EFFECTS OF VARIOUS THIRD CUTTING DATES ON SUBSEQUENT PRODUCTION AND CARBOHYDRATE RESERVES OF ALFALFA (*Medicago sativa* L.)

Thesis for the Degree of M. S.
MICHIGAN STATE UNIVERSITY

James L. Yager

1968

ABSTRACT

EFFECTS OF VARIOUS THIRD CUTTING DATES ON SUBSEQUENT PRODUCTION AND CARBOHYDRATE RESERVES OF ALFALFA (*Medicago sativa* L.)

By

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The residual effect of cutting Vernal, a hardy alfalfa, for a third time on September 1, September 15, October 1, October 15, November 1, or November 15 was determined in 1966 and 1967 from the first two of three cuttings in the year following cutting treatments at several fertility levels at East Lansing in southern Michigan. In one of the experiments, the cutting treatments were imposed on the same plots for two consecutive years. In another experiment, Cayuga, a hardy alfalfa, and DuPuits, a medium hardy alfalfa, were given similar cutting treatments, and the total available carbohydrates (TAC) in the roots were determined after each cutting treatment and on December 13, April 22, and June 9 on Vernal and DuPuits alfalfa.

Alfalfa cut for the third time on September 15 or October 1 yielded as much the next year as when cut September 1.

Yields of alfalfa did not show a cumulative effect of two consecutive years of cutting treatments made on September 1 or 15 or October 1.

The TAC in roots of DuPuits or Vernal alfalfa cut September 1 or 15 or October 1 increased to a maximum by November 1, then decreased to similar levels by December 13; these levels were lower than in plants cut twice or for a third time on October 15, November 1 or 15; TAC levels were higher on each sampling date in Vernal than in DuPuits. K and PK fertilizer did not affect levels of TAC.

The results suggest that the strict recommendations of not cutting alfalfa in September or early October now in effect in southern Michigan and other northern states should be re-examined. Liberalizing such recommendations would permit "fall cutting" of alfalfa stands for greater flexibility of management.

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James L. Yager

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Crop Science

1968

ACKNOWLEDGMENTS

The author wishes to express his gratitude to Dr. M. B. Tesar for his guidance both in the study and in the preparation of this manuscript. The author also wishes to thank Dr. C. M. Harrison, Professor I. F. Schneider, Dr. C. E. Cress, Nelly Galuzzi, and Wesley Edington for having helped in conducting different aspects of this study. Finally the author wishes to thank the Michigan Agricultural Experiment Station for the financial assistance that made this study possible.

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INTRODUCTION

The detrimental effects of harvesting alfalfa for a third time in September or early October in northern states have been recognized because of more winterkilling and reduced yields in subsequent years than when the alfalfa was cut only twice between one-tenth and one-half bloom (about mid-June and mid-August). In contrast, third harvests in mid-October or later have been considered a safe practice without danger of increasing winter injury or materially reducing yields in subsequent years (Silkett *et al.*, 1937; Rather and Harrison, 1938; Armstrong *et al.*, 1948; and Smith, 1960).

The 3-cut system (cutting in early June, mid-July, and late August) has been recommended for about a decade for alfalfa in southern Michigan because the use of winterhardy varieties and increased fertilizer have made the 3-cut system superior in yield and quality to the 2-cut system (Michigan State University Cooperative Extension Service, 1967, and Fuess and Tesar, 1968). Similar results favoring the 3-cut system have been obtained in other northern states or northern latitudes (Parsons and Davis, 1960; Folkins et al., 1960; Smith, 1960; Chance et al., 1961; Kust and Smith, 1961; and Carter, 1964).

There are several conditions, however, when a third cutting may not be made on time, i.e., by the first week in September, but might be made later in September or early October. First, in some years a drouth after the second cutting in mid-July retards re-growth. Consequently, the third cutting may have very little forage to harvest by September 1. Later in September or early October, there may be good growth of forage because of late summer rains.

Second, with the advent of mechanized forage chopping equipment and the practice of feeding green-chopped forage daily to livestock, the fall growth is chopped daily. Frequently a period of one month elapses from the time a field is first used for green chopping until chopping is complete.

Third, alfalfa can be harvested mechanically and used as grass silage or haylage without the hindrance of adverse weather that restricts hay curing.

This feasibility of a third cutting in September and early October, therefore, is recognized by farmers. The practice, if recommended, would be readily accepted by farmers because they would rather harvest in September than wait until after mid-October, the generally accepted time after which carbohydrate reserves in the roots would not be reduced appreciably and next year's yield would not be lowered materially.

The objectives of this study were to determine: (1) if the reported adverse effects of a third cutting of alfalfa in a 3-cut system in September or early October could be wholly or partly overcome by topdressing with potassium or potassium and phosphorus on established stands of alfalfa, (2) the cumulative effects of a third late summer or fall cutting on alfalfa yields over several consecutive years, and (3) the trend of carbohydrate reserves following September and early October cuttings in a 3-cut system.

LITERATURE REVIEW

A third cutting made in September or early October has been generally regarded as injurious to the yield and permanence of alfalfa in northern states where serious winterkilling may occur. Recommendations have stressed that cutting or grazing of alfalfa during this critical period should be avoided based on research by Graber et al. (1927), Willard (1930), Grandfield (1935), Silkett, Megee, and Rather (1937), Graber and Sprague (1938), Rather and Harrison (1938), and, more recently, by Folkins, Greenshields, and Nowosad (1960).

Such a cutting in September or early October has, at times, resulted in a reduction of the stand due to winterkilling, a decrease in vigor and yield the following year, or a combination of both (Silkett et al., 1937, and Rather and Harrison, 1938). Graber et al. (1927) compared a 2-cut system of alfalfa (Kansas Common, Turkestan, and Grimm) with a 3-cut system (third cutting September 12) in southern Wisconsin and found the three cuttings gave significantly lower average annual yields over a five-year period. They attributed the lower yields to (1) cumulative effects of more rapid exhaustion of the organic food reserves in the roots and (2) more serious degree of winter injury with increased mortality rate. It was shown that alfalfa plants not cut in September were not only higher in storage reserves but had more vegetation to collect snow providing protection against cold weather.

Silkett et al. (1937) working with Hardigan alfalfa in southern Michigan, compared the effects of five third-cutting dates (September 1, September 15, October 1, October 15, and October 31) with two cuttings on the subsequent year's yield at East Lansing. They obtained similar 2-year average yields of 2.75, 2.56, and 2.60 tons per acre for plots cut for the third time the previous fall on September 1, September 15, and October 1, respectively. The average subsequent year's yield of plots cut only twice (second cutting in early August) the previous year was 3.04 tons per acre, about one-half ton higher than when cut on September 15 or October 1. Rather and Harrison (1938) used the same cutting treatments at three different geographic locations in southern Michigan including the East Lansing location reported on by Silkett et al., (1937). They obtained acre yields which were likewise similar--3.15, 3.01, and 3.11 tons--for the year following cutting treatments made the previous fall on September 1, September 15, and October 1, respectively, as compared to a greater acre yield of 3.52 tons when cut only twice the previous year.

The data support their conclusion made in 1938 that "two cuttings are safest in Michigan" since a third cutting resulted in yields about one-half ton lower the next year. Furthermore, in the previous year they obtained yields of only 0.39, 0.52, and 0.50 tons on September 1, September 15, and October 1, respectively, after the second cutting was made in the one-tenth to one-half bloom stage (probably mid-August). Since these yields were only about one-half ton, they concluded the most practical procedure would be to save the alfalfa for fall or early winter pasture.

Recently, Smith (unpublished data) in Wisconsin confirmed what Graber et al. reported from the same state and what Rather and Harrison reported in Michigan, i.e., a third cutting in September or October results in lowered yield the next year when compared to a 2-cut system.

Relative to yields of alfalfa cut twice, Smith reported that alfalfa cut for the third time on September 1, September 15, October 1, October 15, and November 1, yielded 90, 69, 83, 92, and 97% as much for the first cutting the following year. This indicated that, in Wisconsin, in contrast to the reports of Rather and Harrison in Michigan, a third cutting on September 15, and to a lesser extent on October 1, was much more harmful to the next year's yield than a September 1 cutting. The colder winter temperatures and shorter fall growth period in southern Wisconsin, in contrast to southern Michigan, may explain this different reaction from fall cutting.

In an attempt to understand the physiological effects of late summer or fall cutting treatments, several workers have studied the levels of carbohydrate reserves in alfalfa roots in order to explain some of the injurious effects of fall cutting (Nelson, 1925; Graber et al., 1927; Grandfield, 1935; Rather and Harrison, 1938; and recently, Smith, 1960).

Graber et al. (1927) were the first to recognize the importance of carbohydrate reserves in their effect on the production and winter survival of alfalfa. Their hypothesis was that new top growth is initiated and developed largely at the expense of previously-accumulated organic reserves (carbohydrates and nitrogen compounds) in the roots of alfalfa; that the accumulation occurs, principally during the maturation of top growth; that the organic reserves are essential for normal top and root development; that the quantity, quality, and availability sharply limit the amount of plant development; and that progressive depletion of such reserves by early, frequent, and complete top removal results in death of the plant.

Work by Grandfield (1935) in Kansas also supports the Graber hypothesis. Grandfield found that the amount of growth which takes place after the last regular cutting influences appreciably the organic reserves stored in the roots before winter. If the growing time between the last cutting and freezing weather is short, the reserves are depleted and there is little opportunity to restore them. As a result, many plants do not survive the winter. From his observation, Grandfield indicated that there must be at least 8 to 10 inches of growth to permit maximum storage.

Grandfield also showed that in the fall dormant period (late November), there were very small differences in total carbohydrates of roots due to different previous cutting practices, except for severe treatments such as clipping at 10-day intervals after the third cutting or taking five cuttings during the season. Included in the cutting treatments were 3-cut systems in which the third cuttings were taken on September 1, September 15, and October 1. They reported good agreement between stand and root reserves.

Rather and Harrison (1938) examined roots of alfalfa in January for starch content as an indication of carbohydrate reserves. They found that roots from plants not cut for a third time and from plants cut for a third time on October 31 were about equal in starch. Roots from plants cut for a third time on September 1 or October 15 showed depletion of starch, while roots from plants cut on September 15 or October 1 had no starch. The September 15 cutting treatments produced much more freezing injury than any of the others as indicated by the cracking in the roots. Roots in this condition heaved badly during the spring thawing and freezing.

Several researchers have attempted to overcome the adverse effects of fall cutting treatments by fertilization. Two of the early workers who attempted to improve yields and stands by fertilizing during establishment were Graber and Sprague (1938) in Wisconsin. They subjected Canadian variegated alfalfa to two cutting treatments and two fertility levels. The total of three-years' yields for alfalfa at an optimum PK fertility level (14 lbs P + 125 lbs K/acre) cut (1) twice near full bloom and (2) cut twice near full bloom plus one early fall cutting (late September) and one late cutting (about November 1) were 10.4 and 11.15 tons, respectively. The same cutting treatments with no fertilizer applied during establishment gave yields of 7.61 and 6.92 tons for cutting treatments 1 and 2. These data indicate that alfalfa grown at a higher fertility level (14 lbs P + 125 lbs K/acre) will maintain productivity even under adverse fall cutting treatments.

Wang et al. (1953) working in Wisconsin showed that applications of phosphate in addition to lime or in addition to lime and potash produced increased amounts of starch and non-reducing sugars in the roots and crowns of alfalfa. This increase appeared to promote resistance to winterkilling.

A greenhouse study by Jung and Smith (1959) indicated that the ratio of K to P played an important role in plant survival and top-growth production following exposure to freezing temperatures.

Gross et al. (1950) in Iowa reported a significant interaction between alfalfa varieties and phosphorus fertilization. Atlantic, Ladak, and Ranger showed little or no response to P while Buffalo and Grimm responded markedly to P fertilizer. However, under frequent clippings, 4-5 per season, Atlantic, Narragansett, Ranger, and Vernal yielded less with P fertilization than when no P was applied. Buffalo responded well to P when clipped frequently while in contrast, Vernal yielded more when no P was used.

Parsons and Davis (1960) showed phosphorus at 50 lbs per acre helped overcome detrimental effects of severe cutting schedules in Ohio. For one year the increases of dry matter of phosphorus fertilized plots over unfertilized in 5-, 4-, and 3-cut systems were 84, 48, and 38%.

Additional work by Twamley (1960) confirms the work by Gross showing interactions between variety and phosphorus. Twamley showed that phosphorus helped the winterhardy varieties (Vernal and Grimm) more than the less hardy (Ranger and DuPuits); potash was of greater benefit to winter-susceptible varieties.

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MATERIALS AND METHODS

Three experiments were conducted at the Michigan State University Crop Science Experimental Farm, East Lansing, Michigan, on tiled and untiled Conover loam soil, well suited to the production of alfalfa.

Experiment I--Three alfalfa varieties, seven cutting treatments, and three fertility levels for one year--1966

Three alfalfa (*Medicago sativa* L.) varieties, DuPuits (medium hardy), Vernal (hardy), and Cayuga (hardy), were band seeded in plots 7 ft wide with a commercial grain drill at 8 lbs per acre with 35 lbs P and 66 lbs K/acre in early August 1964 on a well tiled and well drained soil. The alfalfa was cut in early June, mid-July, and early September in 1965 as recommended in a 3-cut system (Michigan State University Cooperative Extension Service, 1967). In 1966, the first two cuttings were taken as in 1965. In the late summer of 1966, plots 7 × 18 ft in size were established on a split-plot, randomized complete block design replicated four times. The cutting treatments were as follows:

1. None (2-cut system)
2. September 1 (3-cut system)
3. September 15 (3-cut system)
4. October 1 (3-cut system)
5. October 15 (3-cut system)
6. November 1 (3-cut system)
7. November 15 (3-cut system)

Three rates of fertilizer--no fertilizer, 166 lbs K, and 22 lbs P + 166 lbs K/acre--were applied after the respective cutting treatments.

Yields were determined by mowing an area 2.9 × 15.1 ft from the center of the plots. A moisture sample weighing approximately 2 lbs was obtained for moisture determination, dried at 79 C, yields calculated and reported in tons per acre of hay at 12% moisture.

The residual effect of the seven cutting treatments was determined by measuring the yields from the first and second harvests taken June 9 and July 14, 1967, respectively. Growth ratings were taken on November 8, 1966, and June 1, 1967.

Roots of DuPuits and Vernal alfalfas were sampled for analysis for total available carbohydrates (TAC) from two replications on each fall cutting date of 1966 and on December 13, 1966, April 22, and June 9, 1967. Fifteen to twenty roots were dug from the row adjacent to the outside seeded row in the previously-cut plots, washed free of soil, trimmed of top growth to the crown, and cut to 6 inches. The roots were then dried at 65 C for 12 hours, ground in a Wiley mill to pass through a 40-mesh sieve, and stored in stoppered glass bottles. Before chemical analysis, the samples were dried to constant weight in a forced-air oven at 70 C.

To determine TAC (starch and sugars), 500 mg samples were refluxed with 0.2 N H_2SO_4 for 1 hour (Smith, Paulsen, and Raguse, 1964). The carbohydrate content was determined by analyzing for total reducing sugars using 3, 5 dinitrosalicylic acid reagent (Bernfeld, 1951). Duplicate determinations were made with 2 ml of sample (S) and 2 ml of reagent in test tubes. Test tubes were shaken, heated 5 minutes in a vigorously-boiling water bath, cooled in an ice water bath, diluted with 10 ml of distilled water, mixed thoroughly, and absorbance (A) determined on a Hitachi Perkins-Elmer 139 UV-VIS spectrophotometer at a wavelength of 540 mμ. A 0.5 mg/ml glucose standard (Std) was used. The percentage of total available carbohydrates was calculated with the equation:

$$\%TAC = \frac{\text{mg/ml of Std} \times 100}{A_{Std}} \times \frac{A_S \times \text{dilution} \times 100}{Wt_S \text{ in mg}}$$

Experiment II--Vernal alfalfa, seven cutting treatments, and five fertilizer treatments for two consecutive years--1965 and 1966

Vernal alfalfa was band seeded on untiled soil with good surface drainage in the spring of 1963 at 8 lbs per acre with 35 lbs P and 66 lbs K/acre. The alfalfa was cut in early June and mid-July, 1964, for the first and second cuttings of a 3-cut system. No top-dressing was applied prior to experimental treatments. Plots were 6 × 19 ft in size with four replications in a split-plot, randomized complete block design. The cutting treatments of 1965 were the same as Experiment I.

The fertilizer treatments in pounds per acre were:

1. No fertilizer
2. Fall K - 166
3. Spring K - 166
4. Fall PK - 22 P + 166 K
5. Spring PK - 22 P + 166 K

The fall-fertilized K and PK treatments were applied November 6 in 1965 and after the respective cutting treatments in 1966. The spring fertilizer treatments were applied in early April following the previous fall cutting treatments.

The residual effects of experimental treatments were determined from yields of the first and second cuttings made June 17 and July 26, 1966, and June 13 and July 19, 1967, according to techniques described in Experiment I.

Experiment III--Three-year old Vernal alfalfa, seven cutting treatments, and five fertilizer treatments for one year--1966

The alfalfa was seeded, treated, and harvested the same as Experiment II, except that the plots were 6 × 20 ft in size and the experimental treatments were started in 1966 instead of 1965. Prior to treating, the area was harvested in early June, mid-July, and early September in 1964 and 1965. The second cutting in 1966 was in the first week of August. No topdressing was used before cutting treatments began in 1966. The residual effect of the cutting treatments was determined from three harvests--June 13, July 18, and September 8, 1967.

RESULTS

Experiment I--Three alfalfa varieties, seven cutting treatments, and three fertility levels for one year--1966

Yield.--If fertilized with K or PK, alfalfa cut for the third time on September 15 or October 1 yielded as much (no significant difference at the 1% level) in the first and second cuttings the next year (third harvest year) as when cut on September 1, the recommended date of a third cutting of alfalfa, Figure 1 and Table 1. This is shown in the fertilized alfalfa which when cut on September 15 or October 1 yielded from -0.02 to 0.25 tons per acre more the following year than when cut September 1. When not fertilized, the yield was from 0.14 to 0.22 lower than the September 1 cutting treatment, Table 1. In general, the three varieties (DuPuits, Vernal, and Cayuga) reacted similarly to the cutting treatments.

DuPuits alfalfa topdressed with PK showed a significant lack of response to P. The average yield response of DuPuits fertilized with K was 4.44 tons per acre; when fertilized with PK the yield was 4.41 tons, Table 1 and Figure 2.

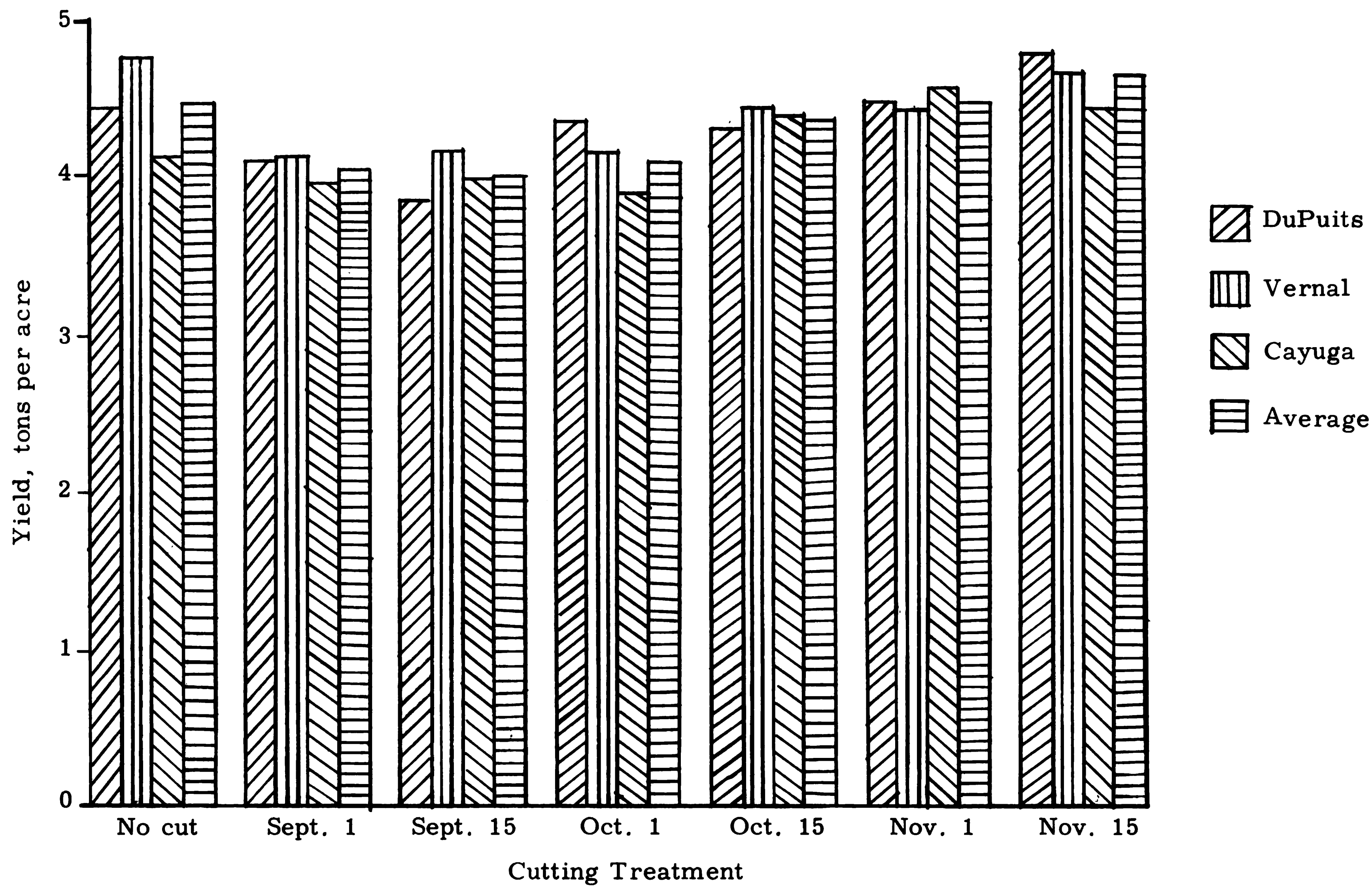

FIGURE 1.--The residual effects of 7 third cutting treatments on 3 varieties of alfalfa as measured by the yields of the first 2 of 3 cuttings the next year

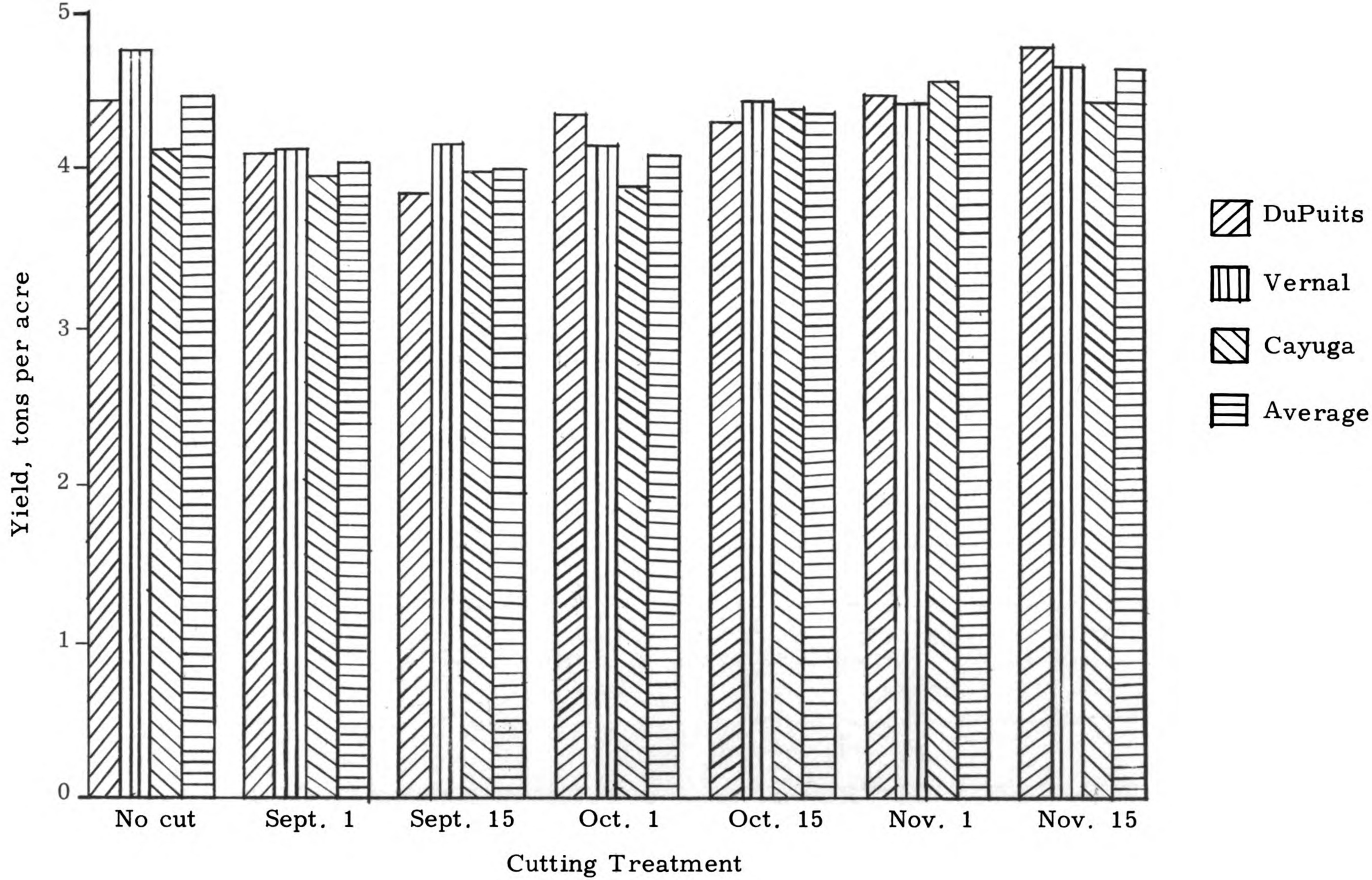

FIGURE 1. -- The residual effects of 7 third cutting treatments on 3 varieties of alfalfa as measured by the yields of the first 2 of 3 cuttings the next year

TABLE 1.--Residual effects of 7 third cutting treatments and 3 fertilizer treatments on the total yields of the first and second cuttings of 3 alfalfa varieties the year following treatments

Date, third cutting	Yield, tons per acre															
	DuPuits				Vernal				Cayuga				Average			
	O	K	PK	Avg	O	K	PK	Avg	O	K	PK	Avg	O	K	PK	Avg
2-cut system																
No cut	4.38	4.36	4.59	4.44	4.51	5.06	4.76	4.78	3.75	4.42	4.22	4.13	4.21	4.61	4.52	4.45
3-cut system																
Sept. 1	4.14	4.02	4.13	4.10	4.05	4.04	4.25	4.11	3.64	4.05	4.09	3.96	3.94	4.03	4.16	4.04
Sept. 15	3.70	4.10	3.73	3.84	3.87	4.16	4.43	4.16	3.59	4.07	4.27	3.98	3.72	4.11	4.14	3.99
Oct. 1	3.93	4.76	4.34	4.34	3.74	4.13	4.59	4.15	3.72	3.96	4.04	3.90	3.80	4.28	4.32	4.13
Oct. 15	4.08	4.47	4.39	4.31	4.17	4.62	4.45	4.41	4.31	4.24	4.59	4.38	4.19	4.44	4.47	4.37
Nov. 1	4.28	4.41	4.74	4.48	4.31	4.39	4.56	4.42	3.97	4.72	4.96	4.55	4.19	4.51	4.75	4.48
Nov. 15	4.34	4.88	5.12	4.78	4.40	4.51	4.98	4.63	4.18	4.37	4.71	4.42	4.30	4.59	4.93	4.61
Average, 3-cut systems	4.08	4.44	4.41	4.31	4.09	4.31	4.54	4.32	3.90	4.23	4.44	4.19	4.02	4.33	4.46	4.27

TABLE 1. -- Continued

Planned Comparisons	Significance			
Variety				
DuPuits vs Vernal #				NS
DuPuits vs Cayuga #				*
Vernal vs Cayuga #				*
Cutting treatment	DuPuits	Vernal	Cayuga	Avg
Sept. 1 vs Sept. 15 and Oct. 1	NS	NS	NS	NS
Sept. 15 < Oct. 1	**	NS	NS	NS
Sept. 1 vs Sept. 15 #	NS	NS	NS	NS
Sept. 1 vs Oct. 1 #	NS	NS	NS	NS
Variety × Cutting treatment				NS
Fertilizer treatment				
0 < K #				**
K < PK #				*
0 < PK #				**
Variety × Fertilizer treatment				
Response of P on DuPuits vs Response of P on Vernal and Cayuga				**
Cutting treatment × Fertilizer treatment				
Response of 0 fertilizer when cut Sept. 1 vs Response of K and PK when cut Sept. 15 and Oct. 1				*
Variety × Cutting treatment × Fertilizer treatment				NS

*, ** -- Significant at the 1 and 5% levels, respectively
NS -- Not significantly different
-- Not an orthogonal comparison

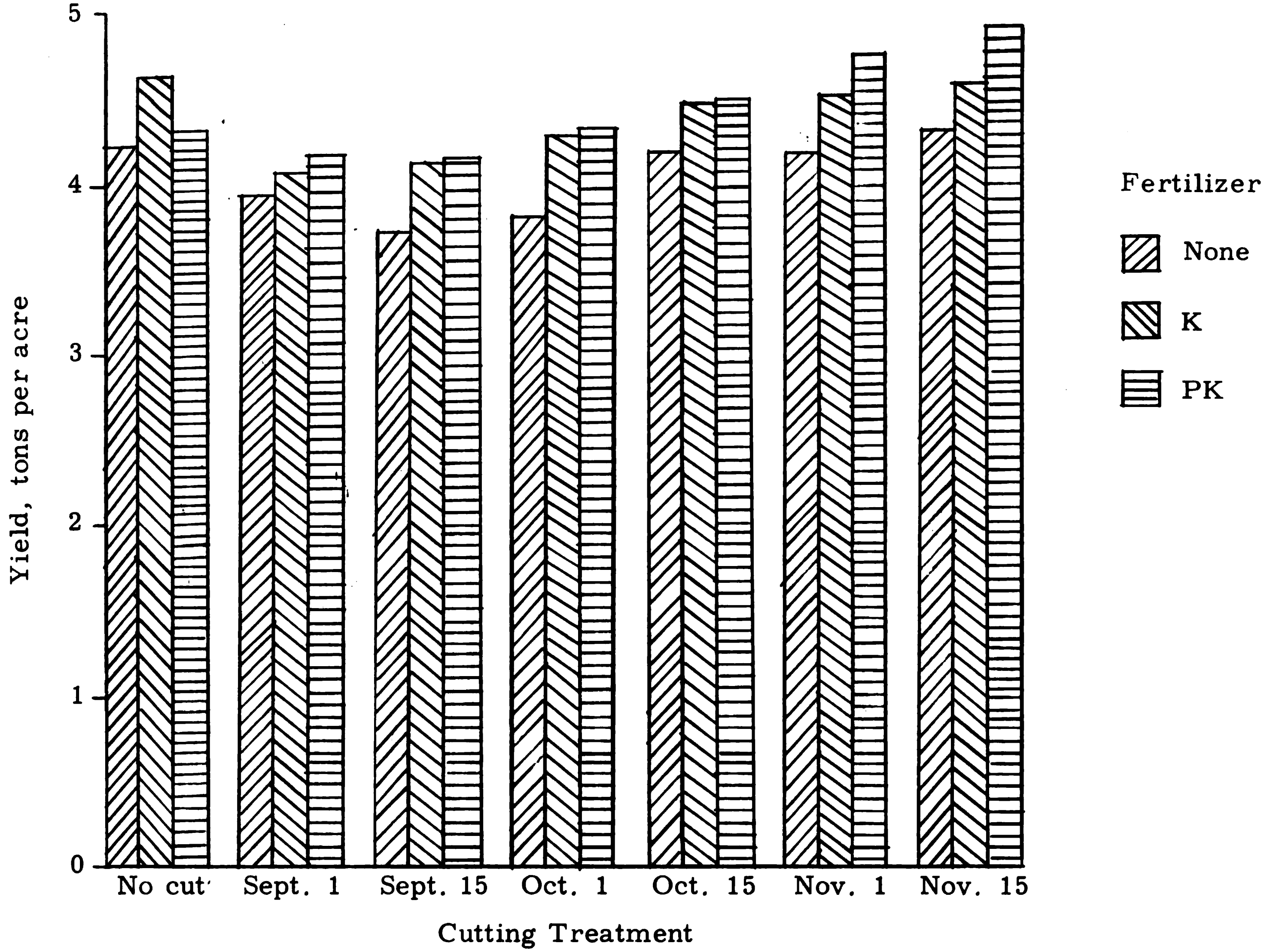

FIGURE 2. -- The residual effects of 7 third cutting treatments and K and PK fertilization as measured by average yield of 3 alfalfa varieties in the first 2 of 3 cuttings the next year

Alfalfa cut in late fall (October 15, November 1, and November 15) yielded an average of 0.45 tons per acre more (significant at 1%) the following year than alfalfa cut on September 1, Table 1.

The actual yield of alfalfa obtained from the fall cuttings taken after October 15 decreased until by November 15, there was little harvestable topgrowth, Table 2. These later fall cuttings were very low in quality since most of the leaves had dropped off, leaving mostly stems to be harvested.

TABLE 2.--Alfalfa yields of a third cutting taken at 7 different dates in the fall

Variety	Yield, tons per acre							
	No Cut	Sept. 1	Sept. 15	Oct. 1	Oct. 15	Nov. 1	Nov. 15	Average
DuPuits	0	0.97	1.05	0.99	0.84	0.76	-	0.92
Vernal	0	0.92	1.05	0.95	0.77	0.65	-	0.87
Cayuga	0	0.88	0.98	0.82	0.76	0.59	-	0.81
Average	0	0.92	1.03	0.92	0.79	0.66	-	0.87

- Yield not obtained

Alfalfa regrowth in the fall was greatest for DuPuits cut September 1. DuPuits alfalfa cut September 15 and October 1 was comparable in regrowth to Vernal and Cayuga cut September 1 and September 15, Table 3. The two hardy varieties, Vernal and Cayuga, were about equal in amount of fall regrowth.

TABLE 3.--Height of fall regrowth of alfalfa on November 8, 1966, after fall cutting and topdressing

Date, third cutting	Height, inches								
	DuPuits			Vernal			Cayuga		
	0	K	PK	0	K	PK	0	K	PK
3-cut system									
Sept. 1	7.0	5.5	5.5	2.4	2.7	4.2	2.5	3.0	2.7
Sept. 15	2.1	2.0	2.0	1.3	1.0	1.0	1.0	1.0	1.0
Oct. 1	1.5	1.1	1.8	1.0	0.8	0.9	1.0	0.9	1.0
Oct. 15	+	+	+	+	+	+	+	+	+
Nov. 1	+	+	+	0	0	0	0	0	0
Nov. 15	-	-	-	-	-	-	-	-	-

- Plants were not cut when data were collected.
+ New growth had visibly started.

Spring growth in the year following treatment, Table 4, was generally greater for the alfalfa cut twice or for the later fall cutting treatments--October 15, November 1, and November 15. Fertilized alfalfa had more growth than unfertilized alfalfa.

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TABLE 4. --Alfalfa growth ratings* in the spring following treatment

Date, third cutting	Growth rating								
	DuPuits			Vernal			Cayuga		
	0	K	PK	0	K	PK	0	K	PK
				2-cut system					
No cut	9	10	10	9	10	10	8	9	9
				3-cut system					
Sept. 1	9	9	9	8	9	9	7	8	9
Sept. 15	8	9	9	8	9	9	7	8	8
Oct. 1	8	10	9	8	9	9	7	8	8
Oct. 15	9	10	10	9	10	9	8	9	9
Nov. 1	9	10	10	9	10	9	8	10	9
Nov. 15	9	10	10	9	10	10	9	9	9

*Rating scale, June 1, 1967
10 = 22 inches or more
9 = 20-22 inches
8 = 18-20 inches
7 = 16-18 inches

Carbohydrates. --By November 1, the maximum level of TAC in the roots of alfalfa was attained, Table 5 and Figure 3. On December 13, roots of plants cut October 15, November 1, and November 15 were significantly higher in average TAC (27.86, 27.83, and 28.12%, respectively) than plants cut September 1, September 15, and October 1 (27.29, 26.96, and 26.44%, respectively), Table 5.

TABLE 5. -- Trends of total available carbohydrates in DuPuits and Vernal alfalfa roots after 7 cutting treatments and 3 fertilizer treatments

Date, third cutting	Fertilizer	% Total Available Carbohydrates												
		DuPuits									Vernal			
		Sampling date												
		Sept. 6	Sept. 15	Oct. 1	Oct. 15	Nov. 1	Nov. 15	Dec. 13	April 22	June 9	Sept. 6	Sept. 15	Oct. 1	Oct. 15
		2-cut system												
No cut	0	24.81	25.13	26.15	27.12	30.73	28.31	26.94	16.22	19.77	26.42	28.62	27.87	29.39
	K	-	-	-	29.30	28.52	29.22	27.03	16.63	20.75	-	-	-	30.84
	PK	-	-	-	29.12	29.88	29.53	25.96	15.89	19.75	-	-	-	31.12
	Avg	24.81	25.13	26.15	28.51	29.71	29.02	26.64	16.25	20.09	26.42	28.62	27.87	30.45
		3-cut system												
Sept. 1	0	24.81	-	24.20	27.35	29.68	29.32	26.22	15.06	20.45	26.42	-	27.05	29.03
	K	-	-	26.06	28.72	29.91	28.79	27.62	17.31	19.74	-	-	27.18	30.05
	PK	-	-	25.09	28.60	30.92	29.22	26.60	17.59	18.70	-	-	28.04	30.74
	Avg	24.81	-	25.12	28.22	30.17	29.11	26.81	16.65	19.63	26.42	-	27.42	29.94
Sept. 15	0		25.13	22.13	25.03	30.85	26.89	25.95	13.85	19.58		28.62	25.32	28.58
	K		-	22.22	24.35	29.83	28.81	27.13	13.46	20.72		-	26.00	26.98
	PK													
	Avg		25.13	22.52	24.75	29.64	28.05	26.65	13.46	19.89		28.62	25.43	27.65
Oct. 1	0			26.15	25.99	29.03	27.11	25.29	13.49	20.91			27.87	28.07
	K			-	27.63	29.90	27.83	26.50	13.44	18.94			-	26.32
	PK			-	26.25	29.49	27.73	24.85	14.16	20.33			-	21.58
	Avg			26.15	26.62	29.47	27.56	25.55	13.70	20.06			27.87	27.32
Oct. 15	0				27.12	30.34	29.89	25.82	13.99	20.84				29.39
	K				-	29.17	28.34	27.74	13.97	21.69				-
	PK				-	28.75	27.92	28.26	13.72	17.55				-
	Avg				27.12	29.42	28.72	27.27	13.89	20.02				29.39
Nov. 1	0					30.73	28.85	26.87	16.79	19.39				
	K					-	27.77	27.03	15.52	20.97				
	PK					-	29.15	27.54	15.32	18.25				
	Avg					30.73	28.59	27.15	15.88	19.54				
Nov. 15	0						28.31	29.02	17.67	18.50				
	K						-	28.68	14.64	18.60				
	PK						-	27.60	14.37	18.29				
	Avg						28.31	28.12	16.34	20.25				

- No roots sampled

TABLE 5. -- Continued

% Total Available Carbohydrates													
Vernal					Average								
Sampling date													
Nov. 1	Nov. 15	Dec. 13	April 22	June 9	Sept. 6	Sept. 15	Oct. 1	Oct. 15	Nov. 1	Nov. 15	Dec. 13	April 22	June 9
2-cut system													
32.39	30.94	28.73	17.34	22.31	25.62	26.88	27.01	28.86	21.56	29.63	27.84	16.78	21.04
32.69	29.46	29.09	17.14	20.97	-	-	-	30.07	20.61	29.34	28.06	16.89	20.86
30.84	29.47	28.46	16.52	21.67	-	-	-	30.12	30.36	29.50	27.21	16.21	20.71
31.97	29.96	28.76	17.00	21.65	25.62	26.88	29.01	29.48	30.84	29.49	27.70	16.62	20.87
3-cut system													
32.43	30.12	29.11	17.60	23.37	25.62	-	25.63	28.19	31.06	29.72	27.67	16.35	21.91
31.85	30.07	26.51	18.08	22.45	-	-	26.62	29.39	30.88	29.43	27.07	17.70	21.10
31.73	30.59	27.67	20.21	22.21	-	-	26.57	29.67	31.33	29.91	27.14	18.90	20.46
32.00	30.26	27.76	18.63	22.68	25.62	-	26.27	29.08	31.09	29.69	27.29	17.65	21.15
30.59	29.43	26.23	16.25	21.48		26.88	23.73	26.81	30.72	28.16	26.09	15.05	20.53
29.95	28.91	27.88	15.90	21.01		-	24.06	25.67	29.89	28.86	27.51	14.68	20.87
30.97	29.26	27.68	16.64	22.19		-	24.14	26.12	29.61	28.86	27.28	14.86	20.78
30.50	29.20	27.26	16.26	21.56		26.88	23.98	26.20	30.07	28.63	26.96	14.86	20.73
29.74	28.86	27.84	17.28	20.68			27.01	27.03	29.39	27.99	26.57	15.39	20.80
29.80	30.09	26.50	16.15	20.15			-	26.98	29.85	28.96	26.50	14.80	19.55
31.21	29.23	27.64	15.77	22.25			-	26.98	30.35	28.48	26.25	17.97	21.29
30.25	29.39	27.33	16.40	21.03			27.01	26.97	29.86	28.48	26.44	15.05	20.54
31.83	30.75	29.85	17.80	23.09				28.26	31.09	30.32	27.84	15.90	21.97
32.71	30.87	27.55	17.92	21.33				28.26	30.97	29.61	27.65	15.95	21.51
30.62	30.36	27.91	15.96	21.53				28.26	29.69	29.14	28.09	14.84	19.54
31.74	30.66	28.44	17.23	21.98				28.26	30.58	29.69	27.86	15.56	21.01
32.39	29.47	28.14	17.68	22.46					31.56	29.16	27.51	17.24	20.93
-	29.35	29.33	18.34	21.79					31.56	28.56	28.18	16.93	21.38
-	30.14	28.06	16.80	21.60					31.56	29.65	27.80	16.06	19.93
32.39	29.65	28.51	17.61	21.95					31.56	29.12	27.83	16.74	20.74
	30.94	28.11	17.34	21.83						29.63	23.57	17.51	20.17
	-	26.56	18.15	21.79						29.63	27.62	16.40	20.20
	-	28.75	15.84	22.47						29.63	28.18	15.11	20.38
	30.94	27.81	17.11	22.03						29.63	28.12	16.34	20.25

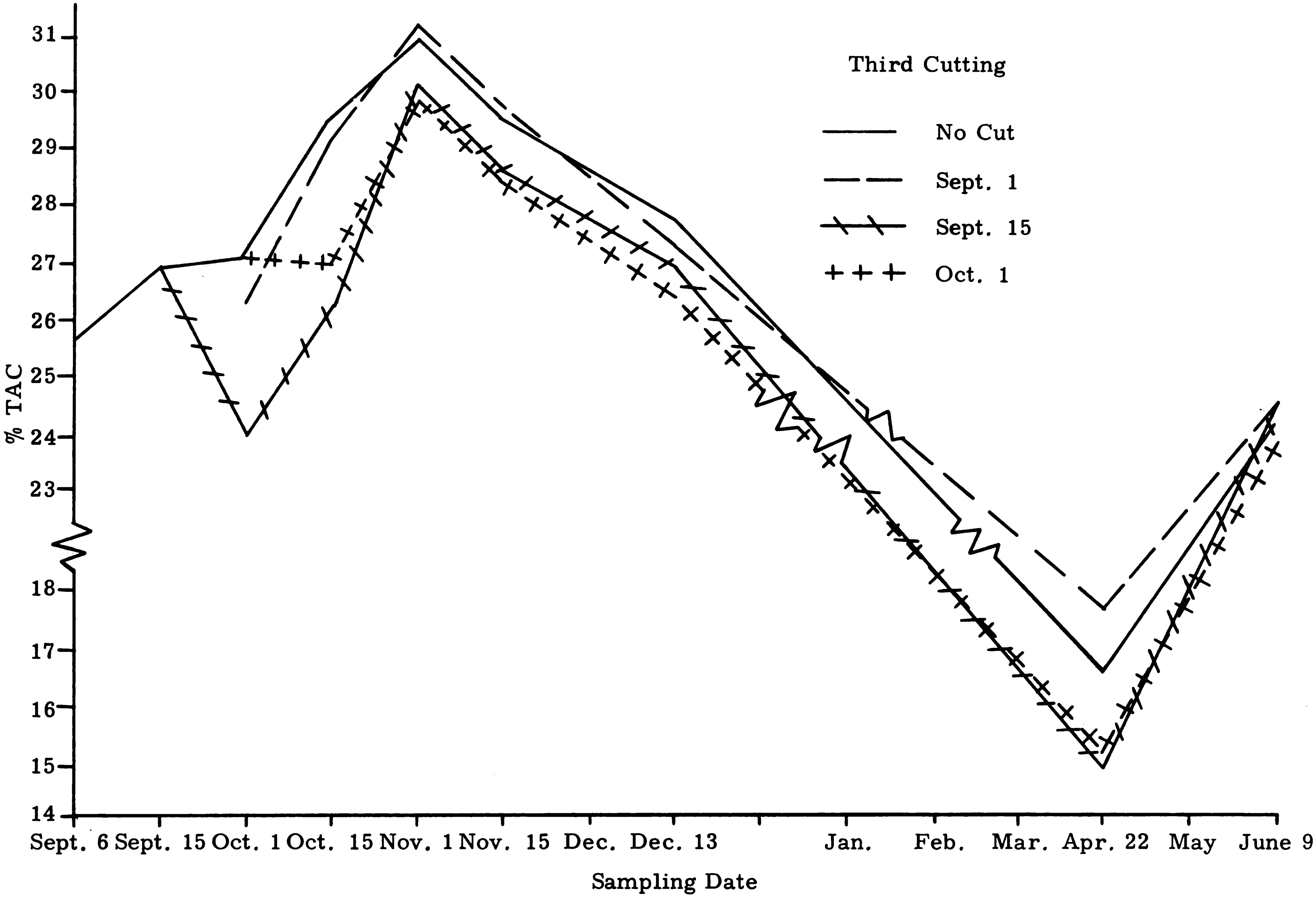

FIGURE 3. -- Trends of average total available carbohydrates in roots of DuPuits and Vernal alfalfa with 4 third cutting treatments

The percentage of TAC in roots from plants cut during the critical period, September 15 and October 1, was not significantly different from the September 1 cutting treatment, Table 5 and Figure 3. On April 22 the percentage of TAC in roots from September 15 and October 1 cutting treatments was significantly lower (at 1% level) than roots of the September 1 treatment, Figure 3. Topdressing with fertilizers did not produce any significant difference in TAC in roots of either fertilized or unfertilized alfalfa cut in late summer or fall, Table 5.

The average percentage of TAC in Vernal alfalfa roots was significantly higher (26.20 vs 24.41%) than in DuPuits for all cutting treatments and sampling dates, Figure 4 and Table 5.

Experiment II--Vernal alfalfa, seven cutting treatments, and five fertilizer treatments for two consecutive years--1965 and 1966

The average yields of the first and second cuttings of Vernal alfalfa cut the previous season on September 15 and October 1 in two consecutive years were not significantly different at the 1% level from the September 1 cutting treatment in each year, Figure 5. In both years following the cutting treatments made the previous year, the yield of the first and second cuttings of each of the September 1, September 15, and October 1 cutting treatments was less (significant

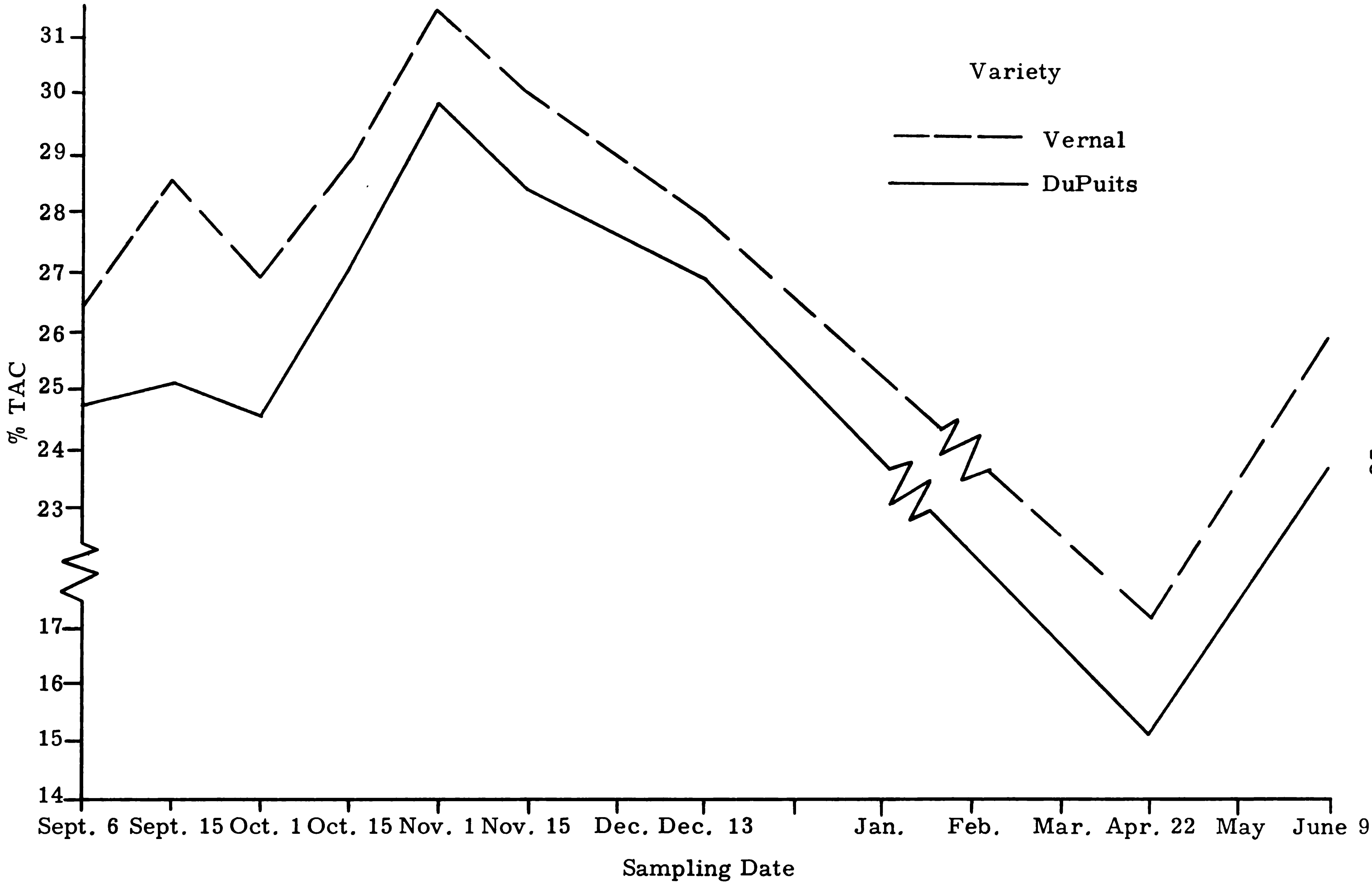

FIGURE 4. -- Average trends of TAC in roots of DuPuits and Vernal alfalfa during the fall and winter

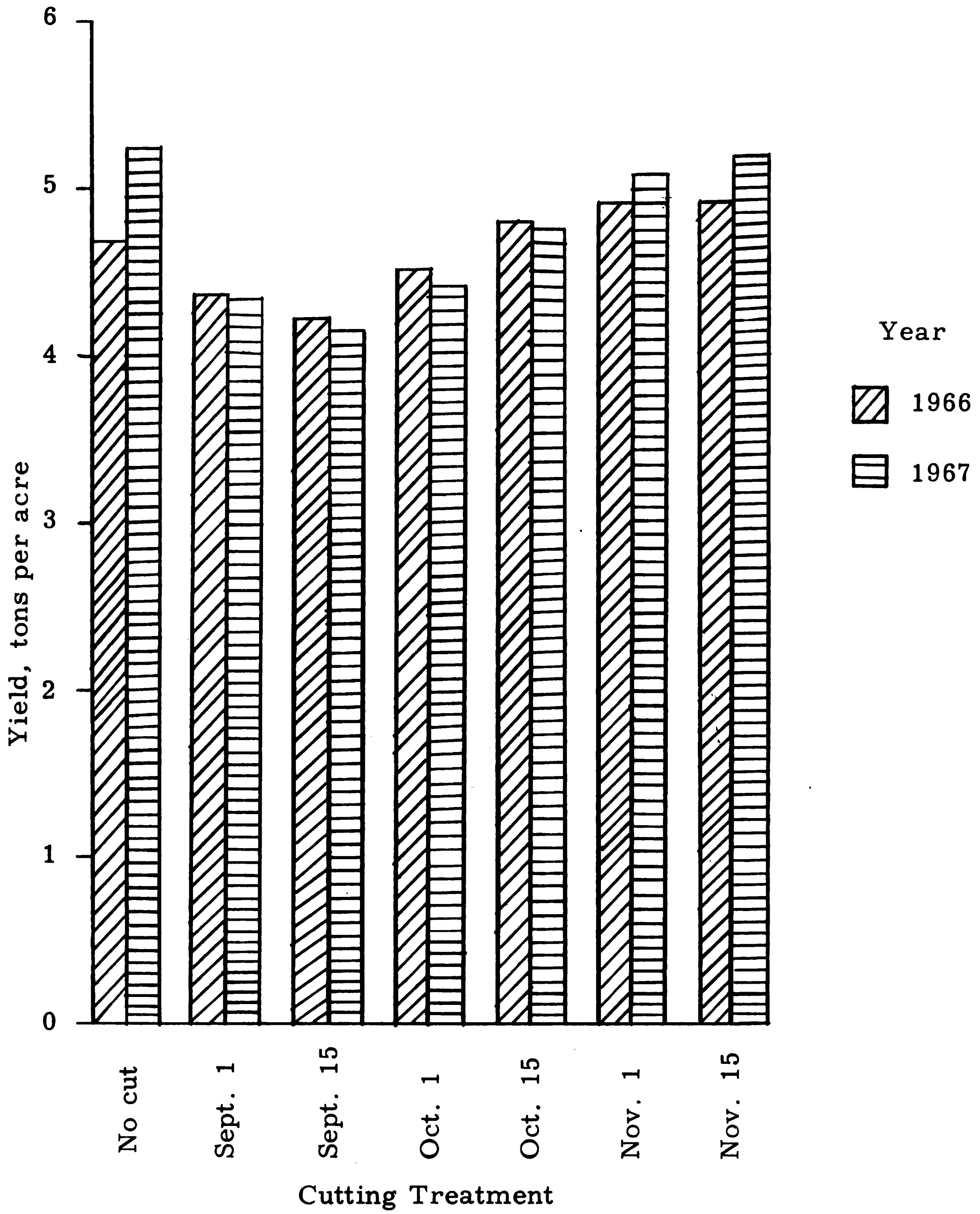

FIGURE 5.--The residual effects of 2 consecutive years of 7 third cutting treatments on Vernal alfalfa as measured by the yields of the first 2 of 3 cuttings the following years

TABLE 6.--Residual effects of 2 consecutive years of treatment with 7 third cutting treatments and 5 fertilizer treatments on the total yields of the first and second cuttings of Vernal alfalfa the following year

Date, third cutting	Yield, tons per acre																	
	1966						1967						Average, 2 years					
	No Fertilizer	Fall K	Spring K	Fall PK	Spring PK	Average	No Fertilizer	Fall K	Spring K	Fall PK	Spring PK	Average	No Fertilizer	Fall K	Spring K	Fall PK	Spring PK	Average
	2-cut system																	
No cut	4.53	4.56	4.61	4.60	4.73	4.61	4.82	5.15	5.28	4.88	5.78	5.18	4.67	4.86	4.95	4.74	5.25	4.89
	3-cut system																	
Sept. 1	4.16	4.40	4.37	4.29	4.40	4.32	3.80	4.41	4.19	4.49	4.63	4.31	3.98	4.41	4.28	4.39	4.52	4.31
Sept. 15	3.97	3.84	4.37	4.34	4.43	4.19	3.64	4.22	4.14	4.25	4.44	4.14	3.80	4.03	4.26	4.29	4.43	4.16
Oct. 1	4.20	4.50	4.47	4.62	4.39	4.44	3.85	4.54	4.33	4.64	4.53	4.38	4.02	4.52	4.40	4.63	4.46	4.41
Oct. 15	4.48	4.80	4.40	5.26	4.83	4.75	4.17	4.72	4.98	4.79	4.89	4.71	4.32	4.76	4.69	5.02	4.86	4.73
Nov. 1	4.70	4.75	4.51	5.21	5.00	4.83	4.46	5.16	5.03	5.05	5.35	5.01	4.58	4.95	4.77	5.13	5.17	4.92
Nov. 15	4.41	4.95	4.95	5.03	4.81	4.83	4.73	5.27	5.19	5.14	5.32	5.13	4.57	5.11	5.07	5.08	5.07	4.98
Average, 3-cut system	4.32	4.54	4.51	4.79	4.64	4.56	4.11	4.72	4.64	4.73	4.86	4.61	4.21	4.63	4.58	4.76	4.75	4.58

TABLE 6. -- Continued

Planned Comparisons	Significance		
	1966	1967	Avg
Fertilizer treatments (F)			
0 fertilizer < fertilizer	**	**	**
K < PK	*	NS	*
0 fertilizer < K #	*	**	**
0 fertilizer < PK #	**	**	**
Fall applied fertilizer vs spring application	NS	NS	NS
Cutting treatment			
Sept. 1, Sept. 15, and Oct. 1 < Oct. 15, Nov. 1, and Nov. 15	**	**	**
Sept. 1 vs Sept. 15 #	NS	NS	NS
Sept. 1 vs Oct. 1 #	NS	NS	NS
Sept. 1 vs Sept. 15 and Oct. 1	NS	NS	NS
Sept. 15 < Oct. 1	NS	NS	NS
Fertilizer × Cutting treatment			NS
Fertilizer × Year			
1966 × F vs 1967 × F			NS
1966 × K and PK vs 1967 × K and PK			NS
1966 × 0 fertilizer and fertilizer vs 1967 × 0 and fertilizer			*
Cutting treatment × Year			NS
Fertilizer × Cutting treatment × Year			NS

*, ** -- Significant at the 1 and 5% levels, respectively
NS -- Not significantly different
-- Not an orthogonal comparison

at 1% level) than each of the October 15, November 1, and November 15 cutting treatments, Table 6.

Topdressing with K or PK produced average annual yields of 0.39 and 0.53 tons per acre more, respectively, (significant at 1%) than unfertilized alfalfa, Table 6. The yields of alfalfa topdressed with PK were significantly higher (0.14 tons per acre) than alfalfa topdressed with K alone.

The yields of third cuttings taken in the late summer or fall were similar to Experiment I, Table 7.

TABLE 7.--Vernal alfalfa yields of third cuttings taken 2 consecutive years at 7 different dates

Year	Yield, tons per acre							
	Cutting date							
	No Cut	Sept. 1	Sept. 15	Oct. 1	Oct. 15	Nov. 1	Nov. 15	Average
1966	0	0.85	1.24	1.32	1.12	0.94	0.25	0.95
1967	0	0.96	1.12	1.03	0.91	0.39	-	0.88*
Average	0	0.90	1.18	1.17	1.01	0.66	0.25	0.92

- Yield not obtained
* Nov. 15 not included

Experiment III--Three-year old Vernal alfalfa, seven cutting treatments, and five fertilizer treatments for one year--1966

Alfalfa cut on September 15 and October 1 yielded significantly more at the 1% level the next year than plants cut September 1 (3.52 and 3.94 vs 3.36 tons per acre, respectively), Table 8, in a 3-year old stand of Vernal alfalfa.

Topdressing the alfalfa with PK gave an average increase in yield of 0.5 tons per acre more than unfertilized alfalfa and 0.38 tons per acre more than alfalfa topdressed with K alone (significant at 1%), Table 8 and Figure 6. Topdressing with K alone did not give a significant yield increase.

Topdressing with PK in the fall gave higher yields (significant at 1%) the next year than when fertilized in the spring. Yield differences between plants fertilized with PK in the spring and fall, Table 8, were greatest for the earlier fall cutting treatments, September 1, September 15, and October 1.

Alfalfa cut later in the fall--October 15, November 1, and November 15--yielded significantly more (average of 0.92 tons per acre) at the 1% level the next year than alfalfa cut on September 1, September 15, and October 1. The actual fall hay yield from the two later fall cuttings, November 1 and November 15, was not determined

TABLE 8.--The total yields of 3 cuttings of Vernal alfalfa the year following 7 third cutting treatments and 5 fertilizer treatments

Date, third cutting	Yield, tons per acre							
	No Fert.	Fall K	Spring K	Fall PK	Spring PK	Avg K	Avg PK	Avg ‡
2-cut system								
No Cut	4.37	4.41	4.76	4.32	5.27	4.59	4.80	4.62
3-cut system								
Sept. 1	3.09	3.27	3.07	3.90	3.45	3.17	3.67	3.36
Sept. 15	3.34	3.48	3.31	4.14	3.31	3.40	3.73	3.52
Oct. 1	3.80	3.82	3.70	4.43	3.97	3.76	4.20	3.94
Oct. 15	4.10	4.15	4.18	4.88	4.47	4.17	4.67	4.35
Nov. 1	4.32	4.46	4.21	4.82	4.90	4.34	4.86	4.54
Nov. 15	4.20	4.90	4.69	4.75	4.80	4.80	4.78	4.67
Average, 3-cut system	3.81	4.01	3.86	4.49	4.15	3.94	4.32	4.06

Planned comparisons	Significance
Fertilizer treatments	
0 fertilizer < fertilizer	**
0 < K #	**
K < PK	**
Fall applications > spring applications	**
Cutting treatments	
Sept. 1, Sept. 15, and Oct. 1 < Oct. 15, Nov. 1, and Nov. 15	**
Sept. 1 < Sept. 15 and Oct. 1	**
Sept. 15 < Oct. 1	**

*, ** -- Significant at the 1 and 5% levels, respectively
-- Not an orthogonal comparison
‡ -- Average for the 5 fertilizer treatments

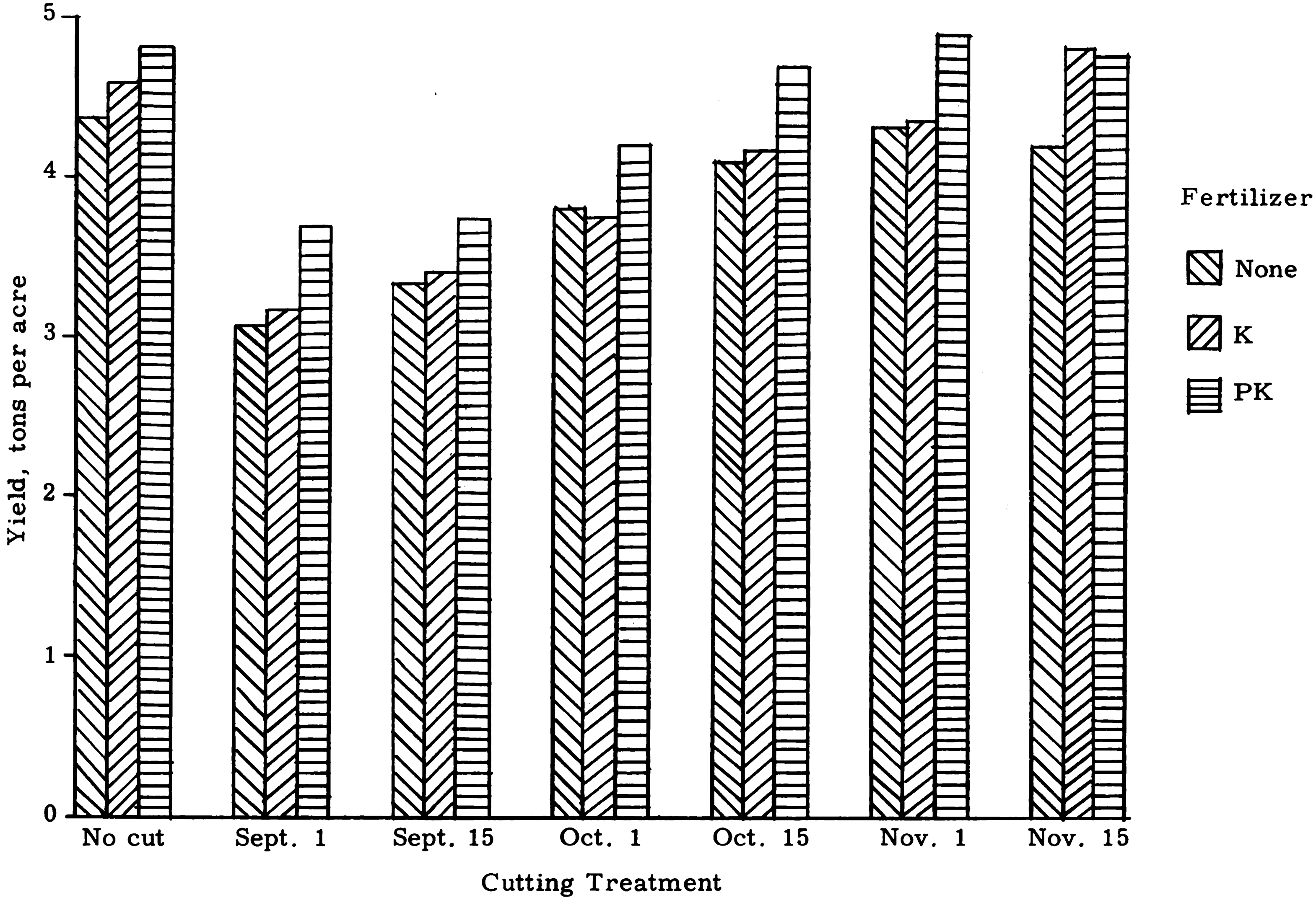

FIGURE 6. -- The residual effects of 7 third cutting treatments and K and PK fertilization as measured by the yields of Vernal alfalfa in 3 cuttings the next year

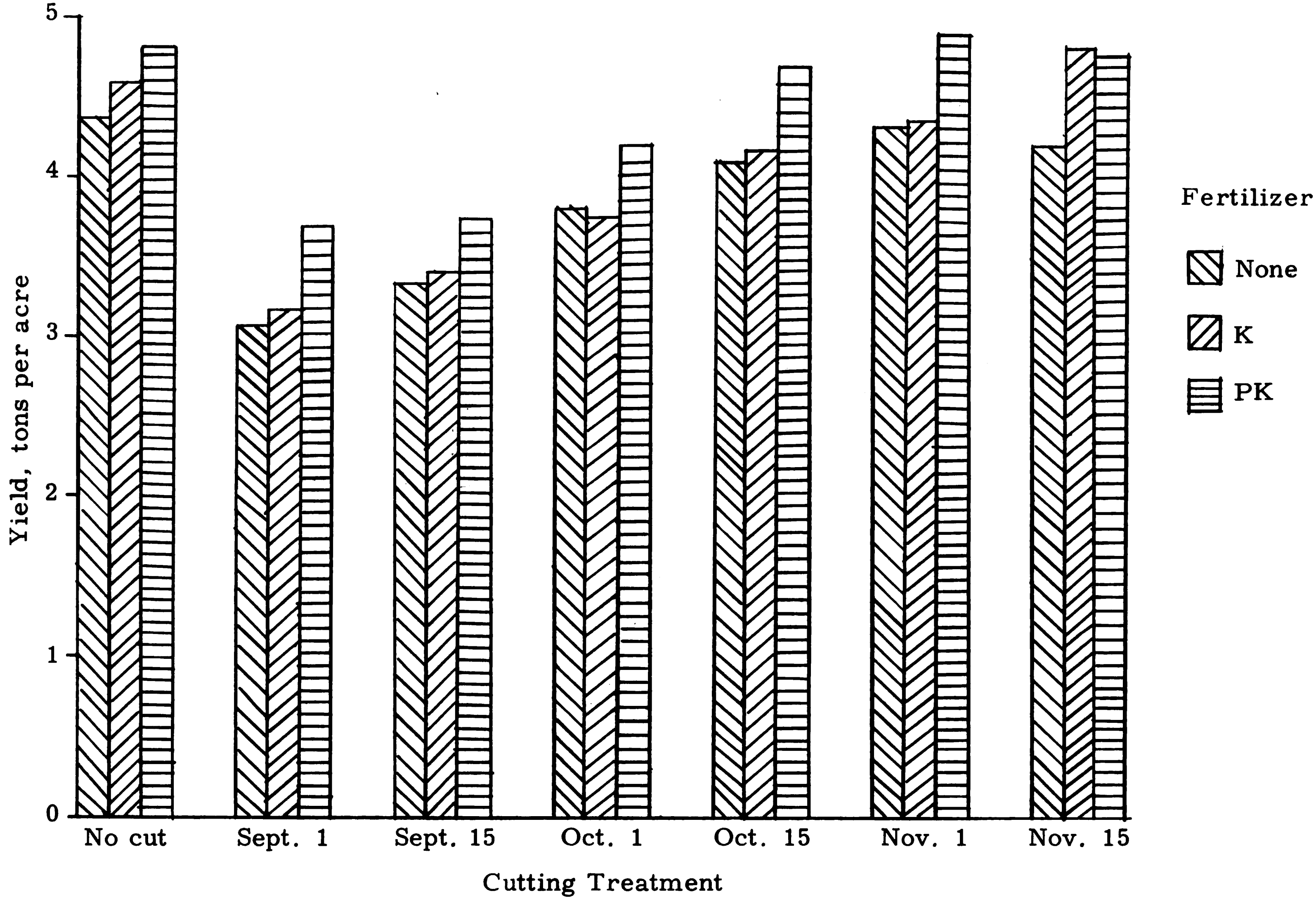

FIGURE 6. -- The residual effects of 7 third cutting treatments and K and PK fertilization as measured by the yields of Vernal alfalfa in 3 cuttings the next year

since climatic factors were such that little harvestable hay could be removed, Table 9.

TABLE 9.--Third cutting yields in tons per acre on 7 different dates of 3-year old Vernal alfalfa

No cut	Sept. 1	Sept. 15	Oct. 1	Oct. 15	Nov. 1	Nov. 15
0	0.94	1.01	0.90	0.72	-	-

- Yield not obtained

<u>Summary of Experiments I, II, and III with Vernal alfalfa</u>

The residual effect of the late summer and fall cutting treatments as reflected by the yield of the first two cuttings in Experiments I and II and three cuttings in Experiment III is shown in Table 10 as a summary. Vernal alfalfa cut on September 15 or October 1 yielded the same (average of 3.96 and 4.18 tons) as when cut September 1 (3.93 tons).

In each experiment, the next year's yields of Vernal alfalfa cut September 1, September 15, and October 1 were less than alfalfa not cut or cut October 15, November 1, and November 15, Table 10.

For the average of the three experiments, subsequent year's yields of alfalfa cut September 1 or September 15 or October 1 were increased by PK and, to a lesser extent, by K.

TABLE 10. -- Summary of the residual effects of 7 third cutting treatments and 3 fertilizer treatments on the total yield of first and second cuttings* of Vernal alfalfa the first year following treatments in 3 experiments

Date, third cutting	Yield, tons per acre															
	Experiment I				Experiment II				Experiment III				Average			
	O	K	PK	Avg	O	K	PK	Avg	O	K	PK	Avg	O	K	PK	Avg
2-cut system																
No cut	4.51	5.06	4.76	4.78	4.53	4.58	4.66	4.61	4.37	4.59	4.80	4.62	4.47	4.73	4.73	4.67
3-cut system																
Sept. 1	4.05	4.04	4.25	4.11	4.16	4.38	4.34	4.32	3.09	3.17	3.67	3.36	3.77	3.86	4.09	3.93
Sept. 15	3.87	4.16	4.43	4.16	3.97	4.11	4.38	4.19	3.34	3.40	3.73	3.52	3.73	3.89	4.18	3.96
Oct. 1	3.74	4.13	4.59	4.15	4.20	4.49	4.50	4.44	3.80	3.76	4.20	3.94	3.91	4.13	4.43	4.18
Oct. 15	4.17	4.62	4.45	4.41	4.48	4.60	5.04	4.75	4.10	4.17	4.67	4.35	4.25	4.46	4.72	4.50
Nov. 1	4.31	4.39	4.56	4.42	4.70	4.63	5.10	4.83	4.32	4.34	4.86	4.54	4.44	4.45	4.84	4.60
Nov. 15	4.40	4.51	4.98	4.63	4.41	4.95	4.92	4.83	4.20	4.80	4.78	4.67	4.34	4.75	4.89	4.71
Average, 3-cut system	4.09	4.31	4.54	4.32	4.32	4.52	4.72	4.56	3.81	3.94	4.32	4.06	4.07	4.26	4.53	4.31

*Cuttings made on: Experiment I--June 9 and July 14, 1967
Experiment II--June 17 and July 26, 1966
Experiment III--June 13, July 18, and September 8, 1967

DISCUSSION

Data obtained in two years in the three experiments reported show that well fertilized alfalfa can be cut for the third time in the vicinity of East Lansing, Michigan, (and probably elsewhere under similar conditions) on September 15 or October 1 and yield as much the following year as alfalfa cut for the third time on September 1.

In contrast to this work in Michigan, Graber et al. (1927), and Smith (1960) in southern Wisconsin showed that third-cutting treatments on September 15 or October 1 decreased the following year's yields when compared to September 1 cuttings. These yield decreases are understandable since southern Wisconsin has a shorter fall growing season to replenish root reserves and yet has more serious hazards attributed to lower temperatures which frequently result in more winterkilling and decreased yields the next year.

The work reported in these experiments is in good agreement, however, with that of Rather and Harrison (1938), working in Michigan. They showed that the September 1, September 15, and

October 1 cutting treatments yielded the same the next year. They compared the total yields of two cuttings of a 2-cut and a 3-cut system the year following late summer or fall cutting treatments. By taking this approach, they determined that alfalfa cut for a third time in late summer or fall yielded less in the two cuttings the following year than alfalfa cut twice the previous year. They logically recommended the 2-cut system as the safest practice. It should be noted that their second cutting was harvested in the "1/10 to 1/2 bloom" stage, probably in mid-August, later than the first and second cuttings harvested in early bloom in this experiment (early June and July 15 to early August). As a result, their third cutting was considerably lower yielding than third cuttings harvested in this experiment and there was less time for replenishment of carbohydrate reserves.

To make a valid comparison of a 2-cut and a 3-cut system, one must consider some other factors in addition to the total yield of the two cuttings the next year. First, the yield of the first two cuttings of a 2-cut system is the total yield for a 2-cut system while the total yield for a 3-cut system must have a third cutting added to the first two cuttings. This is shown in Table 11 for Vernal alfalfa topdressed with PK and for the data of Rather and Harrison (1938) using Hardigan alfalfa with no topdressing. By comparing these totals of 2-cut and 3-cut systems, it can be seen that Rather and Harrison were right in concluding that the 2-cut system was "safest in Michigan" since the total yield of the 2-cut system was similar to the total yields of a 3-cut system which lowered the carbohydrate reserves and made the plants susceptible to winter injury and bacterial wilt.

TABLE 11.--Comparison of 1938 alfalfa yields with recent yields of Vernal alfalfa fertilized annually with PK under identical cutting treatments

Date, third cutting	Rather and Harrison Summary*			Avg Experiments I, II, and III		
	First and second cutting	Third cutting	Total	First and second cutting**	Third cutting ***	Total
2-cut system						
No cut	3.51	0	3.51	4.73	0	4.73
3-cut system						
Sept. 1	3.15	0.30	3.45	4.09	0.90	4.69
Sept. 15	3.01	0.44	3.45	4.18	1.10	4.91
Oct. 1	3.11	0.44	3.55	4.43	1.05	5.13
Oct. 15	3.27	0.35	3.62	4.72	0.87	5.30
Nov. 1	3.40	0.26	3.66	4.84	0.79	5.37
Nov. 15	-	-	-	4.89	0.25	5.06

*Average of eight trials (Rather and Harrison, 1938), second cutting taken in early August, southern Michigan.
**From Table 10, Experiments I and II. Experiment III had 3 cuttings.
***Average of Vernal alfalfa in Tables 2, 7, and 9, added to Experiments I and II only.

Their recommendation made three decades ago with non-wilt resistant varieties and little, if any, topdressing needs to be re-examined since in these three experiments, the average total yield of Vernal alfalfa cut September 1, September 15, and October 1 was 0.52 tons per acre more the next year than the yield of alfalfa cut twice, Table 11. Various reports in northern states and northern latitudes (Armstrong et al., 1948; Folkins et al., 1960; Smith, 1960; Chance et al., 1961; Carter, 1964; Michigan State University Cooperative Extension Service, 1967; and Fuess and Tesar, 1968) show that three cuttings yield more than two when the third cutting is harvested in late August or early September. The results of this study, Table 11, show further that the third cutting can be made any time after September 1 until November 1 with a gradual increase in total yield from 4.69 to 5.37 tons in the following year.

Quality is a second factor that must be considered when comparing a 2-cut and a 3-cut system. Hay from a 3-cut system is higher in quality since it is younger plant tissue with less fiber and also because it has more leaves which are of prime importance because they contain a much higher concentration of nutrients than the stems (Reid et al., 1959). Fuess and Tesar (1968) reported that two-thirds of the yield difference between 2- and 3-cut systems was due to leaf drop in the 2-cut system.

Alfalfa cut September 1, September 15, or October 1 generally yielded less the next year than alfalfa cut the previous year on October 15, November 1, or November 15, Table 11. Here one must consider the practicality of harvesting alfalfa after October 1 when average yields of a third harvest are low (average of 0.64 tons per acre), Table 11, and quality is lower, especially at the last date when most of the leaves have dropped leaving only stems with a high percentage of dry matter. By November 15, the quality of the forage left standing was so low that yields were not determined.

No cumulative effect of fall cutting or fertilizer treatment occurred when Vernal alfalfa was given the same treatments for two consecutive years, which is in contrast to reports of Kust and Smith (1961), who used a somewhat more severe cutting treatment in a state having more severe winters. Since Vernal alfalfa was able to maintain the same yield level the next year for plants cut the previous September 1, September 15, and October 1, it would be unreasonable to expect a major cumulative effect of cutting treatments on the yield of Vernal alfalfa. Apparently Vernal alfalfa cut on September 1 had adequate time to replenish most of the root reserves before cold weather stopped or severely reduced storage of carbohydrates. Even though plants cut September 15 or October 1 regrew only one inch, this regrowth apparently replenished carbohydrate reserves to the extent that they were as high on December 13 as in plants cut on September 1; therefore, next year's yields were similar.

In contrast, DuPuits alfalfa, a medium hardy and non-wilt resistant variety, may not maintain the same level of production as did Vernal when cut two consecutive years during the critical period. Table 1 shows a tendency for the average yield of DuPuits to decrease the following year when cut the previous September 15. The fall regrowth of DuPuits, Table 3, indicates that the regrowth of DuPuits was somewhat greater than that of Vernal. With its greater growth, it should be able to replenish carbohydrate reserves to a higher level than Vernal. Therefore, its inherent lower potential winterhardiness may be the primary reason it is less resistant to severe fall cuttings even though it regrows more rapidly as noted above.

In Table 8, Experiment III, the following year's yield of Vernal alfalfa cut the previous September 1 was lowest. In this experiment, the second cutting of the treatment year was made in early August. It is probable that the interval between the September 1 cutting and the previous second cutting in early August was insufficient for adequate regrowth. As a result, root reserves were not replenished between the second and third cutting. Thus, the

September 1 cutting treatment caused a decrease in yield the following year, similar in effect to the data of Kust and Smith (1961), who found that when cut on June 28, August 30 and October 1, the second year's yields of Vernal alfalfa were severely reduced.

In Experiment III, PK fertilizer applied in the fall gave greater yields than when applied in the spring. Since the stand was two years old and had not previously been topdressed, the additional amount of PK fertilizer becoming available to the plants by the earlier application may have made a significant difference. The fertility level was likely low since no fertilizer was applied after seeding. The failure of K alone to give a significant yield increase was probably due to P being more limiting than K in this experiment.

The fact that topdressing alfalfa after cutting treatments did not show any difference in TAC of roots indicates that PK and K alone do not affect the level of carbohydrates but must react in some other way in the plant to increase winterhardiness. The following year's yields of all cutting treatments were increased by fertilizer, particularly by PK for Vernal and Cayuga.

Vernal alfalfa, a hardy variety, was higher in TAC in the roots than DuPuits, a medium hardy variety, indicating that the higher TAC levels may have contributed to the greater winterhardiness of Vernal and the generally higher yields of Vernal cut

September 1, September 15, and October 1 the previous year. DuPuits having lower TAC levels and little or no wilt resistance would be expected to show lower yields the next year when a third cutting was taken September 15 and October 1.

On December 13, the TAC in roots of plants cut on September 1 appeared to be slightly higher than when cut September 15 or October 1 but the difference was not significant. However on April 22, the TAC in roots of plants cut September 15 and October 1 were significantly lower than September 1 cut plants, Figure 3. By June 9, there was no difference in TAC levels apparently since the spring growth had replenished carbohydrate reserves.

This research indicates that greater flexibility in fall management of alfalfa is likely in southern Michigan. Farmers can cut hardy, wilt resistant varieties of alfalfa such as Vernal (and probably less hardy wilt resistant varieties) for the third time after harvesting a second cutting mid- to late July and not materially reduce yields of alfalfa the next year. From two years' data, there appears to be no cumulative effect of cutting September 15 or October 1 when compared to a September 1 cutting.

SUMMARY AND CONCLUSIONS

The residual effect of cutting Vernal, a hardy alfalfa, for a third time on September 1, September 15, October 1, October 15, November 1, and November 15 was determined in 1966 and 1967 from the first two of three cuttings in the year following cutting treatments at several fertility levels in each of three separate experiments at East Lansing in southern Michigan. In one of the experiments, the cutting treatments were imposed for two consecutive years in the same experiment. In another experiment, Cayuga, a hardy alfalfa, and DuPuits, a medium hardy alfalfa, were given similar cutting treatments. The TAC in the roots were determined after each cutting treatment and on December 13, April 22, and June 9 on Vernal and DuPuits alfalfa. The results show that:

1. In each of the three experiments, alfalfa cut for the third time on September 15 or October 1 yielded as much in the first two of three cuttings the next year as when cut September 1. Alfalfa cut on October 15, November 1, or November 15 yielded more than when cut September 1, September 15, or October 1.

2. In one of the three experiments, fertilizing with K or PK in contrast to no fertilizer gave relatively higher yields the next year after cutting on September 15 or October 1 than when cut on the previous September 1.
3. Yields of alfalfa did not show a cumulative effect of two consecutive years of September 1, September 15, or October 1 cutting treatments and fertilizer treatments.
4. The roots of alfalfa cut twice and those cut for a third time on September 1, September 15, October 1, and October 15 attained their maximum TAC level by November 1, then decreased.
5. On December 13, no significant difference occurred in levels of TAC in roots of alfalfa cut September 1, September 15, and October 1.
6. The level of TAC in roots of plants cut September 1, September 15, and October 1 was generally lower on December 13 than in roots of plants cut twice or a third time on October 15, November 1, and November 15.
7. Topdressing with K and PK after late summer and fall cutting treatments did not affect the level of TAC in the roots of alfalfa during the fall and winter.
8. The level of TAC in Vernal alfalfa was higher than DuPuits alfalfa during the late summer, fall, and winter.

9. PK applied in the fall gave a higher yield the following year than when applied in the spring.
10. Topdressing with PK gave a higher yield than K alone.

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