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Timothy Culture

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TIMOTHY CULTURE

Seeding, Fertilization, Cutting at Different Stages Permanence of Stand[1]

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INTRODUCTION

In the meadows and permanent pastures of Ohio, two families of plants, the grasses and the legumes, are grown. In districts not well adapted to legumes, the grasses continue to occupy an important place. In meadows, the one most universally grown is timothy. Many reasons may be given for this choice. Among the most important are: (a) palatability, (b) relatively low cost of seeding and harvesting, (c) infrequent failure of new seedings, (d) permanency of stand under favorable conditions, and (e) high rank among the grasses in productivity.

Hay made from legumes is richer in protein and minerals, particularly calcium and phosphorus, than timothy or any other grass. Unfortunately, the area in which the clovers and alfalfa can be grown successfully is more restricted than is that in which the grasses are adapted. Much has been and is now being done to extend the territory in which legumes can be produced. As their soil and climatic requirements become more clearly defined and more universally understood, it is probable that the regions in which they can be grown, either alone or in combination with grasses, will be appreciably extended.

In some of the feeding experiments conducted in earlier years with timothy, more or less unfavorable results were obtained, due in part, apparently, to the use of a poor quality of hay. Quality is dependent in large measure on the cultural and harvesting methods employed. Timothy cut after it has passed out of bloom usually contains less than 6, and not infrequently less than 5 per cent of protein. If cut in early bloom or even in full bloom, it may contain 6 to 7 per cent of protein. If cut when the heads are appearing, or if heavy applications of a nitrogenous fertilizer are used, the air-dry timothy hay may contain 8 to 9 per cent of protein. Even the latter percentages are considerably less than that found in alfalfa or in clover, for Morrison (16) gives the crude protein content of alfalfa, all analyses, as 14.7 per cent, and that of red clover, all analyses, as 11.8 per cent. Morrison, and also Willard, Thatcher, and Cutler (32) state that the percentages of protein in alfalfa and clover are even higher if the alfalfa and clover are cut at early stages of growth. Timothy hay of the best quality, however, may excel even alfalfa in net energy value. Hunt, Record, and Bethke (14) have shown that it is also a valuable source of certain vitamins.

PRESENT STATUS OF TIMOTHY CULTURE

That timothy has been and still is an important crop in the agriculture of the United States is shown by the census reports which reveal that the acreage devoted to it, grown either alone or in combination with clover, was 34,228,775,

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[1]Most of the records upon which this report is based were obtained at the Timothy Breeding Station, North Ridgeville, Ohio, conducted cooperatively from 1915 to 1935 by the Department of Agronomy, Ohio Agricultural Experiment Station, and the Division of Forage Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture. Some of the records were obtained independently by the Ohio Agricultural Experiment Station at Wooster.

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30,290,752, and 25,547,279 acres in 1909, 1919, and 1929, respectively, (26) (27). In the latter year in Ohio there were 1,903,347 acres of timothy growing alone or in mixture with clover; this area constituted 72.5 per cent of the total acreage of hay in the State. Timothy is grown chiefly in the northeastern quarter of the United States; Ohio is one of the states in which production is densest (24). In fact, in many Ohio counties, particularly those located in the northeastern part of the State, approximately one-half of the cultivated land is in meadow, and most of these meadows consist chiefly of timothy. The superiority of timothy in yield over other grasses in this section is illustrated by its performance on the farm of the Ohio Agricultural Experiment Station at Wooster. The average yield of 11 grasses, including timothy, grown under uniform conditions on this farm for varying periods extending through 20 years was as shown in table 1.

The major reason for the absence of legumes in some localities is unfavorable soil conditions, such as poor drainage, lack of limestone, infertility, or some combination of these. Probably on considerable areas of such land, timothy will continue to be the dominant grass. However, Bachtell, Allen, and Monroe (2) have shown that some of the land on which timothy has predominated previously can be made hospitable, if not for legumes alone, at least for the growing of timothy mixtures including legumes.

In permanent pastures, Kentucky bluegrass, Canada bluegrass, orchard grass, and redtop, especially the first named, are grown more extensively than timothy. When new pastures are established, however, timothy is usually a constituent of the mixture sown. Timothy meadows are very often used for pasturage after the first cutting of the season has been harvested for hay, and frequently a timothy meadow is pastured for one or more entire seasons before the land is plowed for some other crop.

During the past few years the need for soil conservation has become recognized as an important problem. Within much of the timothy-producing area in the northeastern United States, there is a trend toward the production of less grain and more soil-conserving crops. With an increased dependence upon forage crops, there is need for better utilization of timothy, not only as hay, but also in other ways. At the Vermont Agricultural Experiment Station (28), studies have been made of the use of timothy cut very early and artificially dried. At the same Station it has been found that timothy cut and placed in silos when it contains 30 to 40 per cent of dry matter and mixed with 1 to 2 per cent of molasses makes silage of a high quality. At the New Jersey Agricultural Experiment Station (5), on soil which had been well fertilized with a nitrogen-carrier in both years, and also with superphosphate and muriate of potash in the second year, the average yield in 1935 and 1936 of timothy for silage was 11 tons per acre, compared with 13 tons of corn silage from land fertilized with manure and superphosphate. The report of this work states that "Yields of green timothy of between 9 and 13 tons an acre compare favorably with average acre yields of silage corn. Timothy need not be planted annually, and it needs no cultivation. When cut at an early stage of growth and ensiled, it produces a silage higher in protein than corn silage." The silage made from timothy was produced at a lower cost per ton than that made from corn. The New Jersey Station further states that "The carotene content, which is pro vitamin A, is high. In fact timothy silage contains more carotene on the dry basis than does the best dehydrated alfalfa hay which is fed during the winter months."

TABLE 1.—Yield of eleven grasses*—Wooster

Kind	Pounds of hay per acre																	Relative yields
	1905	1906	1907	1910	1911	1912	1913	1914	1915	1918	1919	1920	1921	1922	1923	1924	Average†	
Timothy	5,840	5,240	7,200	9,700	6,160	6,740	3,080	5,700	....	4,080	7,140	3,750	3,260	4,620	1,820	....	$5,309^{14}$	100
Kentucky bluegrass..	3,120	4,360	4,300	5,720	4,560	4,000	3,400	3,600	2,910	....	3,400	3,360	2,000	1,780	800	2,540	$3,323^{15}$	63
Redtop.......	5,500	5,920	4,440	6,680	5,640	6,140	1,940	3,600	2,030	7,280	4,520	1,840	1,000	1,280	....	....	$4,129^{14}$	78
Orchard grass......	3,300	4,680	4,440	5,160	4,960	3,200	5,700	5,900	4,030	5,700	4,100	2,880	2,300	2,880	1,660	2,120	$3,938^{16}$	74
Meadow fescue......	3,700	4,200	4,020	4,880	3,640	....	....	3,000	1,350	6,180	3,100	3,760	2,800	1,840	....	....	$3,539^{12}$	67
Tall fescue ..	3,900	4,360	5,180	6,040	4,720	....	....	4,200	2,610	....	....	....	....	....	....	....	$4,430^{7}$	83
Brome grass......	2,900	....	....	5,960	3,600	4,100	700	3,900	2,530	5,560	4,300	4,220	2,800	3,800	2,400	2,680	$3,532^{14}$	67
Tall oat grass......	3,500	4,800	4,640	5,040	5,240	4,900	4,400	5,000	4,310	6,060	4,900	3,800	3,800	2,820	2,320	2,880	$4,276^{16}$	81
Perennial rye grass..	3,440	3,400	4,220	3,520	3,560	....	2,800	1,900	1,850	7,500	1,800	2,040	1,700	1,540	....	....	$3,021^{13}$	57
Italian rye grass......	....	....	....	5,120	3,600	....	....	....	....	....	....	....	....	....	....	....	$4,360^{2}$	82
Meadow foxtail.....	....	....	....	....	....	....	....	2,300	1,470	....	4,700	3,580	2,200	1,840	1,160	....	$2,464^{7}$	46

*In the periods 1908-1909 and 1916-1917 the grasses were being reseeded. The plot of perennial rye grass was reseeded also in 1912, and the plots of meadow fescue and tall fescue were reseeded in 1913.

†Superior figures represent the number of years included in the average.

Improved Varieties of Timothy

For a number of years the Ohio Agricultural Experiment Station, in cooperation with the United States Department of Agriculture, has been conducting a program for the improvement of timothy. One improved early strain is now being introduced under the name Marietta. In northern Ohio it is about 4 days earlier, and in southern Ohio, about a week earlier than ordinary timothy. One late strain has been introduced as Huron timothy (10). It has been grown in Ohio to a limited extent, especially in Lorain County, but seems less well adapted in this State than in certain parts of the Pacific Northwest. Other late selections of timothy, better than Huron timothy under Ohio conditions, have been developed. A new variety of this type probably will be introduced soon. In southern Ohio late varieties do not grow well; early timothy is better adapted there. In northern Ohio either early or late varieties may be grown. In this part of the State it might be feasible for any farmer having a large acreage of timothy to grow an early variety, ordinary timothy which blooms at a medium time, and a late variety. With such a combination of varieties the season for harvesting timothy hay of a high quality would be extended.

OBJECT OF THE EXPERIMENTS CONDUCTED

The general purpose of the experiments reported in this bulletin is to determine the best cultural practices by which to obtain maximum yields consistent with best quality of hay. The experiments pertain particularly to methods of seeding and fertilization, time of harvesting, and the effect of the latter on the permanence of stand.

METHODS USED

The work was done in part at the Main Station at Wooster and in part at the Timothy Breeding Station located at North Ridgeville, Lorain County, operated cooperatively from 1915 to 1935 by the Ohio Agricultural Experiment Station and the United States Department of Agriculture.

At both Wooster and North Ridgeville all experiments were carried out at least in triplicate, with the exception of the experiment at North Ridgeville in which the effects of nitrogen, phosphorus, potassium, and manure were compared in duplicate plots. At North Ridgeville in the fertilizer tests—(a) time of application, (b) rate of application, and (c) carriers of nitrogen—check plots were included at regular intervals in each series. In the stage-of-cutting test, the plots were in quadruplicate.

Some of the rates of seeding and rates of fertilization were excessive—more than would ordinarily be used in practice. The results obtained from some of these excessive rates, however, were useful in determining some of the principles involved.

Hay, when air dry, commonly contains approximately one-eighth moisture. Accordingly, the yields, as reported herein, are for air-dry hay assumed to contain 12.5 per cent of moisture. Correspondingly, the percentages of protein (nitrogen multiplied by 6.25) were calculated to a 12.5 per cent moisture basis. To reduce to a moisture-free basis, multiply the yields of hay, or divide the percentages of protein by 0.875.

DESCRIPTION OF SOILS

At Wooster, the experiment with chemical fertilizers was located on the Canfield silt loam. The area was not artificially drained. The general level of fertility was low. The experiment with carriers of nitrogen was situated on Wooster silt loam which was artificially drained and in a relatively high state of fertility. At North Ridgeville, the plots were located chiefly on the dark-colored phase of the Caneadea silty clay loam, extending into the dark-colored Lorain soil at both ends of the field. In prolonged dry periods both crack badly.

SEEDING IN DIFFERENT WAYS

Timothy is most commonly sown with some cereal as a companion crop. In Ohio it is seeded generally with wheat, occasionally with rye, in the fall; not infrequently in some parts of the State, especially northeastern Ohio, with oats in the spring. Occasionally, it is sown without a companion crop, and then most often in late summer. Red clover, mammoth clover, alsike clover, alfalfa, or some combination of these is usually seeded with timothy. Rarely is it seeded without the addition of some legume.

The purpose of these experiments was to determine the most favorable rate and time at which to sow timothy. Preliminary results have already been published (8). The fall seedings were made at the same time as the companion crop. The spring seedings on wheat or rye were made at the same time as the clover, i. e., in late March or early April, and on the surface of the ground, depending upon subsequent freezing and thawing to cover; the spring seedings with oats, at the same time as the oats. The yields as recorded in the tables represent the average of three plots, each 5 by 66 feet.

Rate of Sowing

TIMOTHY WITH CLOVER

With winter wheat as a companion crop.—In the tests in which winter wheat was used as a companion crop, three sets of plots were sown, each in a different year. The crops of the first season were harvested in 1925, 1927, and 1929; the crops of the second season from the same plots, in 1926, 1928, and 1930. The rates of seeding, the yields of hay in the first and second seasons, the average percentages of timothy, clover, and weeds in the first crop, and the yields of each of these were as shown in table 2. In these tests, the first-season crops consisted chiefly of timothy and clover in the first cutting and of clover in the second; the second-season crops were practically all timothy.

The increasing yields of mixed timothy and clover hay harvested in 1925 from one set of plots in which timothy was sown at progressively lower rates are illustrated in figure 1.

In the first-season crops, the highest yields in both the first and second cuttings were obtained from the use of 1.25, 2.5, and 5 pounds in 1925, 1927, and 1929, respectively.

Botanical analyses, the results of which are shown in table 2, were made of the first-season crops only. With each increment of timothy seed, there was a gradual increase in percentage of timothy and a corresponding decrease in percentage of clover in the hay. The falling-off in yield from the heavier seedings, illustrated in figure 2, was due chiefly to a decrease in the production of clover and, to some extent also, particularly in the excessively heavy rates (20, 40, and 80 pounds), to a decrease in timothy.

TABLE 2.—Yield and constituents of hay obtained from seeding timothy at different rates, clover at a uniform rate, *with wheat as a companion crop*—North Ridgeville

Seed		Pounds of hay per acre, 3-year average					Constituents of hay*					
		First season					Percentage			Pounds per acre		
Kind	Pounds per acre	First cutting	Second cutting	Total	Second season	Total both seasons	Timothy	Clover	Weeds	Timothy	Clover	Weeds
Timothy in fall No clover	10.00	1,391	129	1,520	1,528	3,048	98.9	0.9	0.2	1,376	12	3
Red clover only	10.00	2,325	1,437	3,762	1,402	5,164	3.2	93.9	2.9	74	2,183	68
Timothy in fall Red clover	1.25 10.00	2,919	1,538	4,457	2,678	7,135	39.9	59.1	1.0	1,165	1,725	29
Timothy in fall Red clover	2.50 10.00	3,053	1,526	4,579	2,744	7,323	43.9	55.3	.8	1,340	1,688	25
Timothy in fall Red clover	5.00 10.00	2,928	1,525	4,453	2,656	7,109	47.9	51.9	.2	1,403	1,520	6
Timothy in fall Red clover	10.00 10.00	2,644	1,436	4,080	2,448	6,528	56.2	43.6	.2	1,486	1,153	5
Timothy in fall Red clover	20.00 10.00	2,219	1,464	3,683	1,966	5,649	58.4	39.6	2.0	1,296	879	44
Timothy in fall Red clover	40.00 10.00	1,830	1,361	3,191	1,883	5,074	61.7	38.1	.2	1,129	697	4
Timothy in fall Red clover	80.00 10.00	1,652	1,231	2,883	1,795	4,678	68.4	31.5	.1	1,130	520	2
Timothy in spring Red clover	10.00 10.00	2,953	1,590	4,543	2,527	7,070	39.1	60.3	.6	1,155	1,781	17
Timothy in fall Timothy in spring Red clover	2.50 7.50 10.00	2,936	1,522	4,458	2,608	7,066	46.9	52.7	.4	1,377	1,548	12

*First cutting of first season only, 3-year average.

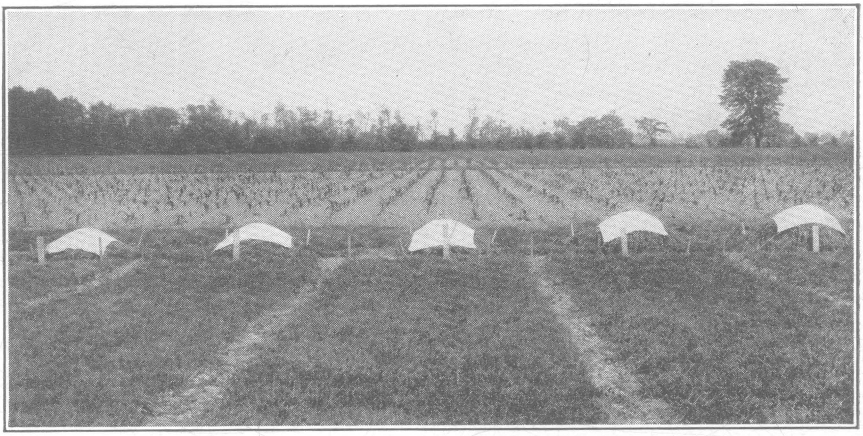

Fig. 1.—Mixed timothy and clover harvested at North Ridgeville in the first cutting in 1925

Timothy was sown with wheat in the fall at the rates of 80 (left), 40, 20, 5, and 2.5 pounds per acre.

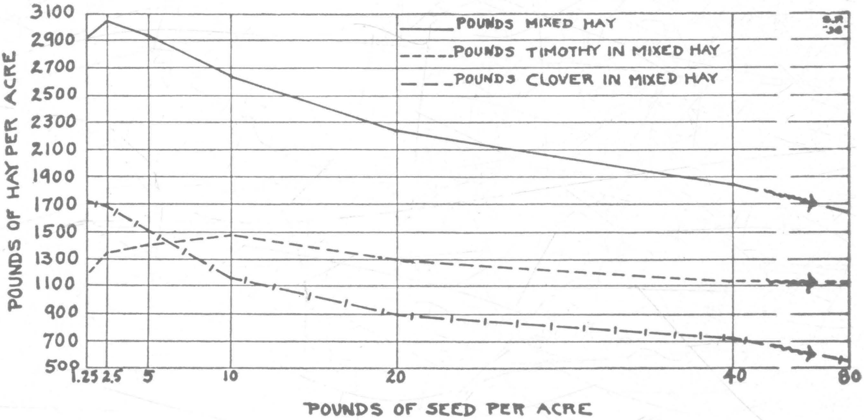

Fig. 2.—Effect of rate of sowing timothy in the fall upon the total yields, and upon the yields of timothy and clover in the first cutting of mixed hay

The records illustrated in this graph represent the averages of crops harvested in 1925, 1927, and 1929.

In the second cutting of the first-season crops, the effect of the rate of seeding on the yield of timothy was largely masked because the hay consisted almost exclusively of clover; the timothy seeded alone yielded but 129 pounds per acre. In this cutting the yields gradually decreased as the rate of seeding increased, but the amount of the decrease was not great even where the rates of seeding were excessive.

In the second-season crop, the highest yields were obtained from the use of 2.5 pounds in 1926 and 1928, and from 5 pounds in 1930.

As an average of all the tests, and regardless of the criterion used, whether the first-season or second-season crops or the sum of both, the highest yield was obtained from the use of 2.5 pounds per acre, and with each increment of seed it became progressively less. The maximum was approximately 200 pounds per acre higher than that obtained from either 1.25 or 5 pounds per acre, the nearest competitors. Considering 7,323 pounds, the maximum, as 100, then the relative yields from the use of 1.25, 2.5, 5, 10, 20, 40, and 80 pounds of seed per acre were 97, 100, 97, 89, 77, 69, and 64, respectively.

Further information in regard to the relation of rate of seeding timothy in the fall to yields was obtained in connection with another experiment, conducted largely for the purpose of determining the effect of nitrogenous fertilizer. The timothy was sown with winter wheat as a companion crop. Red clover was sown the following spring at the rate of 10 pounds per acre. The yields of mixed timothy and clover in 1932 are presented in table 3. The yields of almost pure timothy in 1933 and 1934 are included in the average yields shown in table 14. From each of these tables it may be noted that in this experiment the highest yields came from the use of 5 pounds of seed per acre.

TABLE 3.—Yield, constituents, and protein content of mixed hay* obtained from seeding timothy at different rates, clover at a uniform rate, with wheat as a companion crop—North Ridgeville

Seed	Pounds of hay per acre average of nine plots				Percentages of different constituents in first cutting, average of six plots†			Protein in first cutting, average of nine plots	
Kind	Pounds per acre	First cutting	Second cutting	Total	Timothy	Clover	Weeds	Percentage	Pounds per acre
Timothy in fall Red clover	2.5 10.0	4,067	1,764	5,831	53.3	43.4	3.3	9.05	368
Timothy in fall Red clover	5.0 10.0	4,238	1,717	5,955	65.1	34.1	.8	8.78	372
Timothy in fall Red clover	10.0 10.0	4,044	1,589	5,633	67.1	31.4	1.5	8.53	345
Timothy in fall Red clover	20.0 10.0	3,786	1,577	5,363	67.5	31.4	1.1	8.48	321
Timothy in fall Red clover	40.0 10.0	3,610	1,547	5,157	68.7	28.3	3.0	8.48	306

*The records are of air-dry hay containing approximately 12.5 per cent of moisture. To reduce to a moisture-free basis, multiply the yields of hay, or divide the percentages of protein by 0.875.
†Average of five plots for 5-pound rate of seeding.

With winter rye as a companion crop.—In the rye series timothy was sown in the fall of 1930 at five different rates—2.5, 5, 7.5, 10, and 20 pounds per acre. Red clover was sown in the spring of 1931 at the rate of 10 pounds per acre. The rates of sowing timothy, the yield per acre, the percentage of protein, and the yield of protein per acre in three successive seasons were as shown in table 4. The yields from year to year were somewhat inconsistent, but as a 3-year average, the highest was obtained from the 5-pound rate. The difference between it and the 2.5-pound rate, however, was negligible. With each increment above the 5-pound rate, there was a progressive decrease in yield.

TABLE 4.—Yield and protein content of hay obtained from seeding timothy at different rates, clover at a uniform rate, with rye as a companion crop—North Ridgeville

Seed		Pounds of hay per acre						Percentage of protein					Pounds of protein per acre					
Kind	Pounds per acre	1932—mixed hay			1933	1934	3-year average	1932		1933	1934	3-year average*	1932			1933	1934	3-year average
		First cutting	Second cutting	Total				First cutting	Second cutting				First cutting	Second cutting	Total			
Timothy in fall.... Red clover.........	2.5 10.0	3,586	1,468	5,054	2,667	1,632	3,118	8.67	11.84	5.87	5.76	6.77	311	174	485	157	94	245
Timothy in fall.... Red clover.........	5.0 10.0	3,647	1,453	5,100	2,709	1,577	3,129	7.91	11.84	6.55	6.05	6.84	288	172	460	177	95	244
Timothy in fall.... Red clover.........	7.5 10.0	3,487	1,315	4,802	2,522	1,471	2,932	8.03	12.48	5.64	5.53	6.40	280	164	444	142	81	222
Timothy in fall.... Red clover.........	10.0 10.0	3,275	1,274	4,549	2,585	1,534	2,889	7.74	11.84	5.58	5.25	6.19	253	151	404	144	81	210
Timothy in fall... Red clover.........	20.0 10.0	3,152	1,145	4,297	2,609	1,444	2,783	7.51	12.24	6.04	5.59	6.38	237	140	377	158	81	205
Timothy in spring Red clover.........	10.0 10.0	3,044	1,635	4,679	2,692	1,858	3,076	11.15	11.72	6.21	5.82	7.73	339	192	531	167	108	269
Timothy in fall... Timothy in spring Red clover........	2.5 7.5 10.0	4,142	1,597	5,739	3,296	1,935	3,657	8.32	11.84	5.58	5.59	6.50	345	189	534	184	108	275
Red clover only ...	10.0	2,857	1,643	4,500	1,993	1,531	2,675	10.29	13.48	5.58	5.42	7.10	294	221	515	111	83	236

*Exclusive of second cutting in 1932.

With oats as a companion crop.—In a test with oats as a companion crop, timothy was sown at three different rates, 5, 10, and 20 pounds, together with 10 pounds of medium red clover per acre. There were three series of plots, sown in 1927, 1928, and 1929, respectively. The crops from these seedings consisted of a mixture of timothy and clover in each of the first years, and of almost clear timothy in each of the second seasons, 1929, 1930, and 1931. Two cuttings were obtained in the first-season crops in 1928 and 1929 and one cutting in 1930. One cutting only was obtained of each of the second-season crops. The yields in each year of both the first- and second-season crops, the 3-year averages of each separately and of both combined, and the percentages of timothy in the first-season crops were as shown in table 5.

In these spring seedings, the yields, especially in the second-season crops, were not influenced greatly by the rates of seeding. In the first-season crop, however, a consistent though small lead was maintained by the 10-pound rate. This result differed from the fall seedings in that the quantity of seed required for maximum growth was higher, 10 pounds instead of 2.5 or 5 pounds. Moreover, the use of 20 pounds per acre did not reduce materially the yield; whereas in the fall seedings, made with either wheat or rye as a companion crop, the yield became progressively and markedly less with each increment of seed beyond 2.5 or 5 pounds. It appears evident that timothy plants grown from seed sown at the same time as the clover in the spring do not compete as severely with the clover as do timothy plants which have already made considerable growth from seed sown in the preceding autumn.

TIMOTHY WITHOUT CLOVER

With rye as a companion crop.—In a series of timothy plots sown with rye as a companion crop, and without clover, seedings were made in the fall of 1930 at four different rates—2.5, 5, 10, and 20 pounds per acre. The rates of seeding, the yields per acre, the percentages of protein, and the yields of protein in 3 successive years, 1932, 1933, and 1934, were as shown in table 6. The yields obtained were highest from the lightest rate of seeding in each of the 3 years, and with each increment of seed there was a decrease. As an average of 3 years, the 2.5-pound rate led its nearest competitor, the 5-pound rate, by over 300 pounds per acre.

Alone: no companion crop.—Further information in regard to the relation of rate of sowing to the yields of hay, where timothy is grown without either companion crop or clover, was obtained in 1932. The results for this year are included in the average for 3 years shown in table 14. In the unfertilized plots, the yields produced by 2.5, 5.0, 10.0, 20.0, and 40.0 pounds of timothy seed were, respectively, 4,694, 4,929, 4,637, 3,549, and 2,991 pounds of hay per acre. In these plots, and also in the plots fertilized with nitrogen at different times and rates, the yields from the 5-pound rate exceeded all others. With each increment of seed the yields became progressively less, on both unfertilized and fertilized plots, and regardless of the time or rate of application of the nitrogen.

SUMMARY OF RESULTS OF THE RATE-OF-SEEDING TESTS

When timothy was sown with oats in the spring, somewhat higher yields were obtained from 10 pounds of timothy seed per acre than from any other rate. However, with no exceptions, in the tests in which timothy seed was sown in the fall, whether with wheat or with rye or without any companion crop,

TABLE 5.—Yield of hay obtained from seeding timothy at different rates, clover at a uniform rate, with oats as a companion crop—North Ridgeville

Seed		Pounds of hay per acre													
		First season—mixed hay								Second season—mostly timothy					
		1928			1929										
Kind	Pounds per acre	First cutting	Second cutting	Total	First cutting	Second cutting	Total	1930	3-year average	1929	1930	1931	3-year average	Total first and second seasons 3-year average	Average percentage of timothy in first cutting
Timothy .... Red clover............	5.0 10.0	1,921	599	2,520	2,744	2,601	5,345	2,305	3,390	2,686	1,529	3,834	2,683	6,073	41
Timothy .... Red clover............	10.0 10.0	2,003	747	2,750	2,702	2,874	5,576	2,337	3,554	2,792	1,585	3,853	2,743	6,297	44
Timothy .... Red clover............	20.0 10.0	1,985	726	2,711	2,634	2,828	5,462	2,327	3,500	2,920	1,574	3,854	2,783	6,283	43

TABLE 6.—Yield and protein content of hay obtained from seeding timothy at different rates in the fall with rye as a companion crop, no clover—North Ridgeville

	Pounds of hay per acre						Percentage of protein					Pounds of protein per acre					
	1932						1932					1932					
Pounds of seed per acre	First cutting	Second cutting	Total	1933	1934	3-year average	First cutting	Second cutting	1933	1934	3-year average*	First cutting	Second cutting	Total	1933	1934	3-year average
2.5........................	3,016	282	3,298	2,056	1,597	2,317	6.47	7.97	5.47	5.42	5.79	195	23	218	112	87	139
5.0..................	2,602	232	2,834	1,848	1,305	1,996	6.24	7.73	5.30	5.99	5.84	162	18	180	98	78	119
10.0.......................	2,312	171	2,483	1,680	1,170	1,778	6.64	8.02	5.87	5.42	5.98	154	14	168	99	63	110
20.0............	2,167	160	2,327	1,581	1,134	1,681	5.90	9.84	6.21	5.93	6.01	128	16	144	98	67	103

*Exclusive of second cutting in 1932.

and whether grown in mixture with red clover or alone, higher yields were obtained from 5 pounds or less of seed than from any higher rate. In the crops of 16 seasons harvested in these tests, the highest yield was obtained once from 1.25 pounds, seven times from 2.5 pounds, and eight times from 5.0 pounds of timothy seed per acre.

Time of Sowing

FALL VERSUS SPRING

A comparison of fall and spring seeding of timothy, both at the rate of 10 pounds per acre and supplemented with medium red clover sown at the same rate, is afforded in tables 2 and 4 with wheat and rye, respectively, as companion crops. There was a gain in favor of the spring seeding in the first-season crops of the 3 years, 1925, 1927, and 1929, and in two of the second-season crops, 1926 and 1928. The total increase in both, as an average of 3 years, was 542 pounds per acre. The increase, at least in the first-season crops, was due to the heavier growth of clover, for the proportion of clover in the fall and spring seedings was approximately 44 and 60 per cent, respectively.

Likewise, timothy seeded in rye as a companion crop (table 4) gave a higher yield from spring than from fall seeding in 3 successive years. The gain, however, was small, being, as an average of the entire period, only 187 pounds per acre.

In both series of plots, however, smaller yields of hay were obtained from 10 pounds of timothy sown in the spring than from 2.5 or 5 pounds sown in the fall.

PART IN FALL AND PART IN SPRING

From tables 2 and 4 it is possible also to note the effect of split seedings, that is, part in the fall and part in the spring. In the tests with wheat as a companion crop the split seeding outyielded the fall, where 10 pounds of seed were used. The increase was due largely to the approximately 9 per cent more clover in the first-season crops. In this connection, it is perhaps worthy of note that the addition of 7.5 pounds of seed in the spring to the 2.5 pounds sown in the fall yielded, in the first-season crop, as an average of 3 years, 121 pounds less than did the 2.5 pounds used alone in the fall. In the tests with rye as a companion crop the split seeding yielded, in each one of the 3 years, more than any one of the fall seedings, regardless of the quantity of seed used.

The sowing of one-fourth of the timothy in the fall and three-fourths of it in the spring compared with sowing all in the spring gave, as an average of 3 years, practically the same yields, with wheat as a companion crop. With rye as a companion crop, however, and with one seeding only, there was, as an average of 3 years, a gain of 581 pounds in favor of the split seeding.

Timothy Alone, Clover Alone, and Timothy and Clover Combined

With wheat as a companion crop (table 2), timothy and red clover, each seeded alone and each at the rate of 10 pounds per acre, yielded, as an average of 3 years, in the first season 1,520 and 3,762 pounds, respectively; both seeded together and each at the rate of 10 pounds per acre yielded 4,080 pounds. This yield is more than either alone, thus showing that in yield the two complement each other.

In each of the three second-season crops in the plots where both timothy and clover were sown, the yield was practically clear timothy; almost all of the clover had died out and disappeared. The second-season crops from mixed seeding yielded, as an average of 3 years, 2,448 pounds, an increase of 920 pounds over the yield of timothy which had been sown alone. Presumably this increase was due to the residual effect of the clover growing in the meadow in the preceding year. On the clover plots the growth of volunteer timothy and other plants amounted, on the average, to 1,402 pounds, only 126 pounds less than that from plots seeded to timothy.

Protein Content of the Hay as Affected by Rate and Time of Seeding

PERCENTAGE OF PROTEIN IN THE HAY

The percentages of protein in the first crop of mixed hay, on the plots in which timothy was grown with red clover, decreased as the rate of seeding increased, as is shown by the records in table 3. This may be attributed to the larger percentage of clover in the hay from plots in which the timothy had been sown at the lighter rates.

In timothy sown with rye and without clover (table 6) there was on the average a gradual increase from 6.00 per cent of protein in the hay from plots sown at the rate of 2.5 pounds per acre to 6.13 per cent in plots sown at the rate of 20 pounds per acre. On the other hand, in timothy harvested in 1932 which was grown without a companion crop and not in mixture with clover, as the rate of seeding increased from 2.5 to 40 pounds per acre, there was a gradual decrease from 5.70 to 5.24 per cent of protein in the hay. The net results of these experiments indicate that as the rate of sowing timothy is increased from 2.5 to 40 pounds per acre, there is not likely to be any substantial increase, and there may be a slight decrease in the percentage of protein.

YIELDS OF PROTEIN

Tables 3, 4, and 6 and the data included in the average in table 14 show that as the rate of sowing timothy increased, there was a gradual decrease in the yield per acre of protein. This statement applies to mixed timothy and clover, also to timothy grown alone. The yields of protein are correlated closely with the yields of hay.

Duration of the Effect of Different Rates of Seeding

Four of the tests, none of which was continued longer than 3 years, afforded opportunity to observe the lasting effect of seedings made at different rates. In the two series of tests with rye as a companion crop, the effect of the rate of seeding was perceptible in the third year, but it was less pronounced where the timothy was accompanied by clover (compare tables 4 and 6). In each instance, the highest yields in the third year, 1934, were obtained from the 2.5-pound rate. In the series with clover, the relative yields from 2.5, 5, 7.5, 10, and 20 pounds of timothy seed were 100, 97, 90, 94, and 86; in the series of timothy alone, the relative yields from plots sown with 2.5, 5, 10, and 20 pounds of timothy per acre were 100, 82, 73, and 71.

In the tests using wheat as a companion crop (table 2) the effect of the rate of seeding timothy in a timothy-clover mixture was clearly evident in the second-season crops. Beyond the use of 2.5 pounds per acre, the average yields decreased with each increment of seed. If the relative yield from the use of 2.5 pounds per acre is considered as 100, then those from the use of 5, 10, 20, 40, and 80 pounds were 97, 89, 69, and 65, respectively. In these tests, yields were obtained in the third successive year from one series only, and although these are not recorded, they showed no decline from the heavier rates of seeding. In fact, the yield from the extremely heavy rates—40 and 80 pounds per acre—exceeded those from the lighter rates.

In the fourth test, mixed timothy and clover were harvested in 1932 (table 3) and timothy in 1933 and 1934 (table 14). In this test, on the unfertilized plots, the highest yield was obtained in each season where timothy had been sown at the rate of 5 pounds per acre. If the yield from these plots is rated at 100, then the relative yields in the third season from plots sown at the rates of 2.5, 5, 10, 20, and 40 pounds per acre were 90, 100, 95, 94, and 94, respectively.

It may be concluded from these tests that the effect of different rates of seeding tends to diminish as the meadows become older, but may persist for at least 3 years.

FERTILIZATION

Kinds and Quantities of Fertilizers

EXPERIMENT AT NORTH RIDGEVILLE

To note the response of timothy to commercial fertilizers and manure, a test was conducted at North Ridgeville from 1918 to 1927, inclusive. A summary of the results was given in an earlier publication (9).

In this test all treatments were made in duplicate and each series of plots contained three checks. All the fertilizers, including the open-yard manure, were applied in the spring, and all except a part of the manure top-dressings were made annually. Some of the latter were made biennially. The kind and quantity of fertilizers used, the annual and 10-year average yields, and the increases were as shown in table 7.

In the first 2 years the stand on all plots was practically clear timothy. In the third year, 1920, however, volunteer clover, principally alsike, appeared in the check plots and in all the fertilized plots except the ones receiving nitrate of soda alone; in these the stand of practically clear timothy existed. As the experiment progressed, clover continued to form a constituent of the hay crop, more in some years than in others, and its distribution was much the same as in 1920, though the percentages were smaller in plots where nitrate was used with mineral fertilizers than in the plots fertilized only with superphosphate. There were comparatively few weeds in the plots until 1926, when the stand of timothy in all plots began to decrease and the proportion of weeds to increase.

Nitrate of soda was very effective in causing increases in the yields of hay. The use of superphosphate also resulted in definite increases in the yields of hay. During the first 2 years the gains from superphosphate were small, but during and after the third season they were more marked; in some seasons the gains from 240 pounds of superphosphate were greater than those from 120 pounds of nitrate of soda. The increases in the yields of hay where superphosphate was used were due largely to the increased growth of volunteer clover. Nitrate of soda alone was less effective than nitrate used in combination with superphosphate. The yields were still further increased by the addition of 80 pounds of muriate of potash to the other two fertilizers.

TABLE 7.—Yield obtained from top-dressing timothy with different kinds and quantities of fertilizer, on the same plots continuously, 1918-1927, inclusive—North Ridgeville

Fertilizer		Pounds of hay per acre											
Kind	Quantity per acre*	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	10-year average	Increase
	Pounds												
None	....	2,692	2,741	2,580	2,594	3,149	2,121	2,881	1,359	2,248	1,561	2,393	....
Superphosphate (16 per cent)	240	2,786	2,884	2,986	3,283	3,921	2,858	3,376	1,749	3,460	2,325	2,963	570
Nitrate of soda	120	3,400	3,817	3,421	3,646	3,827	3,002	3,975	1,754	3,057	1,960	3,186	793
Superphosphate (16 per cent) Nitrate of soda	120 60	3,219	3,563	3,182	3,453	4,105	3,069	3,900	1,798	3,576	2,669	3,253	860
Superphosphate (16 per cent) Nitrate of soda	240 120	3,690	3,995	3,562	3,705	3,942	3,400	4,052	1,880	3,785	2,818	3,483	1,090
Superphosphate (16 per cent) Muriate of potash Nitrate of soda	240 80 120	3,629	3,895	3,617	3,850	4,175	3,544	4,733	2,206	4,118	3,220	3,699	1,306
	Tons												
Manure	5	2,471	3,144	3,227	3,676	4,309	2,943	4,117	1,881	3,902	3,171	3,284	891
Manure biennially	5	2,706	2,871	3,107	3,101	4,031	2,898	3,770	1,728	3,324	2,558	3,009	616
Manure biennially	10	2,386	2,930	3,443	3,199	4,085	2,815	3,716	1,580	3,540	2,266	2,996	603

*Annually unless otherwise specified.

Five tons of barnyard manure applied annually were approximately equal to applications of 120 pounds of superphosphate and 60 pounds of nitrate of soda. Applications of manure in alternate years did not give as great gains. In this experiment, smaller yields were obtained from 10 tons than from 5 tons of manure applied biennially; possibly some inequality of soil conditions in different plots may explain this result.

EXPERIMENT AT WOOSTER

A similar test, in which different kinds and quantities of fertilizers were used, was started at Wooster on the Snyder farm in the spring of 1927. The timothy was seeded on a well-prepared seedbed at the rate of 15 pounds per acre and with Fulghum oats as a companion crop; the latter was sown at the rate of 1 bushel per acre. The seedings were made on triplicate 1/60-acre plots (5.35 by 136 feet). Before seeding, the various fertilizer treatments were applied directly and worked into the soil. After the initial treatment, applications were made annually in the spring about the first of April as top-dressings. The kind and quantity of fertilizer, the yields and increases per acre of hay, the percentages and the yields and increases per acre of protein, and the recoveries of added nitrogen were as shown in table 8.

At Wooster, neither the superphosphate alone nor the mixture of superphosphate and potash increased the yield, but the addition of nitrate of soda to the mixture gave a gain, and with each increment there was not only a further increase in yield, but also an increase in the percentage of protein and a marked increase in yield of protein. The wide variability in yield of hay from year to year was closely correlated with the May and early June rainfall, as shown in figure 3.

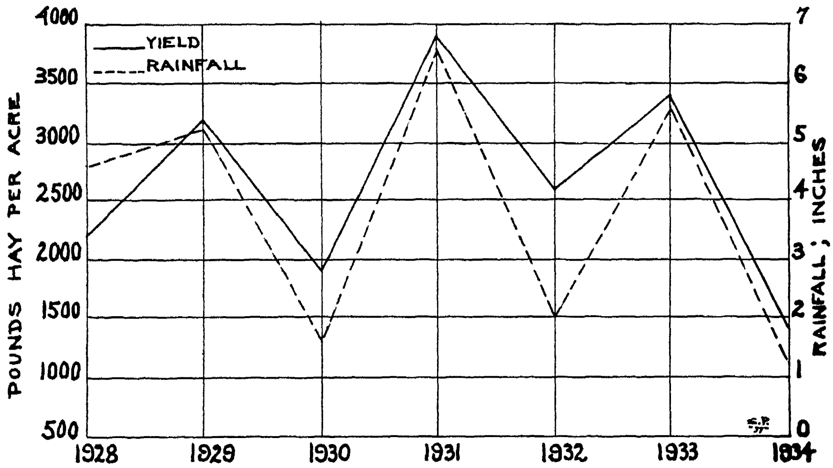

Fig. 3.—Relation of yield of hay to May and early June rainfall
(May 1-June 15, inclusive)

TABLE 8.—Yield and protein content of hay obtained from top-dressing timothy with different kinds and quantities of fertilizer, 1928-1934, inclusive*—Wooster

(Seeded in the spring of 1927 with oats)

Plots No.	Fertilizer: Kind	Fertilizer: Pounds per acre annually	1928	1929	1930	1931	1932	1933	1934	7-year average	Increase + Decrease —	Recovery of added nitrogen per cent
	Pounds of hay per acre											
1- 8-15	None	....	1,260	1,820	1,060	2,440	2,460	2,140	840	1,717	....	....
2- 9-16	Superphosphate (20 per cent)	140	1,300	1,900	1,020	3,040	2,020	2,240	640	1,737	+ 20	....
3-10-17	0-14-6	200	1,360	1,840	1,180	2,560	1,680	2,340	760	1,674	— 43	....
4-11-18	0-14-6 Nitrate of soda	200 50	1,460	2,600	1,460	3,680	1,960	2,920	860	2,134	+ 417	....
5-12-19	0-14-6 Nitrate of soda	200 100	1,900	3,160	1,900	4,240	2,260	3,240	820	2,503	+ 786	....
6-13-20	0-14-6 Nitrate of soda	200 200	2,980	4,540	2,720	5,380	3,140	4,840	920	3,503	+1,786	....
7-14-21	0-14-6 Nitrate of soda	200 400	5,140	6,120	3,920	5,980	4,520	6,180	1,340	4,743	+3,026	....
	Average of all plots	....	2,200	3,140	1,894	3,903	2,577	3,414	883	....	....	....
	Per cent of protein											
1- 8-15	None	....	8.12	4.79	5.66	4.90	6.49	6.05	4.97	5.85	....	....
2- 9-16	Superphosphate (20 per cent)	140	8.01	5.30	5.31	4.48	6.38	6.11	5.80	5.91	....	....
3-10-17	0-14-6	200	8.43	5.90	5.59	4.72	6.43	5.24	5.97	6.04	....	....
4-11-18	0-14-6 Nitrate of soda	200 50	7.42	4.32	5.89	5.14	6.61	5.29	5.73	5.77	....	....
5-12-19	0-14-6 Nitrate of soda	200 100	7.39	4.91	6.23	6.08	6.61	5.17	5.44	5.98	....	....
6-13-20	0-14-6 Nitrate of soda	200 200	7.83	3.80	6.75	6.19	6.43	5.48	5.97	6.06	....	....
7-14-21	0-14-6 Nitrate of soda	200 400	10.33	4.19	8.13	7.84	7.32	5.24	5.85	6.98	....	....

*The records are of air-dry hay containing approximately 12.5 per cent of moisture. To reduce to a moisture-free basis, multiply the yields of hay, or divide the percentages of protein by 0.875.

TABLE 8.—Yield and protein content of hay obtained from top-dressing timothy with different kinds and quantities of fertilizer, 1928-1934, inclusive*—Wooster—continued

(Seeded in the spring of 1927 with oats)

Plots No.	Fertilizer: Kind	Fertilizer: Pounds per acre annually	1928	1929	1930	1931	1932	1933	1934	7-year average	Increase + Decrease —	Recovery of added nitrogen per cent
			Pounds of protein per acre									
1- 8-15	None	....	102	87	60	120	160	129	42	100	....	....
2- 9-16	Superphosphate (20 per cent)	140	104	101	54	136	129	137	37	100	....	....
3-10-17	0-14-6	200	115	109	66	121	108	123	45	98	....	....
4-11-18	0-14-6 Nitrate of soda	200 50	108	112	86	189	130	154	49	118	+ 18	37
5-12-19	0-14-6 Nitrate of soda	200 100	140	155	118	258	149	168	45	148	+ 48	50
6-13-20	0-14-6 Nitrate of soda	200 200	233	173	184	333	202	265	55	206	+106	55
7-14-21	0-14-6 Nitrate of soda	200 400	531	256	319	469	331	324	78	330	+230	59

*The records are of air-dry hay containing approximately 12.5 per cent of moisture. To reduce to a moisture-free basis, multiply the yields of hay, or divide the percentages of protein by 0.875.

Rate of Application of Nitrogen

The Wooster test and also the earlier test at North Ridgeville (9) leave some doubt as to the quantity of nitrogen that may well be applied. Further information on this point is afforded by a rate-of-application experiment at North Ridgeville. The plots were measured off in the spring of 1930 in an established timothy meadow. It had produced a crop of mixed clover and timothy in 1928, mostly timothy in 1929, and was practically free from clover and weeds in 1930. Triplicate series of 13 plots each were established, and every sixth plot in each series was left as a check. The plots contained one-eightieth of an acre, approximately 68 by 8 feet. All plots, including the checks, were given a basic treatment of an 0-14-6 fertilizer at the rate of approximately 200 pounds per acre, April 2, 1930, and again May 2, 1932. The quantities of nitrate of soda applied annually on the plots receiving nitrogen, the yields and increases of hay, the percentages of protein, the pounds of protein per acre, and the recoveries of added nitrogen were as shown in table 9.

With the exception of 1 year, 1931, when the highest total yield was obtained from the 1,600-pound rate, the results were fairly uniform; the maximum fell on the 400-pound rate in 1930 and 1932 and on the 300-pound rate in 1933 and 1934. In the very dry season of 1934, the 200-pound rate ranked second. On the basis of the 5-year average, however, there was with each increment of nitrate of soda, an increase in yield up to and including the 400-pound rate. After that, the yields, with one exception, became progressively smaller.

In 2 years a second crop was obtained. In each case it constituted a relatively small part of the whole. It was only 9 and 5 per cent as great as the first crop in 1931 and 1932, respectively.

Returning again to the yields (table 9), the gradual decline which accompanied the rates of application heavier than 400 pounds of nitrate of soda was probably due to a progressive thinning of the stand of plants.

In the fall of 1934, after five annual treatments had been made, the contrast between the stands in the checks and the plots receiving the heaviest application was very marked, as illustrated in figure 4. In the plots fertilized with 1,600 pounds of nitrate of soda per acre, there was a much less dense growth of aboveground parts of the plants. The effects upon root development are shown in table 10, which gives the calculated root growth per acre on check plots and on those to which nitrate of soda had been applied at the rates of 200, 400, and 1,600 pounds per acre. The weights as recorded in table 10 were calculated from the quantity of roots found in a volume of soil 4⅛ inches in diameter and 10 inches deep. After the stubble had been removed, the roots were carefully washed out of the soil, oven-dried to constant weight at approximately 101° C., and weighed. Since it is impractical to remove the last traces of closely adhering soil particles, the dried samples were then ashed at a low red heat. If it is assumed that all the adhering material was noncumbustible, then the loss by ignition represented the approximate weight of the roots. In all cases the results represent the average of six determinations—two from each plot and a plot from each of the three series.

TABLE 9.—Yield and protein content of hay obtained from top-dressing timothy with nitrate of soda at 10 different rates, 1930-1934, inclusive*—North Ridgeville

Plots No.	Pounds of nitrate per acre	1930	1931 Cutting First	1931 Cutting Second	1931 Total	1932 Cutting First	1932 Cutting Second	1932 Total	1933	1934	5-year average	Increase per acre 5-year average	Recovery of added nitrogen per cent
						Pounds of hay per acre							
Checks (nine)	None	2,800	2,749	421	3,170	2,935	269	3,204	2,359	1,467	2,600†	....	....
2-15-28......	50	3,017	3,259	377	3,636	3,288	191	3,479	2,872	1,710	2,943	343	....
3-16-29......	100	3,628	3,691	368	4,059	3,815	158	3,973	3,478	1,951	3,418	818	....
4-17-30......	200	4,088	4,640	405	5,045	4,428	170	4,598	4,370	2,212	4,063	1,463	....
5-18-31......	300	4,682	5,100	448	5,548	5,260	188	5,448	5,198	2,252	4,626	2,026	....
6-19-32......	400	4,839	5,488	384	5,872	5,461	195	5,656	5,037	2,184	4,718	2,118	....
8-21-34......	500	4,588	5,295	418	5,713	5,289	238	5,527	4,828	2,080	4,547	1,947	....
9-22-35.....	600	4,791	5,349	459	5,808	5,258	269	5,527	4,842	2,128	4,619	2,019	....
10-23-36......	800	4,693	5,498	436	5,934	4,949	262	5,211	4,532	2,036	4,481	1,881	....
11-24-37......	1,200	4,742	5,251	458	5,709	4,831	280	5,111	4,390	1,843	4,359	1,759	....
12-25-38......	1,600	4,718	5,496	462	5,958	4,870	331	5,201	4,122	1,725	4,345	1,745	....
						Per cent of protein							
Checks (nine)	None	4.84	5.77	9.27	....	5.38	10.66	....	6.67	7.53	6.04‡	....	....
2-15-28.....	50	4.52	6.29	8.55	....	5.00	10.50	....	5.84	7.37	5.80	....	....
3-16-29......	100	4.76	5.90	7.86	....	4.65	9.07	....	5.65	7.94	5.78	....	....
4-17-30......	200	5.00	6.47	8.83	....	4.82	9.18	....	5.58	8.53	6.08	....	....
5-18-31......	300	4.44	8.26	8.31	....	5.34	9.30	....	5.83	9.00	6.57	....	....
6-19-32......	400	5.71	7.10	9.53	....	5.79	9.30	....	6.18	9.34	6.82	....	....
8-21-34......	500	5.47	8.08	9.13	....	6.43	9.58	....	6.81	9.47	7.21	....	....
9-22-35......	600	6.47	7.62	10.52	....	7.40	9.99	....	7.33	9.76	7.72	....	....
10-23-36......	800	6.41	8.26	10.52	....	7.46	9.82	....	8.04	10.04	8.04	....	....
11-24-37......	1,200	6.41	8.08	10.74	....	6.77	10.90	....	8.95	9.63	7.97	....	....
12-25-38......	1,600	6.75	9.53	11.96	....	7.29	11.24	....	9.37	9.99	8.59	....	....

*The records are of air-dry hay containing approximately 12.5 per cent of moisture. To reduce to a moisture-free basis, multiply the yields of hay, or divide the percentages of protein by 0.875.
†Includes both first and second cuttings.
‡All averages in last column are for first cuttings only.

TABLE 9.—Yield and protein content of hay obtained from top-dressing timothy with nitrate of soda at 10 different rates, 1930-1934, inclusive*—North Ridgeville—continued

Plots No.	Pounds of nitrate per acre	1930	1931 Cutting First	1931 Cutting Second	1931 Total	1932 Cutting First	1932 Cutting Second	1932 Total	1933	1934	5-year average	Increase per acre 5-year average	Recovery of added nitrogen per cent
						Pounds of protein per acre							
Checks (nine)	None	135	159	39	198	158	29	187	157	110	157§	....	....
2-15-28.....	50	136	205	32	237	164	20	184	168	126	170	13	27
3-16-29......	100	173	218	29	247	177	14	191	197	155	193	36	37
4-17-30......	200	204	300	36	336	213	16	229	244	189	240	83	43
5-18-31.....	300	208	421	37	458	281	17	298	303	203	294	137	47
6-19-32......	400	276	390	37	427	316	18	334	311	204	310	153	39
8-21-34......	500	251	428	38	466	340	23	363	329	197	321	164	34
9-22-35......	600	310	408	48	456	389	27	416	355	208	349	192	33
10-23-36......	800	301	454	46	500	369	26	395	364	204	353	196	25
11-24-37......	1,200	304	425	49	474	327	30	358	393	178	341	184	16
12-25-38......	1,600	319	524	55	578	355	37	392	386	172	369	212	14

*The records are of air-dry hay containing approximately 12.5 per cent of moisture. To reduce to a moisture-free basis, multiply the yields of hay, or divide the percentages of protein by 0.875.

†Includes both first and second cuttings.

‡All averages in last column are for first cuttings only.

§Includes both first and second cuttings.

Fig. 4.—No nitrate of soda (left); nitrate of soda (right) at the rate of 1,600 pounds per acre in the spring of 1930, 1931, 1932, 1933, and 1934

September 14, 1934. North Ridgeville.

In view of the great difficulty in securing representative samples, the figures should be regarded as rough approximations only. This meadow had produced a crop of hay for seven seasons. A new set of timothy shoots with new root systems had developed each year. A very large part of the combustible material recorded in table 10 as roots actually may have been partially decayed roots accumulated from the growth of previous seasons and no longer a part of the growing plants. Woods (33) found a much smaller quantity, 2,444 pounds per acre, to a depth of 12 inches. On the other hand, Weaver and Harmon (30) found similar quantities of roots and rooting stems in the soil in prairies of eastern Nebraska. They concluded that the amount of plant materials in the soil far exceeds the tonnage of hay produced.

TABLE 10.—Effect of nitrate of soda on root development of timothy

Pounds of nitrate of soda per acre......................	Check	200	400	1,600
Pounds (oven-dried) of roots per acre	6,240	7,008	6,129	5,984

Table 9 shows that during the 5-year period at North Ridgeville, as the applications of nitrate of soda gradually increased above 400 pounds per acre, the average yields were progressively smaller. With the smaller applications of 100, 200, 300, and 400 pounds of nitrate of soda per acre, for each 100-pound unit of fertilizer used there were gains, respectively, of 818, 731, 675, and 529 pounds of hay, and of 36, 41, 46, and 38 pounds of protein per acre. These figures, illustrating the economic law of diminishing returns, indicate that applications of nitrogen are more efficiently made at rates of 200 to 300 pounds of nitrate of soda, or their equivalent in the form of some other nitrogen carrier, than at higher rates.

A second test was conducted at Wooster in which 11 different nitrogenous carriers were used, each in such quantities as to supply nitrogen at the rates of 31 and 62 pounds per acre (equivalent to 200 and 400 pounds of nitrate of soda per acre). The test extended through 5 years, 1930-1934, inclusive. In the first year of the test, 1930, the yield of 10 of the 11 carriers was greater from the heavier than from the lighter applications, and in the other case it was equal. In succeeding years, however, two carriers only gave a higher yield from the heavier applications. Both organic and inorganic carriers were used, and the average performance of each group from both rates of application is shown graphically in figure 5.

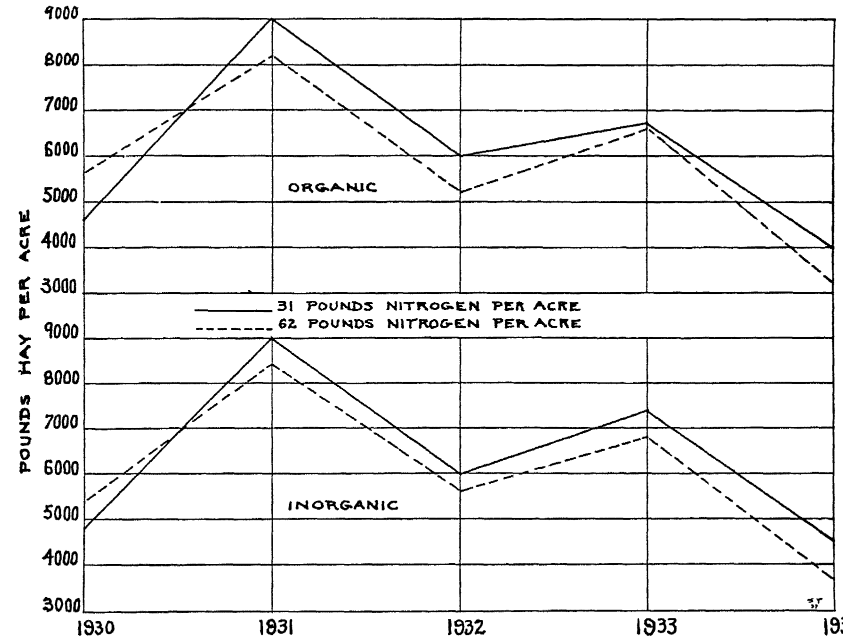

Fig. 5.—Comparative yield of timothy from organic and inorganic carriers of nitrogen, both used at two different rates

Experiment conducted at Wooster

Time of Application of Nitrogen

To determine the most favorable time to top-dress timothy with a nitrogenous fertilizer, an experiment was started in 1930 at North Ridgeville, in which nitrate of soda was applied at the rate of 200 pounds per acre at different times. The number and size of plots and their basic treatments were identical with those in the rate-of-application test. The location of this series was parallel and adjacent to the rate-of-application test. The times of application of the nitrate of soda, the yields and increases per acre, the percentages and yields of protein, and the recoveries of added nitrogen were as shown in table 11.

TABLE 11.—Yield and protein content of hay obtained from top-dressing timothy with nitrate of soda (200 pounds per acre) at different times, 1930-1934, inclusive*—North Ridgeville

Plots No.	Time of application	1930	1931 Cutting First	1931 Cutting Second	1931 Total	1932 Cutting First	1932 Cutting Second	1932 Total	1933	1934	5-year average	Increase per acre 5-year average	Recovery of added nitrogen per cent
	Pounds of hay per acre												
Checks (nine)	None	2,886	2,716	621	3,337	2,476	292	2,768	2,702	1,487	2,636†	....	....
2-15-28	October 1 (April in 1930)	4,293	4,606	670	5,276	3,622	244	3,866	4,296	2,136	3,893‡	1,320‡	....
3-16-29	March 15	4,228	4,579	593	5,172	4,128	212	4,340	4,701	2,148	4,118	1,482	....
4-17-30	April 1	4,477	4,701	606	5,307	4,109	191	4,300	3,979	2,240	4,061	1,425	....
5-18-31	April 1 and 10 days before cutting	4,618	4,937	815	5,752	4,327	451	4,778	4,679	2,352	4,436	1,800	....
6-19-32	April 1 and immediately after cutting	4,309	5,375	989	6,364	4,495	579	5,074	4,572	2,351	4,535	1,899	....
8-21-34	April 15	4,215	4,565	654	5,219	4,083	198	4,281	4,673	2,297	4,137	1,501	....
9-22-35	May 1	4,280	4,736	595	5,331	3,932	183	4,115	4,239	2,137	4,020	1,384	....
10-23-36	May 15	3,757	4,738	644	5,382	3,412	252	3,664	4,002	2,110	3,783	1,147	....
11-24-37	June 1	3,206	4,006	665	4,671	2,746	422	3,168	3,503	2,040	3,318	682	....
12-25-38	June 15	2,939	3,189	931	4,120	2,602	480	3,082	3,245	1,955	3,068	432	....
	Per cent of protein												
Checks (nine)	None	5.00	6.20	9.37	....	5.17	10.15	....	5.09	7.30	5.75§	....	....
2-15-28	October 1	5.77	5.49	9.53	....	4.35	9.04	....	4.12	7.41	5.43	....	....
3-16-29	March 15	4.68	5.90	9.13	....	4.58	9.15	....	4.00	7.48	5.33	....	....
4-17-30	April 1	4.76	5.88	8.43	....	5.03	9.21	....	3.82	8.07	5.51	....	....
5-18-31	April 1 and 10 days before cutting	5.77	6.24	9.13	....	5.66	8.01	....	4.52	9.07	6.25	....	....
6-19-32	April 1 and immediately after cutting	5.40	5.83	10.05	....	5.21	9.15	....	4.29	9.07	5.96	....	....
8-21-34	April 15	4.51	6.64	9.88	....	5.21	8.41	....	5.09	8.12	5.91	....	....
9-22-35	May 1	5.15	6.29	8.26	....	5.21	7.83	....	4.92	8.90	6.09	....	....
10-23-36	May 15	5.94	8.72	8.72	....	6.07	8.98	....	5.60	9.48	7.16	....	....
11-24-37	June 1	6.24	9.13	9.47	....	6.23	8.47	....	6.40	8.36	7.27	....	....
12-25-38	June 15	6.53	8.31	9.24	....	6.18	9.04	....	6.23	8.36	7.12	....	....

*The records are of air-dry hay containing approximately 12.5 per cent of moisture. To reduce to a moisture-free basis, multiply the yields of hay, or divide the percentages of protein by 0.875.

†Includes both first and second cuttings.

‡4-year averages, 1931-1934, inclusive.

§All averages in last column are for first cuttings only.

TABLE 11.—Yield and protein content of hay obtained from top-dressing timothy with nitrate of soda (200 pounds per acre) at different times, 1930-1934, inclusive*—North Ridgeville—continued

Plots No.	Time of application	1930	1931 Cutting First	1931 Cutting Second	1931 Total	1932 Cutting First	1932 Cutting Second	1932 Total	1933	1934	5-year average	Increase per acre 5-year average	Recovery of added nitrogen per cent
	Pounds of protein per acre												
Checks(nine)	None	144	168	58	227	128	30	158	138	108	155‖	....	....
2-15-28	October 1	248	253	64	317	157	22	179	177	158	216	61	31
3-16-29	March 15	198	270	54	324	189	19	208	188	161	216	61	31
4-17-30	April 1	213	276	51	327	207	18	225	152	181	220	65	34
5-18-31	April 1 and 10 days before cutting	267	308	74	382	245	36	281	212	213	271	116	30
6-19-32	April 1 and immediately after cutting	233	313	99	412	234	53	287	196	214	268	113	29
8-21-34	April 15	190	303	65	368	213	17	230	238	186	242	87	45
9-22-35	May 1	221	298	49	347	205	14	219	208	190	237	82	42
10-23-36	May 15	223	413	56	469	207	23	230	224	200	269	114	59
11-24-37	June 1	200	366	63	429	171	36	207	224	171	246	91	47
12-25-38	June 15	192	265	86	351	161	43	204	202	163	222	67	35

*The records are of air-dry hay containing approximately 12.5 per cent of moisture. To reduce to a moisture-free basis, multiply the yields of hay, or divide the percentages of protein by 0.875.

†Includes both first and second cuttings.

‡4-year averages, 1931-1934, inclusive.

§All averages in last column are for first cuttings only.

‖Includes both first and second cuttings.

Barring plots 5 and 6 and their replicates, to which second applications of nitrate of soda were made in midsummer, one before heading and one after cutting, the highest yields were obtained from the applications made April 1 in 1930, May 15 in 1931, March 15 in 1932 and 1933, and April 15 in 1934. As an average of 5 years, the applications made on all dates gave increases over the checks; the highest increase came from the April 15 application, after which the increases became progressively less. Between March 15 and May 1, inclusive, however, the gains were not markedly different.

In 2 years, 1931 and 1934, the fall application compared favorably with the spring; but in 1932 and 1933 it gave a considerably lower gain. The favorable showing made in 1931 was due possibly to the plot's being fertilized twice in 1930, not only in October but also in the preceding April; the latter application was made because the test was not started until the spring of 1930 and hence no application was made in October of 1929. In 1934 the small gains were probably due to the extremely dry weather, for the low yields generally in that season indicate that timothy did not respond normally to applications made on any date. Both seasons, 1931 and 1934, were preceded by weather with less than normal precipitation in late fall and winter months, during which time there was probably less loss of soil nitrogen through leaching than in years with normal precipitation. In 1932 and 1933, both seasons preceded by approximately normal fall and winter precipitation, the yields from the plots fertilized in October were 415 and 377 pounds less, respectively, than those from the plots fertilized on April 15. Over the 4-year period, 1931 to 1934, the average gains from nitrate of soda applied in October were only 224 pounds less than those from the plots fertilized April 15.

The highest yields were obtained from those plots receiving a second application in midsummer. In neither case, however, was the gain sufficient to pay for more than the added cost of fertilizer.

The weights of the second crops were approximately 16 and 9 per cent as large as the weight of the first crop in 1931 and 1932, respectively.

Carriers of Nitrogen

To study the effectiveness as top-dressing materials of various sources of nitrogen, including three organic carriers, a third experiment was started in 1930 at North Ridgeville parallel and adjacent to the rate-and-time-of-application tests. The size and number of plots were identical to those in the two companion tests. Plots 2, 15, and 28 received no basic treatment; all the other plots were fertilized with 200 pounds per acre of an 0-14-6 fertilizer in the spring of 1930, 1931, and 1932. Each nitrogen-carrier was applied in such quantity as to supply 31 pounds per acre of nitrogen (equivalent in nitrogen to the amount contained in 200 pounds of nitrate of soda). The carriers used, the yields and increases per acre, the percentages and yields of protein, and the recoveries of added nitrogen were as shown in table 12.

As an average for 5 years, the yields per acre from the use of nitrate of soda supplemented with the basic treatment exceeded that from the use of nitrate of soda alone by 422 pounds, or 11 per cent.

All the carriers gave significant increases over the unfertilized plots, but as a group, the inorganic carriers were more effective than were the organic. The highest yield each year except 1934 came from an inorganic carrier, from sulfate of ammonia in 1930, from Cal-Nitro in 1931 and 1932, from Ammo-Phos B in 1933, and from Cyanamid, a synthetic organic compound, in 1934. As an average of 5 years there was practically no difference in the yields from sulfate of ammonia, Ammo-Phos B, and Cal-Nitro, and the yield of none of the others except Cyanamid and soybean meal was significantly lower. Svinhufvud (21), working in Finland, obtained similar increases from calcium nitrate, Cyanamid, leunasalpeter, nitrate of soda, and sulfate of ammonia.

TABLE 12.—**Yield and protein content of hay obtained from top-dressing timothy with different carriers of nitrogen, 1930-1934, inclusive*—North Ridgeville**

(31 pounds of nitrogen per acre, i. e., 200 pounds of nitrate of soda or its equivalent)

Plots No.	Kind of fertilizer	1930	1931	1932	1933	1934	5-year average	Increase per acre 5-year average	Recovery of added nitrogen per cent
		Pounds of hay per acre							
Checks (nine)	None	3,328	2,701	2,884	2,928	1,461	2,660	....	....
2-15-28	Nitrate of soda—no basic treatment	4,233	4,130	4,353	4,673	2,070	3,892	1,232	....
3-16-29	Nitrate of soda	4,727	4,917	4,582	5,061	2,283	4,314	1,654	....
4-17-30	Calcium nitrate	4,891	4,593	4,584	4,823	2,116	4,202	1,542	....
5-18-31	Cal-Nitro	5,022	5,244	4,813	4,826	2,152	4,411	1,751	....
6-19-32	Cyanamid	4,528	4,071	4,276	4,769	2,342	3,997	1,337	....
8-21-34	Sulfate of ammonia	5,076	5,081	4,642	5,116	2,089	4,401	1,741	....
9-22-35	Ammo-Phos B	4,888	5,025	4,726	5,251	2,167	4,411	1,751	....
10-23-36	Nitrophoska	4,608	5,102	4,764	5,101	2,246	4,364	1,704	....
11-24-37	Urea	4,691	4,517	4,578	4,649	2,138	4,115	1,455	....
12-25-38	Soybean meal	4,127	4,099	3,958	4,214	1,795	3,639	979	....
		Per cent of protein							
Checks (nine)	None	4.70	6.00	5.68	5.29	6.61	5.66	....	....
2-15-28	Nitrate of soda—no basic treatment	4.76	5.49	5.42	5.12	7.78	5.71	....	....
3-16-29	Nitrate of soda	5.08	5.26	5.19	4.44	8.13	5.62	....	....
4-17-30	Calcium nitrate	4.51	5.08	4.84	4.26	7.72	5.28	....	....
5-18-31	Cal-Nitro	4.76	4.67	4.55	4.38	7.72	5.22	....	....
6-19-32	Cyanamid	4.92	5.60	4.84	4.33	7.38	5.41	....	....
8-21-34	Sulfate of ammonia	4.68	6.29	5.19	4.33	7.61	5.62	....	....
9-22-35	Ammo-Phos B	4.02	4.62	4.15	4.26	7.54	4.92	....	....
10-23-36	Nitrophoska	4.45	5.66	4.37	4.61	7.78	5.37	....	....
11-24-37	Urea	4.51	5.49	5.07	4.10	7.72	5.38	....	....
12-25-38	Soybean meal	4.36	4.85	4.37	3.93	7.38	4.98	....	....
		Pounds of protein per acre							
Checks (nine)	None	156	162	164	155	96	147	....	....
2-15-28	Nitrate of soda—no basic treatment	201	227	236	239	161	213	66	34
3-16-29	Nitrate of soda	240	259	238	224	186	229	82	42
4-17-30	Calcium nitrate	221	233	222	205	163	209	62	32
5-18-31	Cal-Nitro	239	245	219	212	166	216	69	36
6-19-32	Cyanamid	223	228	207	206	173	207	60	31
8-21-34	Sulfate of ammonia	238	320	241	222	159	236	89	46
9-22-35	Ammo-Phos B	197	232	196	224	163	202	55	28
10-23-36	Nitrophoska	205	289	208	235	175	222	75	39
11-24-37	Urea	212	248	232	191	165	210	63	33
12-25-38	Soybean meal	180	199	173	166	132	170	23	12

*The records are of air-dry hay containing approximately 12.5 per cent of moisture. To reduce to a moisture-free basis, multiply the yields of hay, or divide the percentages of protein by 0.875.

Note: The percentages of nitrogen in different nitrogenous carriers used are as follows: nitrate of soda, 15.5; calcium nitrate, 15.5; Cal-Nitro, 15.0; Cyanamid, 22.0; sulfate of ammonia, 21.0; urea, 44.0; soybean meal, 6.5. The analysis of Ammo-Phos B is 16-20-0, and of Nitrophoska, 15-30-15.

In the last year of the test, the relatively high yields from nitrate of soda and Cyanamid on the one hand, and the relatively low yield from sulfate of ammonia on the other, may be the reflection of a cumulative effect of these carriers on the reaction of the soil, for as shown in table 13, the two former seem to have decreased, and the latter, to have increased the acidity somewhat. As shown by Thorne (22) and others, however, this detrimental effect of sulfate of ammonia may be counteracted by the application of lime.

TABLE 13.—Reaction of timothy plots—North Ridgeville

Plot	Treatment	May 23, 1935	
		pH*	pH†
27	Check	....	5.03
28	Nitrate of soda (no basic treatment)	....	5.20
29	Nitrate of soda	5.54	5.66
30	Calcium nitrate	....	5.03
31	Cal-Nitro	....	4.98
32	Cyanamid	5.46	5.51
33	Check	....	5.29
34	Sulfate of ammonia	5.14	4.50
35	Ammo-Phos B	....	4.59
36	Nitrophoska	....	4.79
37	Urea	....	5.03
38	Soybean meal	....	5.12
39	Check	....	5.22
	Average of checks	....	5.18

*Soil samples taken to a depth of 4 inches.
†Soil samples taken to a depth of 1 inch.

Relation of Nitrogenous Fertilizers to the Protein Content of the Hay

The fertilizer tests show clearly that the protein content of timothy can be changed through the use of nitrogenous fertilizers applied at different rates and times.

In the rate-of-application test, first cutting (table 9), the percentage of protein as a 5-year average increased in general with each increment above 200 pounds per acre of nitrate of soda. The lighter applications reduced the percentage slightly. The heaviest application increased the protein content to 8.59 per cent, or 2.55 per cent higher than the check. Approximately one-half of the gain was obtained from the use of 500 pounds of nitrate of soda; the other half required the use of an additional 1,100 pounds. The protein content of the two second crops was considerably higher than that of the first, being, on the average, 9.57 per cent in 1931 and 9.96 per cent in 1932, or a gain over the first crop of 2.17 per cent and 3.93 per cent, respectively. In yield of protein per acre there was, with one exception, a gradual increase with each increment, but the most economical gain was obtained from the use of 300 pounds per acre; that was the rate of application at which the highest percentage of added nitrogen was recovered.

The protein content of the hay was affected by the date of application of the nitrate of soda. In the first crop, the later the application was made, the higher, in general, the percentage of protein. The maximum, 7.27 per cent, obtained from the plots fertilized June 1, was 1.52 per cent higher than the percentage from the unfertilized plots. Sprague (20) obtained a larger increase. He reports that an application of 33 pounds of nitrogen per acre in the form of sulfate of ammonia (160 pounds per acre) made June 13, 1931, increased the percentage of protein from 6.1 to 9.4, or 3.3 per cent. An equivalent quantity of nitrate of soda (213 pounds per acre) increased it to 10.5 per cent, a total gain of 4.4 per cent. The hay was harvested 21 days after fertilization.

Barring the plots fertilized in midsummer, the highest production of protein, 269 pounds, came from the applications made May 15. This was a gain of 114 pounds over the unfertilized plots. As compared, however, with the plots which gave the highest yields of hay (fertilized April 15) the gain amounts to 27 pounds only.

These results obtained with timothy grown for hay are very similar to those obtained in experiments with wheat grown for grain. Both Bayfield (3) and Davidson (6) have reported that the effectiveness of nitrogenous fertilizers in increasing yields decreases but that their effectiveness in increasing the protein content increases, as the time of application approaches the stage of heading.

The protein content was higher in the second than in the first cutting by 2.42 per cent in 1931 and 3.51 per cent in 1932. In these 2 years, in the first cutting the average yield of protein was 243 pounds, and in the second, 46 pounds per acre, which is 19 per cent as great as that in the first cutting.

The percentages of protein in the hay in 1934 were unusually high on all plots. This may have been due to the dry weather of that year. In such seasons nitrates may accumulate in the soil (1). The total yields of protein, however, were less than in any other season because of the low yields of hay. In all seasons, the yield of protein was closely correlated with the yield of hay.

In this connection, attention is called to the fact that in all the fertilizer tests (tables 8, 9, 11, 14, 20, 22, and 24) the use of nitrate of soda at the rate of 200 pounds or less per acre not only did not increase materially the percentage of protein but in most cases was accompanied by a decrease. In the time-of-application test this applies to the earlier applications only, not to those made May 15 or later. The decreases were not large, but the regularity of their recurrence suggests that the use of nitrogenous fertilizer in moderate quantities may result in the production of hay of slightly lower protein content and, consequently, of slightly inferior quality. Presumably the reason for this is that under the stimulus of small quantities of nitrogenous fertilizer, the metabolic processes associated with the total growth are increased relatively more rapidly than are the processes of protein synthesis. The lesser percentage of protein, however, is more than offset by the larger quantity of total protein resulting from the greater yield of hay per acre. Even the smallest quantity of nitrate of soda gave an increase in both hay and protein per acre (table 9). With each increment of fertilizer the yield of protein was increased, and with the use of 1,600 pounds per acre it was more than doubled

THE RELATION OF LIME TO THE GROWTH OF TIMOTHY

Timothy is commonly regarded as more or less indifferent to the reaction of the soil. This is probably due to the fact that it will usually continue to give a pretty good account of itself on land that has become too acid for the profitable growth of many crops, particularly legumes like red clover and alfalfa. Evidence is accumulating, however, to the effect that the yield of timothy may be materially modified by the reaction of the soil. This was shown in the so-called Legume-Reaction Experiment at Wooster.

This experiment includes, among others, a 3-year rotation of corn, small grain, and timothy, all grown on plots representing five different soil reactions—pH 4.7, 5.0, 5.7, 6.8, and 7.5.[5] The plots were divided into halves. Both halves received muriate of potash at the same rate—90 pounds per acre per rotation. One-half received in addition superphosphate (20 per cent) at the rate of 600 pounds per acre per rotation. No manure or nitrogenous fertilizer was applied to either half; the nature of the experiment as a whole was such that the introduction of nitrogen into the fertilizer treatment would have interfered with other rotations involved in which legumes were included.

As an average of 8 years the yields of timothy from the plots representing pH 4.7, 5.0, 5.7, 6.8, and 7.5 were 633, 964, 997, 1,491, and 1,630 pounds per acre, respectively, on the unphosphated half and 701, 1,013, 1,261, 1,761, and 1,671 pounds per acre, respectively, on the phosphated half. The total yields were somewhat greater owing to the presence of some weeds and, on the plots with the higher pH values, the presence also of some volunteer clover.

These results show that under the conditions of this test the yield of timothy was influenced markedly by the reaction of the soil; the higher the acidity the greater the reduction in yield. On the unphosphated plots the maximum yield was obtained from pH 7.5, the highest reaction in the test. On the phosphated plots the maximum production came from pH 6.8, approximate neutrality.

COMBINATION OF VARIOUS RATES OF SEEDING WITH VARIOUS RATES AND TIMES OF FERTILIZATION

In this experiment, which is to some extent a repetition of others already described, the effects of different rates of sowing timothy and different rates and times of application of nitrate of soda, dealt with separately in other tests, are all combined. In September 1930, two series of triplicate plots were started in which timothy was seeded at five different rates, in one case without a companion crop, in the other, with wheat. In the latter, medium red clover was sown in the spring of 1931 at the uniform rate of 10 pounds per acre.

Records in table 14 represent the 3-year averages of crops of clear timothy. One crop was harvested in 1932 from the series of plots in which timothy had been sown alone in 1930. Crops were also harvested in 1933 and 1934 from the other series of plots from which the crop of mixed timothy and clover recorded in table 3 was harvested in 1932; these plots were not fertilized in 1932.

The series of timothy seeded alone was fertilized with nitrate of soda in April (April 7) and in May (May 26 and 27), 1932, and the series sown with the timothy-clover mixture, with sulfate of ammonia also in April (April 20) and in May (May 26), 1933, and in April (April 18) and in May (May 25), 1934. These materials were applied in such quantities as to supply nitrogen at the rates of 31, 62, and 93 pounds per acre, in 200, 400, and 600 pounds, respectively, of nitrate of soda or in 150, 300, or 450 pounds, respectively, of sulfate of ammonia.

In experiments described on previous pages, it has been shown that as the rate of sowing is increased above 2.5 or 5.0 pounds per acre, there is a decrease in the yields of hay. The chief object of this experiment was to determine

[5]In this method of expression pH 7 indicates neutrality; any figure above pH 7 indicates alkalinity; any figure below pH 7 indicates acidity; and the lower the figure the greater the degree of acidity.

whether through fertilization this tendency toward decreased yields resulting from heavy seeding could be overcome, and, at the same time, the quality of the hay improved by fertilizing with nitrogen.

TABLE 14.—The quantity and quality of timothy as affected by rate of sowing and time and rate of applying nitrogenous fertilizer, 3-year average*

Pounds per acre		Pounds of hay per acre	Per cent of protein	Pounds of protein per acre
Timothy seed	Nitrate of soda†—time and rate of application			
2.5	Unfertilized	3,105	6.63	206
5.0	Unfertilized	3,346	6.16	206
10.0	Unfertilized	3,221	6.21	200
20.0	Unfertilized	2,771	7.43	206
40.0	Unfertilized	2,634	6.15	162
	Average	3,015	6.50	196
2.5	200 pounds April	3,759	7.02	264
5.0	200 pounds April	4,060	6.97	283
10.0	200 pounds April	4,092	6.45	264
20.0	200 pounds April	3,883	6.18	240
40.0	200 pounds April	3,861	6.34	245
	Average	3,931	6.59	259
2.5	200 pounds May	3,420	7.57	259
5.0	200 pounds May	3,633	7.57	275
10.0	200 pounds May	3,486	7.89	275
20.0	200 pounds May	3,309	6.74	223
40.0	200 pounds May	3,141	7.35	231
	Average	3,398	7.42	252
5.0	400 pounds April	4,304	7.74	333
40.0	400 pounds April	4,156	7.41	308
	Average	4,230	7.56	320
5.0	400 pounds May	3,829	8.41	322
40.0	400 pounds May	3,317	7.87	261
	Average	3,573	8.14	291
5.0	600 pounds April	4,457	8.39	374
40.0	600 pounds April	4,240	7.97	338
	Average	4,349	8.21	357
5.0	600 pounds May	3,698	8.19	303
40.0	600 pounds May	3,378	8.47	286
	Average	3,538	8.31	294

*This table represents the averages of the crops of 3 years. The records are of air-dry hay containing approximately 12.5 per cent of moisture. To reduce to a moisture-free basis, multiply the yields of hay, or divide the percentages of protein by 0.875.

†Sulfate of ammonia in equivalent quantities was substituted for nitrate of soda in 1933 and 1934.

With the increasing density of the stand of timothy plants resulting from heavy seeding, there are a decrease in the proportion of stems with heads and a corresponding increase in the proportion of relatively fine short and leafy shoots without heads. This tendency is illustrated in table 15. In an earlier experiment (7), it was found that applications of nitrogenous fertilizers result in an increase in the total number of shoots per unit of area, an increase in the proportion of shoots producing heads, and a corresponding decrease in the number of shoots without heads.

Where 200 pounds of nitrate of soda per acre were applied about April 1 on plots seeded at the rates of 20 or 40 pounds per acre, the average yields of hay over a period of 3 years were approximately the same as on the unfertilized plots sown at the rate of 5 pounds per acre.

TABLE 15.—Relation of the rate of seeding timothy to the constituents of the hay*

Timothy seed per acre, pounds	Percentage of—		
	Timothy stems		Clover and weeds
	With heads	Without heads	
2.5	80.0	18.5	1.5
5.0	75.9	22.4	1.7
10.0	75.5	23.8	0.7
20.0	62.5	37.1	0.4
40.0	49.4	50.6	0

*These records were obtained in 1932 from unfertilized plots on which timothy had been sown alone in September 1930 Red clover was sown in the spring of 1931 on all plots at the rate of 10 pounds per acre. The percentages are based on weights, not numbers.

In 1932, there were 40 and 47 per cent, respectively, of the fine leafy timothy stems without heads on plots seeded at the rates of 20 and 40 pounds per acre and fertilized early in April, compared with only 22 per cent of stems of this type on the unfertilized plots sown at the rate of 5 pounds per acre.

Although with increased rates of seeding there were larger numbers of fine leafy stems without heads, the leaves became brown earlier in the plots seeded at heavy rates than in those seeded at light rates. In another investigation (13) it has been shown that as the proportion of green leaves on timothy plants decreases and there is a corresponding increase in the proportion of brown leaves, the percentage of protein in the hay decreases.

Table 14 shows that in the 3 years from 1932 to 1934, both in the plots fertilized with nitrogen early in April and in those fertilized late in May, the yields of hay, the percentages of protein, and the yields of protein were less from the seedings made at the rate of 20 or 40 pounds than from 5 pounds per acre. Even though as the rate of seeding increased above 5 pounds per acre there was an increase in the proportion of fine leafy stems without heads, the leaves became brown earlier, and, with an increased rate of seeding, there was a decrease, not only in the quantity but also in the quality of the hay.

CUTTING AT DIFFERENT STAGES OF GROWTH

An experiment was conducted at North Ridgeville, the purpose of which was, primarily, to determine the effect of cutting at different stages of growth on the yield and quality of timothy hay and, secondarily, to determine the effect of such cutting on the permanence of stand. The field was sown with seed of ordinary timothy without a companion crop in September 1929. The plants came through the winter in good condition, and although they were relatively small in the spring of 1930, the stand was comparatively even, and the meadow, therefore, was fairly well adapted for the purpose desired. This experimental tract was divided into four equal blocks. Each block was subdivided into 24 plots, each 5 by 66 feet. Hay was harvested from areas containing 1/176 of an acre (5 by 49.5 feet); 16.5 feet were cut off from the inner end of each plot and reserved as a place from which to collect samples for chemical analysis and on which the mowing machine could be turned. The plots were separated from each other by pathways 1 foot wide. For the purpose of cutting at the six stages of growth desired, the plots in each block were divided into six groups of four plots each. The four plots in each group differed from each other with respect to fertilizer treatment. One received no fertilizer. The others received nitrate of soda: one, in the spring only; one, in the spring and again in the summer about 10 days before cutting; and one, in the spring and again a few days after harvest. At each application the nitrate of soda was applied at the rate of 200 pounds per acre; this made a total of 400 pounds per acre for each of the two fertilized in midsummer. The arrangement of the groups within the blocks and the arrangement of the four blocks with reference to each other were as shown in the accompanying diagram.

From the diagram, it may be noted that the arrangement of the plots was such that the earliest cut in one series joined, end to end, the latest cut in another, thus overcoming, as far as possible, any inequalities of the soil. The experiment extended through 5 years, 1930-1934, inclusive.

Yield

UNFERTILIZED AND SPRING FERTILIZATION

The stages of development at which the timothy was cut, the yields obtained on both the unfertilized and spring-fertilized plots, and the 5-year average increase, in percentage, were as shown in table 16.

On the unfertilized land the highest yield was not obtained at the first three stages of cutting in any year. It was obtained at the fourth stage in 1930, at the fifth in 1931 and 1933, and at the sixth in 1932 and 1934. On the spring-fertilized plots the maximum yields were found at the same stages as on the unfertilized plots in 1930, 1931, and 1933, but at earlier stages in the other 2 years—at the third stage in 1932 and at the fourth stage in 1934. As an average of 5 years, and on both the unfertilized and fertilized plots, the yield was highest at the fifth stage (earliest heads straw color), and with each earlier stage of cutting it was progressively less. The spring application of nitrate of soda increased the yield regardless of the time at which the timothy was cut, but the percentage of increase became progressively less with advance in stage of maturity.

SPRING AND MIDSUMMER FERTILIZATION

For a study of the effect of spring and midsummer fertilization combined as contrasted with no fertilization or spring fertilization only, yields were available, not for 5, but for 3 years only—1931, 1932, and 1933. On this 3-year basis the effect of midsummer applications was as shown in table 17. The nitrate of soda applied before cutting increased the yield over that added in the spring only by 19, 14, 5, 9, 6, and 5 per cent on the stages represented by A, B, C, D, E, and F, respectively; that applied after cutting increased the yield by 13, 11, 7, 8, 6, and 6 per cent, respectively, for the same stages. In this connection, it should, perhaps, be added that the increase of spring application over the unfertilized was 132, 102, 83, 79, 75, and 74 per cent on the successive dates of cutting, respectively.

Diagram of plots used in cutting timothy at different stages of growth

Time of harvesting						Time of harvesting
	48	S and a h	-- -- --:-- -- --	S and a h	48	
Beginning	47	S and b h	-- -- --:-- -- --	S and b h	47	Seeds
to head	46	S	-- -- --:-- -- --	S	46	mature
	45	U	-- -- --:-- -- --	U	45	
	44	S and a h	-- -- --:-- -- --	S and a h	44	
Fully	43	S and b h	-- -- --:-- -- --	S and b h	43	Earliest heads
headed	42	S	-- -- --:-- -- --	S	42	straw color
	41	U	-- -- --:-- -- --	U	41	
	40	S and a h	-- -- --:-- -- --	S and a h	40	
Early	39	S and b h	-- -- --:-- -- --	S and b h	39	Just past
bloom	38	S	-- -- --:-- -- --	S	38	full bloom
	37	U	-- -- --:-- -- --	U	37	
	36	S and a h	-- -- --:-- -- --	S and a h	36	
Just past	35	S and b h	-- -- --:-- -- --	S and b h	35	Early
full bloom	34	S	-- -- --:-- -- --	S	34	bloom
	33	U	-- -- --:-- -- --	U	33	
	32	S and a h	-- -- --:-- -- --	S and a h	32	
Earliest heads	31	S and b h	-- -- --:-- -- --	S and b h	31	Fully
straw color	30	S	-- -- --:-- -- --	S	30	headed
	29	U	-- -- --:-- -- --	U	29	
	28	S and a h	-- -- --:-- -- --	S and a h	28	
Seeds	27	S and b h	-- -- --:-- -- --	S and b h	27	Beginning
mature	26	S	-- -- --:-- -- --	S	26	to head
	25	U	-- -- --:-- -- --	U	25	

N

W←+→E

S

	24	S and a h	-- -- -- -- -- --	S and a h	24	
Seeds	23	S and b h	-- -- --:-- -- --	S and b h	23	Beginning
mature	22	S	-- -- --:-- -- --	S	22	to head
	21	U	-- -- --:-- -- --	U	21	
	20	S and a h	-- -- --:-- -- --	S and a h	20	
Earliest heads	19	S and b h	-- -- --:-- -- --	S and b h	19	Fully
straw color	18	S	-- -- --:-- -- --	S	18	headed
	17	U	-- -- --:-- -- --	U	17	
	16	S and a h	-- -- --:-- -- --	S and a h	16	
Just past	15	S and b h	-- -- --:-- -- --	S and b h	15	Early
full bloom	14	S	-- -- --:-- -- --	S	14	bloom
	13	U	-- -- --:-- -- --	U	13	
	12	S and a h	-- -- --:-- -- --	S and a h	12	
Early	11	S and b h	-- -- --:-- -- --	S and b h	11	Just past
bloom	10	S	-- -- --:-- -- --	S	10	full bloom
	9	U	-- -- --:-- -- --	U	9	
	8	S and a h	-- -- --:-- -- --	S and a h	8	
Fully	7	S and b h	-- -- --:-- -- --	S and b h	7	Earliest heads
headed	6	S	-- -- --:-- -- --	S	6	straw color
	5	U	-- -- --:-- -- --	U	5	
	4	S and a h	-- -- --:-- -- --	S and a h	4	
Beginning	3	S and b h	-- -- --:-- -- --	S and b h	3	Seeds
to head	2	S	-- -- --:-- -- --	S	2	mature
	1	U	-- -- --:-- -- --	U	1	

U—unfertilized; S—nitrogen in spring; S and b h—nitrogen in spring and about 10 days before heading; S and a h—nitrogen in spring and a few days after harvest.

TABLE 16.—Effect of time of cutting on the yield of timothy, unfertilized and spring-fertilized—North Ridgeville

Stage of growth at time of first cutting	Pounds of hay per acre												Increase over unfertilized plots per cent
	Unfertilized						Nitrate of soda in spring, 200 pounds per acre*						
	1930	1931	1932	1933	1934	5-year average	1930	1931	1932	1933	1934	5-year average	
A Beginning to head	1,073	1,389	1,440	1,273	1,100	1,255	1,319	3,162	3,638	2,700	1,954	2,555	104
B Fully headed	1,925	2,059	1,781	1,800	1,339	1,781	1,996	4,157	3,949	3,291	2,089	3,096	74
C Early bloom	2,337	2,993	1,916	1,979	1,339	2,113	2,472	5,102	4,036	3,507	1,982	3,420	62
D Just past full bloom	2,614	3,393	1,814	1,982	1,335	2,228	2,809	5,496	3,857	3,547	2,128	3,567	60
E Earliest heads straw color	2,527	3,695	1,945	1,999	1,335	2,300	2,798	5,790	4,014	3,585	2,057	3,649	59
F Seed mature	2,372	3,624	1,958	1,921	1,359	2,247	2,434	5,623	3,948	3,525	2,026	3,511	56
Average	2,141	2,859	1,809	1,826	1,301	1,987	2,305	4,888	3,907	3,359	2,039	3,300	66

*Fertilization:

A basic treatment of 0-14-6 applied to all plots including checks May 2, 1932, at the rate of approximately 200 pounds per acre.

Nitrate of soda applied May 2 and 3, 1930; April 1931; April 20, 1932; April 12 and 13, 1933; and April 24, 1934. Fertilization was at the rate of 100 pounds in 1930 and 200 pounds per acre in succeeding years.

Cuttings:

1930:	A—June 11;	B—June 21;	C—June 25;	D—July 5;	E—July 16;	F—July 25.
1931:	A—June 12;	B—June 18;	C—June 24;	D—July 3;	E—July 13;	F—July 23.
1932:	A—June 14;	B—June 18;	C—June 22;	D—July 1;	E—July 12;	F—July 20.
1933:	A—June 9;	B—June 14;	C—June 19;	D—June 29;	E—July 7;	F—July 17.
1934:	A—June 9;	B—June 14;	C—June 19;	D—June 28;	E—July 6;	F—July 16.
Average:	A—June 11;	B—June 17;	C—June 22;	D—July 1;	E—July 11;	F—July 20.

TABLE 17.—Effect of time of cutting on the yield of timothy, unfertilized, spring-fertilized, and summer-fertilized—North Ridgeville*

Stage of growth at time of first cutting	Pounds of hay per acre															
	Unfertilized				Nitrate of soda in the spring†—											
					Only				And again before cutting				And again after cutting			
	1931	1932	1933	3-year aver-age	1931	1932	1933	3-year aver-age	1931	1932	1933	3-year aver-age	1931	1932	1933	3-year aver-age
A Beginning to head	1,389	1,440	1,273	1,367	3,162	3,638	2,700	3,167	3,966	3,920	3,455	3,780	3,655	3,823	3,283	3,587
B Fully headed	2,059	1,781	1,800	1,880	4,157	3,949	3,291	3,799	4,725	4,475	3,839	4,346	4,608	4,381	3,614	4,201
C Early bloom	2,993	1,916	1,979	2,296	5,102	4,036	3,507	4,215	5,302	4,206	3,829	4,446	5,482	4,258	3,848	4,529
D Just past full bloom	3,393	1,814	1,982	2,396	5,496	3,857	3,547	4,300	5,847	4,308	3,964	4,706	5,744	4,172	4,033	4,650
E Earliest heads straw color	3,695	1,945	1,999	2,546	5,790	4,014	3,585	4,463	5,060	4,299	3,915	4,725	5,994	4,174	4,014	4,727
F Seed mature	3,624	1,958	1,921	2,501	5,623	3,948	3,525	4,365	5,778	4,053	3,919	4,583	5,940	3,998	3,944	4,627
Average	2,859	1,809	1,826	2,164	4,888	3,907	3,359	4,051	5,263	4,210	3,820	4,431	5,237	4,134	3,789	4,387

*Yields for 1930 omitted because those on plots to which nitrate of soda was added after cutting were, of course, by the nature of the experiment, meaningless the first season.

Yields for 1934 omitted because nitrate of soda was not applied in that year.

†Fertilization:

Basic treatment and spring fertilization the same as indicated for corresponding years in footnote to table 16. Summer applications before cutting were made as follows:

1930: A—June 9; B—June 13; C—June 17; D—June 25; E—June 27; F—July 3.
1931: A—May 28; B—June; C—June 16; D—June 25; E—July 1; F—July 7.
1932: A—June 6; B—June 9; C—June 18; D—June 20; E—June 24; F—July 6.
1933: A—May 27; B—June 2; C—June 10; D—June 19; E—June 26; F—July 10.
Average: A—June 3; B—June 8; C—June 15; D—June 22; E—June 27; F—July 7.

Summer applications after cutting were made usually within a few days after removing the crop. Cutting dates were the same as shown in the footnote to table 16.

On the plots on which the summer application of nitrate of soda was made after the first crop had been harvested, it is of interest to note that the increases in the yields of the first crop in the following season were very nearly as great as on those plots on which the summer application of nitrogen was made before harvesting.

SECOND CUTTING

In the 5 years of this test, a second cutting was obtained in two seasons only, 1931 and 1932. The yields are shown in table 18. In both years the yields from all stages of cutting were much less than were those from the first cutting. As might be expected, the yields, in general, became progressively less as the date of the first cutting had been delayed. Nitrate of soda applied in the spring only gave little increase in yield; in two cases it gave no increase. The summer applications of nitrogen materially increased the yields. The ones made after harvest were somewhat more effective than were the ones made before harvest. As an average of 2 years, fertilization after harvest and on the earliest stage of cutting was the combination which gave the largest yield of the second crop; this yield amounted to 1,251 pounds per acre.

RAINFALL AND YIELD

Presumably, more satisfactory second crops would have been obtained in years of plentiful, or even normal rainfall. Undoubtedly, the dry weather which characterized the period of this test as a whole had a depressing effect on the yield not only of the second, but of the first crop as well. In each of the 5 years, 1930-1934, inclusive, the yearly rainfall was less than the average annual precipitation. The rainfall, month by month during the growing season for each of the 5 years, and the 58-year average for the same months were as shown in table 19.

Quality of the Hay as Indicated by Chemical Composition

PROTEIN CONTENT OF FIRST CUTTING

From the standpoint of the protein content of timothy, the importance of cutting early is well illustrated in table 20, which shows the content of protein at the various stages of harvesting in each of the 5 years, as grown on unfertilized and on spring-fertilized plots. In general, the percentage of protein became progressively less as the date of cutting was delayed. As an average of 5 years, the decline exceeded 3.50 per cent on both levels of fertility, ranging from 8.60 to 4.89 per cent on the unfertilized, and from 7.91 to 4.76 per cent on the spring-fertilized plots.

The yield of protein, given in table 21, shows that the maximum was obtained by cutting in the stage of fully headed to early bloom. The higher yield of protein on the spring-fertilized plots was due chiefly to a greater yield of hay.

The effect of midsummer, in addition to spring, applications on the percentages of protein in the timothy was as shown in table 22. In general, applications both before and after harvest increased the protein content. The effect, however, was not marked. The one made after harvest was less effective than the one made before. The yields of protein obtained were as shown in table 23. With one exception, early bloom, they were greater from the ones made before, than from ones made after harvest, and both exceeded the yields from the spring applications alone.

TABLE 18.—Effect of time of cutting on the second growth of timothy,* unfertilized, spring-fertilized, and summer-fertilized—North Ridgeville

Stage of growth at which first crop was cut†	Pounds of hay per acre in second cutting‡												Increase per acre from nitrate of soda in spring—		
	Unfertilized			Nitrate of soda in the spring—											
				Only			And again before cutting			And again after cutting			Only	And before cutting	And after cutting
	1931	1932	2-year average	1931	1932	2-year average	1931	1932	2-year average	1931	1932	2-year average			
A Beginning to head	800	244	522	788	232	510	1,068	788	928	1,610	893	1,251	—12	406	729
B Fully headed	688	227	457	714	237	475	1,091	761	926	1,172	944	1,058	18	469	601
C Early bloom	605	188	396	578	193	385	943	723	833	1,070	825	947	—11	437	551
D Just past full bloom.......	414	77	245	459	98	278	1,117	411	764	1,148	552	850	33	519	605
E Earliest heads straw color	263	11	137	391	11	201	801	154	477	995	199	597	64	340	460
F Seed mature.	175	8	91	329	3	166	948	60	504	1,063	88	575	75	413	484
Average.................	491	126	308	543	129	336	995	483	739	1,176	584	880	....	....	....

*To reduce to a moisture-free basis, multiply the yields by 0.875.
†Cut October 3, 1931, September 17, 1932.
‡For actual dates of cutting see the footnote to table 16.

There were a lower percentage and yield of protein in the hay cut in early bloom and fertilized in the spring and again before harvesting than in that fertilized only in the spring. This result may be due in part to some experimental error. On the C plots, however, the summer application of nitrate of soda was made, on the average for 1931, 1932, and 1933, 7 days only before harvesting. On the A plots it was made 12 days, on the D plots 10 days, and on the E plots 14 days before harvesting. The shorter time that the nitrate had to produce an increase in the protein content of the timothy cut in early bloom, in this instance, probably explains in part the decreased effectiveness of the nitrate of soda applied before harvesting.

TABLE 19.—Rainfall in inches*

Month	Year					58-year average
	1930	1931	1932	1933	1934	
April	2.08	3.46	2.09	2.42	2.43	2.48
May	1.87	2.36	3.71	2.86	.58	3.06
June	1.84	3.51	1.88	.39	2.26	3.26
July	.74	2.17	2.42	1.26	2.70	3.55
August	1.84	2.75	4.31	1.98	2.46	2.86
Total	8.37	14.25	14.41	8.91	10.43	15.21

*U. S. Weather Bureau, Cleveland, Ohio, 22 miles east of North Ridgeville.

PROTEIN CONTENT OF SECOND CUTTING

The percentages and yields per acre of protein in the second cutting were determined in one season only, 1931; these were as shown in table 24. The percentages were somewhat higher than in the first cutting, and as the date of harvesting the first cutting had been delayed, they became, in general, progressively higher—the reverse of what occurred in the first cutting. With the exception of the E and F plots, fertilized in the spring only, all applications of nitrate of soda increased the percentage, and all increased the yields of protein. The midsummer applications, however, were more effective than were those made in the spring. The applications made after the first harvest gave greater increases than did the ones made before.

TOTAL NUTRIENTS

A more accurate index of the value of timothy than the total yield of cured hay is the digestible nutrients, for with age the plants become increasingly fibrous and woody and consequently less and less palatable and digestible. In the absence of facilities with which to conduct digestion experiments, there were determined, on the first crops in 1930, 1931, and 1934, the total nutrients—ash, crude protein, ether extract, crude fiber, and nitrogen-free extract. In general, the 3-year average results, tabulated in table 25, show that the ash, crude protein, and ether extract became progressively less and that the crude fiber and nitrogen-free extract became progressively greater as the time of cutting was delayed. The desirable time to cut is, of course, the stage of development at which can be obtained the maximum of total digestible nutrients. From digestion experiments, Waters (29) concluded that timothy plants "in full bloom, gave the largest yields of digestible dry matter, digestible protein, digestible fat, digestible crude fiber and digestible nitrogen-free extract."

TABLE 20.—Percentage of protein in hay cut at different stages of growth, 5-year period*

Stage of growth at time of first cutting	Unfertilized						Nitrate of soda in the spring					
	1930	1931	1932	1933	1934	5-year average	1930	1931	1932	1933	1934	5-year average
A Beginning to head	12.43	8.14	6.86	7.87	8.47	8.75	13.52	7.73	6.33	6.27	9.62	8.69
B Fully headed	9.10	7.31	4.88	7.01	7.49	7.16	10.41	7.31	7.15	6.04	8.29	7.84
C Early bloom	7.72	5.59	5.70	6.39	7.26	6.53	8.52	5.83	6.98	5.59	8.29	7.04
D Just past full bloom	6.27	4.17	5.24	5.25	6.68	5.52	6 62	4.17	4.65	4.44	6.85	5.35
E Earliest heads straw color	5.18	4.34	5.12	5.13	6.62	5.28	5.58	4.52	4.59	4.09	5.88	4.93
F Seeds mature	5.87	4.17	4.59	4.16	6.50	5.06	5.98	4.17	4.59	3.82	6.85	5.08

*To reduce the percentages of protein to a moisture-free basis, divide by 0.875.

TABLE 21.—Pounds of protein per acre in hay cut at different stages of growth, 5-year period

Stage of growth at time of first cutting	Unfertilized						Nitrate of soda in the spring					
	1930	1931	1932	1933	1934	5-year average	1930	1931	1932	1933	1934	5-year average
A Beginning to head	133	113	99	100	93	108	178	244	230	169	188	202
B Fully headed	195	150	87	126	100	128	208	303	282	199	173	233
C Early bloom	180	167	109	126	97	136	211	297	282	196	164	230
D Just past full bloom	164	141	95	104	89	119	186	229	179	157	146	179
E Earliest heads straw color	131	160	100	102	88	116	156	262	184	147	121	174
F Seeds mature	139	151	90	80	88	110	146	234	181	135	139	167

TABLE 22.—Percentage of protein in hay cut at different stages of growth, 3-year period*

Stage of growth at time of first cutting	Unfertilized				Nitrate of soda in the spring—											
					Only				And again before cutting				And again after cutting			
	1931	1932	1933	3-year average	1931	1932	1933	3-year average	1931	1932	1933	3-year average	1931	1932	1933	3-year average
A Beginning to head.........	8.14	6.86	7.87	7.62	7.73	6.33	6.27	6.78	10.88	7.56	8.50	8.98	8.98	7.15	6.85	7.66
B Fully headed.............	7.31	4.88	7.01	6.40	7.31	7.15	6.04	6.84	9.09	6.98	6.85	7.64	6.66	6.86	5.59	6.37
C Early bloom..............	5.59	5.70	6.39	5.89	5.83	6.98	5.59	6.47	5.65	5.52	5.71	5.62	6.31	6.10	5.59	6.00
D Just past full bloom.......	4.17	5.24	5.25	4.89	4.17	4.65	4.44	4.42	4.76	6.10	5.59	5.48	5.59	4.88	4.39	4.95
E Earliest heads straw color.	4.34	5.12	5.13	4.86	4.52	4.59	4.09	4.40	5.41	5.87	5.07	5.45	5.83	4.71	4.33	4.96
F Seed mature..............	4.17	4.59	4.16	4.31	4.17	4.59	3.82	4.19	4.22	5.76	3.82	4.60	4.17	5.06	3.82	4.35

*To reduce the percentages of protein to a moisture-free basis, divide by 0.875.

TABLE 23.—Pounds of protein per acre in hay cut at different stages of growth, 3-year period

Stage of growth at time of first cutting	Unfertilized				Nitrate of soda in the spring—												Average of all
					Only				And again before cutting				And again after cutting				
	1931	1932	1933	3-year average	1931	1932	1933	3-year average	1931	1932	1933	3-year average	1931	1932	1933	3-year average	
A Beginning to head.........	113	99	100	104	244	230	169	214	431	296	294	340	328	273	225	275	233
B Fully headed.............	150	87	126	121	303	282	199	261	430	312	263	335	307	301	202	270	247
C Early bloom..............	167	109	126	134	297	282	196	258	300	232	218	250	346	260	215	274	229
D Just past full bloom.......	141	95	104	113	229	179	157	188	278	263	222	254	321	204	177	234	197
E Earliest heads straw color.	160	100	102	121	262	184	147	198	322	252	198	257	349	197	174	240	204
F Seed mature..............	151	90	80	107	234	181	135	183	244	233	150	209	248	202	151	200	175

TABLE 24.—Percentage and yield of protein per acre, second cutting, 1931*

Stage of growth at time of first cutting	Percentage of protein†				Pounds of protein per acre			
	Unfertilized	Nitrate of soda in spring—			Unfertilized	Nitrate of soda in spring—		
		Only	And again before cutting	And again after cutting		Only	And again before cutting	And again after cutting
A Beginning to head	6.50	6.90	8.68	7.49	52	54	93	121
B Fully headed	6.60	7.31	7.08	8.98	45	52	77	105
C Early bloom	7.49	8.32	8.26	9.75	45	48	78	104
D Just past full bloom	7.67	8.50	8.14	9.51	32	39	91	109
E Earliest heads straw color	9.81	9.16	10.35	11.18	26	36	83	111
F Seeds mature	10.82	10.35	10.99	11.06	19	34	104	118

*Harvested October 3, 1931.
†To reduce the percentages of protein to a moisture-free basis, divide by 0.875.

TABLE 25.—Percentage of total nutrients in first cutting, 3-year average*

Stage of growth at time of first cutting	Unfertilized				
	Ash	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract
A Beginning to head	6.54	9.68	2.99	25.58	42.91
B Fully headed	6.20	7.90	2.60	27.63	43.16
C Early bloom	5.76	6.90	2.42	29.35	43.07
D Just past full bloom	5.47	5.66	2.07	29.31	45.00
E Earliest heads straw color	5.02	5.38	2.39	29.35	45.36
F Seeds mature	5.02	5.50	2.02	29.03	45.92

*These analyses were made in 1930, 1931, and 1934. To reduce to a moisture-free basis, divide by 0.875.

Isaachsen, Ulvesli, and Husby (15) concluded "that cutting when the timothy begins to blossom gives the greatest yield of free units as well as of digestible true protein." In an experiment conducted with sheep at the Ohio Agricultural Experiment Station, Bell, Thatcher, and Hunt (4) found that ".......... the time at which timothy was cut for hay had a definite influence on its value for sheep feeding. Timothy cut when not more than one-third of the heads were in blossom was fully one-third better than timothy cut after the blossoms had fallen and as the seed was ripening. From a practical standpoint, the early-cut timothy was a usable roughage whereas the late-cut .... was decidedly inferior." A marked superiority of early over late cutting of timothy is indicated by the work of others (17, 18, and 19).

U. S. Grades of Hay

From the commercial viewpoint, timothy, if practically free from other grasses, clover, and weeds, is classified chiefly on the basis of its color. This is estimated and expressed in percentages, and on the basis of these percentages the grades are determined.

In order to estimate the quality of the timothy in terms of commercial grades, typical samples were gathered in 1931-1934, inclusive, and to each of these, the percentages of green color and the U. S. grade of hay were assigned by the Hay, Feed, and Seed Division of the Bureau of Agricultural Economics of the United States Department of Agriculture. The 4-year averages of these estimates and assignments are tabulated in table 26.

TABLE 26.—Quality of hay as indicated by color and recorded as grades

Stage of growth at the time of first cutting	Percentage of green color				United States grades*			
	Unfertilized	Nitrate of soda in spring—			Unfertilized	Nitrate of soda in spring—		
		Only	And before cutting	And after cutting		Only	And before cutting	And after cutting
A Beginning to head	87	85	85	80	1 EG	1 EG	1 EG	1 EG
B Fully headed	82	75	71	76	1 EG	1 EG	1 EG	1 EG
C Early bloom	82	65	64	62	1 EG	1 EG or 1	1	1
D Just past full bloom	69	53	50	45	1 EG or 1	1	1 or 2	2
E Earliest heads straw color	46	36	32	32	1 or 2	2	2 or 3	2
F Seeds mature	33	18	20	22	2 or 3	3	3	3

*1EG=Number 1 Extra Green hay.
1 =Number 1 hay.
2 =Number 2 hay.
3 =Number 3 hay.

On the unfertilized land the quality of the hay was such that the Number 1 Extra Green classification was applied to that cut at the first three stages every year, and to that cut in the fourth stage, in every year but one. The spring application of nitrogen restricted the first grade of hay to the first three, and the summer applications, either before or after harvest, to the first two stages of growth. On both the unfertilized and fertilized plots the hay that did not class as Number 1 Extra Green graded progressively lower as the time of cutting was delayed; the poorest was classed as Number 3. The hay cut at any given stage of development after early bloom was in general reduced one grade by spring application of fertilizer and one or two grades by applications made in both spring and summer.

The relatively higher percentage of green color in the hay grown on the unfertilized plots is due in part at least to the development of greater proportions of short leafy stems without heads on poor than on rich soil (7). On such stems, as contrasted with larger ones with heads, the leaves remain green later in the season.

Permanence of Stand

As stated before, the secondary object in the different-stage-of-cutting experiment was to note the effect, if any, of such cutting on the permanence of stand. To ascertain the possibility of such effect, two methods of approach were employed: (a) observations and (b) yields.

OBSERVATIONS

Differences in midsummer before harvesting were not apparent from observation alone even in the later years of the test. As a method of investigation, however, observation can hardly be regarded as final, for unless differences are marked, they may pass quite unnoticed.

Toward the close of the test, however, the difference in weed growth was sufficiently marked to be discernible easily and unmistakably by observation. In 1933 and again in 1934, annual weeds, principally wild lettuce (*Lactuca saligera*) and prickly lettuce (*L. scariola*), appeared in the late summer and fall in much greater profusion on the early, than on the late cut plots. The contrast in 1934 was as shown in figure 6. This difference in weed growth on the early and late cut plots may or may not indicate a thinner stand on the former and, consequently, more bare ground and hence greater ease for the establishment of weed seedlings. Certainly, in view of the arrangement of the plots (see diagram), the difference cannot be explained on the basis of uneven distribution of seeds by the wind or other natural agencies.

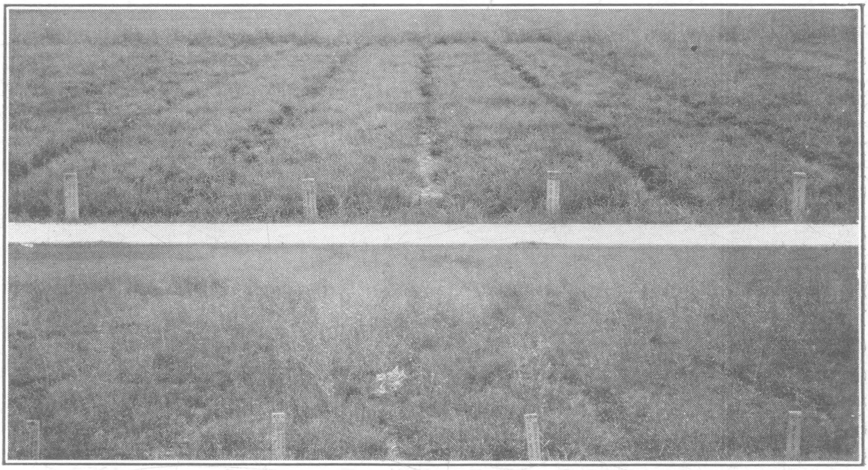

Fig. 6.—Early and late cutting of timothy in relation to weed growth
Top, late cut (early cut in background); bottom, early cut

September 14, 1934, after 5 years of mowing at different stages of growth. North Ridgeville.

It is possible, and indeed quite probable, that the difference in weed growth was a reflection merely of the reaction of the weeds themselves to early and late cutting. Perhaps wild and prickly lettuce are weeds which are controlled more readily by late than by early mowing. If the soil and environmental conditions had been such as to favor the coming in of different types of weeds, types whose habits of growth are such that their development is injured less by late than by early cutting, then the result might have been quite the reverse. Efficient methods of weed control and the effect of early and late cutting on the duration of the timothy plant are not synonymous problems and are not, therefore, to be confused one with the other. The performance of the weeds is at best indirect evidence and should, therefore, be regarded as indicative only. Direct and positive evidence, however, is not lacking.

YIELDS IN THE SEASON FOLLOWING THE TERMINATION OF THE TIME-OF-CUTTING PHASE

In 1935, all the 96 plots were cut at the same time, June 25-29, in order to determine whether any differences in yield were evident. It would seem that if significant differences were found to occur, the cumulative effect of time of cutting throughout the period of the experiment was the causative factor. In that year no nitrate of soda was applied to any of the plots and, as previously stated, none, in midsummer in 1934. The yields obtained were as shown in table 27, and represent the average of quadruplicate plots on each of the four levels of fertility.

TABLE 27.—Yields in pounds of hay per acre in 1935—all plots cut June 25-29

Stage of cutting in preceding 5 years	Unfertilized	Nitrate of soda in spring—			Average of unfertilized and fertilized
		Only	And before cutting	And after cutting	
A Beginning to head	1,772	1,695	1,638	1,681	1,697
B Fully headed	1,940	1,886	1,775	1,689	1,822
C Early bloom	2,070	1,812	1,779	1,692	1,843
D Just past full bloom	2,242	2,188	1,855	1,874	2,040
E Earliest heads straw color	2,622	2,354	1,998	2,068	2,260
F Seeds mature	2,722	2,264	1,992	2,059	2,259

From table 27 it may be noted that at each fertility level the yields from the plots which in previous years had been cut at the two later dates were higher than any from the earlier ones. The check plots harvested at the two latest dates in previous years produced more, in 1935, than any of the fertilized plots harvested at these two stages. This was due to the growth of volunteer alsike clover in the unfertilized check plots; little or no clover grew in those plots which had been fertilized with nitrate of soda. The clover was much more abundant in the late cut check plots, especially in those cut at the two latest stages, than in the early cut plots. Because of the clover in the late cut unfertilized plots, the difference, in the right-hand column in table 27, between the average yields produced in all early cut and all late cut plots is somewhat greater than it would be if the records from the unfertilized plots were not included. However, there would still be a trend toward progressively reduced yields with progressively earlier stages of cutting.

If the average yields obtained on the two later dates of cutting are considered as normal, then the decrease in yield on each of the first three earlier stages was, on the basis of twice the standard error, statistically significant.[6] Whether the differences had become sufficiently great before 1935 to have been measured statistically or otherwise was not determined.

REPRODUCTION

Reseeding in old meadows.—As already stated, timothy, for best quality of hay, should be harvested early. However, if for any reason the timothy plants are allowed to ripen fully, the shattering of the seed would possibly help to maintain or increase the density of thin stands, provided weather conditions at the time of or soon after harvest were favorable for germination and the establishment of the seedlings.

The relation of haplocorms to reproduction.—The chief means, however, by which the stands of plants in timothy meadows are perpetuated is through vegetative reproduction.

After the stem of a timothy shoot has grown in length and produced a culm, and possibly a head on the seed has matured, the shoot gradually dries up and within a few weeks or months, dies, usually about a year or a little more than a year after it began its growth from a seed or bud. Before the old shoot dies, however, usually one or more new ones have developed from buds at nodes at the base of the stem. In timothy meadows these new shoots develop in large numbers about the time the seeds are forming, though additional ones grow from buds during the fall and following spring. Usually they grow from buds

[6]Analysis of data made by J. T. McClure, statistician, Ohio Agricultural Experiment Station.

at nodes adjacent to, most frequently just below, the "bulb" or haplocorm (7). These haplocorms at the bases of the culms begin to form, in northern Ohio, about April 20. As shown in later paragraphs, they continue to increase in weight until about the time when the seeds in the heads are mature. The close association of the buds from which new shoots develop with the haplocorms indicates that the nutrients stored in them become translocated to the young growing shoots.

Apparently the naplocorm of a fully developed timothy shoot has somewhat the same relationship to a vegetative shoot which may develop from an adjacent bud in midsummer as the endosperm of a grass seed has to the primary shoot which grows from its embryo. In both instances, the stored-up nutrients slowly become available to the young shoot and nourish it until it has a well-developed root system.

That the haplocorms continue to develop and increase in size until the timothy plants are mature is shown by a detailed study conducted in the summer of 1935. Haplocorms were gathered at 10-day intervals from June 10 to August 10, inclusive. This period extended from the time of the heading of the plants to 10 days or longer after complete maturity. Five samples consisting of 100 haplocorms each were collected on each date. The haplocorms for each sample were selected at random from each of twenty-five 6-year-old timothy plots, four from each plot. These plots were located at Wooster and had been treated annually with nitrogenous fertilizer for 5 years. For the most part the haplocorms consisted of single internodes. After the removal of the roots and stem, the green and dry weights were determined, the percentage of moisture was calculated, and the number of haplocorms on stems sending out shoots was noted. The results were as tabulated in table 28.

TABLE 28.—Progressive development of timothy haplocorms, 1935—Wooster

Date of sampling	Number of haplocorms	Dry weights per 100	Moisture	Shoots developing
		Grams	*Per cent*	*Per cent*
June 10	500	17.1	70.0	0
June 20	500	17.9	70.7	0
June 30	500	20.5	66.7	0
July 10	500	24.8	61.9	6
July 20	500	29.9	61.3	12
July 30	500	28.7	60.0	37
August 10	500	22.6	62.7	84

From table 28 it is apparent that as the timothy advanced in age the haplocorms became progressively heavier, reaching a maximum about July 20, at which time the timothy was mature (many seeds shattering). The gradual decline after the peak of haplocorm development probably was due to translocation of food reserves to the newly developed shoots at adjacent nodes of the stem. By the last of July, the shoots were appearing on a rapidly increasing number of these stems. This is indicated in the last column of table 28. Concomitantly with the increase in weight, the moisture content of the haplocorms decreased and reached a minimum the last of July. Considering as a basis for comparison that the haplocorms were fully developed July 20 and 30 (average 29.3 grams), the weights indicated on both the earlier and later dates were significantly lower as judged by odds of 99:1.

The results are in substantial agreement with those of Trowbridge, Haigh, and Moulton (23). These workers did not weigh a definite number of haplocorms, but gathered all within a definite area at different stages of growth ranging from the time the timothy was about 1 foot high to maturity. They found a progressive increase in weight during this period. Sampling, however, was not continued beyond maturity.

These results show that the haplocorms continued to develop and to increase in dry matter until the plants reached maturity. Cutting timothy year after year before it is mature, therefore, will more or less restrict the organic food reserves stored in the haplocorms, available for the starting of new shoots. To the cumulative effect of this situation is due probably the progressive decline in yields obtained in 1935 (table 27). Theoretically, therefore, early cutting of timothy should be accompanied by a deterioration in stand, and the evidence of this experiment sustains that theory. How long the process may be continued before the injury becomes sufficiently marked to be detected through field observation may vary with latitude and with environmental conditions in general.

In the aggregate, the findings in this study of injury to the stand from early cutting of timothy agree with the work of Waters (29) but disagree with the conclusion of Wiggans (31). The weed situation reported in Wiggans' work, however, renders difficult a satisfactory evaluation of the influence of time of cutting.

General Recommendations in Regard to Time of Harvesting

On account of the relatively small annual injury which occurred in this experiment as a result of early harvesting, it may not be amiss in concluding the discussion to reiterate an earlier conclusion. From an economic standpoint in which the maximum utility of the timothy crop is concerned, in northern Ohio it is better farm practice to sacrifice the possibility of the maintenance of a maximum stand on the one hand for the annual production of a crop of higher feeding value on the other hand. Unless for some reason it is desired to maintain a stand for a 5-year or a 10-year period, or possibly for an even longer time, it is probably not worth while to give serious consideration to the adverse effect of early cutting on the permanence of stand. In southern Ohio, on the other hand, observations in recent years at four branch stations indicate that early harvesting may result in more definite injury to the stand of plants than occurred at North Ridgeville in northern Ohio.

In this experiment, conducted within about 10 miles of Lake Erie, the average date of cutting timothy in early bloom was June 22. At localities farther south, the date of early bloom would be somewhat earlier. At this time the pressure of other farm work may make it less convenient to harvest timothy than at a later time. This does not alter the fact, however, that delaying the timothy harvest until later stages results in more or less loss in the quality of the hay.

The actual time when the hay is to be harvested is a problem of farm management. The solution may be a different one on different farms, or on the same farm in different seasons. On farms with large acreages of hay, it may be advisable to begin cutting it even earlier than the stage which has been recommended, in order that the harvesting operations may be completed before the timothy is at a too advanced stage.

SEED PRODUCTION

In the production of timothy seed, Ohio, as an average of 10 years, 1925 to 1934, inclusive (25), ranked fourth both in acreage and production, being surpassed by Iowa, Missouri, and Illinois. During this period the average annual acreage has been approximately 39,500 acres, and production, 160,500 bushels of seed.

Timothy harvested for seed generally receives the same cultural treatment as that for hay. Usually a part of an ordinary meadow is reserved for seed, and seldom is it fertilized, though a spring application of nitrogenous fertilizer may result in large increases in yields of seed, even larger increases than in yields of hay (11).

In Ohio most of the seed is harvested with a binder, but in the middle western states, particularly Iowa and Missouri, much of it is harvested with grain headers. Few, if any, headers are used in Ohio, but in recent years grain combines have been used to a limited extent.

Timothy may be threshed with an ordinary grain threshing machine (12). Care must be exercised in the regulation of the current of air through the machine, for, if it is too strong, much of the seed may be carried through with the straw and chaff. Unless the speed of the cylinder is reduced to about 900 revolutions per minute and the teeth of the concave and of the cylinder are in mesh not to exceed about one-fourth inch, the hulls are likely to be removed from a considerable proportion of the seeds. For a few months hull-less seeds will germinate about as well as seeds on which the hulls are retained, but later the hull-less seeds lose their viability more rapidly than the unhulled seeds.

Wherever seed of improved varieties of timothy is produced, care should be taken to grow it in meadows free from the seed of other kinds and to avoid mixture at time of threshing.

More complete information in regard to the production of timothy seed may be obtained in Leaflet 115 of the United States Department of Agriculture, Washington, D. C.

SUMMARY AND CONCLUSIONS

Of 11 meadow grasses grown for various periods at Wooster, timothy produced the highest yields.

In 16 rate-of-seeding tests in which timothy was sown in the fall at rates varying from 1.25 pounds to 20 pounds per acre, or more in some instances, the maximum yields were obtained once from 1.25, seven times from 2.5, and eight times from 5 pounds of seed per acre. These results indicate that 3 or 4 pounds per acre may be regarded as a satisfactory rate of seeding with winter grain in the fall.

Timothy was sown in the spring, with oats as a companion crop, at the rates of 5, 10, and 20 pounds per acre. Slightly larger yields were obtained from the use of 10 pounds per acre than from either of the other rates.

The effect of sowing timothy seed in the fall versus spring, in each instance at the rate of 10 pounds per acre and in mixture with red clover sown in the spring, was compared in nine tests. In eight of these tests somewhat higher yields of hay, containing a higher proportion of clover, were obtained from the spring sowings. The yields, however, were usually less than from the use of 2.5 or 5 pounds of seed in the fall.

In seven out of nine tests, the yields of hay from split seedings (2.5 pounds in fall, 7.5 pounds in spring) were greater than from 10 pounds of timothy sown in either the fall or the spring. In the nine tests, there was not much difference between the average yields from the split seedings and those produced by 2.5 or 5 pounds of timothy sown in the fall.

The effect upon the meadow of different rates of seeding diminished with age, but was evident in some tests for at least 3 years.

No consistent relationship was found between the rate of seeding timothy and the protein content of the hay.

Seeded alone, medium red clover outyielded timothy, but the yield of neither separately equalled that of the two combined.

At Wooster, neither superphosphate nor a mixture of superphosphate and potash increased the yields, but nitrate of soda in mixture with these fertilizers increased the yields per acre of both hay and protein. At North Ridgeville, superphosphate alone and in combination with potash increased the yields of hay, chiefly through a larger growth of volunteer plants of medium red and alsike clover.

As an average of 5 years, the percentage of protein in the hay grown on the unfertilized plots was 6.04 per cent. Applications of 50, 100, or 200 pounds of nitrate of soda per acre did not increase the percentage; applications of 300 to 1,600 pounds increased it 0.53 to 2.55 per cent.

The average yield of the second crop was 7 per cent as large as that of the first. In the second crop, the average content of protein was 9.96 per cent on the unfertilized land, and it increased to a maximum of 11.60 per cent on the plots fertilized at the rate of 1,600 pounds per acre.

Nitrate of soda was applied at the rate of 200 pounds per acre about October 1, and at intervals of approximately 2 weeks from March 15 to June 15, inclusive. The highest yields were obtained in different years on four different dates ranging from March 15 to May 15, inclusive; on the average, the maximum came from applications made April 15. The October applications were nearly as effective in increasing yields as were those made from March 15 to May 1, and were more effective than those made from May 15 to June 15. The average percentage of protein in the unfertilized plots was 5.75 per cent. On the plots fertilized October 1, March 15, and April 1, the percentage of protein was slightly less than on the check plots; on the plots fertilized April 15, May 1, May 15, June 1, and June 15, the percentages of protein were 5.91, 6.09, 7.16, 7.27, and 7.12, respectively. The highest recovery of added nitrogen and the highest yield of protein were obtained from the plots fertilized May 15. A second application of 200 pounds of nitrate of soda before harvesting increased the yield of hay 375 pounds, the protein 0.74 per cent, and the yield of protein 51 pounds.

Nine different forms of fertilizers containing nitrogen were compared. The inorganic forms were somewhat more effective than the organic. Among the various inorganic forms used, there were only relatively small differences in their effects upon the hay yields.

Timothy was cut for 5 years at six different stages of growth: (a) beginning to head, (b) fully headed, (c) early bloom, (d) just past full bloom, (e) earliest heads straw color, (f) seeds mature. On the unfertilized plots the highest yield of hay was obtained when the earliest heads were becoming straw color; the highest percentage of protein (8.60 per cent), when the plants were beginning to head; and the highest acre yields of protein, when the plants were from fully headed to early bloom. The results indicate that for the maximum quantity and best quality of hay combined the timothy should be cut in early bloom. Substantially the same results in respect to time of cutting were obtained from the fertilized as from the unfertilized plots.

Summer applications of nitrate of soda made before harvesting increased the yields of hay and also the percentages and yields of protein, more in the plots cut early than in those cut late. Summer applications made after harvesting produced similar increases the following year in the yields of hay and yields of protein, but not in the percentages of protein. The gain from the second application of 200 pounds per acre in midsummer, either before or after harvesting, was much less than was that from the same quantity of nitrate applied in the spring.

Commercial grades were assigned to the timothy cut at different stages of growth. The earlier cuttings only were graded as Number 1 Extra Green. The use of nitrogen slightly reduced the grade.

In 2 years only, 1931 and 1932, were second crops obtained in any of these tests, and both of these were comparatively light. On the average for both years, they were approximately 13 per cent as great as the first crop on the unfertilized plots; 8 per cent as great as the first crop on the plots fertilized in the spring; 15 per cent as great as the first crop on the plots which received a second application of fertilizer before harvesting; and 18 per cent as great as the first crop on those receiving a second application of fertilizer after harvesting. Inasmuch as the rainfall during the growing season in these 2 years averaged approximately 1 inch only below normal, these percentages may be regarded as a fair approximation of what may usually be expected in a second crop. In seasons of abnormally high rainfall undoubtedly more would be obtained. In the other 3 years of these tests, 1930, 1933, and 1934, the rainfall from April to August, inclusive, was approximately 60 per cent of the normal.

In the stage-of-cutting experiment, all the plots were cut at the same time in 1935, the season following the termination of the time-of-cutting phase of the test. The early cutting had affected adversely, to some extent, the permanence of the meadow, since the yields in that year became progressively less as the time of cutting in previous years had been advanced.

The haplocorms or "bulbs" continue to develop until about the time the plant reaches maturity, after which they gradually decrease in weight. The beginning of the decline in weight occurs simultaneously with the appearance of new shoots.

A few recommendations are made relating to the production of timothy seed.

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