26.61	35.95
1/10 bloom	July 8	33	58	1283		9.04	23.39	4.01	25.73	37.84
Seed[1]	Sept. 7				0					
Total or averages				4538	0	9.72	22.29	3.37	25.33	39.29

[1] Although growth was left for a seed crop, production was so limited that measurable harvest could not be made.

Table 6.—Summary of Hay and Seed Yields in Pounds Per Acre by Years of Alfalfa Cut at Various Stages of Maturity. Hay Yields are in Pounds of Oven Dry Hay Per Cutting.

Type of harvest	Hay yields 1946	1947	1948	1949	1950[4]	Seed yields 1946	1947	1948	1949	Avg.
Meadows Managed for Early Summer Seed Set										
3 Prebud cuttings,	1567	1279	1493	2182	---					
Seed	1099	929	961	1834	861					
	616	338	723	852	441					
Total	3282	2546	3177	4868	1302	39.2	28.8	53.1	13.0	33.5
¼ Bloom	1799	2464	1893	2770	---					
1/10 Bloom, Seed[1]	2176	1419	1435	1932	1553					
Total	3975	3883	3328	4702	1553	133.7	84.1[1]	55.1	83.5	89.1
Meadows Managed for Late Summer Seed Set										
4 Prebud cuttings,	1834	[2]	1426	2062	---					
Seed[2]	1923	[2]	946	1742	725					
	625	[2]	762	755	379					
			730	771	541					
Total	4392	4985[2]	3864	5330	1645	3.2	9.9[2]	0.0	0.0	3.3
3-1/10 Bloom cuttings,	2130	1925	1819	2921	---					
Seed[3]	1772	1447	1436	1976	1325					
		791	1283	1231	1163					
Total	3902	4163	4538	6128	2488	8.8	4.8	0.0	0.0	3.4

[1] In 1946, the practice was ¼ bloom, full bloom, seed. In 1947, the data are averages for two types of management; namely, one series being two cuttings at ½ bloom stage before the seed crop, and the other full bloom, early bloom, seed. See Table 4 for data on these individual practices.

[2] In 1946, the management was ¼ bloom, two cuttings at prebud, seed; in 1947, no late summer seed set type of management which would include prebud cutting was practiced. The data shown are averages for late summer seed set where two different types of harvests were involved; namely, two cuttings at ½ bloom, bud, seed; and full bloom, early seed, seed. See Table 4 for data on these individual practices. The 1947 harvesting practices involved later cuttings than the prebud type and hence, fewer cuttings during the season which probably accounts for the somewhat higher yields of both hay and seed over the three 1/10 bloom, seed practice.

[3] In 1946, the management practice was 2 cuttings at full bloom, seed.

[4] Due to the severity of dry weather and aphids, the plots were all clipped in May for the first cutting. No yield data were taken as the clippings were too sparse for raking. No seed yields were taken for the 1950 season. The seed set was poor generally, although under the management practice; namely, ¼ bloom, 1/10 bloom, seed, the seed set was best.

Table 7.—The Effect of the Exclusive Use of Prebud Harvest on Hay Yields.[1]

(Pounds)

Type of harvest	1946	1947	1948[2]	1948[2]	1949[2]	1949[2]	1950[2]	1950[2]	Avg.
Prebud entirely	3282	2546	3177	3864	4868	5330	1302	1645	3252
Later stages included in whole or in part	3975	3883	3328	4538	4702	6128	1553	2488	3824
Gain or loss for prebud harvest	—693	—1337	—151	—674	+166	—798	—251	—843	—572
Percent decrease or gain	— 17	— 34	— 4	— 15	+ 3	— 13	— 16	— 34	— 15

[1] Only equal seasonal growth periods are considered.
[2] The first columns for the years 1948, 1949, and 1950 are for hay yields under early summer seed set, and the second columns are for the yields under late summer seed set.

Table 8.—A Summary Comparison of Early With Late Summer Seed set on Hay and Seed Yields Using Seasonal Averages.

(Pounds)

Time of seed set	Hay yields per acre					Seed yields per acre				
	1946	1947	1948	1949	Avg.	1946	1947	1948	1949	Avg.
Early summer	3629	3437	3253	4785	3776	86.5	65.7	54.1	48.2	63.6
Late summer	4147	4711	4201	5729	4697	6.0	8.2	0.0	0.0	3.5
Gain or loss	—518	—1274	— 948	—944	—921	+80.5	+57.5	+54.1	+48.2	+60.1

Table 9.—Showing Yield of Feed Constituents Per Acre for 1946, 1947, and 1948.
(Pounds)

Type of Harvest	Ash	Crude Protein	Ether extract	Crude fiber	Nitrogen-free extract
Meadows Managed for Early Summer Seed Set					
3 Prebud cuttings, seed					
1946	293	771	120	718	1373
1947	245	582	80	605	1034
1948	329	716	115	709	1307
Total	867	2069	315	2032	3714
¼ Bloom[1] 1/10 Bloom, seed					
1946	345	775	126	1024	1675
1947	313	679	106	1211	1560
1948	342	726	102	804	1324
Total	1000	2180	334	3039	4559
Meadows Managed for Late Summer Seed Set					
4 Prebud cuttings, seed[2]					
1946	384	900	149	1053	1907
1947	389	968	170	1448	2011
1948	402	907	135	862	1555
Total[3]					
3-1/10 Bloom cuttings, seed[4]					
1946	326	763	124	1015	1675
1947	363	824	126	1126	1723
1948	443	999	150	1142	1803
Total	1132	2586	400	3283	5201

[1] In 1946, the practice was ¼ bloom, full bloom, seed. In 1947, the data are averages for two types of management; namely, one series being two cuttings at ½ bloom stage before the seed crop, and the other full bloom, early bloom, seed.

[2] In 1946, the management was ¼ bloom, two cuttings at prebud, seed; in 1947, no late summer seed set type of management which would include prebud cuttings was practiced. The 1947 data shown are averages for late summer seed set where two different types of harvests were involved; namely, two cuttings at ½ bloom, initial bud, seed; and full bloom, early seed, seed.

[3] No total is made since only the data for 1948 apply for the specific stage of maturity. See footnote 2 above for 1946 and 1947.

[4] In 1946, the management practice was 2 cuttings at full bloom, seed.

Table 10.—Effect of Consecutive Harvests at Variable Maturity Stages in 1947 on the Current, and Subsequent Annual Yields of Alfalfa Hay in 1948.[1]

Successive maturity stages of harvest in 1947	Yield of moisture-free hay per acre and relative values			
	1947 lbs.	Relative Value	1948 lbs.[2]	Relative Value
Prebud, prebud, prebud, seed	2546	100	2987	100
1/2 bloom, 1/2 bloom, seed	4156	163	3845	129
Full bloom, early bloom, seed	3610	141	3615	121
1/10 bloom, 1/10 bloom, 1/10 bloom, seed	4163	163	3060	102
1/2 bloom, 1/2 bloom, initial bud, seed	4991	196	3547	119
Full bloom, early seed, seed	4979	195	3705	124

[1] Averages are for four replications.
[2] All plots harvested uniformly at the full bloom (first cutting) and 1/10 bloom (second cutting) stages of growth in 1948.

Table 11.—Hay Yields Per Acre Under Consecutive Prebud or Bud and 1/10 Bloom Harvests Where the Same or Approximately the Same Length of Annual Growing Season was Involved.
(Pounds)

Season	Stage of growth at harvest	
	Prebud or Bud	1/10 Bloom
1946	4998	5353
1947	4741	5906
1948[1]	3864	4538
1949[1]	5330	6128
1950[2]	1645	2488
Average	4116	4883

[1] Set up for a seed harvest for the last harvest during the season but no seed was produced.
[2] Does not include a first cutting which was practically a failure on all plots because of extreme drouth and aphid damage.

Table 12.—Effect of Consecutive Cuttings at Uniform Maturity Stages on the Root Reserves at the End of the Hay Harvesting Season (October 23-24, 1946). All data are Calculated on a Dry Weight Basis.
(Percent)

		Nitrogen			Carbohydrates				
					Sugars				
Stage of Harvest	Ash	Soluble	Insoluble	Total	Reducing	Sucrose	Total	Starch	Total
Original meadow[1]	4.64	0.60	1.67	2.27	2.41	9.82	12.23	10.70	22.93
Full bloom	4.55	0.59	1.39	1.98	2.13	9.87	12.00	9.85	21.85
One-tenth bloom	4.97	0.56	1.26	1.82	1.98	9.72	11.70	7.49	19.19
Bud	5.67	0.41	1.15	1.56	1.49	9.40	10.89	3.66	14.55

[1] These data are from roots dug November 28, 1945, in the original uniformly-managed meadow before differential harvesting was made. The original meadow had been harvested uniformly at the full bloom stage during 1945.

Table 13.—Late Fall and Winter Losses of Starch and Total Carbohydrates From Roots of Alfalfa Plants Subjected to Different Cutting Treatments During the Preceding Growing Season.
(Percent)

		Starch and Total Carbohydrates					
		At Fall or Early Winter		At winter's end[1]		Losses	
Harvest stages the preceding season	Winter Period	Starch	Total carbohydrates	Starch	Total carbohydrates	Starch	Total carbohydrates
Full bloom only	1945-46	10.70	22.93	5.54	19.79	48[2]	14[2]
Full bloom only	1946-47	9.85[3]	21.85[3]	2.96	14.14	70	35
3-Prebud harvests, seed	1947-48	13.09	27.75	4.56	20.40	65	26
2-1/2 bloom harvests, seed	1947-48	16.09	29.63	4.97	19.68	69	34
Full bloom, early bloom, seed	1947-48	13.13	27.58	4.13	19.08	69	31
3-1/10 bloom harvests, seed	1947-48	17.94	28.26	3.95	20.25	78	28
Full bloom, early seed, seed	1947-48	16.13	30.14	4.22	18.61	74	38
1/2 bloom, 1/2 bloom, initial bud, seed	1947-48	13.89	25.61	1.89	15.13	86	41

[1] These data were from roots dug the latter days in February except as noted in footnote 2.
[2] The roots were collected on February 1, 1946, instead of the latter part of February (normally near winter's end in this area), which probably accounts for the smaller losses.
[3] These data are not from the plots but from an adjacent part of the same meadow on the same soil type where the full bloom type of harvesting was employed. No fall or early winter data were collected from the plots.

Table 14.—Early Spring Growth Effects on the Total Nitrogen, Starch and Total Carbohydrates in the Roots.

Time	Harvest stages preceding year	Content at winter's end			Early spring growth lows					Lapse between low carbo. and low total nitrogen (Weeks)
		Total N (Percent)	Starch (Percent)	Total Carbo. (Percent)	Total N Date	Total N (Percent)	Starch[1] (Percent)	Total Carbo. Date	Total Carbo. (Percent)	
Spring 1946	Full bloom only	2.46	5.54	19.79	Apr 9	2.04	3.50	Mar 25	11.58	2
Spring 1947	Full bloom only	2.34	2.96	14.14	Apr 19	1.74	2.13	Mar 29	7.89	3
Spring 1948	3-prebud, seed	2.31	4.56	20.40	May 1	1.60	1.84	Apr 13	9.78	2
	2-1/2 bloom, seed	2.36	4.97	19.68	Apr 13 May 1[2]	1.87	2.43	Apr 13	10.42	—[4]
	Full bloom, early bloom, seed	2.38	4.13	19.08	Apr 13 May 1[2]	1.78	3.14	Apr 13	10.56	—[4]
	3-1/10 bloom, seed	1.94	3.95	20.25	Apr 13	1.54	4.36	Apr 13	12.24	—[5]
	Full bloom, early seed, seed	2.25	4.22	18.61	May 1	1.73	1.87	Apr 13	8.76	2
	2-1/2 bloom, initial bud, seed	1.86	1.89	15.13	Apr 13	1.39	3.86[3]	Apr 13	10.26	—[5]

[1] The low for starch was on the same date as low for total carbohydrates with only 2 exceptions in which cases the low for starch occurred first.
[2] Same low figure for both sampling dates.
[3] Starch may have been built up or may be due to sampling.
[4] Nitrogen remained at the low level 2 weeks after carbohydrates began to increase.
[5] The total carbohydrate reserves had decreased to low level by March 19.

Table 15.—Height of Alfalfa Plants as Affected by Stage of Growth of Previous Cutting; 1946.

Stage of growth when cut	Date of cutting	Growth period days	Days after cutting (Height of plants[1] in ins.) 5	10	15	20	25	Height at time of cutting (inches)
Bud	April 18	30	--	--	--	--	--	17.0
Bud	May 20	32	[2]	3.0	6.5	11.0	15.0	17.0
Bud	June 17	28	[2]	3.0	6.0	10.0	12.0	14.0
Bud	July 11	24	[2]	2.0	8.0	11.0	--	13.0
One-tenth bloom	April 25[3]	37	--	--	--	--	--	18.0
One-tenth bloom	May 31	36	3.0	6.0	10.0	14.0	17.0	22.0
One-tenth bloom	June 24	24	[2]	3.0	9.0	12.0	--	14.0
One-tenth bloom	July 18	24	[2]	3.0	10.0	11.0	--	13.0
Full bloom	May 14[4]	56	--	--	--	--	--	22.0
Full bloom	June 20	37	3.0	7.0	12.0	16.0	19.0	22.0
Full bloom	July 24	34	[2]	4.0	10.0	16.0	18.0	19.0
1/4 bloom	April 30[5]	44	--	--	--	--	--	20.0
Prebud	May 28	28	3.0	7.0	11.0	15.0	18.0	19.0
Prebud	June 20	23	[2]	3.0	6.5	9.5	--	11.0
Seed	Sept. 4	76	[2]	3.5	10.0	12.5	14.0	15.0
Prebud	April 11	25	--	--	--	--	--	17.0
Prebud	May 14	33	[2]	2.0	5.0	9.0	11.0	15.0
Prebud	June 7	24	[2]	3.0	7.0	11.0	--	13.0
Seed	Aug. 16[6]	70	[2]	3.5	10.0	12.5	14.0	15.0
1/4 bloom	April 30	44	--	--	--	--	--	19.0
Full bloom	June 7	38	3.0	7.0	11.0	15.0	17.5	22.5
Seed	Aug. 16[7]	70	[2]	6.0	8.0	10.0	13.0	16.5
Full bloom	May 14[4]	58	--	--	--	--	--	22.0
Full bloom	June 20	37	3.0	7.0	12.0	15.0	17.5	20.0
Seed	Sept. 4	76	[2]	4.5	12.0	15.0	17.0	17.5

[1] Average of 3 measurements in each of either three or four replicated plots.
[2] New growth barely started.
[3] New growth from crown was in evidence when this crop was cut.
[4] New shoots were seven inches tall when this harvest was made.
[5] New shoots were three inches tall when this harvest was made.
[6] First blossoms appeared on this crop June 29.
[7] First blossoms appeared on this crop June 22.

Table 16.—Stand losses in a five-year old alfalfa meadow (Meadow 1) in 1946, which was under uniform management four seasons preceding the 1946 season in which harvests were made at different maturity stages, and stand counts in another five-year old alfalfa meadow (Meadow 2) which had two seasons (1946-1947) of uniform and careful management followed by three seasons (1948-1950) of harvesting at variable maturity stages.

Successive maturity stages at which the crop was harvested	Dead plants at end of 1946 season. Meadow 1[1] (Percent)	Plants per acre in the early spring of 1951. Meadow 2[1] (Number)
Bud, bud, bud, bud	24.7	---
Prebud, prebud, prebud, seed	16.9	20600
1/10 Bloom, 1/10 bloom, 1/10 bloom, 1/10 bloom	12.1	---
1/4 Bloom, full bloom, seed	10.8	---
1/4 Bloom, prebud, prebud, seed	10.5	---
Full floom, full bloom, full bloom	9.5	---
Prebud, prebud, prebud, prebud, seed	---	27500
1/10 Bloom, 1/10 bloom, 1/10 bloom, Seed	---	68900
1/4 Bloom, 1/10 bloom, seed	---	44500

[1] Dashes indicate that the cutting practices were not used in the respective meadow.

Appendix Table I.—Effect of Cutting Alfalfa at Various Uniform Maturity Stages on Food Reserves of the Roots, 1946.[1]

(Percent)

Date roots were dug 1945-46	Date alfalfa was cut 1946	Root constituents (moisture-free basis)								
						Carbohydrates				
			Nitrogen			Sugars				
		Ash	Soluble	Insoluble	Total	Reducing	Sucrose	Total	Starch	Total[2]
Cut at the Full Bloom Stage										
Nov. 28		4.64	0.60	1.67	2.27	2.41	9.82	12.23	10.70	22.93
Feb. 1		5.22	0.82	1.64	2.46	2.11	12.14	14.25	5.54	19.79
March 15		5.65	0.75	1.51	2.26	1.74	6.30	8.04	4.65	12.69
March 25		5.98	0.75	1.56	2.31	2.41	5.67	8.08	3.50	11.58
April 9		5.57	0.66	1.38	2.04	3.33	6.69	10.02	6.95	16.97
April 26		4.28	0.65	1.46	2.11	3.14	4.95	8.09	12.84	20.93
May 1		4.43	0.71	1.59	2.30	2.87	4.15	7.02	14.81	21.83
May 7		4.42	0.71	1.59	2.30	2.96	4.09	7.05	17.87	24.92
May 14	May 14	4.03	0.72	1.56	2.28	2.53	4.24	6.77	18.01	24.78
May 24		5.33	0.73	1.58	2.31	2.40	4.31	6.71	13.42	20.13
June 1		4.71	0.78	1.53	2.31	2.76	5.36	8.12	11.66	19.78
June 8		4.61	0.72	1.55	2.27	3.43	6.01	9.44	11.10	20.54
June 15		4.63	0.76	1.36	2.12	2.42	5.82	8.24	13.47	21.71
June 21	June 20	4.42	0.74	1.51	2.25	2.70	8.08	10.78	11.90	22.68
June 28		5.39	0.80	1.47	2.27	2.88	12.78	15.66	10.70	26.36
July 8		4.82	0.68	1.22	1.90	2.41	6.52	8.93	7.23	16.16
July 12		5.09	0.60	1.74	2.34	2.25	9.15	11.40	7.37	18.77
July 19		4.84	0.62	1.39	2.01	1.95	13.15	15.10	7.89	22.99
July 25	July 24	4.93	0.61	1.31	1.92	2.00	11.01	13.01	8.02	21.04
August 30	Aug. 30	5.95	0.61	1.25	1.86	1.60	10.16	11.76	7.20	18.96
Sept. 13		5.33	0.57	1.12	1.69	1.79	10.34	12.13	5.90	18.03
Oct. 23		4.55	0.59	1.39	1.98	2.13	9.87	12.00	9.85	21.85

Appendix Table I.—Concluded.

Date roots were dug 1945-46	Date alfalfa was cut 1946	Root constituents (moisture-free basis)								
		Ash	Nitrogen			Carbohydrates				
						Sugars			Starch	Total[2]
			Soluble	Insoluble	Total	Reducing	Sucrose	Total		
Cut at the Bud Stage										
April 19	April 18	5.64	0.58	1.52	2.10	2.42	5.04	7.46	9.62	17.08
May 20	May 20	5.18	0.48	1.30	1.78	2.88	6.88	9.76	9.90	19.66
June 18	June 17	4.65	0.52	1.29	1.80	2.31	7.32	9.63	7.14	16.77
July 12	July 11	5.31	0.44	1.54	1.98	2.12	9.98	12.10	5.47	17.58
Aug. 30	Aug. 30	6.09	0.52	1.09	1.61	1.58	11.97	13.55	4.64	18.19
Oct. 24		5.67	0.41	1.15	1.56	1.49	9.40	10.89	3.66	14.55
Cut at the 1/10 Bloom Stage										
April 26	April 25	4.30	0.65	1.48	2.13	3.17	4.20	7.37	10.26	17.63
June 1	May 31	4.58	0.69	1.20	1.89	2.84	5.03	7.87	14.53	22.40
June 24	June 24	4.09	0.65	1.33	1.98	2.44	9.12	11.56	10.39	21.95
July 19	July 18	5.07	0.54	1.27	1.81	2.21	10.61	12.82	7.18	20.00
Aug. 30	Aug. 30	5.12	0.58	1.14	1.72	1.60	11.72	13.32	5.77	19.09
Oct. 24		4.97	0.56	1.26	1.82	1.98	9.72	11.70	7.49	19.19

[1] Roots from plants for which forage yields are reported in Table 1.
[2] Sum of total sugars and starch.

Appendix Table II.—Effect of consecutive harvests of alfalfa at variable maturity stages on food reserves of the roots, 1946.

(Percent)

Date roots were dug	Date alfalfa was cut	Root constituents (moisture-free basis)								
						Carbohydrates				
			Nitrogen			Sugars				
		Ash	Soluble	Insoluble	Total	Reducing	Sucrose	Total	Starch	Total[1]
Successive maturity stages: prebud, prebud, prebud, and seed										
April 12	April 12	5.38	0.66	1.48	2.14	2.91	5.60	8.51	7.10	15.61
May 14	May 14	5.30	0.56	1.39	1.95	2.21	6.65	8.86	8.31	17.17
June 8	June 7	5.17	0.58	1.38	1.96	2.38	6.71	9.09	6.41	15.50
Sept. 12	Aug. 16	5.26	0.46	1.14	1.60	1.90	11.23	13.13	8.47	21.60
Oct. 23		4.96	0.56	1.32	1.88	1.68	10.80	12.48	7.29	19.77
Successive maturity stages: ¼ bloom, prebud, prebud, and seed										
April 30	April 30	3.95	0.78	1.51	2.29	2.86	3.97	6.83	16.95	23.78
May 29	May 28	4.50	0.69	1.51	2.20	2.66	5.42	8.08	14.39	22.47
June 20	June 20	4.18	0.65	1.30	1.95	2.36	9.64	12.00	9.41	21.41
Sept. 5	Sept. 4	5.20	0.60	1.23	1.83	1.73	9.72	11.45	11.80	23.25
Oct. 23		4.76	0.72	1.42	2.14	2.06	9.50	11.56	10.86	22.42
Successive maturity stages: ¼ bloom, full bloom, and seed										
April 30	April 30	4.19	0.67	1.64	2.31	2.80	4.25	7.05	16.52	23.57
June 8	June 7	4.09	0.83	1.47	2.30	2.31	5.00	7.31	17.60	24.91
Oct. 23	Aug. 16	4.19	0.55	1.68	2.23	1.98	7.68	9.66	17.32	26.98
Successive maturity stages: full bloom, full bloom and seed										
May 14	May 14	4.03	0.72	1.56	2.28	2.53	4.24	6.77	18.01	24.78
June 21	June 20	4.42	0.74	1.51	2.25	2.70	8.08	10.78	11.90	22.68
Oct. 23	Sept. 4	4.55	0.59	1.39	1.98	2.13	9.87	12.00	9.85	21.85

[1] Sum of total sugars and starch.

Appendix Table III.—Effect of Consecutive Harvests of Alfalfa at Variable Maturity Stages in 1947 on Food Reserves of the Roots.[1]
(Percent)

Date roots were dug	Date alfalfa was cut	Root constituents (moisture-free basis)								
			Nitrogen			Carbohydrates				
						Sugars				
		Ash	Soluble	Insoluble	Total	Reducing	Sucrose	Total	Starch	Total[2]
		Successive maturity stages in 1947: full bloom, early seed, and seed								
Jan. 18,-47	....	4.48	0.73	1.62	2.35	1.43	13.12	14.55	3.72	18.27
Feb. 13	....	3.56	0.76	1.62	2.38	1.72	10.97	12.69	2.32	15.01
28[3]	....	3.95	0.89	1.45	2.34	1.38	9.80	11.18	2.96	14.14
Mar. 14	....	4.10	1.18	1.28	2.46	1.25	8.55	9.80	2.33	12.13
29[4]	....	4.23	1.14	1.10	2.24	1.49	4.27	5.76	2.13	7.89
Apr. 11[5]	....	5.18	0.60	1.70	2.30	1.47	6.91	8.38	1.66	10.04
19[6]	....	4.13	0.63	1.11	1.74	1.95	10.92	12.87	2.80	15.67
26	....	4.15	0.66	1.22	1.88	3.38	9.55	12.93	3.94	16.87
May 2[7]	....	4.02	0.58	1.22	1.80	4.08	9.09	13.17	9.22	22.39
10[8]	....	3.25	0.73	1.21	1.94	5.13	6.28	11.41	15.50	26.91
25[9]	....	2.66	0.61	1.28	1.89	5.04	6.50	11.54	13.64	25.18
29[10]	May 29	2.73	0.67	1.26	1.93	4.33	5.25	9.58	19.80	29.38
June 7	....	2.81	0.64	1.28	1.92	4.12	4.70	8.82	15.61	24.43
14[11]	....	2.53	0.55	1.13	1.68	3.54	6.75	10.29	9.98	20.27
21	....	3.16	0.70	1.23	1.93	4.88	6.19	11.07	18.23	29.30
27	....	3.15	0.71	1.22	1.93	3.57	7.56	11.13	18.94	30.07
July 1	....	3.09	0.66	1.24	1.90	3.32	6.68	10.00	19.56	29.56
11	....	2.77	0.55	1.35	1.90	2.80	7.69	10.49	22.90	33.39
15	July 15	2.79	0.61	1.31	1.92	3.21	7.32	10.53	20.27	30.80
19	....	3.12	0.59	1.27	1.86	4.52	5.83	10.08	21.41	31.49
25	....	3.08	0.54	1.43	1.97	3.76	5.17	8.93	20.25	29.18
Aug. 11	....	3.46	0.66	1.10	1.76	3.79	10.71	14.50	10.03	24.53
15	....	3.28	0.49	1.44	1.93	4.04	10.92	14.96	11.44	26.40
22	....	3.83	0.46	1.37	1.83	3.12	11.97	15.09	11.15	26.24

Appendix Table III.—Continued.

Date roots were dug	Date alfalfa was cut	Root constituents (moisture-free basis)								
						Carbohydrates				
			Nitrogen			Sugars				
		Ash	Soluble	Insoluble	Total	Reducing	Sucrose	Total	Starch	Total[2]
Sept 5	....	3.17	0.61	1.32	1.93	1.93	12.28	14.21	15.46	29.67
12	....	4.72	0.41	1.36	1.77	2.39	12.49	14.88	14.14	29.02
19	....	3.35	0.58	1.17	1.75	2.20	11.51	13.71	13.51	27.22
26	Sept 27	3.10	0.59	1.20	1.79	3.05	8.73	11.78	17.64	29.42
Oct. 3	....	3.46	0.51	1.30	1.81	2.50	7.51	10.01	15.06	25.07
10	....	3.28	0.50	1.38	1.88	2.01	6.81	8.82	13.53	22.35
17	....	3.94	0.62	1.29	1.91	2.29	8.58	10.87	8.52	19.39
30	....	3.74	0.62	1.31	1.93	1.95	11.28	13.23	15.67	28.90
Nov. 6	....	3.57	0.53	1.40	1.93	2.43	11.58	14.01	16.13	30.14
13	....	3.53	0.50	1.58	2.08	2.63	10.19	12.82	16.40	29.22
20	....	3.86	0.66	1.32	1.98	2.16	11.51	13.67	16.16	29.83
26	....	3.73	0.69	1.47	2.16	2.03	12.66	14.69	14.16	28.85
Dec. 4	....	4.00	0.67	1.34	2.01	2.01	12.44	14.45	11.63	26.08
11	....	4.01	0.65	1.44	2.09	2.30	13.17	15.47	9.84	25.31
18	....	4.06	0.73	1.61	2.34	2.21	14.16	16.37	7.92	24.29
Feb. 20,-48	....	3.89	0.76	1.49	2.25	1.61	12.78	14.39	4.22	18.61
Mar. 19	....	4.08	0.83	1.38	2.21	1.14	7.30	8.44	2.32	10.76
Apr. 13	....	5.28	0.61	1.15	1.76	0.72	6.17	6.89	1.87	8.76
May 1	....	3.09	0.64	1.09	1.73	2.42	4.98	7.40	23.02	30.42
June 10	....	3.62	0.75	1.26	2.01	2.27	3.41	5.68	21.67	27.35
July 7	....	4.17	0.53	1.29	1.82	3.11	5.55	8.66	11.03	19.69
Nov. 5	....	3.77	0.74	1.41	2.15	2.13	9.56	11.69	16.64	28.33
Successive maturity stages in 1947: prebud, prebud, prebud, and seed										
May 2,-47	May 1	3.74	0.62	1.06	1.68	3.55	8.51	12.06	9.59	21.65
31	May 29	3.82	0.54	1.25	1.79	3.54	7.09	10.63	7.88	18.51

Appendix Table III.—Continued.

Date roots were dug	Date alfalfa was cut	Root constituents (moisture-free basis)								
		Ash	Nitrogen			Carbohydrates				
						Sugars			Starch	Total[2]
			Soluble	Insoluble	Total	Reducing	Sucrose	Total		
June 21	June 20	4.19	0.48	1.00	1.48	2.44	8.99	11.43	5.82	17.25
Sept. 9	Sept. 8	3.83	0.59	1.06	1.65	2.29	12.37	14.66	13.09	27.75
Feb. 20,-48	....	4.02	0.68	1.63	2.31	1.53	14.31	15.84	4.56	20.40
Mar. 19	....	4.05	0.73	1.39	2.12	1.10	8.10	9.20	4.78	13.98
Apr. 13	....	4.99	0.54	1.16	1.70	0.79	7.15	7.94	1.84	9.78
May 1	....	3.22	0.56	1.04	1.60	2.01	4.69	6.70	18.27	24.97
June 10	....	3.69	0.97	1.15	2.12	3.32	3.90	7.22	23.67	30.89
July 7	....	3.31	0.61	1.39	2.00	2.70	5.83	8.53	14.47	23.00
Nov. 5	....	3.75	0.72	1.44	2.16	2.56	10.08	12.64	18.48	31.12
Successive maturity stages in 1947: 1/10 bloom, 1/10 bloom, 1/10 bloom, and seed										
May 14,-47	May 13	3.13	0.67	1.39	2.06	3.83	4.54	8.37	17.63	26.00
June 12	June 12	3.08	0.68	1.09	1.77	3.51	7.52	11.03	12.78	23.81
July 15	July 15	3.43	0.55	0.97	1.52	2.66	11.27	13.93	13.68	27.61
Oct. 3	Sept. 27	3.08	0.52	1.46	1.98	2.33	7.99	10.32	17.94	28.26
Feb. 20,-48	....	3.91	0.60	1.34	1.94	1.56	14.74	16.30	3.95	20.25
Mar. 19	....	4.03	0.63	1.10	1.73	1.10	8.96	10.06	3.70	13.76
Apr. 13	....	5.05	0.48	1.06	1.54	0.70	7.18	7.88	4.36	12.24
May 1	....	3.51	0.61	1.14	1.75	2.31	4.84	7.15	20.00	27.15
June 10	....	3.32	0.86	1.33	2.19	2.48	3.55	6.03	21.95	27.98
July 7	....	3.18	0.63	1.20	1.83	1.54	7.47	9.01	12.78	21.79
Nov. 5	....	3.83	0.57	1.26	1.83	2.16	11.24	13.40	14.08	27.48

Appendix Table III.—Continued.

Date roots were dug	Date alfalfa was cut	Root constituents (moisture-free basis)								
						Carbohydrates				
			Nitrogen			Sugars				
		Ash	Soluble	Insoluble	Total	Reducing	Sucrose	Total	Starch	Total[2]
Successive maturity stages in 1947: ½ bloom, ½ bloom, initial bud, and seed										
May 24,-47	May 22	2.91	0.71	1.32	2.03	4.65	4.78	9.43	19.13	28.56
June 27	June 26	3.24	0.72	1.24	1.96	4.57	5.47	10.04	19.19	29.23
July 15	July 15	3.16	0.51	1.18	1.69	2.94	8.84	11.78	12.13	23.91
Oct. 3	Sept. 27	3.32	0.54	1.06	1.60	2.35	9.37	11.72	13.89	25.61
Feb. 20,-48	. . . .	4.11	0.67	1.19	1.86	1.57	11.67	13.24	1.89	15.13
Mar. 19	. . . .	4.87	0.79	1.32	2.11	1.14	8.91	10.05	3.86	13.91
Apr. 13	. . . .	4.84	0.44	0.95	1.39	0.91	5.46	6.37	3.89	10.26
May 1	. . . .	3.33	0.54	1.18	1.72	1.96	5.32	7.28	21.05	28.33
June 10	. . . .	3.56	0.84	1.36	2.20	2.80	3.85	6.65	22.03	28.68
July 7	. . . .	3.76	0.63	1.11	1.74	1.68	7.89	9.57	10.54	20.11
Nov. 5	. . . .	4.36	0.62	1.32	1.94	2.43	10.94	13.37	10.72	24.09
Successive maturity stages in 1947: ½ bloom, ½ bloom, and seed										
May 24,-47	May 22	2.76	0.68	1.27	1.95	4.12	5.00	9.12	20.15	29.27
June 21	June 20	3.25	0.68	1.23	1.91	4.00	6.72	10.72	17.97	28.69
Sept. 9	Sept. 8	3.61	0.62	1.28	1.90	2.40	11.14	13.54	16.09	29.63
Feb. 20,-48	. . . .	3.93	0.67	1.38	2.36	1.59	13.12	14.71	4.97	19.68
Mar. 19	. . . .	3.97	0.97	1.38	2.35	1.17	8.28	9.45	3.55	13.00
Apr. 13	. . . .	4.89	0.74	1.13	1.87	1.06	6.93	7.99	2.43	10.42
May 1	. . . .	3.15	0.67	1.20	1.87	2.80	4.78	7.58	16.89	24.47
June 10	. . . .	3.36	0.91	1.41	2.32	2.25	3.43	5.68	23.73	29.41
July 7	. . . .	3.59	0.61	1.30	1.91	2.72	6.66	9.38	15.06	24.44
Nov. 5	. . . .	4.03	0.67	1.26	1.93	2.21	10.22	12.43	13.69	26.12

Appendix Table III.—Concluded.

Date roots were dug	Date alfalfa was cut	Root constituents (moisture-free basis)								
		Ash	Nitrogen			Carbohydrates				
						Sugars			Starch	Total[2]
			Soluble	Insoluble	Total	Reducing	Sucrose	Total		
Successive maturity stages in 1947: full bloom, early bloom, and seed										
May 29,-47	May 28	2.92	0.76	1.34	2.10	4.75	3.74	8.49	18.86	27.35
June 21	June 20	3.04	0.70	1.12	1.82	4.10	7.99	12.09	16.95	29.04
Sept. 9	Sept. 8	3.89	0.51	1.28	1.79	2.54	11.91	14.45	13.13	27.58
Feb. 20,-48	....	3.50	0.66	1.72	2.38	2.28	12.67	14.95	4.13	19.08
Mar. 19	....	3.99	0.64	1.50	2.14	1.18	8.41	9.59	3.14	12.73
Apr. 13	....	4.75	0.65	1.13	1.78	0.69	5.26	5.95	4.61	10.56
May 1	....	3.29	0.65	1.13	1.78	2.83	4.83	7.66	18.75	26.41
June 10	....	2.94	0.80	1.31	2.11	2.64	3.82	6.46	21.89	28.35
July 7	....	3.85	0.60	1.31	1.91	3.20	5.57	8.77	13.18	21.95
Nov. 5	....	4.47	0.59	1.24	1.83	2.07	11.68	13.75	8.74	22.49

1 Roots from plants for which yields are reported in Tables 5 and 12.
2 Sum of total sugars and starch.
3 Plants dormant.
4 Vegetative growth in rosette stage.
5 Plants approximately 6 inches tall.
6 Plants approximately 8 inches tall.
7 Prebud stage.
8 Bud stage.
9 ½ bloom.
10 Full bloom stage.
11 Prebud stage.

Appendix Table IV.—Effect of Consecutive Harvests of Alfalfa at Variable Maturity Stages on Food Reserves of the Roots. 1948.[1]

(Percent)

Date roots were dug	Date alfalfa was cut	Root constituents (moisture-free basis)								
						Carbohydrates				
		Ash	Nitrogen			Sugars			Starch	Total[2]
			Soluble	Insoluble	Total	Reducing	Sucrose	Total		
Successive maturity stages: prebud, prebud, prebud, and seed										
Feb. 20	....	3.74	1.00	1.87	2.87	1.15	10.41	11.56	6.38	17.94
Apr. 16	Apr. 16	3.55	0.71	1.11	1.82	1.42	5.78	7.15	15.25	22.40
June 2	May 22	3.90	0.69	1.29	1.98	1.59	4.98	6.57	12.59	19.16
June 19	June 18	3.46	0.69	1.25	1.94	1.52	8.17	9.69	16.28	25.97
Successive maturity stages: ¼ bloom, ¼ bloom, and seed										
Feb. 20	....	3.63	1.00	1.97	2.97	1.03	10.69	11.72	6.47	18.19
May 15	May 13	2.81	0.85	1.20	2.05	2.10	1.81	3.91	27.06	30.97
June 19	June 18	3.38	0.83	1.27	2.10	2.34	6.14	8.48	14.85	23.33
Successive maturity stages: prebud, prebud, prebud, prebud, and seed										
Feb. 20	....	3.37	1.14	1.68	2.82	0.89	10.08	10.96	6.97	17.93
Apr. 16	Apr. 16	3.57	0.67	1.16	1.83	1.67	5.49	7.16	15.20	22.36
June 2	May 22	3.93	0.67	1.17	1.84	1.79	5.07	6.86	9.62	16.48
June 19	June 18	3.78	0.64	1.30	1.94	1.68	8.63	10.31	16.96	27.27
July 9	July 8	3.48	0.59	1.07	1.66	1.80	9.18	10.98	9.88	20.86
Successive maturity stages: 1/10 bloom, 1/10 bloom, 1/10 bloom, and seed										
Feb. 20	....	3.55	1.06	1.81	2.87	1.03	11.81	12.84	8.14	20.98
May 14	May 8	3.31	0.86	1.36	2.22	2.06	2.23	4.29	18.65	22.94
June 5	June 5	3.42	0.83	1.30	2.13	2.09	5.92	8.01	18.76	26.77
July 7	July 7	3.64	0.67	1.08	1.75	2.06	7.28	9.34	11.01	20.35

[1] Roots from plants for which forage and seed yields are reported in Table 5.
[2] Sum of total sugars and starch.