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Alfalfa in Ohio

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C. J. WILLARD, L. E. THATCHER, AND J. S. CUTLER

On lands where it can be grown satisfactorily, no forage crop surpasses alfalfa in yield or quality of forage. Its successful culture in Ohio has depended on the proper coordination of soil treatment, varieties of alfalfa, seeding methods, and management of the stand. For over 30 years the Ohio Agricultural Experiment Station has been conducting experiments on these and other problems connected with alfalfa culture. These investigations have been published in a considerable number of scattered reports, but no comprehensive summary of the work of the Station with alfalfa has been published since 1907 (76)[1].

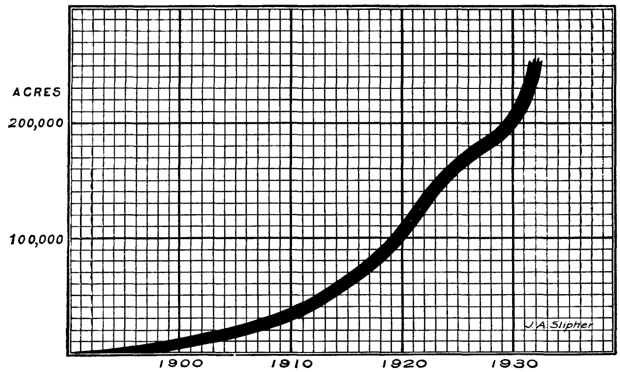

Fig. 1.—Alfalfa acreage in Ohio

This bulletin brings together the experimental work of the Department of Agronomy on the culture and management of alfalfa[2]. The following phases of the subject are presented: Choosing a soil for alfalfa; soil treatments, including tiling, lime, and fertilizers; alfalfa varieties; the culture of alfalfa, including its place in rotations, use in mixtures, and rate, date, and method of seeding; its management, including clipping after seeding, mulching, cultivation, and the proper time and number of cuttings; the normal development of alfalfa stands; and a number of miscellaneous studies.

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[1]Reference by number is to "Literature Cited" (Page 144). Other previous general publications on alfalfa are the following: (24, 33, 55, 74, and 75).

[2]A bulletin of this kind represents contributions by many persons besides the authors. In addition to those directly credited in the text, Robt. M. Salter, Chief of the Department of Agronomy, is in general charge of soil fertility experiments and has largely written that section of the bulletin; Director C. G. Williams, formerly agronomist, planned many of the earlier experiments reported; J. B. McLaughlin, Superintendent of the Northwestern Experiment Farm, has been in particularly close contact with the alfalfa investigations, first at Columbus and then at Holgate; M. A. Bachtell, in charge of the District and County Experiment Farms, has been unfailing in his interest and cooperation, especially in the work with alfalfa mixtures. Many others, far too many to credit individually, have contributed both to obtaining the data and to preparing the manuscript. Among the authors of the bulletin, data from Wooster have been furnished by Thatcher; from Holgate by Willard and Cutler; from the other outlying farms by Cutler; and from Columbus by Willard. The senior author is in general charge of alfalfa projects and was primarily responsible for preparing the material for publication.

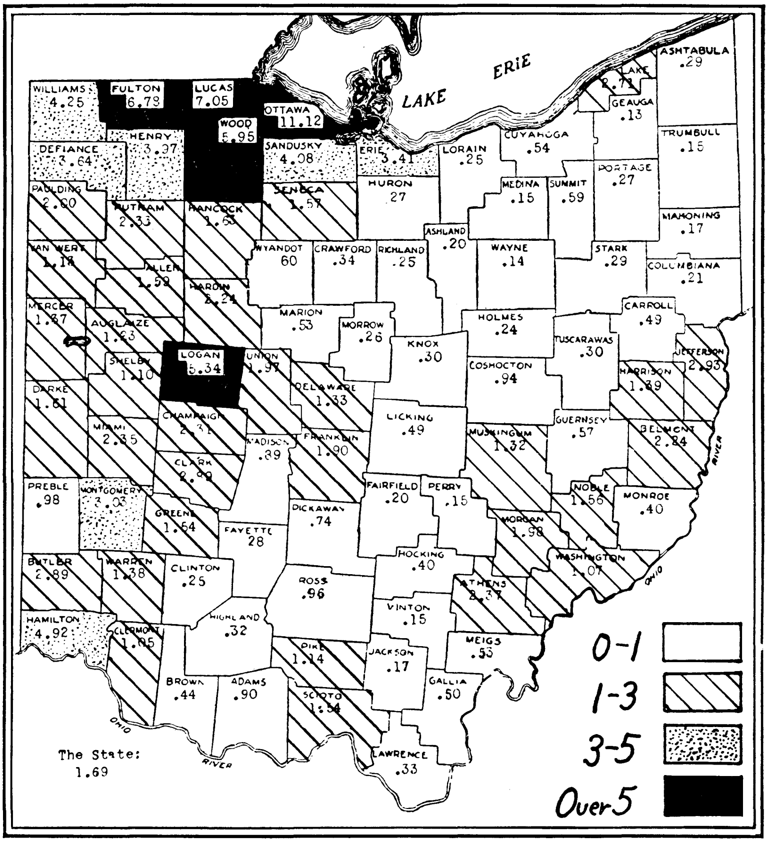

Fig. 2.—Percentage of crop land in alfalfa, 1929

Alfalfa acreage in Ohio.—The fact that the culture of alfalfa in Ohio is beset with problems is reflected in the slow growth of the alfalfa acreage in the State (Fig. 1). Even now, despite the considerable expansion in acreage since 1929, the acreage is by no means as large as it profitably could be. In 1933, alfalfa was reported on 274,000 acres, or 2.75 per cent of the crop land, in the State. Some alfalfa is grown in every county, with the largest amounts, both relatively and absolutely, in the northwestern Ohio counties—Ottawa, Wood, Lucas, Fulton, and adjacent counties (Fig. 2). Logan, Montgomery, and Hamilton Counties are also centers of alfalfa production and have been for a longer time than those counties in the northwest.

SOIL TYPES ON WHICH ALFALFA SUCCEEDS AND FAILS IN OHIO[3]

Alfalfa is adapted to a wide range of soils, varying from sands to heavy clays and even muck soils, providing certain essential conditions exist within the soils. These conditions include: (a) good drainage, either natural or

[3]This section was prepared by Dr. G. W. Conrey.

artificial; (b) fair to high fertility; and (c) good supply of lime. The characteristics of a soil in relation to these three conditions afford a basis for its evaluation as regards adaptation to alfalfa.

Good drainage is a first essential. In fact, all soils naturally adapted to this crop are well drained. However, many soils, which otherwise meet the requirements, are naturally poorly drained and, hence, must be tiled before they can be utilized successfully for alfalfa.

A fairly fertile soil is required. Especially is a good supply of available phosphoric acid needed. Since most Ohio soils are naturally deficient in this constituent, liberal fertilization with phosphate fertilizers is frequently advisable on land that is to be used for alfalfa.

Alfalfa is highly sensitive to acidity and seldom succeeds on acid soils, even where well drained and fairly fertile. On slightly acid soils alfalfa may succeed if the soil is fertile but it usually fails if the fertility is low. For optimum growth the acidity should be not greater than pH 6.5.

Alfalfa soils in western Ohio.—The largest area of soils naturally adapted to alfalfa lies in the western part of the State where the upland soils are derived largely from glacial drift made up chiefly of limestone material. Here, as well as elsewhere in the State where soils are derived from somewhat similar materials, differences have resulted from varying conditions of topography and drainage under which the soils have developed. The brown to reddish-brown soils (Bellefontaine) which occupy the gently rolling areas are well adapted to alfalfa. These soils are naturally well drained, are fairly fertile, and are commonly well supplied with lime. In contrast to these are the dark colored soils (Brookston and Clyde) which occur in level, low-lying areas and are naturally very poorly drained. These soils are dark in color, high in organic matter, usually very fertile, and are commonly neutral in reaction. However, alfalfa will do well on these soils only after artificial drainage. Excellent stands and yields are obtained on the well-tiled land. Intermediate in character are the grayish-brown (Miami), gray (Crosby), and light gray (Bethel) soils. The Miami soils, occurring on undulating to gently rolling areas, are almost as well adapted to alfalfa as Bellefontaine. Miami is not quite so well drained naturally as Bellefontaine; in fact, tiling may be necessary on some fields. Slight acidity is rather common in the Miami; in this case light applications of lime must be made to meet the needs for alfalfa. The gray soil (Crosby), occupying gently undulating areas, is usually acid and naturally poorly drained. Because of a very heavy, impervious layer in the subsoil, it is difficult to secure good artificial drainage. The light gray soil (Bethel) is the extreme in acidity and poor drainage among the light colored soils of this area. The more poorly drained areas of Crosby and the Bethel are the soils of the region on which the growth of alfalfa is difficult, if not questionable.

Associated with the upland soils of western Ohio are the gravel terrace (Fox) and flood plain soils (Genesee and Wabash). The Fox soils are naturally well drained, fairly fertile, and seldom acid in reaction and, hence, are admirably adapted to alfalfa. The light colored flood plain soils (Genesee) are commonly very fertile, are neutral in reaction, and, where adequately drained, are well adapted to alfalfa. Although the Wabash soil, which is dark in color and occupies low-lying areas in the flood plains, is very fertile and neutral in reaction, it is very poorly drained naturally and in places is difficult to drain artificially. Both of these soils are subject to annual inundations, especially during the spring of the year. Where flood water stands for long periods, as in the case of the Wabash soils especially, alfalfa stands may be seriously damaged.

The organic soils, such as peat and muck, can be utilized for alfalfa only after thorough drainage and if well supplied with lime. Such soils usually require the use of fertilizers high in potash, and sometimes in phosphoric acid, in order to supply the mineral elements in which these soils are commonly very deficient.

Alfalfa soils in northwestern Ohio.—In northwestern Ohio in the glacial lake plain there are large areas of soils well adapted to alfalfa. The dark colored soils (Brookston clay and Toledo silty clay), which are the most extensive, are neutral in reaction and very fertile and, hence, where good artificial drainage has been established, are well adapted to alfalfa. Paulding clay is considerably heavier than Brookston and much more difficult to drain adequately; hence, it is not considered to be as satisfactory a soil for alfalfa. The associated light colored soils (Nappanee and Fulton) have fair to poor natural drainage and fair fertility and are acid in reaction. These soils are not well adapted to alfalfa; attempts to grow it on the silty clay loams and clays of these series have usually met with disappointment. The light colored sands (Plainfield and Berrien) are naturally very well drained, of low natural fertility, and slightly acid. Deep sandy areas may prove to be somewhat drouthy. Only with adequate fertilizer treatment and liming can good stands of alfalfa be obtained.

Alfalfa soils in southwestern Ohio.—In the area of old glacial limestone soils in southwestern Ohio, only the slope soils (Edenton and Fairmount) are naturally adapted to alfalfa. The brown soil (Cincinnati) on the rolling uplands and ridge tops, although having good natural drainage, is usually acid and only fairly fertile. On the undulating to gently rolling upland, the soil (Rossmoyne) has only fair drainage, is acid, and is only moderately fertile. The gray soil (Clermont) on the level areas is naturally very poorly drained, very acid, and very low in fertility. Many areas of the Clermont soil are very difficult to drain by tiling, owing to the shallow depth and tight, impervious nature of the subsoil. In these soils, not only is the surface very acid but also the depth to subsoil lime is great, usually not less than 8 or 10 feet. Alfalfa is a questionable crop on Clermont soil, but it can be grown with fair success on the Rossmoyne and Cincinnati soils after heavy fertilization and liming.

Between the area of old glacial limestone soils of southwestern Ohio and the younger Late Wisconsin Drift soils of the western part of the State is an area of soils of intermediate character (Early Wisconsin Drift). The brown soils (Russell) are well drained and only slightly acid; whereas the grayish-brown (Fincastle) soil has fair to poor drainage and is distinctly acid in reaction. The associated gray soil (Delmar) is very poorly drained and quite acid in reaction. Of these soils the Russell is best adapted to alfalfa.

Alfalfa soils in northeastern Ohio.—In northeastern Ohio the soils are derived largely from glacial sandstone and shale material. Practically all the soils are acid except where they have been limed. In general, they are of only fair natural fertility. These soils vary in the conditions of natural drainage and also in the character of the subsoil.

One group of soils has open, porous subsoils. The brown soil (Wooster) occupies gently rolling to rolling areas and has good natural drainage. The light brown soil (Canfield) occupies more level areas and has fair to good drainage. Alfalfa can be grown successfully on these soils only where a definite program of liming and phosphating has been carried out. The brownish-gray (Volusia) soils occupy the more level areas and are naturally very poorly drained. Even with adequate tiling they are not so desirable for alfalfa as the Wooster and Canfield.

A second group includes soils with heavy, impervious subsoils, such as the Ellsworth (light brown) and the Mahoning (grayish-brown) soils. These soils are not only acid in reaction and of only fair fertility but also are very poorly drained naturally. Because of the heavy, impervious subsoil, adequate artificial drainage is difficult to secure. Good stands of alfalfa are uncommon on these soils, especially on the Mahoning. The associated gray soil (Trumbull), because of its very poor drainage and low fertility, is unsatisfactory for alfalfa.

In the northern and northeastern parts of the State there is a narrow lake plain area bordering Lake Erie, where the soils are somewhat similar to those of the northwestern part of the State, except that they are much more acid in reaction. The brown soil (Painesville) is well drained and of fair fertility. The grayish-brown soil (Caneadea) has fair to poor drainage and is very acid in reaction. The heavy textured soils are difficult to drain. The dark colored soils (Lorain) are naturally very poorly drained and are somewhat less acid and more fertile than the Caneadea. Of this group of soils the Caneadea is least desirable for alfalfa. With adequate liming and fertilization it will do fairly well on the Painesville soil; whereas the Lorain soils require adequate drainage as well as liming and fertilizing.

Alfalfa soils in southeastern Ohio.—In southeastern Ohio the soils are largely residual in origin; that is, they have been formed by the weathering in place of the country rock, and the character of the soil is closely related to the type of rock from which it is derived (whether sandstone, shale, clay shale, or limestone). The brown soil, derived from sandstone and shale (Muskingum), is naturally well drained but is low in fertility and quite acid in reaction. Only after adequate liming and fertilizer treatment can alfalfa be grown successfully. The red clay soil (Upshur clay), derived from clay shales, is commonly well supplied with lime, although some fields are quite acid. It is desirable to test individual areas, and, in case the soil proves to be acid, lime must be supplied in order to assure success with alfalfa. The brown to dark brown soil, which is derived from limestone (Brooke), is well supplied with lime and is admirably adapted to alfalfa.

Throughout a considerable area in southeastern Ohio the adaptability for alfalfa may be markedly different in various parts of a field as a result of a mixed soil condition. This is a result of the variations in parent rock, which in places occurs in alternating thin layers of different character, giving a banded distribution to the soils in hillside fields. The Meigs soil, which includes a mixture of Muskingum silt loam and Upshur clay, is dominantly acid in reaction and requires liming for alfalfa. Westmoreland (mixed Muskingum and Brooke) contains a considerable proportion of limestone land which is well adapted to alfalfa. Lime must be applied to included areas of Muskingum silt loam, which tests have shown to be acid, if uniform stands of alfalfa are to be secured. Similarly, areas of the Belmont soil (mixed Muskingum, Brooke, and Upshur) are well adapted to alfalfa, except on included areas of acid soils, which can be located by acidity tests on individual fields. Only those parts of fields of Westmoreland and Belmont soils which tests show to be acid need liming for alfalfa.

The bottom lands throughout the hilly portion of the State are variable in reaction. Commonly, the broad first-bottom lands in the larger valleys, where well drained, are very fertile and are either neutral or only slightly acid (Huntington). On such areas excellent stands of alfalfa can be secured. The well-drained flood plain lands in minor valleys associated with the Muskingum soil (Pope) are acid in reaction and, hence, require liming before alfalfa will succeed. The terrace and second bottom soils of this part of the State vary from slightly acid to very acid, but, where well drained, good stands of alfalfa can be secured after adequate liming.

Soil types at the Experiment Farms contributing data to this bulletin.—The locations at which experiments with alfalfa have been conducted represent a wide range of soil types. For more detailed descriptions of these soil types than just given, see Special Circular 44 and Bimonthly Bulletins 117, 118, 119, 121, 123, 125, and 134 of the Ohio Agricultural Experiment Station, the Soil Survey of Butler County (Russel and Fincastle silt loams), and the Soil Survey of Putnam County (Paulding clay).

At Wooster, the types represented are the Wooster silt loam and the Canfield silt loam.

At Columbus most of the plots are Miami silt loam and Brookston silty clay loam, with small areas of the Crosby and Clyde series. However, no areas of Crosby were used in these experiments. Nearly every range of plots at Columbus included varying proportions of Miami and Brookston soils. These types are of very unequal value for cereals. Borst and McClure (7) report a 6-year average yield of corn under normal cultivation of 60 bushels on Miami and 70 bushels on Brookston; the difference is often even greater. However, when the Miami is limed sufficiently to permit obtaining a stand, it is nearly as productive in alfalfa as the Brookston; hence, the lack of uniformity in the plots does not affect the results to the extent that it does in the experiments with cereal crops.

The types represented on the Madison County Experiment Farm are the Miami silty clay loam and Clyde silty clay loam; on the Miami County Experiment Farm, the Crosby silt loam and Brookston silty clay loam; on the Hamilton County Experiment Farm, Russell silt loam and Fincastle silt loam; on the Clermont County Experiment Farm, Clermont silt loam and Rossmoyne silt loam; on the Southeastern Experiment Farm, Muskingum silt loam and Meigs silty clay loam; on the Trumbull County Experiment Farm, Mahoning silty clay loam and Trumbull silty clay loam; on the Paulding County Experiment Farm, Paulding clay; on the Northwestern Experiment Farm, Brookston clay; on the Timothy Breeding Station, Caneadea silty clay loam and Lorain silty clay loam; on the Mahoning County Experiment Farm, Canfield silt loam and Volusia silt loam.

SOIL TREATMENTS FOR ALFALFA

In modifying soils not naturally adapted to alfalfa so that they will produce alfalfa profitably, the most important practices are tile drainage, the use of lime, and the use of fertilizers. Experiments involving all these factors have been conducted by the Station.

TILE DRAINAGE

Practical farm experience has indicated that adequate tile drainage is necessary to success with alfalfa on many soil types in the State (Fig. 3). Nearly all the alfalfa experiments herein reported have been conducted on tiled land, since most of the areas used for alfalfa experiments on the Experiment Farms in the State have been tiled. The only specific experiment comparing tiled and untiled land for alfalfa was conducted on Block R of the

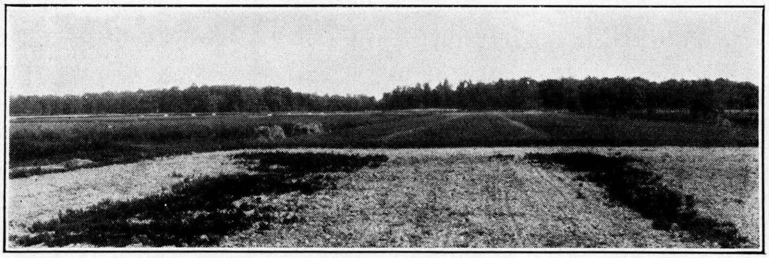

Fig. 3.—Effect of tile on alfalfa at North Ridgeville

Alfalfa sown in July 1926; photo summer of 1927. Alfalfa completely winterkilled except directly over the tile. Area has been disked several times to destroy weeds, during summer of 1927.

Trumbull County Experiment Farm. Most of this block is Mahoning silty clay loam, and the rest is Trumbull clay, soil types on which alfalfa sown alone usually kills out to a considerable extent except for a narrow space directly over the drain tile. The details of this test are given in Table 1. The yields are reported as field weights and hence are subject to a considerable deduction for shrinkage. They should, however, be comparable. It is evident that on this soil type the yield of alfalfa is greatly increased by tiling.

TABLE 1.—Effect of Tile on Alfalfa Yields at the Trumbull County Experiment Farm, 1919-1922

Plot	Treatment	Size of tile	Depth	Width of plot	Yield per acre				
					1919 2 cuts	1920 2 cuts	1921 3 cuts	1922 3 cuts	Av. 4-yr.
		Inches	*Inches*	*Feet*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
1	No tile	....	....	33	2.67	2.96	1.77	2.27	2.42
2	No tile	....	....	33	3.03	3.41	3.21	2.01	2.92
3	Tile in center	4	36	36	3.56	3.14	4.02	3.03	3.44
4	Tile in center	4	36	36	3.86	3.61	4.59	3.08	3.79
5	Tile in center	4	36	36	3.80	3.54	4.47	3.50	3.83
6	Tile in center	4	30	36	3.48	3.08	4.36	2.66	3.40
7	Tile in center Tile at west edge	4 3	30 18	36	3.41	3.47	5.12	3.33	3.83
8	Tile at east edge Tile in center Tile at west edge	3 4 3	18 30 18	36	4.62	3.14	5.24	4.84	4.46
Average of untiled plots					2.85	3.19	2.49	2.14	2.67
Average of all tiled plots					3.79	3.33	4.63	3.41	3.79

LIME FOR ALFALFA

That alfalfa will not succeed on lime-deficient soils was early learned in the humid regions. The impossibility of growing alfalfa on the acid soils of eastern Ohio without liming was demonstrated years ago in tests by the Experiment Station, as well as on many practical farms in the region. The only present experiments comparing lime and no lime for alfalfa are in western Ohio where there occur many soils of a border line character with respect to the adequacy of their lime supply. Attention in this report will be confined to experiments at Wooster designed to determine the response of alfalfa to varying soil reactions and to certain studies of methods of applying lime.

EFFECT OF SOIL REACTION ON ALFALFA

The Legume-Reaction Experiment[4].—In this experiment, begun at Wooster in 1926, alfalfa is one of seven hay crops grown in a 3-year rotation with corn and small grain over a series of five ranges adjusted in soil reaction to approximately pH 4.5, pH 5, pH 6, pH 7, and pH 8. There are three sections, permitting the growing of all crops each year with the exception of the small grain crops, wheat, oats, and barley. Each of the small grains is grown on a single section and, hence, only once in 3 years. The soil is a Canfield silt loam, which at the beginning of the test was rather low in fertility and had a reaction slightly above pH 5.0. Adjustment to higher pH values was made by appropriate additions of pulverized limestone and to lower pH values by applications of aluminum sulfate or sulfur. No manure has been applied, but muriate of potash, at the rate of 40 pounds per acre on corn and 50 pounds per acre on the small grain, has been applied to all ranges. In addition, one-half of each plot has received 200 pounds of 20% superphosphate broadcast on corn and 400 pounds on the small grains. The fertilizer treatment was intended to determine the effect of liberal phosphate additions upon the reaction response of the crops grown.

In Table 2 are presented the 6-year average actual and relative yields of alfalfa on the phosphated soil at the several reactions, and, also, for comparison, the corresponding yields of the other hay crops.

The soil reactions attained approximate closely the intended reactions, except for pH 8, where, in spite of heavy applications of limestone, the actual pH remained considerably below the intended reaction until 1932 when tests showed reactions of 7.70 to 7.85 on this range. Alfalfa has given maximum yields at approximate neutrality, pH 7. The same is true for all of the other hay crops, except sweet clover, which has given the highest yield at the most alkaline reaction. A decrease in reaction from pH 7.0 to pH 6.0 has, in the case of alfalfa, decreased the yield 59 per cent, as compared with corresponding decreases of 27 to 40 per cent for the true clovers and of 24 per cent for soybeans. Apparently, the reaction range between pH 6.0 and pH 7.0 is a critical one for alfalfa and should be given further study. The present practice of Ohio extension agronomists in recommending lime for alfalfa on soils below 6.5 is not out of line with these data.

Value of alfalfa in these rotations.—The yields of both grain and hay crops for the alfalfa rotation on both phosphated and unphosphated land and for the red clover and timothy rotations on the phosphated land are shown in Table 3.

[4]Data from the Legume-Reaction Experiment have been reported previously as follows: (2; 3; 49, p. 52; 50, p. 51; 51, p. 44; 52, p. 22).

TABLE 2.—Yields of Hay in the Legume-Reaction Experiment at Wooster, 1928-1933

Basic treatment: 600 pounds 20% superphosphate and 90 pounds muriate of potash in the rotation

Soil reaction: Intended pH	Soil reaction: Actual* pH	Alfalfa	Sweet clover	Red clover	Mammoth clover	Alsike clover	Soybeans	Timothy
Actual yields in pounds per acre, 6-year average								
4.5	4.7	196	30	572	642	516	1705	827
5.0	5.2	544	170	863	1151	1096	2049	1205
6.0	5.9	1814	2893	1832	2453	2792	1984	1758
7.0	6.8	4410	5774	3069	3661	3805	2625	2678
8.0	7.4	4149	6270	2892	3279	3513	2473	2558
Relative yields—maximum yield=100								
4.5	4.7	4	1	19	18	14	65	31
5.0	5.2	12	3	28	31	29	78	45
6.0	5.9	41	46	60	67	73	76	66
7.0	6.8	100	92	100	100	100	100	100
8.0	7.4	94	100	94	81	92	94	96

*Average of 5 tests covering a 4-year period.

TABLE 3.—Yield of Crops for Three Rotations in the Legume-Reaction Experiment at Wooster

Soil reaction* pH	Hay 6-year yield Lb.	Corn 5-year yield Bu.	Wheat 2-year yield Bu.	Barley 2-year yield Bu.	Oats 1-year yield Bu.
Corn, small grain, alfalfa—unphosphated land					
4.5	121	13.0	4.5	0.0	62.3
5.0	603	26.7	9.3	3.0	56.6
6.0	1648	35.2	15.9	9.6	49.1
7.0	3235	45.9	23.2	16.3	66.9
8.0	4187	48.3	27.4	24.2	69.1
Corn, small grain, alfalfa—phosphated land					
4.5	196	13.9	26.3	0.0	67.5
5.0	544	31.6	29.3	6.6	68.1
6.0	1814	37.2	32.5	17.4	64.4
7.0	4410	49.6	39.5	25.9	73.4
8.0	4149	44.0	38.9	29.0	65.9
Corn, small grain, red clover—phosphated land					
4.5	572	13.5	26.5	0.0	71.1
5.0	863	27.6	29.4	5.9	66.6
6.0	1832	30.1	35.4	20.3	67.4
7.0	3069	34.9	38.9	23.6	66.0
8.0	2892	29.0	37.8	24.2	68.2
Corn, small grain, timothy—phosphated land					
4.5	827	9.2	27.0	0.0	68.8
5.0	1205	20.2	29.8	6.4	72.2
6.0	1758	22.6	28.5	17.8	75.9
7.0	2678	31.6	32.3	22.2	71.9
8.0	2558	29.6	34.6	23.3	79.1

*Intended reactions. For actual reactions see Table 2.

TABLE 4.—Composition of Alfalfa Hay from the Legume-Reaction Plots, 1932

1st cutting, June 13; 2nd cutting, July 19; 3rd cutting, August 9. Based on water-free material

Intended pH	Nitrogen			Phosphorus			Potassium			Calcium			Magnesium			Manganese		
	Cutting			Cutting			Cutting			Cutting			Cutting			Cutting		
	1 Pct.	2 Pct.	3 Pct.	1 Pct.	2 Pct.	3 Pct.	1 Pct.	2 Pct.	3 Pct.	1 Pct.	2 Pct.	3 Pct.	1 Pct.	2 Pct.	3 Pct.	1 Pct.	2 Pct.	3 Pct.
Phosphated land (south ends of plots)																		
5.............	2.19	3.21	4.09	0.20	0.27	0.34	1.56	1.49	2.08	1.69	1.71	1.79	0.37	0.36	0.43	0.017	0.012	0.013
6.............	2.14	2.99	4.00	0.16	0.27	0.34	1.51	1.52	2.12	1.45	1.73	1.71	0.34	0.41	0.46	0.009	0.006	0.009
7.............	2.49	2.99	4.18	0.19	0.27	0.34	1.25	1.49	2.12	1.67	1.47	2.02	0.35	0.36	0.50	0.005	0.004	0.008
8.............	2.49	3.22	3.93	0.22	0.32	0.34	0.86	1.11	1.99	1.67	1.75	2.14	0.35	0.48	0.47	0.005	0.005	0.006
Average.....	2.33	3.10	4.05	0.19	0.28	0.34	1.30	1.40	2.08	1.62	1.66	1.92	0.35	0.40	0.46	0.009	0.007	0.009
Unphosphated land (north ends of plots)																		
5.............	2.09	3.21	3.65	0.16	0.22	0.36	1.28	1.45	2.12	1.54	1.68	1.77	0.33	0.37	0.50	0.016	0.011	0.016
6.............	2.24	3.21	2.64	0.16	0.22	0.30	1.43	1.44	1.76	1.75	1.74	1.98	0.34	0.39	0.34	0.011	0.009	0.013
7.............	2.64	3.46	4.15	0.16	0.21	0.30	1.30	1.73	2.02	1.67	1.52	1.97	0.28	0.29	0.54	0.006	0.006	0.013
8.............	2.38	3.15	4.05	0.17	0.29	0.33	0.82	1.41	1.83	1.74	2.20	2.29	0.37	0.40	0.50	0.005	0.007	0.012
Average.....	2.34	3.26	3.62	0.16	0.24	0.32	1.21	1.50	1.93	1.68	1.78	2.00	0.33	0.36	0.47	0.010	0.008	0.014
Average of all treatments..	2.33	3.18	3.84	0.18	0.26	0.33	1.25	1.46	2.00	1.65	1.72	1.96	0.34	0.38	0.47	0.009	0.008	0.011

Worthy of special note is the superiority of the corn yields in the alfalfa rotation to those in the red clover rotation, amounting to about 15 bushels an acre at the two highest reactions, and also the beneficial effect of phosphate upon the yield of alfalfa hay at the pH 7 reaction. The sensitivity of barley to soil acidity and the tolerance of oats agree with former observations on these crops.

Composition of alfalfa hay grown at different soil reactions.—In Table 4 are presented the results of chemical analyses for nitrogen and minerals made upon the alfalfa hay harvested from the Legume-Reaction Experiment in 1932. It should be noted that the "third cutting" of hay in 1932 was very immature and, hence, not representative of normal third-cutting hay. The average compositions shown in Table 4 are in fair agreement with the results of Ames and Boltz (4, 5), and the variations in phosphorus and calcium content with treatment are similar to those found by them. Ames and Boltz found that the first cutting contained a higher percentage of nitrogen, phosphorus, and potassium than the second cutting. The reverse is true in the present data. That this discrepancy does not arise from differences in the age of growth is indicated by the fact that Ames and Boltz' first cutting was made 6 days later than in the present instance and that the second cutting was 36 days old in both cases. The most outstanding effects of soil reaction on the composition of the hay are the decreases in potassium and manganese at the higher reactions. Contrary to expectation, the contents of calcium and magnesium were not greatly or consistently affected by increasing pH. Superphosphate appears to have produced no notable changes in the composition of the hay except a small, but consistent, increase in the percentage of phosphorus.

TABLE 5.—Composition of Alfalfa Roots from the Legume-Reaction Experiment, October 30, 1933

Based on water-free material

Soil reaction		Nitrogen	Phosphorus	Potassium	Calcium	Magnesium	Manganese
Intended pH	Actual* pH	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Phosphated land (south ends of plots)							
5.0	5.05	1.56	0.22	0.60	0.25	0.15	0.0032
6.0	5.66	2.21	0.22	0.36	0.48	0.20	0.0064
7.0	6.80	2.37	0.22	0.41	0.31	0.20	0.0048
8.0	7.58	2.56	0.28	0.38	0.34	0.21	0.0032
Average ☞		2.18	0.24	0.44	0.35	0.19	0.0044
Unphosphated land (north ends of plots)							
5.0	5.06	1.52	0.22	0.52	0.23	0.15	0.0042
6.0	5.92	2.17	0.21	0.46	0.41	0.24	0.0050
7.0	7.12	2.33	0.20	0.47	0.31	0.16	0.0042
8.0	7.76	2.55	0.27	0.40	0.27	0.24	0.0032
Average ☞		2.14	0.23	0.46	0.31	0.20	0.0042
Average of all ☞		2.16	0.23	0.45	0.33	0.19	0.0043

*Reactions shown are for soil taken in close proximity to the roots harvested.

Composition of alfalfa roots grown at different soil reactions.—Data on the composition of alfalfa roots from this experiment are presented in Table 5. A comparison of the data in Tables 4 and 5 shows that the hay and roots do not differ greatly in nitrogen and phosphorus content but that the hay is considerably higher in its content of the other mineral elements. There is a tendency for the percentages of potassium and manganese in the roots to decrease with increasing pH, and there is an opposite tendency in the case of nitrogen.

METHODS OF APPLYING LIME FOR ALFALFA

In the Legume-Reaction Experiment the amounts of limestone and the methods of incorporation employed are such as to bring the entire 7-inch plowed layer of soil to the desired reaction. To bring this soil from its original reaction of around pH 5.0 to pH 7.0, the optimum for alfalfa, an initial application of over 3 tons of limestone per acre was required. This and other work of the Station indicate that to maintain a reaction of pH 7.0 on this soil, once it has been attained, periodic additions equivalent to about 500 pounds of limestone annually are required.

Light applications of lime.—Recently, considerable interest has arisen in the possibility of economizing on lime by using relatively light applications so incorporated as to bring the soil in the immediate vicinity of the young plants to a satisfactory reaction. One method receiving attention has been the drilling of lime directly with alfalfa or other legume seeds on wheat ground in the spring, or even on spring-prepared land with oats or seedings without a companion crop. The alfalfa seed is placed in the grass seed attachment of the grain drill, the limestone in the fertilizer attachment, and provision made to carry both down the fertilizer tube into the same disc furrow. The maximum amount of limestone that can be applied in this manner is about 700 pounds. One would expect that the use of such light lime applications for alfalfa might succeed best on soils that were only slightly too acid for the crop, perhaps around pH 6.0, or on soils that contained lime at rather shallow depths in the subsoil, a condition that obtains in most of western Ohio north of the area covered by the Illinoian glaciation. Unfortunately, the value of these light applications for alfalfa has not been adequately studied by the Experiment Station.

TABLE 6.—Results from Different Methods of Applying Lime at Wooster

Liming materials experiment. Rotation: Corn, wheat, hay

Material	Method of application	Rate per acre ($CaCO_3$ equivalent)	Increase in yield of hay, 6-yr. av.
		Lb.	*Lb.*
Pulverized limestone	On wheat ground in fall; broadcast; shallow incorporation	500	1125
Pulverized limestone	On wheat ground in fall; broadcast; shallow incorporation	1000	1664
Pulverized limestone	Broadcast in spring at time of seeding clover	500	247
Pulverized limestone	Drilled with clover seed	500	547
Hydrated lime	Drilled with clover seed	500	500

Experiments at Wooster.—The results in the "Liming Materials" Experiment, begun at Wooster in 1926 (2, p. 47; 52, p. 22), are of interest in this connection. The soil is a Canfield silt loam averaging, without lime, about pH 5.5. In Table 6 are given the 6-year average increases in the yield of hay, grown in rotation with corn and wheat, from certain lime treatments, also indicated in the table. The hay seeding has included alfalfa, red clover, alsike clover, and timothy at 4, 4, 2, and 4 pounds per acre, respectively. It is evident that drilling 500 pounds of fine limestone, or its equivalent of hydrated lime, with the seed in the spring has been better than applying the same quantity of limestone in the spring as a surface dressing without incorporation. However, when compared with the same amount of limestone applied broadcast and incorporated to a shallow depth when preparing the land for wheat in the fall, the drilling method appears only about one-half as good. In this comparison one cannot differentiate between the effect of the method of incorporation and the effect of the difference in the time of contact between the limestone and the soil.

Indications that the too-localized placement of light applications of lime may be disadvantageous were obtained in a lime placement test at Wooster in 1931-1932, using sweet clover as the indicator crop. In this test, the use of either 500 or 1000 pounds per acre of precipitated carbonate of lime or fine limestone applied as an all-over application and accurately incorporated to a depth of either 1 or 2 inches was somewhat superior to applying the same amounts in a 2 by 2-inch band in the seed row.

TABLE 7.—Drilling Lime and Fertilizer with Sweet Clover Seed on Miami Silty Clay Loam at Madison County Experiment Farm, 1932

Yields are for hay harvested in the fall of the same year

Materials	Rate per acre	Manner of sowing lime and fertilizer	Yield of hay per acre†
	Lb.		*Lb.*
Basic slag	500	With seed	1850
Ground limestone	500	With seed	1550
Ground limestone 20% superphosphate	500 250	With seed With seed	2400
Ground limestone 20% superphosphate	500 250	With seed Broadcast	2080
Ground limestone 20% superphosphate	500 250	Broadcast With seed	2280
*Ground limestone 20% superphosphate	500 250	Broadcast Broadcast	2160
Ground limestone 0-14-6	500 357	With seed With seed	1870
Ground limestone 20% superphosphate	2000 250	Broadcast Broadcast	1600
Untreated	....	....	310

*Seed sown broadcast, falling in rear of discs.
†Yields from averages of two square-yard samples.

Experiment at the Madison County Experiment Farm.—In Table 7 are presented one year's data from a "method of applying lime test" on Miami soil on the Madison County Experiment Farm. Sweet clover was sown with oats in the spring of 1932. Although conclusions are not warranted from a single season's results, the indications point to considerable increase from 500 pounds of limestone. However, there was no significant advantage from drilling the limestone with the seed compared with an all-over broadcast treatment.

Suggestions.—Although the evidence seems to be somewhat in favor of broadcasting and incorporating light applications of lime to a shallow depth, in preference to drilling with the seed, it is too meagre to be conclusive. The labor economy of the drilling method is worth consideration. It has been demonstrated that relatively small acre quantities so applied as to come in contact with only a limited amount of soil close to the young plant frequently produce proportionately larger effects than large acre quantities applied in the usual manner. Farmers wishing to try the drilling method should confine its use to the following conditions: (a) on soils only slightly too acid for alfalfa; (b) as a supplement to a heavier broadcast treatment, or (c) on soils underlain by lime in the subsoil at a depth of approximately 2 feet or less.

FERTILIZING ALFALFA

Many soils in Ohio are not sufficiently fertile to produce profitable crops of alfalfa without treatment. Proper fertilization of the crop is thus an important problem. Alfalfa is a heavy user of soil nutrients. A good yield of alfalfa may be estimated at 4 tons per acre per year (Table 47) (77). Of this, about half is in the first cutting and half in the second and third cuttings (Table 48). By the use of these assumptions and the chemical data from the Legume-Reaction Experiment at Wooster as a basis, the hay (15% moisture) removed from such a reasonably high-yielding acre in one year would contain 187 pounds of nitrogen, 34 pounds of phosphoric acid, and 111 pounds of potash. To replace these amounts in commercial materials would require 1170 pounds of 16% nitrate of soda, 171 pounds of 20% superphosphate, and 222 pounds of 50% muriate of potash. A large part of the nitrogen represents fixation from the air and, hence, gain rather than loss to the farm if the hay is fed; certainly there is no loss even if the hay is sold. However, the minerals must come from the soil, and a soil capable of furnishing such large amounts of minerals must be either naturally well stocked with minerals or highly fertilized. No doubt, the rapid deterioration of some alfalfa stands is due as much to starvation as to other causes.

Farm experience (77) and most fertilizer experiments in the United States (11, 14, 54, and many others) indicate a nearly universal response of alfalfa to phosphate fertilizers and to barnyard manure applied either before seeding or as a top-dressing. Potash frequently gives good increases and is especially beneficial on sandy soils, peats, and mucks (9, 23, 57). Nitrogen seldom gives an increased yield, except when applied to poor soils in small quantities at seeding time.

The problem of fertilizing alfalfa is two-fold, involving (a) applications made at or prior to seeding and (b) the top-dressing of established stands. Neither phase of the problem has been adequately investigated in Ohio, although each has received some attention[5]. The experiments herein reported are recognized as having limited application—some because they have dealt with alfalfa in mixtures rather than in pure stands; others because they were conducted on soils of above average productivity. Among the latter, those dealing with top-dressing are subject to the further limitation that they were conducted on relatively young stands where the exhaustion of soil nutrients had not yet attained serious proportions. The foregoing limitations should be kept in mind in considering the following experimental results.

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[5]Experiments on fertilizing alfalfa have been previously reported in the following publications: (2; 4; 48, p. 20; 61, p. 543; and 76).

FERTILIZING ALFALFA AT SEEDING TIME

Experiments on the outlying farms.—Alfalfa is included in the hay mixture seeded in wheat in the fertility rotations on seven of the outlying experiment farms. The seeding in most cases has been 4 pounds each of alfalfa, red clover, and timothy and 2 pounds of alsike clover per acre, with a larger proportion of alfalfa in a few instances. In Table 8 are presented the average increases in wheat and hay produced by 20% superphosphate, 0-14-6, and 2-14-4 used in amounts carrying equal acre quantities of phosphoric acid. The period covered is 1928 to 1932, inclusive, for wheat and 1929 to 1932 for hay, with exceptions as indicated.

TABLE 8.—Increases in Wheat and Hay from Fertilizers Applied to Wheat on Outlying Experiment Farms

County	Period		Increases in yield for					
			0-20-0*		0-14-6†		2-14-4†	
	Wheat	Hay	Wheat	Hay	Wheat	Hay	Wheat	Hay
			Bu.	*Lb.*	*Bu.*	*Lb.*	*Bu.*	*Lb.*
Mahoning	1928-1932	1928-1932	6.6	850	9.6	1520	9.2	1870
Belmont	1928-1932	1929-1932	6.3	1330	11.0	2210	13.4	1510
Washington	1928-1932	1929-1932	11.0	1080	15.5	2190	17.6	1820
Clermont‡	1928-1932	1929-1932	11.0	1140	15.9	1280	18.6	1820
Hamilton	1930-1932	1929-1932	10.0	610	13.5	1150	15.2	1150
Madison	1929-1932	1929-1932	18.8	860	17.4	630	19.4	930
Miami	1929-1932	1929-1932	14.3	1280	18.9	1520	19.7	1450
Average	....	....	11.1	1021	14.5	1500	16.2	1507

*Used at the rate of 300 pounds per acre (equivalent to 429 pounds of 0-14-0) on all farms.
†Used at the rate of 429 pounds per acre on all farms except Madison, where rate was 357 pounds.
‡Data are for tile-drained series.

Although the data cover too short a period to permit definite conclusions for individual farms, it is evident that fertilizers applied to the small grain companion crop have produced notable effects on the following hay crop. In general, both phosphoric acid and potash have been very effective in increasing the yield of hay. On the other hand, substituting 2 per cent of nitrogen for 2 per cent of potash in the fertilizer has, on the average, produced no significant increase in the hay crop. The average increase of 1500 pounds of hay for the 0-14-6 analysis, if valued at $6.00 per ton, has been sufficient to pay three-fourths of the cost of the fertilizer applied to the wheat, figuring 0-14-6 at $28.00 per ton.

Early Wooster experiments.—Early experiments in fertilizing alfalfa on Wooster silt loam at Wooster, of which the first year's results were reported in Bulletin 181 (76), are summarized in Table 9. The 1906 and 1907 records are from a test sown in July and August 1905, on plots which were fertilized as indicated for the initial application 2 years before for a seeding which failed. The 1908-1911 records are from a seeding made July 8, 1907, the indicated amounts of fertilizer having been applied on April 7 previous. Half the indicated amounts of fertilizer were again applied on April 14, 1909. In 1910 the full amounts of fertilizer were applied, but no manure was applied to Plots 6 or 7.

An excellent response to phosphoric acid, potash, and manure is indicated. Nitrate of soda used in addition to superphosphate also was effective, although

TABLE 9.—Fertilizing Alfalfa, 1906-1911

No.	Fertilizer material	Initial rate per acre	Average annual rate per acre	Yield of hay per acre							Yearly average increase over check	
				1906	1907	1908	1909	1910	1911	6-year average		
		Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Pct.*
1	None	....	....	8930	5461	7981	6612	4492	4139	6269	....	....
2	0-16-0	320	187	10151	5667	8582	7331	4856	4273	6810	541	8.6
3	0-16-0 Muriate of potash	320 60	187 35	10164	6732	9215	8203	6551	5184	7675	1406	22.4
4	0-16-0 Nitrate of soda	320 80	187 45	9815	6225	9270	7895	5981	5075	7377	1108	17.7
5	0-16-0 Muriate of potash Nitrate of soda	320 60 80	187 35 45	9921	6828	9287	8178	6503	4996	7619	1350	21.5
6	Manure	8 tons	3.3 tons	10277	7230	9758	8921	5922	6517	8104	1835	29.3
7	0-16-0 Manure	160 4 tons	93 1.7 tons	9162	6411	9032	7890	5602	5182	7213	944	15.1

the lack of response when used in addition to muriate of potash on Plot 5 suggests that its effect may have been due to its sodium rather than to its nitrogen. A similar indication was obtained in later top-dressing experiments at Wooster.

Experiments at the Northwestern Experiment Farm.—In an alfalfa top-dressing experiment on Brookston clay at the Northwestern Experiment Farm, basic treatments of phosphates were applied in strips (Page 28) prior to seeding on August 20, 1929. Although good stands were obtained, the plants were small and heaved out during the winter. On Strip C, which had received 900 pounds per acre of 0-20-0, the plants came through the winter conspicuously better than on the other strips. The yield of roots in this strip the following spring was over three times as great as in the unfertilized strip.

An even more pronounced response to fertilizer at seeding has been noted on other ranges of the farm. In the beet rotation, which consists of corn, beets, oats, alfalfa, wheat (sweet clover), the untreated checks could easily be picked out by the smaller growth of alfalfa in the fall of 1932. Samples were not taken until late but they indicated over twice the amount of top growth on the fertilized plots. Two samples of roots were also harvested in the check and in the adjacent plot, which received 300 pounds of 0-14-6 broadcast for the oats. The root yields were, respectively, 1150 and 1530 pounds per acre.

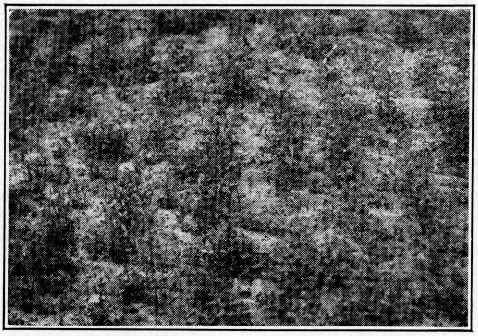


Fig. 4.—Fertilizer helps establish seedlings

Rows in alfalfa seedlings, due to 500 pounds per acre of 0-14-6, drilled with a grain drill before seeding. Columbus, September 19, 1933. Sown July 28, 1933. The actual rows of plants are diagonal to the direction of drilling the fertilizer. Some of them can still be distinguished in the lower left center of the picture.

In the corn-oats-alfalfa-wheat (sweet clover) rotation, in which the main variable is the method of fertilizing corn, the alfalfa at the second cutting in 1932 showed a distinct residual effect of the hill fertilization of corn in 1930. The alfalfa was short and badly yellowed. Every hill-fertilized plot had a succession of spots of taller, greener alfalfa where each corn hill had been in 1930. Since the spots were only about a foot across, no accurate estimate of relative yields was possible, but the spots were estimated to yield from half again to double what the surrounding area yielded. It is clear that under some conditions alfalfa responds to fertilizer on this soil.

A striking demonstration of the value of fertilizer in establishing seedings is given in Figure 4.

Applications of phosphate fertilizers at or before seeding permit thorough mixing through the soil. This is important as the movement of phosphoric acid in the soil is extremely slow. The same is true in less degree for potash fertilizers. While phosphoric acid has been noted to hasten the maturity of the small grain crops, it is doubtful if this earlier removal of the companion crop benefits the alfalfa to any extent in most seasons. Too heavy fertilization may cause a rank growth of the companion crop to the detriment of the stand of alfalfa, which is sensitive to heavy shading. At the Miami County Experiment Farm the proportion of alfalfa in the hay mixture has been noted as being inversely proportional to the yields of wheat, the best initial stands being obtained on the unfertilized plots where the wheat was thin. General observations indicate that nitrogen in the fertilizer makes for rank growth and a greater tendency to lodge than does either phosphoric acid or potash.

Recommendations.—Definite conclusions regarding the proper fertilization of alfalfa at seeding time under various soil conditions cannot be drawn from the data here reported. However, these data combined with many observations of the results of fertilizer treatment on private farms are believed to warrant the following suggestions:

On light colored sandy soils	300-400 pounds 2-12- 6
On the poorer, light colored silt loams and clays	300-400 pounds 2-14- 4
On dark colored silt loams and clays and on the better, light colored soils	250-350 pounds 0-14- 6
On peats and mucks	250-350 pounds 0-12-12

Especially on soil types where a stand of alfalfa is difficult to obtain, liberal applications of manure in preparing the land for seeding or to the preceding crop are very beneficial in obtaining a stand. Where manure is used, it should be supplemented with superphosphate at the rate of 200 to 300 pounds per acre of 0-20-0. Light, winter top-dressing of wheat with manure has been observed to be very beneficial to the following spring seeding of alfalfa.

TOP-DRESSING ALFALFA WITH FERTILIZER AND MANURE

Experiments at Wooster.—In 1926 a top-dressing experiment was begun at Wooster on alfalfa seeded in 1925. Previous to seeding the alfalfa, the entire field received an application of 300 pounds of 2-12-2 fertilizer per acre well worked into the seedbed. An examination of the soil to a depth of 24 inches showed that previous lime applications had corrected soil acidity to a depth of 16 inches; hence, no lime was applied. This land had been in alfalfa for several years previously, was well inoculated, and was in a fairly high state of fertility. The soil is classified as Wooster silt loam and is tile drained. The field was laid off into four parallel strips 68 feet wide. August 3 the first and third strips were seeded to Utah common alfalfa and the second and fourth to Idaho Grimm, at the rate of 10 pounds to the acre.

In the spring of 1926, at the time of the first cutting, 84 1/40-acre plots were laid off crossing the strips, and yields obtained. Immediately following this cutting, a series of seven sections of 12 plots each (six Utah common and six Idaho Grimm) were selected for the top-dressing experiment.

Two top-dressings were made after the first cutting in the spring, one in 1926 and one in 1927. The treatment was omitted in 1928 because the stand of alfalfa was getting thin on certain plots and it was thought best to plow the ground for corn in 1929. Series 1 received no treatment; Series 2 received 150 pounds of 0-14-4 fertilizer; Series 3, 300 pounds of 0-14-4; Series 4, 600 pounds of 0-14-4; Series 5, 300 pounds of 0-14-0; Series 6, 300 pounds of 0-14-14; and

Series 7, 300 pounds of 0-14-0 and 6 tons of stall manure applied with a manure spreader. The fertilizer was broadcast with a fertilizer grain drill. In 1927 the manure application on Series 7 was omitted and only superphosphate applied.

The results of this experiment are presented in Table 10. There was no significant difference between the response of the common and the Grimm alfalfas. Each of the yields reported is an average of 12 plots, six each of Idaho Grimm and Utah common.

TABLE 10.—Top-dressing Alfalfa with Fertilizers and Manure, Wooster

Each numbered series is an average of 12 plots

Date cut	Yield per acre						
	(1) No treatment Lb.	(2) 150 lb. 0-14-4 Lb.	(3) 300 lb. 0-14-4 Lb.	(4) 600 lb. 0-14-4 Lb.	(5) 300 lb. 0-14-0 Lb.	(6) 300 lb. 0-14-14 Lb.	(7) 6 T. manure 300 lb. 0-14-0 Lb.
Yields of cutting prior to first top-dressing							
1926 1st cutting, June 17	5033	5010	5113	5186	5083	5073	5116
Fertilizers and manure applied after first cutting in 1926							
1926 2nd cutting, Aug. 6	1793	1906	2037	2040	1863	2030	1903
1927 1st cutting, June 27	4849	5108	5237	5415	5239	5425	5375
Fertilizers applied after first cutting; no manure on (7)—1927							
1927 2nd cutting, Aug. 11	3000	3243	3470	3790	3193	3797	3420
1928 1st cutting, June 21	2300	2577	2757	3060	2663	3233	2850
2nd cutting, Aug. 10	1700	1957	2077	2340	2040	2483	2097
3rd cutting, Oct. 5	254	310	342	410	356	437	381
Total since first fertilizer application	13,896	15,101	15,920	17,055	15,345	17,405	16,026
Increase, lb.	....	1205	2024	3159	1449	3509	2130
Per cent increase—total	....	8.7	14.6	22.7	10.4	25.2	15.3
Per cent increase—1926*	....	6.3	13.6	13.7	3.9	13.2	6.1
Per cent increase—1927	....	6.4	10.9	17.3	7.4	17.5	12.1
Per cent increase—1928	....	13.9	21.7	36.6	18.9	44.6	25.2
Increase per pound of fertilizer applied†	....	4.0	3.4	2.6	2.6	5.8	3.6
Value of increase‡, dol.	....	3.62	6.07	9.46	4.33	10.53	6.39
Cost of fertilizer‡, dol.	....	3.86	7.72	15.44	5.48	10.83	5.48†
Residual effect on 1929 corn crop							
Yield of corn (15½% moisture), bu.	43.4	47.0	47.1	49.0	45.6	47.2	46.1
Increase, bu.	....	3.6	3.7	5.6	2.2	3.8	2.7

*Second cutting only.
†Commercial fertilizers only.
‡Valuations used:
0-14- 0=$18.27 (Equivalent to 0-20-0 at $26.10)
0-14- 4= 25.75
0-14-14= 36.10
Alfalfa hay in the field=$6.00 per ton

TABLE 11.—Top-dressing Alfalfa, Wooster

300 pounds per acre applied to all plots after first cutting in 1931. In 1932 and 1933, 300 pounds per acre were applied to Sections A and B in early spring and to Sections C and D after first cutting

Section, plot, and treatment	Yield per acre of checks and increase per acre for fertilized plots										
	July 24, 1931	June 3, 1932	July 8, 1932	Sept. 2, 1932	Total 1932	June 13, 1933	July 20, 1933	Sept. 1933	Total 1933	Grand total	Increase in hay per lb. of fertilizer
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Section A											
1 Check	2000	3360	1910	440	5710	2900	770	750	4420	12130	....
2 0–14–0	284	565	325	100	990	468	392	362	1222	2496	....
3 0–14–6	537	1100	720	160	1980	707	453	603	1763	4280	....
4 C–14–14	590	1085	865	220	2170	1165	935	755	2855	5615	....
5 0–0–6	253	650	260	60	970	754	307	157	1218	2441	....
6 0–0–14	267	475	485	70	1030	1032	398	258	1688	2985	....
Section B											
7 Check	2160	4410	2240	500	7150	3810	1240	1280	6330	15640	....
8 4–14–0	118	730	245	12	987	377	108	195	680	1785	....
9 4–14–6	337	1160	410	—17	1553	793	227	140	1160	3050	....
10 4–14–14	405	1260	725	75	2060	1090	415	295	1800	4265	....
11 4–0–6	243	820	320	67	1207	487	253	310	1050	2500	....
12 4–0–14	402	1340	455	58	1853	874	272	175	1321	3576	....
Section C											
13 Check	1990	4110	2090	730	6930	4010	1190	1310	6510	15430	....
14 0–14–0	—228	—338	—90	37	—391	—627	—222	5	—844	—1463	....
15 0–14–6	73	74	130	53	257	—173	—33	170	—36	294	....
16 0–14–14	115	385	380	110	875	100	135	245	480	1470	....
17 0–0–6	67	—53	80	7	34	—7	—7	—10	—24	77	....
18 0–0–14	408	558	500	193	1251	707	202	215	1124	2783	....
Section D											
19 Check	1920	4340	2150	630	7120	3990	1140	1280	6410	15450	....
20 4–14–0	170	—30	510	200	680	410	320	310	1040	1890	....
21 4–14–6	640	300	930	610	1840	1080	450	820	2350	4830	....
22 4–14–14	750	710	1070	720	2500	1060	690	880	2630	5880	....
23 4–0–6	550	10	660	180	850	750	10	170	930	2330	....
24 4–0–14	590	350	900	320	1570	960	—210	250	1000	3160	....

TABLE 11.—Top-dressing Alfalfa, Wooster—Continued

Section, plot, and treatment	Increase per acre for fertilized plots										
	July 24, 1931 Lb.	June 3, 1932 Lb.	July 8, 1932 Lb.	Sept. 2, 1932 Lb.	Total 1932 Lb.	June 13, 1933 Lb.	July 20, 1933 Lb.	Sept. 1933 Lb.	Total 1933 Lb.	Grand total Lb.	Increase in hay per lb. of fertilizer Lb.
Summary, average increases from phosphorus and potassium, ignoring nitrogen											
Sections A, B, C, and D											
0-14-0 and 4-14-0	86	232	248	87	566	157	150	218	525	1177	1.31
0-14-6 and 4-14-6	397	164	548	202	1408	602	274	433	1309	3114	3.46
0-14-14 and 4-14-14	445	860	760	281	1901	854	544	544	1942	4308	4.79
0-0-6 and 4-0-6	278	357	330	78	765	496	141	157	794	1838	2.04
0-0-14 and 4-0-14	472	681	585	160	1426	893	166	224	1283	3181	3.54
Effect of time of application											
Average increase of:											
10 fertilized plots, Sections A and B	344	920	481	80	1481	1074	376	325	1775	3600	....
10 fertilized plots, Sections C and D	314	197	507	243	947	426	133	306	865	2126	....
Gain for early application	30	724	—26	—163	534	648	243	19	910	1474	....
Effect of nitrogen											
Average increase of:											
5 fertilized plots, Section B	301	1062	431	39	1532	724	255	223	1202	3035	....
5 fertilized plots, Section A	386	777	531	121	1428	825	497	427	1749	3563	....
Gain for nitrogen	—85	285	—100	—82	104	—101	—242	—204	—547	—528	....
Average increase of:											
5 fertilized plots, Section D	540	268	814	406	1488	852	252	486	1509	3618	....
5 fertilized plots, Section C	87	125	200	80	405	0	15	125	140	632	....
Gain for nitrogen	453	143	614	326	1083	852	237	361	1450	2986	....
Average gain for nitrogen—10 plots with N and 10 without	184	214	257	122	594	375	—2	78	452	1230	....

In considering the response to fertilizers in this experiment it should be kept in mind that the land had previously received generous treatment with manure and superphosphate, that a basic fertilizer treatment was made at seeding time, and that it was a young stand. The relatively small total increases for fertilizer, especially for phosphoric acid, are probably explained by these facts, since Wooster silt loam of average fertility is normally highly responsive to fertilizer treatment. When the results for the experiment as a whole and 1932 spring prices were taken as the basis of calculation, none of the treatments were profitable. It is notable, however, that the effect of the treatments increased with the age of the stand, as indicated by the percentage increases for the individual years. Of special significance is the increasing response to potash shown by comparing Plots 5 and 6. In fact, at the end of the test the stand of alfalfa on Plot 6 was still good; whereas on the remaining plots it had become so thin that plowing down was advisable. These facts suggest that proper fertilization may be effective in lengthening the life of a stand on this soil and that on good soil with fertilizer treatment at seeding time top-dressings should be delayed at least until the second year of mowing.

Reference should be made to the method of stating increases in terms of yield per pound of fertilizer applied, which is employed in Table 10 and in later tables in this section. Since both hay and fertilizer are sold by the ton, it is easy to calculate whether an increase is profitable for any given combination of prices for each; e. g., if hay in the field is worth $5.00 and fertilizer $20.00, fertilizer is worth four times as much as the hay and so must return more than 4 pounds of hay per pound used to be profitable. Since, after hay is cut and raked, the cost of all subsequent operations is proportional to the yield, it is not proper in fertilizer calculations with hay crops to figure a greater value for the increase than the hay is worth in the field before hauling in, storing, or baling.

After discontinuing the foregoing experiment the land was plowed in the spring of 1929 and planted to corn without additional manure or fertilizer. The residual effects of the previous treatments to alfalfa are shown in the last two lines of Table 10.

In 1930, this field was reseeded to alfalfa, using spring-sown winter wheat at the rate of 1 bushel per acre as a companion crop. An excellent stand was obtained despite the dry season. After the first cutting in 1931, which averaged 3000 pounds per acre, fertilizers were applied as outlined in Table 11, at the uniform rate of 300 pounds per acre. In 1932 and 1933, Sections A and B were top-dressed in the early spring; Sections C and D after the first cutting.

The yields of the checks and the increases for fertilizer are given by plots in Table 11 and are summarized in Table 12. These increases were calculated by the usual method of interpolating between checks to obtain a theoretical yield for each plot, but it was not very satisfactory since Plot 1 was obviously low yielding. This plot was probably influenced by an adjacent orchard, as well as by the usual (Page 127) border-plot effect. It is clear that Plots 14-17 were also abnormally low in yield, whether compared to the checks or to the corresponding plots in Sections B and D. These small or negative increases in Section C result in a large indicated gain for nitrogen when C and D are compared and for spring application when A and C are compared; however, from a comparison of A and B for nitrogen and B and D for time of application, it is doubtful if either difference is real or significant. Certainly no conclusions about nitrogen applications can be drawn.

The summary for phosphorus and potash indicates, as in the previous experiment, a considerable response to potash and a definite, but lower, response to phosphoric acid. Phosphoric acid alone (the 0-14-0 and 4-14-0) has given a total increase of 1177 pounds. Comparing the 0-14-6 and 4-14-6 with the 0-0-6 and 4-0-6, the gain for phosphoric acid is 1276 pounds; comparing the 0-14-14 and 4-14-14 with the 0-0-14 and the 4-0-14, the corresponding gain is 1127 pounds. Since the land had been heavily phosphated in the past, these consistent gains for phosphoric acid are larger than might have been anticipated.

The average gain for 6 per cent of potash used alone (the 0-0-6 and 4-0-6) is 1838 pounds. Comparing the 0-14-6 and 4-14-6 with the 0-14-0 and 4-14-0, the gain for 6 per cent of potash is 1937 pounds. The average gain for 14 per cent of potash used alone (the 0-0-14 and 4-0-14) is 3181 pounds. Comparing the 0-14-14 and 4-14-14 with the 0-14-0 and 4-14-0, the gain for 14 per cent of potash is 3121 pounds.

TABLE 12.—Average Yield of Checks and Increases per Acre for Fertilizer from Four Plots Receiving Each Fertilizer Indicated, at the Rate of 300 Pounds per Acre

Second cutting, 1931: Total yield for year, 1932-1933. Fertilizer applied after first cutting in 1931 and to two sections in 1932-1933; the other two sections treated in the early spring in 1932-1933. Four per cent of nitrogen was applied to two sections each year but is ignored in this table.

	0-14-0 and 4-14-0	0-14-6 and 4-14-6	0-14-14 and 4-14-14	0-0-6 and 4-0-6	0-0-14 and 4-0-14
Average increase per acre, Lb.—1931	86	397	445	278	472
Average increase per acre, Lb.—1932	566	1408	1901	765	1426
Average increase per acre, Lb.—1933	525	1309	1942	794	1283
Average increase per acre, Lb.—total	1177	3114	4308	1838	3181
Total yield of checks (average), Lb.	14660	....	....	....	....
Increase, per cent of untreated	8.0	21.2	29.4	12.5	21.7
Increase per pound of fertilizer applied, Lb.	1.3	3.5	4.8	2.0	3.5
Cost of fertilizer*, Dol.	8.22	12.49	16.25	2.70	6.30
Value of increase, Dol.	3.53	9.34	12.92	5.51	9.54

*Omitting nitrogen.
Valuations used:
0-14- 0 — $18.27 per ton
0-14- 6 — 27.75 per ton
0-14-14 — 36.10 per ton
0- 0- 6 — 6.00 per ton
0- 0-14 — 14.00 per ton
Hay in field — 6.00 per ton

It is evident from the foregoing that the effects of phosphoric acid and potash have been essentially additive in this experiment and that the response to potash has considerably exceeded that to phosphoric acid. In fact, if the valuations used in Table 12 are employed potash was decidedly profitable when used alone on this previously well-phosphated land; whereas superphosphate used alone and both of the mixtures containing phosphoric acid were unprofitable.

Experiments at Columbus.—An experiment to study the variations in the response of alfalfa to potash at different soil reactions was started on Brookston silty clay loam at Columbus in 1930. Four blocks, 31, 32, 33, and 34, each comprising ten 1/20-acre plots, were used. Each plot was divided into thirds. The north third received sulfur calculated to be sufficient to reduce the upper

7 inches of soil to pH 6; the center received ground limestone sufficient to bring the surface soil to pH 7; the south third received hydrated lime estimated to bring the reaction to pH 8. These applications were made in the spring of 1930, just previous to sowing the seed. In November 1930, each third of each plot was sampled and the pH determined. Unfortunately, through an error these samples were taken to a depth of 12 inches; hence, the following pH values are presented merely to show that the treatments had been effective.

Average Reaction of Soils from 0 to 12 Inches

	North section pH	Center section pH	South section pH
Block 31	6.39	6.55	6.96
Block 32	6.15	6.66	6.66
Block 33	6.33	6.78	7.06
Block 34	6.12	6.49	7.16

In March 1931, the south sections of Plots 3 and 9 in each block were sampled to a depth of 6 inches. These eight samples averaged 7.83 pH. The north sections of the same plots were sampled in December 1933 to a depth of 6 inches and averaged 5.91 pH.

Blocks 33 and 34 received 200 pounds of sulfate of ammonia and all blocks received 300 pounds of 16% superphosphate annually in the spring as a basic treatment. In addition to the basic treatments, the following applications of muriate of potash per acre were made on all sections:

Plot 1	None	Plot 6	75 pounds
Plot 2	12½ pounds	Plot 7	None
Plot 3	25 pounds	Plot 8	100 pounds
Plot 4	None	Plot 9	200 pounds
Plot 5	50 pounds	Plot 10	None

These plots had also received applications of potash and superphosphate at these rates each year since 1923 and much heavier applications in 1922. Yields were taken in 1931 and 1932. The plot yields are not given in detail. The block yields and the increases for potash are given in Table 13. This range was cut without further treatment in 1933 and was an outstanding piece of alfalfa; no differences visible to the eye appeared in the plots.

There was no suggestion of a response to nitrogen, the 2-year average of 60 plots without nitrogen being 484 pounds per acre more than that of 60 plots with nitrogen. There was an evident response to potash, although it is difficult to account for the apparent negative effect of the smaller applications. Two things are notable in this test: the high average yields and outstanding vigor of the alfalfa on the check plots which had received liberal applications of superphosphate for 9 years (a total of 3300 pounds per acre in this period); and the contrast in the effect of 6 pH at Columbus, where the subsoil is well stocked with lime, and at Wooster, with an acid subsoil (Table 2).

A test of top-dressing previously established alfalfa was started on Brookston silty clay loam in March 1930. The field was reasonably uniform, with a very satisfactory stand of alfalfa sown in oats in 1928 and cut three times in 1929. The treatments, applied (except for nitrate of soda) in late

TABLE 13.—Summary of Alfalfa Yields and Increases for Potash at Different Reactions, Columbus

Block, plot, and treatment	1931			1932			2-year average				Increase per pound muriate of potash applied
	pH 6 Lb.	pH 7 Lb.	pH 8 Lb.	pH 6 Lb.	pH 7 Lb.	pH 8 Lb.	pH 6 Lb.	pH 7 Lb.	pH 8 Lb.	Av. pH 6, 7, 8 Lb.	Lb.
Yield per acre											
Block 31	10,110	12,948	12,102	10,686	11,260	10,440	10,398	12,104	11,271	11,258	.....
Block 32	12,948	12,552	12,714	12,512	11,184	10,170	12,730	11,868	11,442	12,013	.....
Block 33	9,960	9,282	9,390	10,404	10,482	9,972	10,182	9,882	9,681	9,915	.....
Block 34	14,628	13,668	13,500	11,442	10,722	10,368	13,035	12,190	11,934	12,386	.....
Average all blocks	11,912	12,113	11,927	11,261	10,912	10,238	11,586	11,511	11,082	11,393	.....
Average all checks (Plots 1, 4, 7, 10)	11,760	11,899	11,569	10,542	10,676	10,170	11,151	11,288	10,869	11,103	.....
Average Blocks 33 and 34	12,294	11,475	11,445	10,923	10,602	10,170	11,609	11,036	10,807	11,151	.....
Average Blocks 31 and 32	11,529	12,750	12,408	11,599	11,222	10,305	11,564	11,986	11,356	11,635	.....
Gain for nitrogen	765	—1,275	—963	—676	—620	—125	45	—950	—549	—484	.....
Increase for potash, average of 4 blocks (nitrogen variable ignored)											
2 12½ lb. KCl	145	—130	—185	—225	—375	—430	— 40	—252	—307	—200	—16.0
3 25 lb. KCl	95	145	—145	— 90	— 90	— 47	2	27	— 96	— 22	— 0.9
5 50 lb. KCl	—290	35	525	235	405	111	— 27	220	318	170	3.4
6 75 lb. KCl	290	355	825	860	795	455	575	575	640	597	8.0
8 100 lb. KCl	825	1290	1130	520	780	155	672	1035	642	783	7.8
9 200 lb. KCl	870	1260	1345	995	1185	385	932	1222	865	1006	5.0
Average all rates	322	492	582	382	465	105	352	471	344	389	.....

March of each year, are shown in Table 14. The nitrate of soda was applied to Plots 11 and 22 after the first cutting. In addition, Plots 2 and 13 were cultivated with a spring-tooth harrow after the first cutting, and Plots 3 and 14, after both the first and second cuttings.

TABLE 14.—Top-dressing Alfalfa, Columbus

Plots and yearly treatment	Yield per acre			Gain over nearest checks		
	1930	1931	Average	1930	1931	Average
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
2, 13 300 lb. 0-14-6*......	5365	11,550	8458	20	676	348
3, 14 300 lb. 0-14-6†......	5465	11,490	8478	85	507	296
4, 15 300 lb. 0-14-0......	5150	11,810	8480	—255	718	232
5, 16 300 lb. 0-14-6.......	5470	11,630	8550	35	429	232
7, 18 300 lb. 0-14-14.....	5240	11,365	8302	—160	12	—74
8, 19 300 lb. 0-0-14.......	5325	11,460	8392	—15	64	24
9, 20 600 lb. 0-14-6.......	5970	11,730	8850	690	290	490
10, 21 4 tons manure....	5810	11,980	8895	590	496	543
11, 22 300 lb. 0-14-6..... 150 lb. $NaNO_3$...	5350	11,885	8618	190	358	274
1, 6, 12, 17, 23 checks......	5182	11,132	8157	....	....	....

*Cultivated once each season.
†Cultivated twice each season.

The extremely dry weather of 1930 precluded any return from top-dressing in that season. Although 1931 was a season of large alfalfa yields, again there was no significant return from fertilizers. None of the indicated gains are statistically significant. There were no visible differences in the plots. The last cutting on this field in 1931 was made on September 30. This late cutting, together with a severe attack of bacterial wilt, nearly destroyed the field in 1932, and it was plowed up after the second cutting. Over two-thirds of the first cutting was weeds, and fertilizer treatments had had no visible or measurable effect in maintaining stands or reducing weed infestation. The first-cutting yields were too inconsistent to be of value, and the test was discontinued.

Experiments on the outlying farms.—A fertilizer experiment with alfalfa on Brookston clay was conducted at the Northwestern Experiment Farm, Holgate. It included three sections, each containing 40 plots 26⅔ feet square, with 2-foot alleys between the numbered plots. The plan was a checkerboard system, with five basic treatments with phosphates running the long way of the series and three sets of eight numbered plots running across the series. The basic treatments were as follows:

Strip A. 82 pounds of 44% superphosphate annually in March.
Strip B. 180 pounds of 20% superphosphate annually in March.
Strip C. 900 pounds of 20% superphosphate at seeding.
Strip D. 1300 pounds raw rock phosphate at seeding.
Strip E. None.

Plots 4, 12, and 20 also received 2 tons of ground limestone before seeding, across all basic treatments.

The cross plot treatments, applied as top-dressings in March (except nitrate of soda), were as follows:

1- 9-17, A to E, 24 pounds muriate of potash
2-10-18, A to E, 48 pounds muriate of potash
3-11-19, A to E, 72 pounds muriate of potash

4-12-20, A to E, 48 pounds muriate of potash
5-13-21, A to E, 72 pounds muriate of potash and 180 pounds 20% superphosphate.
6-14-22, A to E, 48 pounds muriate of potash and 200 pounds nitrate of soda after first cutting.
7-15-23, A to E, 48 pounds muriate of potash and 200 pounds nitrate of soda after second cutting.
8-16-24, A to E, basic treatments only (E no treatment)

Before these top-dressings were applied it was decided to include manganese in the test and manganese sulfate was applied to the north half of Plot 4 at the same time the other fertilizers were applied.

The basic treatments were applied August 8, 1929, and the range seeded August 20, 1929. A very good stand was secured, but the plants were too small to go through the winter satisfactorily. Strip C, which had received 900 pounds of superphosphate, came through the winter with very conspicuously better stands than any of the other strips. However, the entire range was disked up in the spring of 1930 and reseeded in oats without applying additional fertilizer. In spite of the drouth, a very good stand was obtained in 1930. There was enough alfalfa left from the 1929 seeding on Strip C to shade out many areas of the new seeding so that this strip never had as uniform a stand as the others. The yearly fertilizer treatments were applied in 1931 and 1932. The average yields from the plots are given in Table 15. It is

TABLE 15.—Alfalfa Fertilizer Experiment, Northwestern Experiment Farm, Holgate

Two-year average yields (1931-1932)

Plot No.	Cross treatments per acre, applied annually in March (except as noted)	Basic treatments, yields per acre					Average yield per acre for cross treatments
		A 82 lb. 0-44-0 annually in March	B 180 lb. 0-20-0 annually in March	C 900 lb. 0-20-0 at seeding	D 1300 lb. rock phosphate at seeding	E None	
		Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
1, 9, 17	24 lb. muriate of potash	6540	6740	6770	7140	6580	6754
2, 10, 18	48 lb. muriate of potash	6600	6640	6590	6870	6780	6696
3, 11, 19	72 lb. muriate of potash	6780	7020	6520	6840	6480	6728
4, 12, 20 S*	48 lb. muriate of potash	6700	6940	7140	7160	7110	7010
4, 12, 20 N*	48 lb. muriate of potash; 100 lb. manganese sulfate	6680	6500	6740	6940	7040	6780
5, 13, 21	72 lb. muriate of potash; 180 lb. 0-20-0	6660	6590	6140	6280	6680	6470
6, 14, 22	48 lb. muriate of potash; 200 lb. nitrate of soda after 1st cutting	7190	6960	6820	6620	6860	6890
7, 15, 23	48 lb. muriate of potash; 200 lb. nitrate of soda after 2nd cutting	7480	7100	6700	6700	6700	6936
8, 16, 24	None	7330	7340	6980	6940	6540	7026
Average yield per acre for basic treatments		6884	6870	6711	6832	6752	6810

*Plots 4, 12, and 20 also received 2 tons of limestone per acre as a basic treatment.

obvious that no treatment or combination of treatments had any statistically significant effect on the yield of alfalfa. The yields for the individual cuttings and years were similarly uniform. No visible differences appeared on the plots at any time, except that the manganese plot was a darker green in May of 1931. This effect disappeared before harvest. Because of reduced funds, no fertilizer applications were made or yields taken in 1933, but the field continued to appear uniform.

TABLE 16.—Alfalfa Fertility Test, Paulding County Experiment Farm

Average two plots each treatment

Date of cutting	Yield per acre			
	No treatment	300 lb. 0-14-0 per acre	300 lb. 0-14-6 per acre	300 lb. 0-14-14 per acre
	Lb.	*Lb.*	*Lb.*	*Lb.*
1929				
1st cutting, June 17	4680	4096	4480	4576
Fertilizers applied after 1st cutting—1929				
1929				
2nd cutting, July 22	2776	2816	3120	2880
3rd cutting, September 2	2320	2496	2400	2640
1930				
1st cutting, June 12	3200	3520	3496	3336
Total since application	8296	8832	9016	8856
Fertilizers applied after 1st cutting—1930				
1930				
2nd cutting, July 15	2536	3160	3000	3296
3rd cutting, August 26	376	440	520	576
1931				
1st cutting, June 9	4800	5040	5580	5240
Total since latest application	7712	8640	9100	9112
Fertilizers applied after 1st cutting—1931				
1931				
2nd cutting, July 11	2960	3480	2800	3720
3rd cutting, August 24	1580	1940	2060	1900
Total since latest application	4540	5420	4860	5620
Total since first application	20548	22892	22976	23588
Increase	....	2344	2428	3040
Increase per pound fertilizer applied	....	2.6	2.7	3.3
Increase, per cent	....	11.4	11.8	14.8
Cost of fertilizers*, dollars	....	8.21	12.48	16.29
Value of increase*, dollars	....	7.03	7.28	9.12

*Valuations used:
0-14- 0=$18.27 per ton
0-14- 6=$27.75 per ton
0-14-14=$36.10 per ton
Alfalfa hay in the field=$6.00 per ton

It is unfortunate that this experiment was laid out in a part of the farm that had been in permanent pasture for many years before the Station leased the farm. If the field had been heavily cropped for some years before seeding to alfalfa a different result might have ensued.

Top-dressing tests were conducted on Paulding clay at the Paulding County Experiment Farm and on Brookston silty clay loam at the Miami

County Experiment Farm from 1929 to 1931. The Paulding County test was started on alfalfa seeded in 1927; the Miami County test was seeded in 1928. Details of the tests are given in Tables 16 and 17. While the alfalfa showed a response to fertilizers at both farms, there was little difference in the different analyses, suggesting that phosphorus gave the greater response on these two farms. None of the treatments were profitable at any ordinary relations between prices of hay and fertilizer.

TABLE 17.—Alfalfa Fertility Test, Miami County

Average five varieties each treatment

Year and cutting	Yield per acre		
	No treatment	300 lb. 0-14-6 per acre	300 lb. 0-14-14 per acre
	Lb.	*Lb.*	*Lb.*
1929			
1st cutting	3282	3283	3005
Fertilizers applied after 1st cutting—1929			
1929			
2nd cutting	2298	2500	2323
1930			
1st cutting	1187	1717	1515
Total since 1929 application	3485	4217	3838
Fertilizers applied after 1st cutting—1930			
1930			
2nd cutting	1667	1918	1768
3rd cutting	960	1187	1364
1931			
1st cutting	3540	4380	4590
Total since 1930 application	6167	7485	7722
Fertilizers applied after 1st cutting—1931			
1931			
2nd cutting	3390	3780	3900
3rd cutting	1650	2160	2100
1932			
1st cutting*	2220	2710	2820
Fertilizers applied after 1st cutting—1932			
1932			
2nd cutting*	3410	4310	4450
Total since 1931 application	10670	12960	13270
Total since 1st application	20322	24662	24830
Increase	....	4340	4508
Increase per pound of fertilizer applied†	....	4.82	5.01
Increase, per cent	....	21.4	22.2
Cost of fertilizer†, dol.	....	12.49	16.24
Value of increase, dol.	....	13.02	13.52

Valuations used:
0-14- 6=$27.75 per ton
0-14-14=$36.10 per ton
Alfalfa hay in the field=$6.00 per ton

*Average of four varieties.

†Based on 1929-1930-1931 applications only, since the test was plowed in 1933 and in practice the 1932 application would not have been made. There is no evidence that it influenced the yield of the 2nd cutting in 1932 appreciably.

An unusual fertilizer effect appeared on the Miami County test in early May of 1932. The fertilized plots had conspicuously heavy stands of shepherd's purse[6], while the unfertilized ones were nearly free of this weed (Fig. 5). The Connecticut Station (15) has reported the same result from phosphate fertilization.

Alfalfa fertilizer top-dressing demonstrations were conducted in seven northwestern Ohio counties in 1931 under the direction of E. P. Reed, then extension agronomist for that section. Although 1931 was characterized by low fertilizer response on all crops throughout the State, probably resulting from the 1930 drouth, fair response was shown in these demonstrations, located for the most part on Brookston soils. In nine tests, an average application of 251 pounds per acre of 0-20-0 in March gave an average increase of 440 pounds of hay, or 1.8 pounds per pound of fertilizer applied. The same average amount of 0-12-12 gave an increase of 680 pounds, or 2.7 pounds per ton of fertilizer applied. An 0-14-6 analysis was applied in 14 tests, the average rate being 294 pounds per acre and the average increase, 840 pounds of hay, or 2.9 pounds per pound of fertilizer applied. It is probably worth noting that in these demonstrations the average yield of the untreated plots was 3.73 tons, which is nearly double the average yield of alfalfa for the State as a whole.

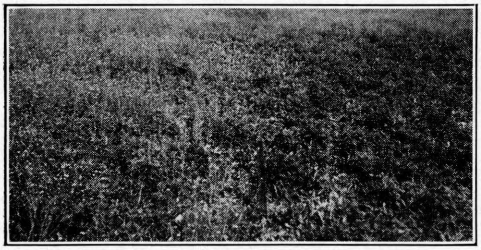


Fig. 5.—Phosphate encourages Shepherd's purse

Miami County Experiment Farm, May 6, 1932—Left, 0-14-6; right, no fertilizer. Background also fertilized.

Recommendations.—The investigations on top-dressing alfalfa here reported are too limited in scope to serve as a basis for definite recommendations. It would appear that on fairly fertile land capable of producing yields of 3.5 tons or more of alfalfa hay per acre per year, the top-dressing of alfalfa with fertilizers is not apt to be highly profitable, particularly in the first or second hay year. The need for such top-dressings probably increases as the age of the stand increases. The response to fertilizers is apt to be higher in eastern Ohio than on the limestone soils of western Ohio. Top-dressing is also likely to be more profitable on light colored soils of medium fertility than on the more fertile, dark colored soils.

As a tentative recommendation it is suggested that alfalfa be top-dressed in the early spring of the third hay year and each alternate year thereafter, using an 0-14-6 analysis on silt loams, clay loams, and clays and an 0-12-12 on sands or mucks, at rates ranging from 200 to 350 pounds per acre varied in accordance with the productivity of the soil. The fertilizer should preferably be incorporated in the soil with a disk drill or spring-tooth harrow. Where manure is available for top-dressing, it should be supplemented with 20% superphosphate at the rate of 150 to 250 pounds per acre.

[6]Bursa bursa-pastoris.

ALFALFA VARIETIES[7]

Successful alfalfa culture has not depended on adapted varieties to the same extent in Ohio that it has in more northern states, but there have been and are enough poorly adapted strains of alfalfa commercially obtainable to make the testing of varieties and strains a matter of great importance. The first test of alfalfa varieties and regional strains at Wooster was started in 1908. The results have only historical interest now, but, for those strains which can be identified with present-day sources, the results were similar to those obtained later.

Oakley and Westover (41) have described the varieties and strains of alfalfa which have been grown in the United States so that it does not seem necessary to give descriptions of them here. It has been common experience that it is not satisfactory to sow common alfalfa further north than the seed was produced. For purposes of this discussion, the commercially available varieties and strains have been divided into four groups: variegated alfalfas, adapted common alfalfas (those produced in Kansas, Colorado, Utah, and north), non-adapted common alfalfas (those produced further south than Kansas), and foreign alfalfas.

TABLE 18.—Comparisons of Grimm and Common Alfalfa, Wooster

Duplicate 0.84-acre plots

Year	Yield per acre	
	Grimm	Common
	Lb.	*Lb.*
Sown in 1917:		
1918	8539	7600
1919	6671	7633
Sown in 1921:		
1922	4381	4245
1923	5519	5676
1924	5887	5401
Sown in 1925:		
1926	6590	5494
1927	8567	8628
1928	4790	5439
8-year average	6368	6264

Experimental work.—Grimm and common alfalfas were compared in 0.84-acre plots used for cultural experiments with alfalfa, sown in 1917, 1921, and 1925, and reported in Table 18. Systematic tests of commercially available strains were sown at Wooster in 1914, 1916, 1924, 1925, 1926, 1928, 1930, and 1931. The yields from these tests are summarized in Table 19.

Plots of a few alfalfa strains were included in the legume work at Columbus in 1922, 1923, and 1924. Systematic alfalfa strain tests were sown in 1925, 1927, and 1929; the results of these are summarized in Table 19. The seed for a considerable number of the strains tested both at Wooster and Columbus was obtained through the cooperation of the Division of Forage Crops and Diseases, United States Department of Agriculture.

At the Timothy Breeding Station at North Ridgeville, conducted cooperatively by the Ohio Agricultural Experiment Station and the Division of Forage Crops and Diseases, United States Department of Agriculture, variety and strain tests have been conducted since 1923. Seedings were made in 1923, 1924, 1927, 1928, 1929, and 1930. The results of these tests are summarized in Table 19.

[7]Experiments on varieties of alfalfa in Ohio have been previously reported in the following publications: (1; 2; 20; 43, p. 29; 47, p. 17; 49, p. 40; and 55).

TABLE 19.—Summary, Alfalfa Variety Tests

Average yield per acre

Station	Wooster								Columbus		
Years sown	1931[9]	1930[10]	1928[11]	1926[12]	1925[13]	1923[14]	1916[15]	1914[16]	1929[17]	1927[18]	1925[19]
No. of years averaged	2	2	4	1	3	1	3	3	3	4	5
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Variegated											
1 Grimm	12330[6]	7340[8]	8240[5]	5610[2]	11660[2]	6240[3]	8110[4]	8970	8000	6800	6940[4]
2 Hardigan	13700	7490	9430	5400	11150	4980	....	....	8580	....	7480[2]
3 Ontario Variegated	13380	8000	9660	6020	10380	....	8860	....	....	8200	6940
4 Cossack	13020[2]	6890[3]	8530[2]	5860	9910	5190[2]	8590	....	....	....	7340
5 Baltic	....	....	....	....	....	....	....	....	....	....	6840
6 Ladak	15320	....	8740	....	....	....	....	....	8440	6840	....
7 Ohio Variegated	13320	....	....	....	....	....	....	....	....	....	....
Adapted Common											
8 Ohio	13720	....	....	....	....	....	....	....	....	....	....
9 LeBeau	15600	....	....	4870	....	4100	....	....	....	....	7140
10 Utah	11620	6570[2]	8820	4200[2]	8710[2]	4800	7430	....	8160	7360[2]	....
11 Idaho	12500	6160	....	....	....	....	7670	....	....	....	....
12 Montana	14020	6790	7860	....	....	....	8890	....	....	....	....
13 Dakota	....	7210	8760	4730[2]	....	4280	....	8910	7460	6820[2]	7200
14 Nebraska	....	....	....	....	....	....	8140	8360	....	....	....
15 Kansas	12180	7320	8040	4320	10260	4680[2]	8870	8550	7970	....	6600[2]
16 Colorado	....	....	....	....	....	....	....	....	....	....	....
Non-adapted Common											
17 Oklahoma	....	....	....	....	....	....	....	....	....	....	....
18 New Mexico	....	....	....	....	....	....	....	....	7250	....	....
19 Arizona	14110	4770	5590	....	....	....	....	....	7090	....	....
20 California	12990	6340	7250	....	7850	....	....	....	....	....	....
21 Peruvian	12470	5280	6120	1160	4790	....	....	6210	....	....	....
22 Hardistan	10870	4960	....	....	....	....	....	....	....	....	....
Foreign											
23 Turkestan	....	....	....	....	7030	....	....	6180	6700	....	....
24 Agentine	13500	....	8730	1100	9420	4180	....	....	7710[3]	7280[2]	....
25 South Africa	13340	....	6650	1010	5480	....	....	....	....	....	....
26 Italian	13310	5920	8540	3450	6180	....	....	....	....	....	....
27 French	12440	....	6750	4180	....	....	....	....	....	....	....

2, 3, 4, 5, 6, and 8—Number of strains averaged.
9—Duplicate 1/80-acre plots in 1932. Single 1/50-acre plots in 1933.
10—Duplicate 1/200-acre plots.
11—Duplicate 1/100-acre plots.
12—Duplicate 1/116-acre plots.
13—Duplicate 1/77-acre plots.
14—Single 1/25-acre plots.
15—Single 1/160-acre plots.
16—Quadruplicate square-rod plots.
17—Quadruplicate and duplicate 1/104-acre plots.
18—Duplicate and single 1/33-acre plots.
19—Single 1/33-acre plots.

TABLE 19.—Summary, Alfalfa Variety Tests—Continued

Average yield per acre

	Station ☞	North Ridgeville*						Paulding Co.	Hamilton Co.	Miami Co.	Madison Co.
	Year sown ☞	1930[20]	1929[20]	1928[20]	1927[20]	1924[21]	1923[21]	1927	1928	1928	1928
	No. of years averaged ☞	2	3	4	2	3	4	4	3	3	3
		Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
	Variegated										
1	Grimm	6700	6510	5620[5]	4730[2]	5330	5060	5980	7860	6640	7380
2	Hardigan	7000	6910	....	4630	5320	4750	6180	8740	7100	8920
3	Ontario Variegated	5960	6690	5770[3]	4860[6]	....	....	5500	8840	6780	....
4	Cossack	....	....	....	5530	5470	5030	....	....	....	....
5	Baltic	....	....	5480	....	....	....	....	....	....	....
6	Ladak	6590	7110	....	5330	5730	4730	....	....	....	8580
7	Ohio Variegated	....	....	....	....	....	....	....	....	....	....
	Adapted Common										
8	Ohio	....	....	....	....	....	....	....	....	....	....
9	LeBeau	....	....	....	3560	5440	5240	....	....	....	....
10	Utah	6280	6240[2]	5150	3810[3]	4810	....	5320	9380	5100	8280
11	Idaho	....	6540	....	....	....	....	....	....	....	....
12	Montana	....	....	....	....	....	....	5360	8600	6420	10280
13	Dakota	6450	6570	5580	3720[2]	4880	4510	....	....	....	....
14	Nebraska	....	6400	....	....	....	....	....	....	....	....
15	Kansas	6340	6570[2]	....	4370	5120	4670	....	....	....	7240
16	Colorado	6180	....	5110	....	....	....	....	....	....	....
	Non-adapted Common										
17	Oklahoma	....	6640	5520	....	....	....	....	....	....	....
18	New Mexico	....	6440[2]	....	....	....	....	....	....	....	....
19	Arizona	....	5620	4670	1890	....	....	....	7560	1480	6120
20	California	4890	6000[2]	4650[3]	....	....	....	....	....	....	....
21	Peruvian	....	....	....	990[2]	....	....	....	....	....	6460
22	Hardistan	....	....	....	....	....	....	....	....	....	....
	Foreign										
23	Turkestan	5420	5420[2]	....	3980[4]	....	....	....	....	....	....
24	Argentine	6620	6900	5600	1220	5070	4980	....	....	....	....
25	South Africa	....	6190[2]	....	....	....	....	....	....	....	....
26	Italian	....	6390[2]	....	3310	....	....	....	....	....	....
27	French	6120	....	....	3980[4]	....	....	....	....	....	....

*In cooperation with Division of Forage Crops and Diseases, Bureau of Plant Industry, U. S. D. A.
2, 3, 4, 5, 6, and 8—Number of strains averaged.
20—Triplicate 1/132-acre plots.
21—Triplicate 1/80-acre plots.

Further data on these tests are given in Table 25, which gives the number of cuttings in each season for each test and the average distribution of the total hay among the different cuttings.

There were a few comparisons of Grimm and common alfalfa on the outlying farms before 1928, but the more extensive variety tests have all been conducted since that date. A summary of the results of these tests on four farms in western Ohio is given in Table 19. The Madison County test was seriously affected by non-uniformity of soil and failure to obtain a uniform stand, and, consequently, the results from it are not included in Tables 21, 22, and 23.

At the Northwestern Experiment Farm, Holgate, Henry County, operated cooperatively by the U. S. Department of Agriculture, Division of Forage Crops and Diseases, and the Ohio Agricultural Experiment Station, Department of Agronomy, the U. S. Department of Agriculture is conducting the most extensive tests of alfalfa varieties in the State. The detailed results are not yet available for publication, but the general superiority of the variegated alfalfas for that section has been abundantly demonstrated in the appearance of the plots, longevity of the stands, and preliminary yield data.

In a number of cultural experiments with alfalfa at Holgate, conducted by the Experiment Station, duplicate tests have been made, using Grimm in one test and common in the other. These are summarized in Table 20. Winterkilling was not a factor in any of these comparisons, except in 1933, but the superiority of Grimm over Utah common was evident to the most casual observer of the ranges.

TABLE 20.—Comparisons of Grimm and Common Alfalfa from the Cultural Experiments at Holgate

Total yield for the season

Experiment	Year sown	Year harvested	Source of common	Plots of each averaged	Yield per acre		Common (Grimm=100)
					Grimm	Common	
				No.	*Lb.*	*Lb.*	*Pct.*
Time of cutting alfalfa....	1929	1930	Kansas	15	5680	5580	98.2
Time of cutting alfalfa....	1929	1931	Kansas	15	7920	8120	102.5
Time of cutting alfalfa....	1930	1931	Utah	16	6750	5700	84.4
Time of cutting alfalfa....	1930	1932	Utah	16	6460	6030	93.3
Time of cutting alfalfa....	1930	1933	Utah	16	4520	3940	87.2
Rate of seeding alfalfa.....	1931	1932	Utah	10	5140	3770	73.4
Rate of seeding alfalfa.....	1932	1933	Utah	10	3400	2940	86.5

Value of individual varieties and strains.—Since Grimm alfalfa was included in every test reported, the relative yields of the different strains are more readily studied by expressing all yields in terms of Grimm as 100 per cent. This has been done for the more important strains in each group and the tests for each strain averaged in Table 21.

The differences between individual varieties of variegated alfalfa are small. Hardigan and Ontario Variegated, which have yielded 4.1 and 4.7 per cent, respectively, more than Grimm as averages of 45 comparisons each, are certainly equal to Grimm in Ohio and may be slightly superior. Cossack and Baltic seem substantially equal to Grimm.

Ladak (63) is quite different from the other variegated strains. It often makes a notably poor recovery in the second and later cuttings. Nevertheless, it is outstanding in total yield, although the study of its distribution by cuttings (Table 26) shows that from 5 to 7 per cent more of the season's yield is produced in the less desirable first cutting than with the other variegated strains. Western experience shows that it is more winter-hardy than Grimm, but here, where that quality is less important, there is nothing really to recommend it, although it certainly cannot be condemned.

Comparisons of Grimm alfalfa from different sources have been made at Wooster, Columbus, and North Ridgeville. While strains from different sources naturally differ in yield, there is as yet no evidence that any one source is consistently superior to another.

Since 1930 there has been a small amount of Ohio-grown seed available, both variegated and common. The Wooster test seeded in 1931 is the only one which included any Ohio-grown seed, but it indicated, as would have been expected, that such seed was at least equal to, and generally better than, any other seed on the market. Because this has not been generally appreciated, such seed has sold at a discount and the best bargains in alfalfa seed obtainable in the last 4 years have been well-cleaned lots of Ohio-grown seed.

The various "adapted" strains of common alfalfa did not appear to differ greatly from each other. Colorado, the lowest, was included in only two tests. There was some tendency for seed from the Great Plains States to outyield seed from Idaho and Utah. Perhaps there would have been more contrast between Kansas and Dakota seed if winterkilling had been a factor in more of the years covered by the tests.

Of the regional strains usually classified as non-adapted, Oklahoma and New Mexico showed up well in the two trials in which each was included, but, since there was no winterkilling to speak of in the period covered by those tests, they do not justify changing the usual recommendation that seed produced south of Kansas and Utah should not be purchased for Ohio. The others in this group are clearly out of the question.

Of the foreign alfalfas, Turkestan has always given unsatisfactory results in this region and did in these tests. Hardistan, a Nebraska selection from Turkestan, was equally undesirable here. Italian showed up much better in three of these six tests than it has elsewhere in this latitude. South African, in five tests, averaged only three-fourths as much as Grimm. Argentine gave very conflicting results. As an average of two plats at Columbus, seeded in 1927, and of three at Wooster, seeded in 1928, it out-yielded Grimm; in fact, for 3 years it was the leading strain at Columbus. The same seed gave poor results in the 1929 seeding at Columbus. Argentine also gave good results at North Ridgeville in 1928-1929-1930 seedings. Some earlier tests were very unsatisfactory, essentially failures. It would seem that there are distinctly different sources and strains in the Argentine. The Argentine alfalfa was very distinctive—a coarse-growing, late-maturing, large-leaved type suggestive of sweet clover. No imported alfalfa except Canadian is recommended in Ohio.

Should the Ohio farmer buy variegated or common alfalfa?—Table 21 clearly indicates that the variegated strains, as a group, have outyielded the adapted commons, as a group. The yields of the different varieties and strains in each group are so similar that the obvious, important, practical question for

TABLE 21.—Relative Yields of Alfalfa Varieties

Grimm=100

Station ☞	All*	Wooster								Columbus		
Date sown ☞		1931	1930	1928	1926	1925	1923	1916	1914	1929	1927	1925
No. of years averaged ☞		2	2	4	1	3	1	3	3	3	4	5
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Variegated												
1 Grimm	100.0	100	100	100	100	100	100	100	100	100	100	100
2 Hardigan	104.1	111	102	114	96	100	80	...	...	107	...	108
3 Ontario Variegated	104.7	108	109	117	107	93	...	109	...	...	121	100
4 Cossack	101.8	106	94	104	104	89	83	106	...	...	...	106
5 Baltic	98.1	...	...	...	...	...	...	...	...	...	...	99
6 Ladak	105.0	124	...	106	...	...	...	...	...	106	101	...
7 Ohio Variegated	108.0	108	...	...	...	...	...	...	...	...	...	...
Adapted Common												
8 Ohio	111.3	111	...	...	...	...	...	...	...	...	...	...
9 LeBeau	99.5	126	...	...	87	...	66	...	...	...	...	103
10 Utah	93.8	94	90	107	75	78	77	92	...	102	108	...
11 Idaho	95.3	101	84	...	...	...	...	95	...	...	...	...
12 Montana	100.0	114	92	95	...	...	...	110	...	...	...	...
13 Dakota	97.4	...	98	106	84	...	68	111	99	93	100	104
14 Nebraska	97.0	...	...	...	...	...	...	100	93	...	...	...
15 Kansas	96.0	99	100	98	77	92	75	109	95	100	...	95
16 Colorado	91.3	...	...	...	...	...	...	...	...	...	...	...
Non-adapted Common												
17 Oklahoma	99.4	...	...	...	...	...	...	...	...	...	...	...
18 New Mexico	94.3	...	...	...	...	...	...	...	...	91	...	...
19 Arizona	73.8	114	65	68	...	...	...	...	...	89	...	...
20 California	84.8	105	86	88	...	70	...	...	...	...	...	...
21 Peruvian	61.3	101	72	74	21	43	...	...	69	...	...	...
22 Hardistan	77.8	88	68	...	...	...	...	...	...	...	...	...
Foreign												
23 Turkestan	76.5	...	...	...	...	63	...	...	69	84	...	...
24 Argentine	92.8	110	...	106	20	84	67	...	...	96	107	...
25 South Africa	75.9	108	...	81	18	49	...	...	...	...	...	...
26 Italian	80.2	108	81	104	62	53	...	...	...	...	...	...
27 French	86.9	101	...	82	74	...	...	...	...	...	...	...

TABLE 21.—Relative Yields of Alfalfa Varieties—Continued

Grimm=100

Station ☞		North Ridgeville†						Paulding Co.	Hamilton Co.	Miami Co.
Date sown ☞	All*	1930	1929	1928	1927	1924	1923	1927	1928	1928
No. of years averaged ☞		2	3	4	2	3	4	4	3	3
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Variegated										
1 Grimm	100.0	100	100	100	100	100	100	100	100	100
2 Hardigan	104.1	104	105	...	99	100	94	103	111	107
3 Ontario Variegated	104.7	89	102	103	103	...	...	92	112	102
4 Cossack	101.8	...	...	...	117	103	99	...	...	...
5 Baltic	98.1	...	...	98	...	...	...	...	...	...
6 Ladak	105.0	98	108	...	113	107	93	...	...	...
7 Ohio Variegated	108.0	...	...	...	...	...	...	...	...	...
Adapted Common										
8 Ohio	111.3	...	...	...	...	...	...	...	...	...
9 LeBeau	99.5	...	...	...	75	102	104	...	...	...
10 Utah	93.8	94	95	92	81	90	...	89	119	77
11 Idaho	95.3	...	100	...	...	...	...	...	...	...
12 Montana	100.0	...	...	...	...	...	...	90	109	97
13 Dakota	97.4	96	100	99	79	92	89	...	...	...
14 Nebraska	97.0	...	97	...	...	...	...	...	...	...
15 Kansas	96.0	95	100	...	92	96	92	...	...	...
16 Colorado	91.3	92	...	91	...	...	...	...	...	...
Non-adapted Common										
17 Oklahoma	99.4	...	101	98	...	...	...	...	...	...
18 New Mexico	94.3	...	98	...	...	...	...	...	...	...
19 Arizona	73.8	...	86	83	40	...	...	...	96	22
20 California	84.8	73	91	83	...	...	...	...	...	...
21 Peruvian	61.3	...	...	...	21	...	...	...	...	...
22 Hardistan	77.8	...	...	...	...	...	...	...	...	...
Foreign										
23 Turkestan	76.5	81	82	...	84	...	...	...	...	...
24 Argentine	92.8	99	105	100	26	95	98	...	...	...
25 South Africa	75 9	...	94	...	...	...	...	...	...	...
26 Italian	80.2	...	97	...	70	...	...	...	...	...
27 French	86.9	91	...	...	84	...	...	...	...	...

*Average weighted according to number of years each test continued.
†In cooperation with Division of Forage Crops and Diseases, Bureau of Plant Industry, U. S. D. A.

the Ohio farmer is: "Shall I buy variegated or adapted common alfalfa?" To answer this question, a summary of the comparisons between these groups is given in Table 22.

TABLE 22.—Summary of Comparisons of Variegated and Adapted Common Alfalfa

	Years averaged, inclusive	Plots averaged		Yields per acre		Common (Variegated=100)
		Variegated	Adapted common	Variegated	Adapted common	
		No.	*No.*	*Lb.*	*Lb.*	*Pct.*
Wooster:						
Sown 1914	1915, 1917, 1918	4	12	8968	7897	88.1
Sown 1916	1917–19	6	6	8317	8203	98.6
Sown 1923	1924	6	5	5679	4505	79.3
Sown 1925	1926–28	10	6	10753	9226	85.8
Sown 1926	1928	10	12	5700	4510	79.1
Sown 1928	1929–32	18	8	8598	8371	97.4
Sown 1930	1931–32	26	12	7300	6780	93.0
Sown 1931	1932–33	22	12	12766	13274	104.0
Sown 1917, 0.84-acre plots	1918–19	2	2	7605	7616	100.1
Sown 1921, 0.84-acre plots	1922–24	2	2	5262	5170	97.0
Sown 1925, 0.84-acre plots	1926–28	2	2	6649	6520	98.1
Average 27 comparisons*	....	....	....	8184	7730	94.5
Columbus:						
Sown 1925	1926–30	9	6	7092	6540	92.2
Sown 1927	1928–31	3	6	7265	7149	98.4
Sown 1929	1930–32	4	6	8287	7876	95.0
Average 12 comparisons*	....	....	....	7448	7077	95.0
North Ridgeville:						
Sown 1923	1924–27	9	9	4949	4807	97.1
Sown 1924	1925–27	9	12	5375	5062	94.2
Sown 1927	1928–29	12	21	4918	3829	77.8
Sown 1928	1929–32	27	9	5654	5278	93.3
Sown 1929	1930–32	6	21	6799	6447	94.8
Sown 1930	1931–32	6	12	6476	6312	97.4
Average 18 comparisons*	....	....	....	5651	5286	93.5
Outlying Farms:						
Hamilton County Expt. Farm	1929–31	3	2	8480	9000	106.1
Miami County Experiment Farm	1929–31	3	2	6860	5760	84.0
Paulding County Expt. Farm	1928–31	3	2	5880	5340	90.8

*Each year in each test considered one comparison.
Note: Ladak has not been included in the variegated varieties compared.

It is clear from this table that in central and northern Ohio the variegated strains are superior. At Wooster, North Ridgeville, and Columbus, the differences, although small (averaging only 5 to 7 per cent), are very consistent. For 57 yearly averages of variety ranges at these three stations, adapted common outyielded variegated only 11 times.

In southern Ohio only the one test from Hamilton County is available, but its results are consistent with the recommendations of Oakley and Westover (41) in favoring common alfalfas for that section.

Is the superiority of variegated alfalfa due to its winter-hardiness?—In most comparisons of variegated and common alfalfas, the greater winter-hardiness of the former is given as the reason for their higher yields. It would appear that this was not the major factor in Ohio. While there is no possible doubt [See review of literature and bibliography (62)] but that the variegated varieties are less susceptible to winterkilling from the effect of cold than are the common varieties, most winterkilling in Ohio is caused by heaving and the variegated strains are little, if any, less susceptible to heaving than the common strains (Fig. 6).

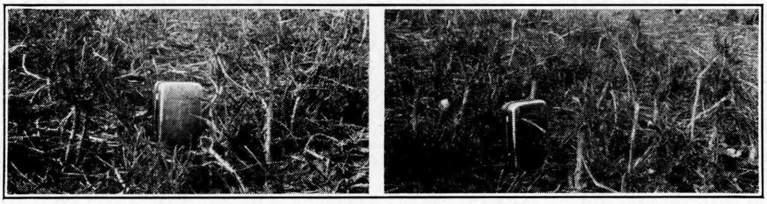


Fig. 6.—Heaving, Grimm versus Kansas common

Columbus, April 11, 1927—Left, Grimm; right, Kansas common. Both cut five times in 1926. Almost no heaving where cut only three times. Box in foreground is 3 inches high.

However, since heaving causes greater exposure of the roots to variable temperatures, it seems probable that the death loss from heaving would be less in variegated alfalfa than in common, even though both heaved to the same extent. There have been several instances in these tests in which variegated strains have seemed to recover better from severe heaving than common strains.

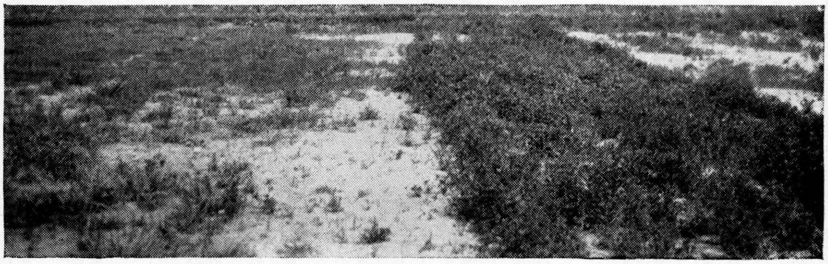


Fig. 7.—Grimm versus common alfalfa

Columbus, May, 1924. Left, common alfalfa; right, Grimm. Both sown August 17, 1923. Nearby stands of a year older were similarly affected.

In all the variety trials reported herein the only ones in which a variegated alfalfa survived while adapted common was killed to an unprofitable point were in two of the early Grimm-common comparisons at Columbus, following the winter of 1923-1924. In 1924 Grimm sown in August 1923 made 3520 pounds per acre at the first cutting (Fig. 7), and Grimm sown in July 1922 made 4920 pounds per acre at the first cutting, while adjacent plots of common alfalfa were not worth cutting and the yields were not taken. This was the only winter during the period covered by the tests at Columbus in which there has been extensive winterkilling from freezing. The common alfalfa was not heaved in either of these tests; it was killed by the low temperatures. It is hardly necessary to point out that this resistance to winterkilling is excellent insurance against the occasional Ohio winter which does cause killing by freezing.

Other reasons for the superiority of variegated varieties.—It seems that other factors besides resistance to winterkilling must help to account for the uniformly superior results from variegated alfalfas. On several occasions they have been less affected by leafhopper yellowing than the common strains. In the spring they often have a darker green, more vigorous appearance than the common alfalfas, which are often a yellowish-green. Possibly, their generally greater vigor and resistance to diseases and insects are sufficient to account for their superiority even under many conditions where winterkilling is only a minor factor.

TABLE 23.—Does the Lead of Variegated over Adapted Common Increase as the Stands Grow Older?

Station, test, and years reported	Plots averaged		Yield of adapted common (Variegated=100)				
			Age of stand				
	Variegated	Common	1 year	2 years	3 years	4 years	5 years
	No.	*No.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Wooster:							
Sown 1914; 1915-17-18	4	12	87.5	....	92.3	86.0	....
Sown 1916; 1917-18-19	6	5	97.8	98.7	99.4	....	....
Sown 1925; 1926-27-28	10	6	79.2	96.1	75.1	....	....
Sown 1928; 1929-30-31-32	18	8	98.7	96.0	98.4	97.4	....
Sown 1930; 1931-32	26	12	89.8	95.1	....	....	....
Sown 1931; 1932-33	11	6	110.2	101.6	....	....	....
Sown 1917; 1918-19	2	2	89.0	114.4	....	....	....
Sown 1921; 1922-23-24	2	2	96.9	102.8	91.7	....	....
Sown 1925; 1926-27-28	2	2	83.4	100.7	113.5	....	....
Columbus:							
Sown 1925; 1926-27-28-29-30	9	6	91.5	97.7	96.7	86.0	89.5
Sown 1927; 1928-29-30-31	3	6	100.6	100.0	93.4	97.4	....
Sown 1929; 1930-31-32	4	6	90.7	97.7	90.9	....	....
North Ridgeville:							
Sown 1923; 1924-25-26-27	9	9	96.6	101.4	98.2	86.0	....
Sown 1924; 1925-26-27	9	12	90.0	92.5	103.5	....	....
Sown 1927; 1928-29	12	21	73.8	81.2	....	....	....
Sown 1928; 1929-30-31-32	27	9	91.6	90.9	95.8	93.3	....
Sown 1929; 1930-31-32	6	21	91.0	97.8	92.8	....	....
Sown 1930; 1931-32	6	12	101.0	93.8	....	....	....
Outlying Farms:							
Hamilton County, 1929-30-31	3	2	108.8	104.3	105.0	....	....
Miami County, 1929-30-31	3	2	93.9	53.3	92.1	....	....
Paulding Co., 1928-29-30-31	3	2	122.6	92.1	65.4	82.9	....
Northwestern Experiment Farm, 1931-32-33	16	16	84.4	93.3	87.2	....	....

Does the lead of variegated over adapted common increase from year to year?—It is rather generally recommended that the longer it is desired to leave a field in alfalfa, the more advantage there is in using variegated alfalfa. There could be no question of this if winters like 1923-1924 at Columbus were of frequent occurrence. In Table 23 the year-by-year comparisons of variegated and common are given for all tests in which the data cover more than one year. There is little evidence in this table that adapted common in Ohio tends to yield progressively less and less than variegated as the stands become older. This table emphasizes the small part which winterkilling from the direct effect of cold played in the adaptation of alfalfa in Ohio during the period covered by these tests.

It is interesting to note that common alfalfa outyielded variegated generally over the State in 1931. This was a year of large yields following the 1930 drouth.

How do the actual stands of variegated and common alfalfas compare?—Stand counts of plants in the field were made in one test at Wooster and in one at Columbus and are reported in Table 24. Although in every instance these stand counts showed that the common gave a higher percentage of winterkilling than the variegated, the stands of the two did not vary greatly from year to year. (See Pages 131-133).

TABLE 24.—Comparative Stands* of Variegated and Common Alfalfa

Strains compared	Plants per square yard		Winterkilling	
	Idaho Grimm	Kansas common	Idaho Grimm	Kansas common
	No.	*No.*	*Pct.*	*Pct.*
Wooster:				
Fall, 1921	169	173	....	....
Spring, 1922	162	155	4.0	10.2
Fall, 1922	140	93	....	....
Spring, 1923	132	80	5.9	14.1
Nov., 1923	64	64	....	....
Fall, 1923	65	72	....	....
Spring, 1924	56	55	14.7	23.3
Fall, 1924	36	33	....	....
Spring, 1925	19	15	46.4	55.2

Strains compared	Plants per square yard		Winterkilling	
	Variegated	Adapted common	Variegated	Adapted common
	No.	*No.*	*Pct.*	*Pct.*
Columbus:				
Fall, 1926	118	112	....	....
Spring, 1927	99	85	16.0	22.9
Fall, 1927	55	52	....	....
Spring, 1928	45	40	18.1	22.5
Aug., 1929	23	24	....	....
Spring, 1930	12	11	....	....
Fall, 1930	9	11	....	....

*Counted in the field; roots not dug.

Encroachment of weeds on different varieties and strains.—There has been a distinct tendency for weeds to encroach on the common strains more than on the variegated. The yields from Wooster and Columbus in Table 19 are of weed-free hay and, hence, are not affected by this, but the commercial quality of the hay produced was greatly influenced by it. To the eye, the most conspicuous difference that appeared between the two types at Columbus was in the amount of weeds in the first cutting of 1929 in the range sown in 1925. The nine plots of variegated averaged 6.8 per cent of weeds in the first cutting; whereas the six plots of common averaged 20.9 per cent. In other years, while the variegated alfalfas have almost always produced cleaner hay, the difference has not been so outstanding.

Proportion of the total yield obtained in the first cutting from different varieties.—In studying the Wooster records, Mr. Thatcher found that the variegated alfalfas made proportionately more growth in the first cutting than the common strains. This study was extended to Columbus and North Ridgeville, as reported in Table 25, which gives the percentage of the total yield for the season produced by each cutting for the same common and variegated strains which are reported in Table 22. At Wooster the variegated varieties produced a larger percentage of the season's yield in the first cutting than common alfalfa 21 times out of 24 and at Columbus every time in 12 comparisons. At North Ridgeville, however, the differences were almost negligible, and variegated produced the larger percentage in the first cutting only 11 times out of 18. The differences were at no time large, the largest single difference being 11.4 per cent of the total hay at Wooster, 5.3 per cent at Columbus, and 3.0 per cent at North Ridgeville; the average difference ranged from 3.6 per cent to 0.2 per cent. The differences may have a greater significance when considered in connection with the corresponding figures for Ladak, reported in

Table 26. Ladak (63) is a variegated alfalfa which possesses the characteristics of *Medicago falcata* to a greater extent than the other variegated varieties studied. *M. falcata* usually produces only one cutting a year (39). It seems from Table 26 that Ladak shares this one-cutting tendency to a much greater extent than the other variegated varieties, although the latter possess it to a slight extent, as indicated in Table 25. (See also Table 27.)

TABLE 25.—Distribution by Cuttings of the Total Yield for the Season in Different Varieties of Alfalfa

	Proportion of total yield in each cutting					
	Variegated			Common		
	1st Pct.	2nd Pct.	3rd Pct.	1st Pct.	2nd Pct.	3rd Pct.
Wooster						
Sown 1916						
1917	51.8	48.2	....	52.0	48.0	....
1918	61.0	20.8	18.2	60.1	22.1	17.8
1919	51.3	25.4	23.3	48.2	24.7	27.1
Sown 1923						
1924	77.5	22.5	....	70.1	29.9	....
Sown 1925						
1926	73.7	26.3	....	69.9	30.1	....
1927	42.2	42.7	15.1	40.1	43.4	16.5
1928	41.2	46.2	12.6	33.6	45.8	20.6
Sown 1926						
1928	80.6	19.4	....	73.3	26.7	....
Sown 1928						
1929	41.9	58.1	....	36.3	63.7	....
1930	69.2	23.3	7.5	69.0	21.9	9.1
1931	59.6	24.0	16.4	61.1	22.3	16.6
1932	54.9	34.8	10.3	51.3	35.1	13.6
Sown 1930						
1931	63.3	36.7	....	62.5	37.5	....
1932	56.0	32.3	11.7	54.4	32.8	12.8
Sown 1931						
1932	48.2	36.0	15.8	48.1	35.6	16.3
1933	60.4	18.4	21.2	57.2	19.0	23.8
Duplicate 0.84-acre plots						
Sown 1917						
1918	60.4	22.4	17.2	53.9	24.4	21.7
1919	64.9	16.5	18.6	53.5	18.9	27.6
Sown 1921						
1922	72.3	27.7	....	70.4	29.6	....
1923	52.2	29.2	18.6	48.8	28.4	22.8
1924	63.0	37.0	....	64.6	35.4	....
Sown 1925						
1926	70.6	29.4	....	69.8	30.2	....
1927	62.2	37.8	....	60.1	39.9	....
1928	56.8	39.0	4.2	52.2	39.8	8.0
Average, 2 cuttings	65.7	34.3	....	62.9	37.1	....
Average, 3 cuttings	55.6	29.4	15.0	52.2	29.6	18.2
Columbus						
Sown 1925						
1926	45.9	24.5	29.6	42.4	24.2	33.4
1927	45.7	34.7	19.6	43.1	36.6	20.3
1928	46.7	26.7	26.6	43.9	27.8	28.3
1929	39.6	36.4	24.0	34.3	40.1	25.6
1930	42.7	37.7	19.6	41.0	36.9	22.1
Sown 1927						
1928	43.8	31.4	24.8	40.9	29.9	29.2
1929	46.7	32.4	20.9	43.3	33.4	23.3
1930	44.7	35.7	19.6	43.3	36.9	19.8
1931	37.1	32.5	30.4	35.4	32.0	32.6
Sown 1929						
1930	55.7	34.8	9.5	53.8	35.0	11.2
1931	44.5	30.8	24.7	41.3	32.9	25.8
1932	26.7	48.8	24.5	23.1	51.0	25.9
Average	43.3	33.9	22.8	40.5	34.7	24.8

TABLE 25.—Distribution by Cuttings of the Total Yield for the Season in Different Varieties of Alfalfa—Continued

	Proportion of total yield in each cutting					
	Variegated			Common		
	1st Pct.	2nd Pct.	3rd Pct.	1st Pct.	2nd Pct.	3rd Pct.
	North Ridgeville					
Sown 1923						
1924	63.7	36.3	....	62.2	37.8	....
1925	64.2	35.8	....	64.6	35.4	....
1926	80.3	19.7	....	80.9	19.1	....
1927	62.8	37.2	....	65.4	36.6	....
Sown 1924						
1925	54.9	45.1	....	53.9	46.1	....
1926	64.6	35.4	....	64.9	35.1	....
1927	82.3	17.7	....	82.1	17.9	....
Sown 1927						
1928	49.8	50.2	....	47.0	53.0	....
1929	47.0	53.0	....	44.1	55.9	....
Sown 1928						
1929	51.5	48.5	....	50.8	49.2	....
1930	78.8	21.2	....	79.7	20.3	....
1931	44.1	37.1	18.8	46.7	33.9	19.4
1932	56.8	43.2	....	58.9	41.1	....
Sown 1929						
1930	77.3	22.7	....	76.0	24.0	....
1931	46.7	35.4	17.9	45.4	35.9	18.7
1932	65.2	34.8	....	65.1	34.9	....
Sown 1930						
1931	37.6	35.3	27.1	35.8	36.2	28.0
1932	59.4	40.6	....	56.4	43.6	....
Average, 2 cuttings	63.9	36.1	....	63.4	36.6	....
Average, 3 cuttings	42.8	35.9	21.3	42.6	35.3	22.0

TABLE 26.—Ladak Alfalfa, Percentage of Total Yield at Each Cutting

Station and year	1st cutting	2nd cutting	3rd cutting	Station and year	1st cutting	2nd cutting	3rd cutting
	Pct.	*Pct.*	*Pct.*		*Pct.*	*Pct.*	*Pct.*
Wooster				North Ridgeville			
Sown 1928:				Sown 1923:			
1929	48.1	51.9	....	1924	72.2	27.8	....
1930	78.9	15.8	5.3	1925	64.2	35.8	....
1931	69.4	16.2	14.4	1926	88.8	11.2	....
1932	60.0	32.4	7.6	1927	65.8	34.2	....
Sown 1931:				Sown 1924:			
1932	56.4	29.5	14.1	1925	53.8	46.2	....
1933	63.1	15.0	21.9	1926	66.2	33.8	....
				1927	90.1	9.9	....
Columbus				Sown 1927:			
Sown 1927:				1928	60.9	39.1	....
1928	55.3	22.9	21.8	1929	51.7	48.3	....
1929	49.3	32.0	18.7	Sown 1929:			
1930	55.9	17.7	26.4	1930	81.5	18.5	....
1931	42.6	30.9	26.5	1931	58.1	29.6	12.3
Sown 1929:				1932	73.2	26.8	....
1930	62.9	29.9	7.2	Sown 1930:			
1931	45.7	25.3	29.0	1931	40.9	36.1	23.0
1932	34.5	46.8	18.7	1932	64.5	35.5	....

Summary

	1st cutting	2nd cutting	3rd cutting
Ladak			
Average, 2 cuttings, 13 comparisons	67.8	32.2	....
Average, 3 cuttings, 14 comparisons	55.2	27.2	17.6
Variegated, from same tests			
Average, 2 cuttings, 13 comparisons	62.6	37.4	....
Average, 3 cuttings, 14 comparisons	48.3	32.4	19.3
Adapted Common, from same tests			
Average, 2 cuttings, 13 comparisons	61.5	38.5	....
Average, 3 cuttings, 14 comparisons	46.4	32.6	21.0

TABLE 27.—Yield of Hay and Height of Growth After Last Cutting, Alfalfa Varieties, Columbus

Variety	1929	1930	1931	1932	1933*	Average
Yield of hay per acre, pounds						
Ladak	....	700	740	410	730	640
Other variegated	....	942	1168	1025	1080	1050
Adapted common	....	847	1458	1162	1140	1150
Non-hardy common	....	691	1630	1271	1130	1180
Turkestan	....	340	600	470	880	560
Height of plants, inches						
Ladak	11.0	5.0	9.0	4.0	4.0	6.6
Other variegated	11.5	7.5	14.8	9.0	6.9	9.9
Adapted common	12.8	7.8	15.2	11.9	9.1	11.4
Non-hardy common	16.7	9.1	18.6	13.0	10.2	13.5
Turkestan	4.0	5.0	13.0	4.0	5.0	6.2

*1933 data from new seeding

Fall growth of variegated and common.—There is typically a distinct difference in the recovery and growth of variegated and common alfalfas in the fall. The variegated strains make a short spreading growth, and the common strains, especially the non-hardy ones, a taller, more erect growth.

This point is illustrated by the data from Columbus in Table 27. There is a distinct correlation between hardiness and small fall growth, although the differences between the variegated and the adapted common strains are not as great as might be expected. Undoubtedly, both natural and artificial selection of the two types in similar regions and under similar cultural practices have tended to make them more and more alike.

TABLE 28.—Comparisons of the Yield of Roots of Variegated and Adapted Common Alfalfa

Date	Locality	Samples of each averaged	Yield of roots per acre	
			Variegated	Common
		No.	*Lb.*	*Lb.*
Season of 1924-25	Columbus	7	1600	1710
Season of 1926	Columbus	10	1710	1600
Season of 1926	Columbus	55	1545	1525
Season of 1927	Columbus	20	1574	1510
September 1930	Columbus	8	2720	2710
November 1930	Columbus	8	3080	3360
October 1930	Paulding County	12- 8	3640	3380
Season of 1930	Hamilton County	15-10	3380	2600
September 1930	Northwestern Experiment Farm	6	2690	2630
October 1932 (Table 55)	Northwestern Experiment Farm	20	3560	2720
October 1932 (Table 55)	Northwestern Experiment Farm	20	1630	1610
November 1932 (Table 78)	Northwestern Experiment Farm	16	4380	3870
September 1933 (Table 55)	Northwestern Experiment Farm	10	3120	2490

Root yields of alfalfa varieties.—A considerable number of determinations of the root yields of alfalfa varieties have been made by harvesting square yard areas to a depth of one foot (Table 28). Except for the 1930 data from Hamilton County and two of the Holgate tests, they have not indicated any significant differences in the total weight of roots produced by different varieties of alfalfa. In these exceptions the stands of the common varieties were smaller in proportion than the acre yields of roots, so that the average plant of common, was as large or larger than the average Grimm plant. It seems hardly likely that the differences in winter-hardiness between common and variegated strains can be explained on the basis of greater root storage in the latter; however, the distribution of the yield of Ladak by cuttings strongly suggests that a larger proportion of the fall growth of Ladak is stored in the roots and less used for top growth than is the case with the common alfalfas. Unfortunately, no root yields of Ladak have been obtained.

Root development of Grimm and common alfalfa.—Because of the widespread belief that the root system of Grimm alfalfa is notably different from that of common, observations on the character of the roots have been made when roots of the two varieties have been dug. When the two varieties were growing side by side on the same soil type, there was no instance in these experiments in which one set of roots could have been distinguished from the other. This was noted in 1922-1924 (55), as well as in the tests reported in Table 28. In a quantitative study at Wooster in 1923, Kansas common actually had slightly more root branches than Grimm. Soil type has much more effect than variety in modifying the structure of alfalfa roots (12) (Page 141).

ALFALFA IN ROTATIONS[8]

In practice, alfalfa in Ohio is not extensively used in short, definite rotations as is red clover. The farmer who obtains a good stand of alfalfa is likely to keep it as long as it produces a satisfactory crop. The reasons most frequently given for not using it in short, regular rotations are the following: (a) It is hard to obtain a stand of alfalfa; (b) seed is expensive; (c) alfalfa is hard to plow up; and (d) old stands are more valuable than first-year stands.

Fig. 8.—Alfalfa succumbs to moist shade

Columbus, October 22, 1931—Left, alfalfa (weeds removed from the area before photographing); right, sweet clover. Areas less than a rod apart. Both sown in wheat on good soil April 15, 1931. Alfalfa germinated well, and the wheat did not lodge but it made a dense growth.

Ease of obtaining a stand.—There is no question but that, under average Ohio conditions, red clover is surer to make a stand than is alfalfa. This is largely a matter of better soil adaptation (Pages 10-11), but it may also be due in part to a greater susceptibility to failure in seeding with a companion crop. Observation of the two crops when sown under identical conditions suggests that alfalfa seedlings are somewhat more susceptible to shade under moist conditions than red clover, alsike clover, or sweet clover seedlings (Fig. 8). On the other hand, alfalfa seedlings are unquestionably better able

[8]Previous publications of the Ohio Station dealing with alfalfa in rotations are: (1; 2; 45, p. 26; and 49, p. 24).

to maintain themselves in a drouth in competition with a companion crop than are red clover, and especially alsike clover, seedlings (Fig. 9). In actual practice for the last 10 years, alfalfa sown with spring grain has been more consistently successful at Columbus than red clover. The recent dry years have furnished a multitude of instances in which alfalfa has produced a stand, while the two true clovers have not. Where the usual legume mixture (red clover, alsike, and alfalfa) was sown on the outlying farms in 1930, alfalfa was usually the only crop left alive.

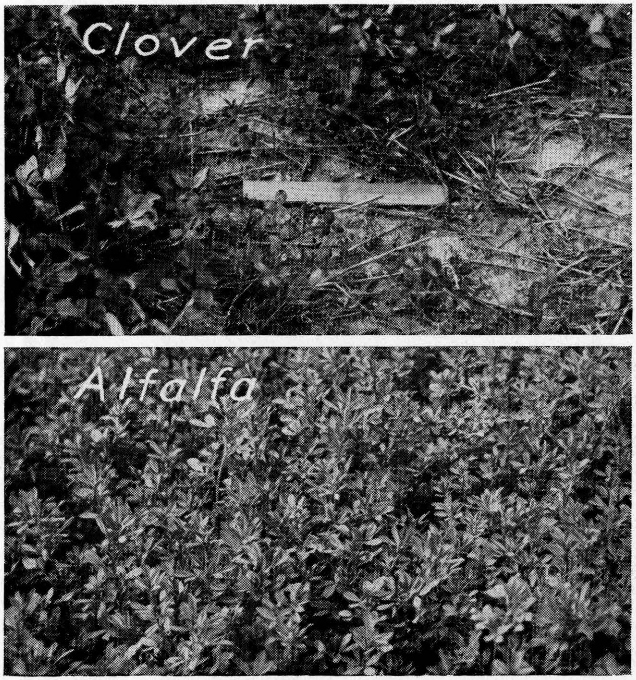


Fig. 9.—Alfalfa establishes itself in dry seasons

Alfalfa and red clover sown April 5 of the drouth year 1930, Columbus. Photos May 15, 1931. Alsike clover was still more nearly a total failure.

Relative cost of seed.—There was a time when alfalfa seed was expensive as compared with that of red clover, but for the past 12 years or more this has not been true (Table 29); in fact, there were 2 or 3 years between 1920 and 1930 when alfalfa was so much cheaper than red clover that red clover seed adulterated with alfalfa was found on the Ohio market.

Power requirements for plowing alfalfa sod.—Alfalfa roots sprout from the crown after plowing more than red clover, and, since its roots are decidedly fibrous and tough, alfalfa is more difficult to plow than red clover. In a series of tests[9] conducted by the Bureau of Agricultural Engineering of the U. S. Department of Agriculture at the Northwestern Experiment Farm in October

[9]Unpublished data furnished by I. F. Reed.

1932, the average draft per square inch of furrow slice for a 12-pound seeding rate of alfalfa was 11.2 pounds as compared with 7.9 pounds for red clover, both sown in April 1931. In a second series of plowing tests made in the following May on the same plots, the average draft per square inch of furrow slice was 10.4 pounds for alfalfa and 6.1 pounds for red clover.

TABLE 29.—Average Wholesale Selling Prices per 100 Pounds for Best Grades at Chicago, February, 1921-1932*

Year	Alfalfa	Red clover	Alsike clover	Sweet clover	Timothy
	Dol.	*Dol.*	*Dol.*	*Dol.*	*Dol.*
1921	17.65	18.05	22.40	8.75	6.50
1922	18.45	24.55	19.25	8.40	7.30
1923	19.05	22.45	16.50	11.50	7.00
1924	22.20	21.55	15.45	14.35	8.25
1925	22.75	36.00	22.35	12.95	6.70
1926	19.05	33.50	27.25	9.70	8.10
1927	21.00	42.30	37.95	13.90	6.05
1928	21.50	30.95	28.10	8.75	4.55
1929	26.00	33.20	33.90	8.05	6.70
1930	25.00	21.35	19.90	7.70	7.20
1931	23.10	26.05	24.00	9.45	10.45
1932	17.00	16.65	15.15	5.50	4.30
Average	21.06	27.22	23.52	9.92	6.92

*Data furnished by Hay, Feed, and Seed Division, Bureau of Agricultural Economics, U. S. Department of Agriculture, Washington, D. C.

When does a stand of alfalfa yield best?—It is usually considered that an alfalfa stand yields more in the second year of cutting than in the first. Data on this question are furnished by Rotation 40 at Wooster, which is Corn-Oats-Alfalfa-Alfalfa-Alfalfa. It is thus possible to compare the yields of 1-, 2-, and 3-year-old stands in the same seasons. As an 11-year average (1921-1931, inclusive), the yields per acre for the season are as follows:

1st year of cutting..................5272 pounds
2nd year of cutting..................6483 pounds
3rd year of cutting..................6812 pounds

The first year has given the largest yield twice in the 11 years. The second year of cutting has led three times; and the third, six times.

Data at Columbus and Holgate bear out this general result, although it is doubtful if the third year is generally superior to the second at Columbus. The superiority of the second year over the first is especially noticeable in summer seedings, or where only a partial stand has been obtained. A stand of 50 to 75 plants per square yard is too thin to give a maximum yield the year after seeding, but, when these plants have grown until they have occupied the ground, they can readily produce a full yield. This is especially important because many stands are thin because of one or another of the vicissitudes of seeding. It is this possibility that makes seeding in corn and soybeans and other less favorable methods more practical than they otherwise would be.

Experiments with alfalfa in rotations.—Even though an alfalfa stand generally yields more in the second year of cutting than in the first, the first-year yields are usually superior to those of red and other clovers if all cuttings are considered. In the rotation experiments at Wooster, Rotations 14 and 13 are identical, except for the legumes used, and offer a 13-year comparison of alfalfa and red clover in rotation on Wooster silt loam (Table 30). Not only was the hay yield larger in the alfalfa rotation but corn yielded 7.3 bushels per acre more following alfalfa than red clover. Alfalfa has shown up well at the Miami County Experiment Farm on Blocks L and M. Three legumes and mixtures of them are being grown in 3-year rotations including corn and both oats and wheat (Table 30).

TABLE 30.—Alfalfa Compared with Other Legumes for Short Rotations

No.	Rotation (Crops in order)	Years averaged No.	Corn Bu.	Yield per acre: Small grain Bu.	Yield per acre: Hay Lb.
	Wooster				
11	Corn-wheat-clover	13	69.1	36.8	3544
14	Corn-wheat-alfalfa	13	75.9	38.9	4649
13	Corn-wheat-sweet clover	12	76.4	37.9	5069
40	Corn-oats-alfalfa-alfalfa-alfalfa	13	82.6	65.9	4815†
	Miami County Experiment Farm				
I	Corn-oats-sweet clover	5	50.5	53.4	‡
II	Corn-oats-red clover	5	53.7	54.4	3780
III	Corn-oats-alfalfa	5	55.9	56.5	4480
IV	Corn-oats-mixture No. 1*	5	58.2	56.3	4670
V	Corn-oats-mixture No. 2*	5	55.9	53.7	3820
VI	Corn-wheat-sweet clover	5	55.1	35.4	§
VII	Corn-wheat-red clover	5	54.8	34.7	3240
VIII	Corn-wheat-alfalfa	5	54.7	35.0	4790
IX	Corn-wheat-mixture No. 1*	5	54.4	33.3	4480
X	Corn-wheat-mixture No. 2*	5	51.1	34.9	4040

*Mixture No. 1: Alfalfa 4 pounds, red clover 3 pounds, alsike 2 pounds, sweet clover 4 pounds.
Mixture No. 2: Alfalfa 5 pounds, red clover 3 pounds, alsike 3 pounds.
Miami oats, a mid-season variety, has been used in this test.
†First-year alfalfa only; average yield, second year, 6025 pounds; third year, 6088 pounds.
‡Three-year average, two cuttings, 1930-1932; first 2 years omitted because only one cutting was made.
§Sweet clover yield not taken.

Except for the greater difficulty in plowing, which need not be decisive, there would seem to be every reason for using alfalfa in short rotations on adapted soils, especially in mixtures. Alfalfa used in this way has the important advantage that, if, for any reason (such as a failure of the new seedings or a desire to reduce the grain acreage), it is advantageous to hold the meadow over for another year, it can be done with no loss in yield.

On the other hand, there are many farms which consist of such varied soil types that one or two fields can be made ready for alfalfa more readily than the rest of the farm, and it is desirable to drain, lime, and fertilize these areas and keep them in alfalfa as much as possible. Examples of such adapted soil types which may be present in limited areas are bottom lands in almost all parts of the State, areas of Wooster soil in northeastern Ohio, Cincinnati soils in southwestern Ohio, Bellefontaine and Fox soils in central and western Ohio, and Brooke and Westmoreland soils in southeastern Ohio.

ALFALFA IN MIXTURES

Alfalfa has largely been grown in pure culture. On soils ideally adapted to the crop, this is generally desirable since few other crops will endure the frequent cutting given to alfalfa. However, alfalfa may be profitably used in a large range of mixtures under conditions which are not ideal for the crop sown alone. These may be divided into two general classes: Mixtures in which alfalfa is a minor ingredient, added to improve the mixture; and those in which alfalfa is a major ingredient, with other crops added to meet special conditions.

INCLUDING ALFALFA IN THE REGULAR ROTATION SEEDING

For many years the regular rotation seedings on the outlying farms have included a proportion of alfalfa, varying according to the degree of adaptation to the crop. In the eastern half of the State, a mixture of 4 pounds of alfalfa, 4 pounds of red clover, 2 pounds of alsike, and 4 pounds of timothy per acre is used; whereas, in the western half of the State, the mixture used is 6 to 8 pounds of alfalfa, 4 pounds of red clover, 2 pounds of alsike, and not more than 2 pounds of timothy, or none, depending on the lime needs of the soil. The amount of alfalfa in the mixture has been increased as the lime and fertilizer needs of the soil have been met. In fact, originally, only 2 pounds of alfalfa were included; this amount gave a scattering stand of plants and doubtless helped in establishing inoculation.

The seed is mixed, and one-half sown usually the last of February or early March and the other half about a month later. This split method of seeding has resulted in good stands more often than when a single seeding was made.

The first cutting usually gives a good grade of mixed legume hay. The red clover usually disappears, especially in southern Ohio, so that the second cutting is largely alfalfa. Frequently, a third cutting of pure alfalfa is obtained. In case the new seeding fails the meadow may be held over another year with satisfactory yields. For a definite comparison of one of these mixtures with alfalfa alone see Table 30.

This gradual working into alfalfa is the most practical use for the crop on many farms. On soils which will grow good red clover, a surprising amount of alfalfa will appear in the mixture and will thus pave the way for more as the land is built up. Alfalfa "catches" in dry seasons better than red clover, so that the mixture will make a seeding under more varied conditions than any single crop. Sown in 1930 at the Northeastern Experiment Farm, this mixed seeding resulted in 1931 in a nearly pure alfalfa meadow on a soil so unfavorable for alfalfa that it is risky to sow it alone. A wider use of alfalfa in the regular rotation seeding would be of great benefit to Ohio farms.

ALFALFA-GRASS MIXTURES

Experiments with alfalfa-grass mixtures have been carried out at Wooster, Columbus, North Ridgeville, and on the outlying farms.

Alfalfa-grass mixtures at the Trumbull County Experiment Farm[10].— Experiments with alfalfa-timothy mixtures at the Trumbull County Experiment Farm (50, p. 232) have given an entirely new conception of the possible place of alfalfa on these heavy soils which are poorly drained naturally and are difficult, or almost impossible, to drain artificially (Page 9). Seedings of alfalfa alone had resulted mostly in failures. Fairly good stands were obtained, but on these clay and silty clay loam soils the plants invariably heaved badly over winter, with the result that the crop was not recommended for this section of the State.

[10]Since this bulletin was submitted for publication, M. A. Bachtell, C. F. Monroe, and Harold Allen have published "Alfalfa-Timothy Hay for the Dairy Farm", Ohio Agricultural Experiment Station Bulletin 538, which discusses this mixture in much greater detail.

The first attempt to grow an alfalfa-timothy mixture was in 1927 on Block P, where a mixture of 12 pounds of alfalfa and 2 pounds of timothy was sown with Fulghum oats as a companion crop and fertilized with 300 pounds 0-14-4. One-fourth of the block was summer seeded. The hay was allowed to get fairly mature, only one cutting being made, except in 1929. The cutting dates ranged from July 11 to 24. In spite of the fact that only a partial stand was obtained on the summer-seeded quarter, the hay yields have averaged 3 tons per acre for 5 years. The yearly yields are given in Table 31.

TABLE 31.—Timothy-alfalfa Mixture, Trumbull County Experiment Farm

Year	Treatment*	Cuttings		Yield per acre
		No.	Dates	
				Lb.
1928	Manure	1	....	5151
1929		2	July 11	6213
			Aug. 10	1136
1930	Manure	1	July 11	5852
1931		1	July 24	7100
1932	Manure	1	July 20	6525

*Applied as a top-dressing, 6-8 T.

The excellent showing of this mixture both in yield and as a feed for dairy cows prompted further seedings, beginning in 1930, in which the seeding mixtures were varied. The yields and field history are given in Table 32. The first hay crop after seeding would pass for an excellent clover crop. After that the first cutting each year consisted of a mixture of timothy and alfalfa, while the later cuttings the same year were pure alfalfa.

These yields for this section are almost phenomenal. The quality of the hay has likewise been outstanding, the proportion of alfalfa in the first cutting ranging from 15 to 50 per cent. The alfalfa has benefited the associated timothy by giving it a better growth, color, and protein content. Nothing else on this farm has equalled these mixtures as a source of high-grade dairy feed.

Through the use of alfalfa-timothy mixtures on adequately limed and fertilized soils, it has been possible to maintain alfalfa in meadows for periods comparable to other parts of the State. The fall growth of the timothy evidently makes an excellent mulch, reducing the fluctuations in the temperature of the soil surface, and keeps heaving at a minimum.

The proportion of timothy in the final alfalfa-timothy mixture is hard to predict. The mixture containing 6 pounds of timothy sown on Field 2C resulted in an excessive amount of timothy in the first cutting. Probably from 2 to 4 pounds of timothy are sufficient in the mixture, the amount varying with the limestone and fertilizer needs of the soil—the lower the plane of fertility, the more timothy should be added to the mixture. In the first-year meadows, the timothy is hardly visible in the first cutting. The plants are small and usually single stalked. In the later cuttings that year, the timothy usually makes up only a small proportion of the hay; however, it makes considerable fall growth, and stand observations in the fall indicate that from 40 to 60 per cent of the ground cover is timothy. Apparently, root storage takes place during this fall growth. The timothy grows much more vigorously in the second-year meadow and considerable stooling takes place, each plant producing several to many heads. Thereafter, the proportion of timothy in the mixture remains more nearly constant.

TABLE 32.—Alfalfa Mixtures at the Trumbull County Experiment Farm

Field	Companion crop	Treatment at seeding	Seeding mixture	1931 Cut	1931 Yield	1932 Cut	1932 Yield	1933 Cut	1933 Yield
					Lb.		*Lb.*		*Lb.*
1A	Oats	1.7 T. limestone	4 lb. alfalfa, 4 lb. red, 2 lb. alsike, 4 lb. timothy...	July 12 Sept. 11	5310* 2340	June 30 Aug. 13	5750 3300	June 12 July 28 Sept. 7	5040 1650 400
2C	Oats	175 lb. 0-44-0 3 T. limestone	10 lb. alfalfa, 2 lb. alsike, 2 lb. red, 6 lb. timothy....	....	....	June 23 Aug. 20	6110* 5730	June 9 June 26 Sept. 2	6050 940 630
R	Oats	200 lb. 0-20-0	4 lb. alfalfa, 4 lb. red, 2 lb. alsike, 4 lb. timothy.....	June 19	6570	June 22 Aug. 6 Oct. 30	8440* 7510 1580	....	....
4	Oats	340 lb. 0-20-0 4 T. limestone meal	10 lb. alfalfa, 2 lb. alsike, 6 lb. timothy	....	....	....	....	June 24 July 23	4820*† 750
1C	Oats	300 lb. 0-20-0 1.5 T. limestone meal	4 lb. alfalfa, 4 lb. red, 2 lb. alsike, 4 lb. timothy.....	....	....	....	....	June 21 Sept. 2	5100 820
E	Wheat	400 lb. 2-14-4	4 lb. alfalfa, 4 lb. red, 2 lb. alsike, 4 lb. timothy.....	....	....	....	....	June 16	6200

*Top-dressed with manure.
†Put in silo; estimated from silage yields.

TABLE 33.—Alfalfa, Grasses, and Alfalfa-grass Mixtures, Wooster

	Alfalfa and orchard	Orchard	Alfalfa and tall oat	Tall oat	Alfalfa	Alfalfa and timothy	Timothy	Alfalfa and brome	Brome	Alfalfa
Pounds of hay per acre										
1930—June 30	545*	488	485†	1114	329	444	422	290	80	329
1930—July 17	793	243	1187	750	1212	974	506	850	343	1212
1931—June 16	4740	4130	5930	4695	5137	5678	3987	5637	4150	5137
1931—Aug. 24	1902	606	2194	1225	1812	1319	412	1644	569	1812
1932—June 1	3741‡	957	3139§	1677	2671	...	...	...	...	...
1932—June 10	...	...	...	...	...	3998‖	1787	3584**	1475	3840
Total yield	11721	6424	13302	9461	11061	12413	7114	12005	6617	12330
Per cent of crude protein in hay—1932										
Alfalfa	19.0	...	19.4	...	19.9	16.0	...	16.0	...	16.9
Grass	9.6	8.8	8.1	7.4	...	7.3	6.2	9.0	8.6	...
Mixed hay	13.4	...	12.2	...	...	10.8	...	12.5	...	...
Pounds of protein per acre—1932										
Alfalfa	290	...	222	...	513	256	...	288	...	648
Grass	213	84	162	125	...	177	112	160	127	...
Total	503	84	384	125	513	433	112	448	127	648

*53.9 per cent grass. †62.0 per cent grass. ‡59.2 per cent grass. §63.5 per cent grass. ‖60.1 per cent grass. **49.7 per cent grass.

Top-dressing the alfalfa-timothy meadow with manure each alternate year has been an important factor not only in keeping up production but in maintaining stands.

The hay yields after wheat have been just as good or better than after oats the first year, but the meadow is not as permanent or productive after the first year, as there is usually much less alfalfa in the mixture than where the seeding is made in oats.

The season in Trumbull County does not normally favor three cuttings a year. If permanence of the meadow is considered, probably two cuttings are preferable, with three cuttings in the last year before plowing, if desired.

Experiments at Wooster.—A seeding was made on limed Canfield silt loam at Wooster August 6, 1929, of quadruplicate 0.004-acre plots of alfalfa and four grasses alone and in mixture (52, p. 24). The alfalfa was sown at 10 pounds per acre alone and in mixture; the orchard grass at 25 pounds alone and 5, 10, and 15 pounds in mixture; the timothy at 15 pounds alone and 2½ and 5 pounds in mixture; brome grass at 30 pounds alone and 15 in mixture; and oat grass, 30 pounds alone and 20 in mixture. The different rates of seeding the grasses made no important difference in the results. The results are combined in Table 33, the data for the orchard-grass mixture being an average of 12 plots and for the timothy mixture an average of eight plots. The alfalfa sown alone heaved badly in the winter of 1929-1930, but that in the mixtures with grasses did not.

TABLE 34.—Yields of Alfalfa and Alfalfa-grass Mixtures, Columbus
Total yield for the season, three cuttings

Range and year	Alfalfa alone	Alfalfa and orchard	Alfalfa and brome	Alfalfa and timothy	Grass in first cutting† Orchard	Grass in first cutting† Brome	Grass in first cutting† Timothy
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Pct.*	*Pct.*	*Pct.*
Range 500, 1932	9010	10180	8860	8200	16	33	37
Range 500, 1925 (Av. 2 plots)	5800	6300	....	....	....	....	....
Range 800, 1926	7740	8360	7840	....	....	....	....
1927	6940	7860	6500	....	....	....	....
1928	6980	8660	7920	....	43	46	....
1929	7640	8780	8400	....	81	52	....
1930	3400	5120	....	....	70	38	....
Av. 1926-1927	7320	8420	7660	....	....	....	....
Range 900, 1929	*	9770	8720	9490	54	....	65
1930	*	5710	4450	5400	52	26	61
1931	*	10110	10290	8020	38	34	50
1932	*	10060	9190	7480	59	26	2
Av. 1929-1932	....	8910	8160	7600	....	....	....

*No alfalfa was sown alone on this range, but alfalfa in other experiments similarly situated but better treated made much the same yields.

†For the entire season, orchard grass made up 55 per cent of the total hay on Plot 16, Range 800, in 1930. On Range 900, orchard grass made 41 per cent of the total hay for the season of 1929, 33 per cent in 1930, 36 per cent in 1931, and 34 per cent in 1932; brome grass made only 16 per cent in 1930, 24 per cent in 1931, and 10 per cent in 1932; timothy 42 per cent in 1929, 36 per cent in 1930, 22 per cent in 1931, and only 1 per cent in 1932.

Experiments at Columbus.—Seedings of alfalfa-grass mixtures have been made at Columbus in comparison with both grasses and legumes. When compared with pure stands of the grasses, they have yielded three times as much as timothy, the highest yielding grass (51, p. 34). Their yields as compared with alfalfa are given in Table 34. Orchard grass has always been seeded at

10 pounds per acre, timothy at 6 to 9 pounds, and brome grass at 20 pounds, in addition to a normal seeding (10 to 12 pounds) of alfalfa. It is notable that the timothy in the alfalfa-timothy mixture sown in 1928 had almost disappeared by 1932, although the first cutting was made 10 days later than that for alfalfa alone or for the alfalfa-orchard grass mixture. It seems that the timothy did not withstand the shading of the very vigorous second and third crops of alfalfa in 1931. The alfalfa - orchard grass mixtures remained in good condition in all seedings as long as they were left. The protein contents of alfalfa, alfalfa-grass mixtures, and the grasses grown with alfalfa and alone are given in Table 35.

TABLE 35.—Composition of Alfalfa-grass Mixtures, Columbus

Range and date	Protein in			
	Alfalfa Pct.	Alfalfa-grass mixture Pct.	Grass in mixture Pct.	Grass grown alone Pct.
Orchard grass				
Range 800, June 11, 1928	18.1*	14.3	9.0	7.7
June 9, 1930	16.7	10.9	8.4	....
Range 900, June 14, 1929	15.2*	12.0	9.3	5.4
July 30, 1929	16.6*	15.6	13.3	8.9
Sept. 12, 1929	19.4	18.5	15.6	....
June 2, 1930	15.8	12.6	9.6	7.2
Sept. 10, 1930	17.8	18.0	20.8	....
June 11, 1931	18.0	15.6	11.8	5.2
July 29, 1931	16.2	16.0	15.3	....
Sept. 12, 1931	19.2	19.1	18.3	....
June 11, 1932	17.0	11.8	8.2	6.9
July 26, 1932	16.1	16.3	17.2	....
Sept. 12, 1932	19.9	19.8	18.8	....
Range 700, Aug. 6, 1932	18.1	17.0	14.2	....
Sept. 12, 1932	22.2	22.0	19.6	....
Average of first cutting	16.8	12.9	9.4	6.5
Average of second cutting	16.8	16.2	15.0	....
Average of third cutting	19.7	19.5	18.6	....
Timothy				
Range 900, June 27, 1929	14.8*	8.7	5.4	4.1
June 17, 1930	15.6	10.4	7.0	5.4
June 18, 1931	15.3	12.2	9.1	4.8
Average of 3 years	15.2	10.4	7.2	4.8

*Estimated from other samples harvested on these dates.

The mixture plots on Range 800 were included in Sections B, D, F, and H of the time-of-cutting test (Page 83). Section B was cut four times, the last prematurely, in 1926; whereas Section D was cut only three times. The alfalfa in the alfalfa - orchard grass mixture in Section B was completely killed and that in the brome grass mixture was almost completely killed in 1927. The stand of grass was not affected, but the effect on the growth and yield of the grass in the mixtures was extraordinary. The orchard grass in Section B was yellow and gave every evidence of nitrogen starvation in both 1927 and 1928.

It was short and produced very few heads (Figs. 10 and 11). The effect on the brome grass was similar but not quite so pronounced. The yields, as obtained from representative duplicate square-yard samples, are given in Table 36. The mixtures were not sorted in 1927.

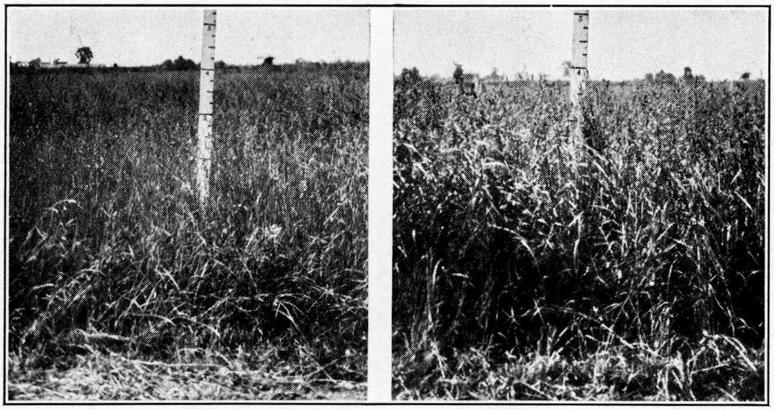


Fig. 10.—Effect of frequent cutting on an alfalfa - orchard grass mixture

Columbus, June 7, 1927—Left, cut three times in 1926; right, cut four times in 1926.

Experiments at the Timothy Breeding Station, North Ridgeville.—Plots of alfalfa and alfalfa-grass mixtures, as described in Table 37, were seeded in August 1915. They were allowed to stand through 1924, when there was still a fair stand of alfalfa in the plots, except where old dead-furrows crossed them. The timothy, both alone and in mixture with alfalfa, died out rapidly after the second season and disappeared entirely within a few years.

TABLE 36.—Effect of One Year of Frequent Cutting on Alfalfa-grass Mixtures

First cutting only

Mixture and date	Yield per acre					
	Section B Cut four times in 1926			Section D Cut three times in 1926		
	Alfalfa	Grass	Total	Alfalfa	Grass	Total
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Alfalfa-orchard grass:						
1927	....	....	1760	....	....	4460
1928	....	1210	1210	2170	1510	3680
Alfalfa-brome grass:						
1927	....	....	2740	....	....	4250
1928	1290	1730	3020	2720	2290	5010

The orchard grass persisted with the alfalfa in about the original proportions, each making up about 50 per cent of the first-cutting hay. Together they made such a dense stand that no other grass, not even Kentucky blue grass, which was abundant along the roadways and encroached on the timothy plots, obtained a foothold. On the other hand, the orchard grass spread to all the other plots so that the yield comparisons were of little value and are not reported after 1919. The spread was by matured seeds, due to late cutting of the meadow and the early maturity of the orchard grass. The orchard grass which volunteered in the alfalfa plots was notably more vigorous than that which volunteered in the timothy plots.

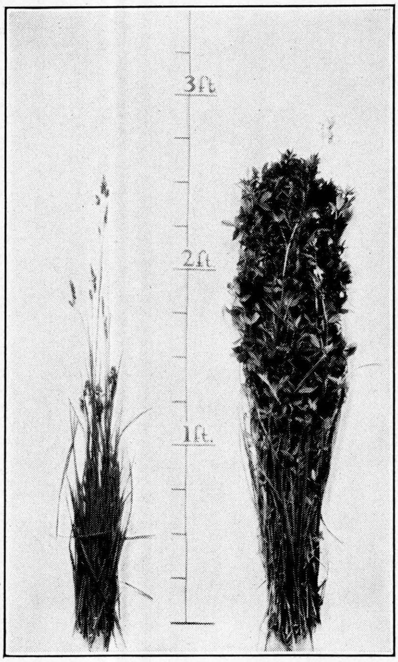


Fig. 11.—Continued effect of frequent cutting, alfalfa – orchard grass mixture

Equal areas (1 square foot), June 11, 1928—Left, cut four times in 1926 and three times in 1927; right, cut three times in 1926 and 1927.

The plots were cut twice each season, but the second cuttings were not recorded in 1918 and 1919. The yields for 1916 to 1919 are reported in Table 37.

Alfalfa-grass mixtures—summary and conclusions.—1. The grasses in an alfalfa-grass mixture protect it so that it does not winterkill by heaving nearly as badly as alfalfa alone. Mixtures are thus especially desirable for late summer seedings or for any seeding on soil types likely to cause heaving of the alfalfa. They make possible the growing of alfalfa on soil types unadapted to the crop grown alone.

2. The alfalfa-grass mixtures generally outyield pure alfalfa and always outyield the pure grass. It is not uncommon for the mixture to yield more grass than the pure grass plots, leaving the alfalfa out of consideration.

3. The protein content of grass grown in mixture with alfalfa was definitely higher than of that grown alone (an average of 44 per cent higher for orchard grass and 50 per cent higher for timothy, at Columbus) (Tables 33 and 35). This was evident not only in the analyses but in the color, height of growth, and general appearance in the field. The grasses were in every way similar to grasses which had received a liberal application of nitrogenous fertilizer. This effect is well known in red clover – grass mixtures; the use of alfalfa instead of clover substitutes a perennial for a biennial legume and so makes the effect a continuous one.

4. Alfalfa-grass mixtures resist the encroachment of weeds, especially winter annuals like white-top (Fig. 12), yellow rocket, field peppergrass, shepherd's purse, and chickweed, in the first cutting much better than does alfalfa alone. In 1929 and 1930, when common alfalfa alone contained respectively 21 and 34 per cent of weeds in the first cutting, the alfalfa – orchard grass mixture contained none. This is a universal experience.

5. Data on rate of curing at Columbus indicate that these mixtures cure more rapidly than alfalfa alone.

TABLE 37.—Yields of Alfalfa and Alfalfa-grass Mixtures, North Ridgeville

Sown August 1915 on duplicate 0.05-acre plots

Crop and variety	Rate of seeding per acre	Yield per acre				
		1916†	1917†	1918‡	1919‡	4-year average
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Timothy	8	3973	4610	4015	2702	3825
Timothy Grimm alfalfa	3 20	4374	4393	4285	3402	4114
Timothy Grimm alfalfa	12 20	4671	4363	4093	3343	4118
Orchard grass Grimm alfalfa	20 20	4032	4291	4344	4469	4284
Alfalfa, Grimm*	25	3640	3860	3840	3580	3730
Alfalfa, Ontario Variegated	25	3643	4123	4006	3723	3874
Alfalfa, Kansas	25	3124	4046	3935	3702	3702
Alfalfa, Dakota	25	2518	3924	4154	3496	3523

*Average three plats. †Two cuttings. ‡First cutting only.

6. The grasses vary in their value for use in these mixtures. Orchard grass has been the most uniformly successful grass. It is very long lived, the stand remaining good as long as any of these experiments have continued; it matures with alfalfa, so that there is no conflict of cutting dates; it makes a good aftermath, so that there is often an appreciable proportion of the grass in the second and third cuttings. This aftermath contains a very high percentage of protein (Table 35). The palatability of orchard grass has been questioned, but orchard grass cut in full bloom or before, as it has been in these mixtures, is reported to make palatable hay. The cost of seed is another objection. In view of the southern adaptation of orchard grass, it seems that this mixture should be especially valuable from Columbus south, wherever a long-lived meadow is desired.

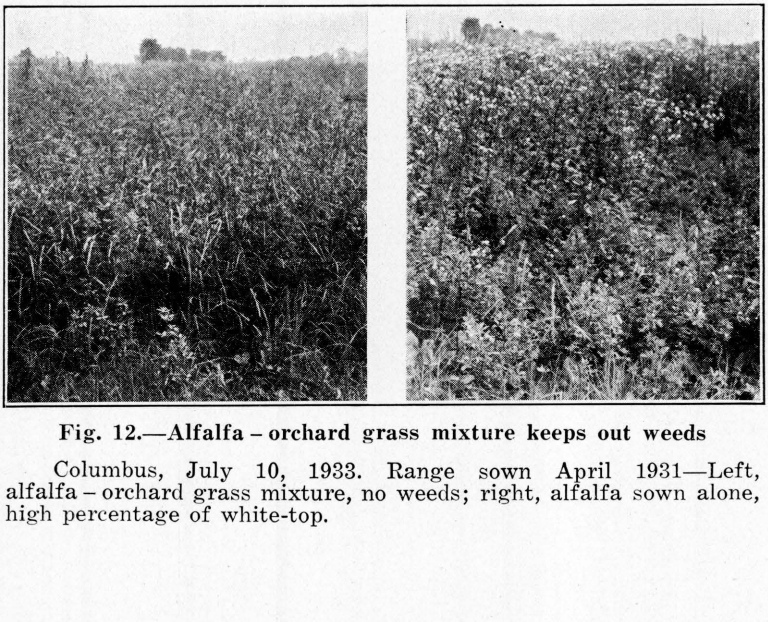


Fig. 12.—Alfalfa - orchard grass mixture keeps out weeds

Columbus, July 10, 1933. Range sown April 1931—Left, alfalfa - orchard grass mixture, no weeds; right, alfalfa sown alone, high percentage of white-top.

Although timothy has some drawbacks, its general adaptability and the low price of its seed make it by far the most important grass for mixtures with alfalfa, especially in the northern half of the State. Since there is a difference of at least 2 weeks in the maturity of alfalfa and timothy, both cannot be cut at the best stage. The protein content of timothy is the lowest of the grasses studied; the aftermath is small, and it has shown a tendency to die out in mixture with vigorous alfalfa.

The alfalfa - oat grass mixture has been high yielding at Wooster, but the lack of palatability of oat grass and the very high price and poor quality of the seed make this mixture impractical. This unpalatability of tall meadow oat grass was confirmed by feeding trials at Columbus in 1925 and at Wooster in 1933.

Brome grass is high in protein content and palatability, matures well with alfalfa, and is longer lived than timothy, but difficulties have been encountered in obtaining stands. The seed is high priced, often germinates poorly, and often contains quack-grass seed as an impurity.

ALFALFA - SWEET CLOVER MIXTURES

These have been used to a certain extent in northwestern Ohio, and a few experiments with them have been conducted both at Wooster and Columbus (Table 38). While the yield per acre at the first cutting is higher for the mixture than for alfalfa alone, the yield at the second cutting is lower and the alfalfa may be nearly killed. In view of the difficulty of curing sweet clover, its coarse stemmy nature, and the likelihood of disease in cattle from the hay, it is hard to see any justification for this mixture.

TABLE 38.—Alfalfa and Sweet Clover Mixtures

Range and date	Yield per acre					
	Mixture				Alfalfa alone	
	First cutting			Second cutting	First cutting	Second cutting
	Alfalfa Lb.	Sweet clover Lb.	Total Lb.	Alfalfa Lb.	Lb.	Lb.
Columbus						
Range 1000, June 10, 1931	2380	3560	5940	....	4400	....
Range 700, June 14, 1932	1960	2070	4030	2400	3370	3350
Range 1500, June 10, 1933	210	4180	4380	1050	2460	990
Average	1520	3270	4780	1720	3410	2170
Wooster						
1929	....	....	5040	2250	4260	3600
1930	....	....	4080	....	3960	....
1931	....	....	3000	1350	3420	1500
1932	....	....	3170	1350	2730	1980
Average	....	....	3820	1650	3590	2360

Because of the self-seeding habits of sweet clover, numerous unintentional mixtures of alfalfa and sweet clover have been obtained in alfalfa seedings at Columbus, Holgate, and elsewhere. This has always been objectionable and sometimes very serious. Experience has shown that the most effective way to deal with these mixtures is to clip them as closely as possible from September 1 to 10 of the seeding year. The effect is to check the sweet clover and not injure the alfalfa; hence, the alfalfa makes up a larger proportion of the mixture and is less overshadowed. A typical example of this is given from Columbus (Table 39), but similar effects have been observed many times. This mixture was about five-eighths alfalfa by count of plants.

TABLE 39.—Effect of Clipping on an Alfalfa - Sweet Clover Mixture, Columbus

Sown April 1931 in oats

Date and crop	Yield per acre			
	Tops or hay		Roots	
	Clipped September 5	Not clipped	Clipped September 5	Not clipped
	Lb.	*Lb.*	*Lb.*	*Lb.*
September 5, 1931				
Alfalfa	800	....	....	....
Sweet clover	950	....	....	....
Total	1750	....	....	....
Alfalfa in mixture, per cent	46	....	....	....
November 7, 1931				
Alfalfa	750	360	630	300
Sweet clover	420	1220	350	1670
Total	1170	1580	980	1970
Alfalfa in mixture, per cent	64	23	64	15
June 1932*				
Alfalfa	2350	1920	....	....
Sweet clover	580	1960	....	....
Total	2930	3880	....	....
Alfalfa in mixture, per cent	80	49	....	....
August 6, 1932				
Alfalfa	2840	2400	....	....
September 12, 1932				
Alfalfa	1710	1510	....	....
Total yield, 1932	7480	7790	....	....
Total alfalfa, 1932	6900	5830	....	....

*The yields for June are averages of square-yard samples taken June 7 and June 14. Cut June 14.

Theoretically, a mixture of alfalfa and Hubam sweet clover should give a larger yield of hay in the seeding year than alfalfa alone, and there are some reports of the practical use of such a mixture. However, it was tried 6 years at Wooster and 3 years at Columbus, and a yield of Hubam hay worth cutting was not obained in any of the trials.

SEEDING ALFALFA

Experiments specifically comparing different methods of obtaining a stand of alfalfa have been conducted at Wooster, at Columbus, and on several of the outlying farms. In addition, every experiment involving alfalfa is also an experiment in the seeding of alfalfa, so that much more information is available on methods of seeding than just that derived from experiments on methods of seeding.

TABLE 40.—Rate of Seeding Alfalfa, Holgate

Yield of hay per acre and percentage of leaves in the hay

Plots	Rate of seeding per acre	Total yield of hay per acre					Leaves in hay				
		1932		1933		2-year average	First cutting		Second cutting		2-year average
		Grimm	Common	Grimm	Common		1932*	1933†	1932*	1933†	
No.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
11-1	2½	4540	3240	2590	2920	3320	55.2	50.0	54.9	65.7	56.4
12-2	5	4930	3370	3010	2430	3440	55.4	49.4	54.6	67.2	56.6
13-3	7½	5230	3890	3350	2530	3750	55.4	48.2	54.0	67.9	56.4
14-4	10	5010	4080	3270	2980	3840	55.0	49.0	59.2	64.5	56.9
18-8	10	5140	3790	3710	3180	3960	55.1	47.4	56.6	64.3	55.8
15-5	12½	5130	4500	3450	2910	4000	55.6	49.6	55.3	65.3	56.4
16-6	15	5570	3950	3560	2980	4020	55.0	50.0	56.0	65.8	56.7
17-7	20	5270	3710	3540	3090	3900	56.0	49.0	55.7	65.0	56.4
19-9	25	5160	3820	3900	3210	4020	53.8	48.8	53.4	64.2	55.0
20-10	50	5370	3360	3640	3160	3880	56.0	49.8	57.8	65.3	57.2
Average of all	....	5140	3770	3400	2940	....	....	....	....	....	....

*Average of one sample each of Grimm and common.
†Average of two samples each of Grimm and common.

RATE OF SEEDING

Although rates of 20 or even 25 pounds per acre have been recommended for Ohio and adjacent states (40), neither Station experiments, Station practices, nor farm practices justify such a recommendation for this State. Early rate-of-seeding tests at Wooster (75) obtained the highest yield at 10 pounds per acre. Stand counts in these experiments showed that the stand remaining after a few years was not greatly different, whatever the initial rate of seeding. At Columbus the standard rate of seeding in 12 years' experiments with alfalfa has been 12 to 15 pounds, with uniformly good results. This is also true of the outlying farms.

A rate-of-seeding test is in progress at the Northwestern Experiment Farm in which the rate of seeding is varied from 2½ to 50 pounds per acre, in an attempt not only to determine the best practical rate but also to find out how alfalfa responds to extreme variations in the rate of seeding. Since the most notable effects of variations in the rate of seeding are seen in the first year, the plots have been plowed after one year of cutting. Seedings were made in 1931 and 1932, and data were taken in 1932 and 1933. The seed was sown with a 4-inch special grass seed drill. Four pecks per acre of early oats were used as a companion crop. Excellent stands (for the rates used) were obtained in both years. Yields of hay have been obtained by taking four representative square-yard samples from each plot (three at the second cutting in 1933).

Yields of hay.—The yields of hay (Table 40) indicated no significant increase for rates of seeding over 10 pounds per acre; indeed, the increase for 10 pounds over 7½ pounds (150 pounds, or 4 per cent) is hardly significant in a 2-year average. These results agree with the earlier tests at Wooster and with farm experience.

Composition of the hay.—It is usually considered that thick planting makes for a high percentage of leaves in the hay, but there was no consistent difference in the percentage of leaves in the hay from any rate of seeding (Table 40). The same is true of the protein content (Table 41), although more extensive data may prove some of these small differences to be significant. In 1933 the leaves and stems were analyzed separately to see if there was any consistent difference between the protein content of the leaves or stems from the plots sown at different rates. The stems were very uniform in composition from all seeding rates; in the second cutting, the leaves from the two thinnest rates were about 2 per cent lower in protein than the thicker rates. This might conceivably be due to greater leafhopper damage to the thinner stand, but it will take more data than are now available to be sure that the difference is a real one. (See also Table 74.) Borst (8) obtained no evidence that hay from thick stands of soybeans contained a higher percentage of leaves and protein than thin stands.

The diameter of the dry stems at the base was measured in 1933, taking a random sample of 25 stems from two areas each of Grimm and common alfalfa at each rate (Table 41). There is an evident decrease in the average diameter of the stems as the rate of seeding increases. The differences seem small, but, since the average weight per stem would be proportional to at least the square of the diameter, the average stem from the 2½-pound rate in the first cutting weighed at least one and one-half times as much as the average stem in the 25 or 50-pound rates. Actually, the difference would be greater, since the thin stands were about 12 per cent taller than the thickest stands.

TABLE 41.—Rate of Seeding Alfalfa, Holgate

Percentage of protein in hay and diameter of stems

Plots	Rate of seeding per acre	Protein in hay						Protein in				Diameter of dry stems at base§	
		First cutting			Second cutting			First cutting§		Second cutting§			
		1932*	1933*	2-year av.	1932†	1933*	2-year av.	Leaves *	Stems *	Leaves *	Stems *	First cutting‡	Second cutting‡
No.	*Lb.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Cm.*	*Cm.*
11-1	2½	19.7	17.6	18.6	16.6	17.2	16.9	24.3	11.2	19.2	13.1	0.189	0.118
12-2	5	19.6	17.4	18.5	16.9	17.6	17.2	23.7	11.1	19.7	13.2	0.181	0.112
13-3	7½	20.4	17.2	18.8	17.0	18.8	17.9	23.7	11.2	21.5	12.8	0.183	0.103
14-4	10	20.6	17.4	19.0	17.1	18.6	17.8	23.3	11.4	21.6	13.1	0.174	0.104
18-8	10	20.4	17.4	18.9	16.9	18.2	17.6	23.9	11.6	21.0	13.4	0.165	0.110
15-5	12½	20.4	17.2	18.8	16.9	18.5	17.7	23.2	11.4	21.1	13.7	0.173	0.098
16-6	15	20.4	17.6	19.0	16.6	18.7	17.6	23.8	11.6	21.6	13.2	0.173	0.101
17-7	20	20.8	17.3	19.0	16.2	18.6	17.4	23.4	11.4	21.4	13.5	0.159	0.096
19-9	25	20.4	17.4	18.9	16.2	18.4	17.3	23.7	11.6	21.2	13.6	0.147	0.094
20-10	50	20.7	17.6	19.2	16.6	18.4	17.5	23.6	11.5	21.4	13.9	0.148	0.098
Average of all rates	....	20.3	17.4	18.9	16.7	18.3	17.5	23.7	11.4	21.0	13.4	....	....

*Average of one sample from each plot of Grimm and common.
†One sample from each plot of Grimm.
‡Average of 50 stems from each plot of Grimm and common.
§1933 only. First cutting, June 12; second cutting, July 27.

Weights of roots and stands.—It is difficult, if not impossible, to obtain accurate data on stands by counts at the surface of the ground. In the late fall of 1932, two square-yard samples were harvested from each plot of Grimm and common alfalfa in both the 1931 and 1932 seedings. In 1933, one square yard was taken from each plot of the 1932 seeding. The data for 1933 were directly comparable with, and were averaged with, those for the 1931 seeding in 1932; on the other hand, the two harvests a year apart in the 1932 seeding give a measure of the way it changed in one year. 1933 was intensely dry at Holgate. For convenience in getting the work done, the 1933 samples were taken in September, but, even so, the roots weighed nearly as much as in November 1932. Four samples taken in November 1933 (Plots 4, 8, 14, and 18) averaged 3680 pounds per acre of roots, a gain of 870 pounds, or 31 per cent, over September 20, 1933, and of 560 pounds, or 18 per cent, over the corresponding plots of the same age in November 1932.

The number of plants per square yard showed reasonably consistent increases with increases in the rate of seeding. The losses in stand from 1932 to 1933 in the 1932 seeding were comparatively small for seeding rates of 10 pounds per acre or less. At the higher rates the stands had decreased considerably but probably not as much as they would have if the season had not been dry. The obvious fact that thicker planting results in smaller individual plants is well brought out by the data on the average weight of each root. By November 1933, the roots in the plots sown at 10 pounds averaged 1.68 grams each.

Varietal responses to different rates of seeding.—Grimm alfalfa outyielded common at every rate of seeding (except the 2½-pound rate in 1933), the 2-year average difference being 27 per cent of the yield of common. A study of the data shows that this difference was rather consistently maintained at all rates. There was no apparent difference in the most economical rate of seeding for Grimm and common. The total weight of roots per acre was greater for Grimm than for common at nearly all rates; on the other hand, the average weight per root was generally greater for common.

Recommendations.—These experiments, as well as the older ones, agree with farm and Station experience in substantiating the recommendation of a standard rate of seeding of 10 to 12 pounds per acre. Eight pounds are as little as one would usually care to risk sowing under even the most favorable conditions, and, if 15 pounds will not give a satisfactory stand, there is no use in throwing still more seed away because the trouble is not in the rate of seeding. Within these limits, the more favorable the seeding conditions, the less seed need be used.

DATE OF SEEDING

The statement has been made that alfalfa may be sown at any time from early spring until September. This is more or less true, if weeds can be controlled, but early experiments at Wooster (76) and observations of farm seedings since indicate that May and June seedings are usually undesirable, because at this time alfalfa seedlings grow comparatively slowly while summer weeds, such as foxtail, red-root pigweed, and lamb's quarters, grow rapidly. Consequently there are two general periods for seeding—spring and summer. (See Page 72 for summer seeding.)

TABLE 42.—Rate of Seeding Alfalfa, Holgate. Weights of Roots and Stands

Data obtained from 2 square-yard samples from each plot of Grimm and common in 1932 and from one sample from each in 1933

Plots	Rate of seeding per acre	After one year of cutting												In fall of seeding year		
		Air-dry weight of roots per acre					Plants per square yard, average Grimm and common			Dry weight of each root, average Grimm and common				1932, average Grimm and common		
		1932		1933		Average 1932-1933										
		Grimm	Common	Grimm	Common		1932	1933	Average	1932	1933	Average		Weight roots per acre	Plants per square yard	Weight each root
No.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*No.*	*No.*	*No.*	*Gm.*	*Gm.*	*Gm.*		*Lb.*	*No.*	*Gm.*
11-1	2½	2920	2050	2330	2200	2380	72	80	76	3.00	2.51	2.76		1230	102	1.08
12-2	5	3140	2600	2300	2220	2560	96	80	88	2.62	2.49	2.56		1120	98	1.02
13-3	7½	3200	3040	3390	2270	2980	185	148	167	1.23	1.71	1.47		1280	156	0.72
14-4	10	3310	2830	2890	2600	2910	190	172	181	1.42	1.42	1.42		1460	213	0.62
18-8	10	4110	2260	3560	2210	3040	178	140	159	1.54	1.80	1.67		1530	218	0.64
15-5	12½	3600	3370	2760	3000	3180	234	231	232	1.30	1.09	1.20		1580	339	0.41
16-6	15	3570	2920	3330	2610	3110	226	296	261	1.32	0.91	1.12		2140	385	0.50
17-7	20	4040	2790	3500	2910	3310	290	406	348	1.04	0.73	0.88		1950	480	0.36
19-9	25	3780	2560	3750	2210	3080	284	362	323	0.97	0.72	0.84		2080	672	0.27
20-10	50	3900	2780	3430	2640	3190	331	525	428	0.88	0.53	0.70		1810	963	0.16
Average of all rates		3560	2720	3120	2490	2970	......	......	......	......	......	......		1620	......	......

Date of seeding in the spring.—A test of dates and methods of seeding alfalfa in wheat has been in progress at Columbus since 1928. Tests have also been conducted at Wooster (44, p. 20) and on the outlying farms. The data in these tests are largely observational. Alfalfa appears not to be as sure as red clover to make a stand if broadcasted on "honey-combed" ground in late February or early March because the seedlings are sometimes killed by later hard freezes. Alfalfa contains fewer hard seeds than red clover and so may germinate more quickly and completely after seeding than red clover. In the date-of-seeding trials at Columbus, the best average date has been April 1, with indications that the period from March 20 to April 1 is preferable to April 1 to April 10. April 15 seedings have usually been markedly inferior to April 1 seedings. It seems clear that the earlier alfalfa is sown the better, provided the seedlings are not killed by freezes. This rule applies to all seedings, whether with companion crops or alone.

When seeding in wheat, dividing the seed (sowing half broadcast about March 10-15, or about the end of the period for "honey-combed" ground seedings, and the remainder either drilled or broadcasted about April 1, or 2 to 3 weeks later) has given excellent results in the Columbus experiments and is the standard practice in making field seedings in wheat on the outlying farms.

SEEDING IN A COMPANION CROP

Should alfalfa be sown in a companion or "nurse" crop?—There are three reasons for using a companion crop: (a) To obtain some return from the land in the seeding year; (b) to prevent weed competition; and (c) to prevent erosion. The term "nurse crop" is somewhat undesirable, because it suggests that the companion crop is directly beneficial to the alfalfa. It is always injurious; but, in many instances, if a companion crop is not sown, a companion crop of weeds will spring up which will do the alfalfa more injury and have less value than the sown crop.

On soils which furnish a comparatively small amount of available moisture to the plants, such as sands and heavy clays, the use of a companion crop may cause the death of the alfalfa from drouth and a companion crop is often inadvisable on such soils. On loams and silt loams, which hold a considerable amount of available moisture, seeding in a companion crop is more likely to be successful.

What is the best small grain companion crop?—The small grains—wheat, oats, rye, and barley—are by far the most common and important companion crops. Of these, barley is usually the most favorable companion crop, because it makes a comparatively short growth and is off the ground early. However, barley is more likely to lodge than oats, and lodging of the small grain is the most serious enemy of legume seedlings. Experiments at Columbus (67, pp. 72-74) showed no great difference between early oats and barley as companion crops but a great difference between late oats and either of them, apparently because late oats not only made a greater shade but were on the ground longer. Spring wheat is so unimportant in Ohio that it is used as a companion crop only occasionally, but it was not materially different from barley in these tests. When a stand of alfalfa is wanted for experimental purposes at Columbus and on the outlying farms in western Ohio, the standard practice has been to seed with 4 pecks of early oats, which have been left for grain. In many seedings in every year from 1922 to the present at Columbus, only one failure to obtain a stand has resulted from this method. This occurred in 1931 when an attempt was made to follow alfalfa with alfalfa, and the oats lodged badly. Even in the dry springs of 1925 and 1930, good stands of alfalfa were obtained. Experiences on the outlying farms have been entirely similar.

In general, winter wheat has not been as favorable a companion crop as oats in the central western part of the State, where it is usually compared with early oats. A study of dates and methods of seeding alfalfa in wheat has been in progress at Columbus since 1928, and there has been no year since in which even the best seeding in wheat equalled the regular seedings in oats (Table 43).

TABLE 43.—Oats Versus Wheat as Companion Crop for Alfalfa, Columbus

Year harvested	Range sown in		Yield of alfalfa per acre, first crop, sown in	
	Oats	Wheat	Oats	Wheat
			Lb.	*Lb.*
1931	1600	1100	4400	3900*
1931	1800	1100	4500	4150†
1932	700	1100	3370	Failure
1933	1500	1200	2810	2260‡
1933	500	1200	3500	2260‡
1933	1800	1800	1580	1080

*Average three best dates of seeding.
†Best date of seeding.
‡Average all dates of seeding closely agreeing.

The reason for this general superiority of early oats to wheat is illustrated in Figure 13. The alfalfa seedlings experience much greater competition with the established and rapidly growing wheat crop than with the oats crop, which starts at the same time as the alfalfa. Even so, root studies show that the oats roots may outgrow the alfalfa roots and leave the alfalfa suffering from drouth (Page 143).

Fig. 13.—Oats versus wheat as a companion crop for alfalfa

Columbus, May 28, 1931—Left, Fulghum oats and alfalfa sown April 9; right, alfalfa sown in winter wheat on April 1. The wheat, 30 inches high, was cut off short in order to photograph the alfalfa plants. Same scale in both.

In the northern, and particularly the northeastern, part of the State, where medium to late oats are generally grown and seeding rates are generally higher, there is a tendency among farmers to regard wheat as preferable to oats as a companion crop. Growing conditions in this section are favorable for oats. They make a dense shade and remain on the ground 10 days to 2 weeks longer than wheat, at a time which is critical for the young alfalfa. However, the Wooster rotation experiments indicate that the two crops are essentially equal there. The indicated 13-year average difference in the yield of alfalfa the year after seeding is 166 pounds per acre in favor of seeding with oats, which is not significant (Table 30). Even in central Ohio, the data from Miami County, given in Table 30, indicate that good stands may often be obtained in wheat. (See also Lloyd, 34.)

Seeding in spring-sown winter wheat.—A companion crop which promises to be important is winter wheat sown in the spring. In the spring of 1927 at Wooster two plots of winter wheat were sown with a number of spring wheats. They made, as expected, only a vegetative growth, but it was observed that no weeds had started in these plots, while the adjacent aisles were filled with the usual summer weeds. This suggested that spring-sown winter wheat might make a good companion crop for alfalfa and sweet clover. It was tried the next year, and a good stand resulted. Several trials have since been conducted at Wooster, Columbus, and on the outlying farms and have almost always given satisfactory results. An outstanding example was the seeding of alfalfa for the fertility experiment at Wooster in 1930 (Page 24), where, despite the drouth, a perfect stand was obtained. Where this method is compared with seeding alone, it is clear that the wheat does reduce the number of weeds in the stand. However, on soils extremely rich in nitrogen the wheat may make such a growth as to kill the alfalfa.

The wheat is drilled exactly as if oats were being sown, and the alfalfa is sown with a grass seed attachment or broadcasted behind the drill. Experiments at Wooster indicate that one bushel of winter wheat is the most desirable rate of seeding. At least one clipping of the alfalfa is usually necessary for weed control. In a favorable season this may yield some hay. Otherwise, there will be no return from the land the first season, which is a decided loss whenever the companion crop is worth more than the cost of seeding and harvesting.

While this method was independently developed at Wooster, as described, a review of the literature reveals that the idea is by no means new (16, p. 25; 77, p. 59).

Seeding in soybeans.—With the increase in the soybean acreage, it has become important to study the possibility of making seedings in this crop. Systematic tests were started at Wooster in 1927 (50, p. 38) and were sufficiently successful so that tests were conducted at Columbus in 1929, 1931, and 1932 and on the outlying farms in 1929, 1930, and 1931. All but the latter were first started with sweet clover and later enlarged to include alfalfa and red clover.

The results at Wooster have been quite favorable. In 1928, two plots of alfalfa seeded in soybeans on May 28 produced perfect stands of alfalfa, as well as an average of 4580 pounds of soybean hay. In 1929 the method resulted in failure. In 1930 and 1931 fair stands were obtained, despite the drouth in the former year. In these tests, success depended upon early seeding, upon a rate of seeding the soybeans not exceeding 6 pecks per acre for the Manchu variety, and upon harvesting the soybeans for hay not later than the last week in August.

The tests at Columbus and on the outlying farms can only be described as failures. Nothing approaching a stand was secured on any of the six farms where the method was tried, in any of the 3 years, except a partial stand on the Washington County Experiment Farm in 1931. At Columbus, partial stands were obtained on poor soil, where the beans had made a poor stand and growth, but not elsewhere. In none of the tests anywhere has a stand been obtained when the beans were left for seed. As a means of obtaining a stand of alfalfa, sowing in soybeans is too risky to be recommended.

Seeding in corn.—Rotation 30 in the rotation test at Wooster is corn, one year, follwed by 3 years of alfalfa. The seeding has been a failure and required reseeding the following spring in 5 years out of 13. The 13-year average yields per acre were as follows:

Corn, bu. (12 years only)	77.6
Alfalfa, first year, lb.	1618
Alfalfa, second year, lb.	4564
Alfalfa, third year, lb.	4917

The yield of alfalfa in the first year for the 8 years it did not require reseeding averaged 2570 pounds. The second- and third-year yields are also decidedly less than those of alfalfa sown in oats.

Fig. 14.—An unusual stand of alfalfa in corn

Sown immediately after last cultivation, not covered, Columbus, July 21, 1933. Photo November 1. Best stand obtained in 6 years' experiments.

At Columbus, a large number of crops, including alfalfa, have been sown in corn at the last cultivation for the last 6 years. In 3 years (1931-1933) stands have been obtained which would have made fairly satisfactory yields the second year after seeding (Fig. 14). No stand which would have made satisfactory yields in the year after seeding has been obtained. However, alfalfa was second only to hairy vetch in its ability to establish itself in corn in normally to extremely dry years. In the abnormally wet summer and fall of 1931, alfalfa did not make as good growth as the true clovers.

The success of sowing in corn depends largely on the weather. If there is sufficient moisture just after seeding to germinate the alfalfa and sufficient rainfall to keep it alive until the corn is cut, it may make a stand. If not, it will fail. In western Ohio, conditions favorable to such seedings probably occur in fewer than half of the seasons. Even if successful, the tendency to winterkilling by heaving is great, and the corn stubs make the harvesting of the first year's hay crop decidedly difficult. There is little to encourage the practice, except in an emergency, and then only on the best alfalfa soils. Corn should be "laid by" early in July if it is planned to sow alfalfa in it. The seed may be sown by hand or from any broadcast seed sower, either just before or just after the last cultivation. In the comparisons at Columbus seeding on top of the loose ground just after cultivation has been preferable to cultivating the seed in.

SEEDING WITHOUT A COMPANION CROP

Seeding alone in the spring.—Most early observations were unfavorable to this practice, because of the effects of weed competition. However, many of these seedings were made after very thorough spring preparation of the land, which brought the seeding date in May, or even June. This was when rapid-growing annual weeds, such as red-root pigweed, velvet leaf, foxtail, and crab-grass, were ready to make their most vigorous growth. Experiments at Columbus and observations elsewhere have indicated that, if sown alone on a fall-plowed or other weed-free, well-settled seedbed in late March or very early April, alfalfa will make a good start before the summer weeds appear, resulting in much better stands and root systems than are usually obtained in summer seeding (Fig. 15). With the present low price of small grains, this

Fig. 15.—Sowing alone early gives good stand

Alfalfa sown alone on fall-plowed land April 4, 1933. Photo September 20, 1933, after two cuttings of over a half ton each had been removed.

seems worth trying, especially on drouthy soils or soils which are so rich that small grains lodge. Such seedings may be safely clipped once or perhaps twice to control weeds, and some hay may result in a favorable season.

Mr. W. L. Robison, of the Department of Animal Industry, has successfully sown Peruvian alfalfa alone early in the spring at Wooster, to be used as hog pasture the same season (50, p. 175.)

Seeding alone in the summer.—Early experiences at Wooster were favorable to summer seeding, and it was the method almost exclusively recommended until recently when better methods of spring seeding have tended to supplant summer seeding. However, it seems that northeastern Ohio is a more favorable section for summer seeding than most of western Ohio. At Columbus from 1921 to 1933, inclusive, summer seedings were satisfactory in only 3 years out of 10.

In practice, the success of summer seeding depends almost entirely upon water relations. If these are favorable for the germination of seed and the establishment of seedlings, summer seeding will be successful; otherwise not. The advantages of summer seeding are:

1. There is much less weed competition, since the ground can be worked until most of the weed seeds which will sprout at that time have sprouted and been killed in the soil preparation. Part of this advantage is lost if the land is plowed just prior to seeding.

2. There is more time to work lime and fertilizers into the soil and prepare a suitable seedbed.

3. With favorable weather conditions, emergency seedings can be made after spring seedings have failed.

The disadvantages of summer seeding are:

1. The chance of unfavorable weather causing a failure of the seeding is much greater in the summer than in the spring. Favorable rains and days with low evaporation are needed after seeding to obtain satisfactory germination. Alfalfa seeds cannot safely be covered deeply, and the surface soil dries out below the level of the seed with extreme rapidity during the frequent, hot, drying days of summer. Furthermore, a rain sufficient to permit germination may be followed by a dry period which kills the seedlings.

2. Even if a good stand is obtained, the root systems are necessarily smaller than those of successful spring seedings, and the top growth for cover is also small; hence, the plants are more likely to winterkill by heaving.

3. In order to produce a satisfactory seedbed it is often necessary in practice to lose the use of the ground for one year.

4. It costs more to prepare a suitable seedbed in the summer than in the spring.

Date of summer seeding.—Since summer seedings are always under the handicap that less time is available for root growth and root storage, the earlier the alfalfa can be sown after July 1 the better, provided moisture conditions are favorable. A possible exception is weedy land freshly plowed early in July, on which it may be desirable to kill one crop of summer weeds before seeding. August 15, in the northern third of the State, and September 1, at Columbus, are about the latest practical dates for successful summer seeding.

Principles and practice of summer seeding.—To be successful, summer seeding must be on a well-prepared seedbed; that is, one which is free of weeds, level, reasonably fine on top, firm, and well connected with the subsoil below, and contains abundant stored moisture. To obtain this, the ground should be plowed several weeks in advance of seeding. When the preparation of the land is delayed because of harvesting a previous crop, disking may be preferable to plowing. Disking does not disturb the capillary relations of the soil as much as plowing, but, on the other hand, it does not kill weeds as effectively. Where established weeds are a factor, the land should usually be plowed.

The seeding is more likely to be successful if no crop precedes it, because any crop tends to use up the stored moisture in the soil and, hence, to reduce the chance that the seeding will have enough. The more vigorous the crop and the later it occupies the ground, the more serious is the probable danger; however, even seedings following wheat or oats left for grain may be entirely successful if sufficient rain follows the grain harvest. This requires more than average rainfall.

Usually the seeding should not be made until after a heavy rain—one which at least wets the entire plowed layer so that sufficient moisture to start and maintain the seedlings may be available. Some very successful seedings have been made in dry soil when good rains followed the seeding. If one could predict the amount of rain which would follow seeding, this would be the most desirable method, since after a rain the seed is able to germinate during those hours when otherwise it would be necessary to wait for the soil to get in condition to work before seeding. If only a light shower follows seeding in dry soil, the seeds may germinate and die, and, again, a heavy dashing rain may make a crust which the seedlings cannot penetrate, so that such seedings are somewhat of a gamble.

The special grass seed drill and the cultipacker (Page 74) are of especial value for summer seeding.

METHODS OF SEEDING ALFALFA

The best method of seeding depends on the soil type, the previous preparation of the soil, and the implements available. Alfalfa seed should be covered but not too deep. No definite depth-of-seeding tests have been conducted here, but from general observation it is unsafe to sow seed deeper than one inch on any but sandy soils, and one-half inch is a better average depth. When seeding with spring grain in loose soil, the seed should never be allowed to go down the grain tubes with the grain. Even when seeded in front of the grain discs, as the grass seed attachments on many drills are arranged, much seed will be covered too deep. Better stands will be obtained if the seed falls behind the grain discs so that the seed is covered only by the covering chains and the settling of the soil. Broadcasting the alfalfa immediately after drilling the grain is also satisfactory.

On the other hand, when seeding in winter wheat on light colored soils which settle firmly during the winter, not only is drilling desirable but also the seed should go through the grain tubes. It may even be necessary to harrow or cultipack the field in order to put some soil over the seeds in the shallow furrows cut by the drill (Fig. 16). The rotary hoe has been suggested for this covering, but under these conditions the rotary hoe does not supply sufficient loose soil to cover the seed. The rotary hoe has not been very effective in experiments in seeding sweet clover at Wooster or on the outlying farms in western Ohio. Dark colored soils, rich in organic matter, are usually so loosened by winter freezing that either no covering or merely a light harrowing in of seed broadcasted in winter wheat is sufficient.

Fig. 16.—More than a drill is needed on settled soils

Columbus, April 17, 1928. Plot of Miami (light colored "clay") soil, showing effect of grain drill sowing alfalfa on April 16, in badly winter-killed wheat. On this plot cultipacking after drilling nearly doubled the stand.

Value of the special 4-inch grass seed drill.—Wherever observed, the special grass seed drill has given good results, under all conditions where a drill could be used. No definite comparisons of this implement with broadcasting are available since the early test at Wooster (75), but, undoubtedly, a wider use of this implement would reduce appreciably the number of failures in seeding. Materially less seed can be sown when the special grass seed drill is used. Even this drill may place the seed too deep if the seedbed is not very firm, and one should always adjust the drill—if necessary by cutting a new notch to hold the discs at a shallower depth—so that it places the seed at the proper depth.

Value of the cultipacker in seeding alfalfa.—The use of the cultipacker is sometimes recommended in making seedings of alfalfa in spring grain to pack the loose soil around the seed to facilitate germination. Through the courtesy of the Dunham Company, a cultipacker was furnished for tests of this question at Holgate. In the seasons of 1930 and 1931, both drier than normal in the spring, cultipacking after seeding alfalfa in oats had no effect on the stand of alfalfa. No yields were taken in 1931, but in 1932 the average yield of alfalfa at the first cutting, cultipacked after seeding, was 2540 pounds; not cultipacked, 2550 pounds. This was an average of 20 plots of each. The results with red, mammoth, and alsike clovers for 2 years were entirely similar.

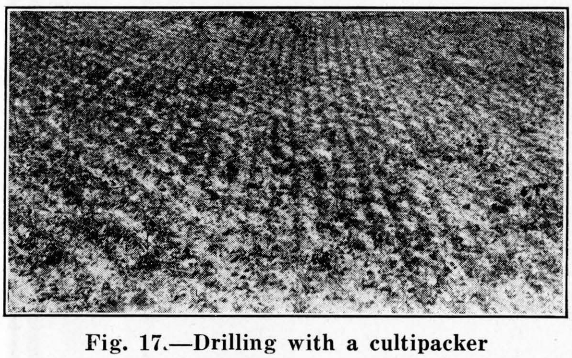


Fig. 17.—Drilling with a cultipacker

The lines running straight back in the picture are young alfalfa plants which have come up in the cultipacker marks; the diagonal marks running to the upper left of the picture are the marks made by the harrow in covering the seed. Columbus, August 26, 1933; sown July 28, 1933.

The cultipacker is especially desirable for summer seedings. At Columbus the cultipacker has been effectively used in summer seedings of alfalfa (also for clovers and grasses, including fairways on golf courses). As soon as the ground is dry enough to work after a rain which penetrates the entire plowed layer, it is harrowed and cultipacked (at one operation, if a tractor is used), and the seed sown broadcast and covered either by cultipacking or by harrowing lightly crosswise of the cultipacking. The seed falls in the furrows of firm soil left by the cultipacker, is covered to a uniform shallow depth, and germinates in rows as though drilled (Fig. 17). This is one of the most satisfactory methods that has been found for making summer seedings, if not the most satisfactory. This method may also be satisfactorily used for spring seedings in many instances.

At Columbus, the effect of cultipacking after drilling alfalfa and sweet clover in fall-sown wheat was studied for 3 years, 1928-1930. In 1928 and 1929, when timely rains came after seeding, cultipacking had no effect; for the last date of seeding in 1930, when there was little rain for some time after seeding, cultipacking improved the stand of alfalfa nearly 50 per cent (Fig. 16). The immediate effect of the cultipacker on the wheat seemed a little severe, but no difference could be noted at harvest.

TREATMENTS AFTER SEEDING

CUTTING OR CLIPPING ALFALFA THE YEAR IT IS SOWN

After the companion crop has been removed in June or July from alfalfa sown in the spring with small grain, it may be desirable to cut or clip the young stand because: (a) weeds often come up so thickly as to threaten the stand; (b) it is desirable to dispose of the stubble, amounting to about a half ton to the acre, so that it will not reduce the quality of next year's hay; and (c), in a favorable season on good soil, there may be a hay crop worth removing.

The effect of such clipping or cutting the first year has long been debated. An early book on alfalfa (13) says: "Alfalfa is invigorated by cutting at frequent intervals,...... . It should be mowed at such frequent intervals that there will not be enough of the clippings to smother the plants if left for a mulch." In recent years, when studies of root reserves (21, 32, 35) have shown the folly of this recommendation, there has been a tendency to regard any clipping as unsafe and to recommend no clipping unless necessary to combat weeds and then clipping with a high stubble.

Experiments at Columbus.—Preliminary studies of clipping first-year alfalfa were made in 1925 and 1926. In 1927 and since, plots have been cut every half month from August 1 to November 1, and a plot has been left uncut except by the binder. Since 1929 plots have also been included on which the companion crop was cut for hay on July 1 and July 15. A summary of some of the data from this test is given in Table 44. Yields have been obtained from square-yard samples. In the first 4 years of the test, systematic root harvests were made on the dates of clipping, giving a study of the development of young alfalfa (Table 70), and also in November, in order to have a measure of the effect of clipping on root reserves. Since then, the test has largely been limited to making the clippings, taking observations, and obtaining yields of hay the following June.

Effect of clipping on yield the next year.—In 1927-1928 it was quite obvious (Fig. 18) that the plot cut November 1 had been injured by the clipping, although not to the same degree that red clover was injured under the same conditions. In 1928-1929 volunteer sweet clover prevented the obtaining of yields from the alfalfa test, but there was nothing in the appearance of the alfalfa to suggest that it had been injured by clipping on any of the dates. Incidentally, this series furnished a suggestion on handling volunteer sweet clover in alfalfa, since the plots clipped before October 1 were not seriously injured by the sweet clover. The sweet clover was so weakened by the clipping that it did not compete seriously with the alfalfa (Page 60). In 1929-1930 red clover showed serious injury from all clippings later than September 1.

TABLE 44.—Yield and Composition of Alfalfa After Clipping on Various Dates in the Year Sown

Alfalfa sown in early oats, Columbus

Year of test	Number of samples averaged	Date of clipping									
		July 1-3	July 15-17	Aug. 1	Aug. 15	Sept. 1	Sept. 15	Oct. 1	Oct. 15	Nov. 1	Not cut (Nov. 10)†
Pounds of tops per acre, early November of year sown											
1927–1928	2	...	...	1520	1050	1210	1090	1160	...	...	1280
1928–1929	2	...	1420	1620	1190	1090	750	720	...	...	1280
1929–1930	2	830	840	890	1010	890	640	620	...	...	1540
1930–1931	2	790	940	1190	1120	890	1040	740	...	...	970
Average	...	810	1070	1300	1090	1020	880	810	...	...	1270
Pounds of roots per acre, early November of year sown											
1927–1928	2	...	...	1330	1060	1100	1100	1230	970	920*	1070
1928–1929	2	...	1570	1240	1540	1400	1390	1270	760*	890*	1090
1929–1930	2	1110	1220	1370	1360	1370	1240	1350	1360*	1640*	1860
1930–1931	2	600	740	800	920	730	880	780	880	910	880
Average	...	880	1180	1180	1220	1150	1150	1160	990	1090	1220
Percentage of nitrogen in tops, early November of year sown											
1927–1928	1	...	...	3.32	3.11	3.19	3.51	3.44	...	...	2.92
1928–1929	1	...	3.32	2.84	3.27	3.40	3.73	3.96	...	...	2.72
1929–1930	1	2.96	2.95	2.80	3.13	3.32	3.39	3.60	...	...	2.55
1930–1931	...			Not anal	yzed becau	se of drouth					2.82
Average	...	2.96	3.08	2.99	3.17	3.30	3.54	3.67	...	...	2.75
Percentage of nitrogen in roots, early November of year sown											
1927–1928	1	...	...	2.67	2.51	2.28	2.37	2.58	2.53	2.59*	2.60
1928–1929	1	...	3.02	2.94	2.90	2.66	2.85	2.89	2.92*	2.84*	3.01
1929–1930	1	3.03	2.92	2.84	2.88	2.76	2.66	2.87	2.77*	2.77*	3.01
1930–1931	1	3.08	2.86	2.91	2.94	2.88	2.84	3.20	2.98	2.91	3.12
Average	...	3.06	2.93	2.84	2.81	2.64	2.68	2.88	2.80	2.78	2.94

*On date of clipping. †Approximate date of sampling.

TABLE 44.—Yield and Composition of Alfalfa After Clipping on Various Dates in the Year Sown—Continued

Alfalfa sown in early oats, Columbus

Year of test	Number of samples averaged	Date of clipping									
		July 1-3	July 15-17	Aug. 1	Aug. 15	Sept. 1	Sept. 15	Oct. 1	Oct. 15	Nov. 1	Not cut
Pounds of nitrogen per acre in roots, early November of year sown											
4-year average		26.0	34.4	33.6	34.4	30.3	31.0	33.0	27.6	30.2	36.0
Pounds of total nitrogen per acre, early November of year sown											
4-year average		48.9	66.6	71.8	67.6	62.5	59.9	60.6	...	...	70.4
Percentage of dry matter in the green roots, early November											
1927–1928	2	...	...	39.9	41.2	40.2	42.0	35.9	35.2	41.7	37.8
1928–1929	2	...	35.3	36.6	36.3	35.3	33.6	35.6	...	...	36.5
1929–1930	2	35.6	36.3	36.2	35.1	35.4	32.2	33.9	...	...	36.9
1930–1931	2	28.6	28.5	30.7	33.2	29.6	32.1	29.5	30.0	30.8	29.4
Average	...	32.1	33.4	35.8	36.4	35.1	35.0	33.7	32.6	36.2	35.2
Percentage of dry matter in the green roots, early spring											
1928–1929	2	...	21.3	19.5	19.3	18.3	25.0	23.8	20.8	22.4	20.2
1930–1931	2	19.9	19.8	19.4	18.4	20.0	19.5	19.6	19.0	20.5	18.2
Average	...	19.9	20.6	19.4	18.8	19.2	22.2	21.7	20.0	21.4	19.2
Pounds of hay per acre, June of year after seeding											
1927–1928	2	...	...	3570	2180	3270	2780	2560	2880	2100	3060
1928–1929	...			Volunteer sweet clover prevented obtaining yields							
1929–1930	6	2390	2730	2880	2650	2720	2810	2590	2900	2690	2870
1930–1931	6	4000	4060	3870	4290	4110	3770	3950	3990	4420	4310
1931–1932	4	...	...	3670	3260	3180	3200	3370	3180	3670	3210
1932–1933	4	3790	Volunteer sweet clover prevented obtaining yields						3080	3120	3880
Average 1927–1933	...	3340	3400	3500	3100	3320	3140	3120	3210	3200	3450

Alfalfa immediately adjacent showed no injury whatever on any date of clipping, and the yields of hay did not indicate any difference. In 1930-1931 the growth was so small that the mower hardly touched it on any date of clipping, and no effect from clipping was expected or noted. In 1932-1933 the yields suggest a slight injury from very late clipping, but it was not sufficient to be evident to the eye. In 1932 two plots were cut both in July and on September 1 without injury to the stand.

Fig. 18.—Clipping alfalfa late the year sown may kill it

April 20, 1928—Left, not clipped in 1927; center, clipped August 1, 1927; right, clipped November 1, 1927.

It seems that alfalfa is not likely to be either injured or benefited by clipping in the summer up until the usual time of making the last cutting of hay. At times it may be injured by late clipping, but it is clearly not as susceptible to injury by late clipping as is red clover.

Effect on root reserves and dry matter production.—The 4 years' data on weights of roots do not suggest that the root reserves of young alfalfa are seriously affected by clipping. There is a suggestion that the roots from the clipped plots tend to have a lower nitrogen content than roots from those not clipped, but the difference is not significant. The nitrogen in the tops in November increases, as would be expected, as clipping is done later in the season. If the total top growth for the season is calculated, by adding the material removed on the dates of clipping (Table 70) to that present on November 1, it is clear that the effect of clipping (especially from August 1 to September 15, inclusive) has been to increase the total production of dry matter in the seeding year by about the amount of the hay removed in clipping. The appearance of the plots would lead one to expect this, since the old growth loses many of its leaves from leafhopper yellowing and age, so that it can hardly be very efficient in photosynthesis; whereas the new growth is healthy and vigorous. At the same time, it should be noted that there has never been any suggestion in these specific experiments or in many other observations that failure to clip has injured the stand of alfalfa in any way (except as weeds were a factor). New growth finally appears at the base of the plants as conditions become favorable for growth, even if some of the old growth remains.

Height of clipping.—It should be noted that all of these clippings have been made with the mowing machine set as low as possible and the clippings removed whenever there was enough material to rake. Under Ohio conditions there is no apparent point to the recommendation frequently made to clip young alfalfa high if it is clipped at all. The recovery of the alfalfa is always from the crown, regardless of the height of cutting (Fig. 19) (Page 110); hence, it is desirable to clip alfalfa as low as possible, since low clipping kills many weeds which would not be killed by high clipping and has no injurious effect on the alfalfa.

Recommendations.—Young alfalfa sown in small grains in the spring may be clipped any time before September 1, if it seems likely that weeds are going to injure it, if it is desirable to get the small grain stubble out of the way in order to have clean hay the following year, or if there is a profitable crop of hay to remove. Otherwise, it does not seem to be necessary, but these conditions are so generally prevalent that they make clipping the spring seeding between August 15 and September 1 a desirable practice. The clippings should be taken off if they are sufficient to injure the stand. Removing them is not important otherwise, as very little is left of them by the following June even if they are not removed.

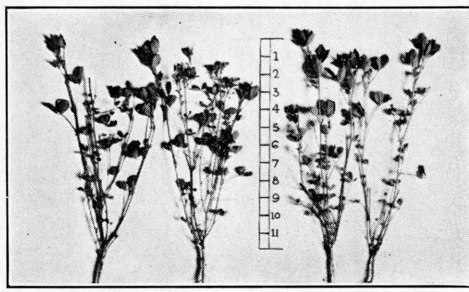


Fig. 19.—Effect of clipping alfalfa at different heights

Columbus, August 4, 1928. Alfalfa sown in oats April 4, 1928—Left, cut with binder July 17 (note dead stubble, 9 inches high, among the new shoots); right, cut with mowing machine same day.

Observations at Wooster and the outlying farms, including a duplication of the Columbus test at Holgate for 2 years, support these general recommendations. No tests of clipping summer seedings have been conducted since the early one at Wooster (74), but the practice is inadvisable unless it is essential in order to control weeds.

Mulching alfalfa.—Since winterkilling by heaving is a major hazard to alfalfa in Ohio, the use of straw as a protective mulch has often been suggested. At the Timothy Breeding Station, North Ridgeville, Mr. Morgan W. Evans describes their practices as follows:

"When alfalfa is sown as late as August, or even in late June or July, the plants do not grow to a very large size in that season. On a clay loam soil, like that at the Timothy Breeding Station, alfalfa plants, especially when young, are subject to injury due to heaving. For this reason, it has been the practice to cover the plats with straw, or old hay, during the first winter. Early December has been found to be a suitable time for applying the mulch. Enough straw is used to cover practically all plants. When the straw has partially settled, there is a covering usually two or three inches thick. This is left on the plats, usually, until early in April; the plants are observed frequently in the spring, and when the young shoots have begun to grow up through the straw the mulch is removed. It has been found that injury due to heaving can be quite effectively prevented in this way, though if the plants are of a non-hardy variety they may be winterkilled, even though little or no heaving occurs."

Mulching older alfalfa is less frequently suggested, except for the very common recommendation that a good growth be left for winter protection when making the last cutting in the fall. System 5 in the time-of-cutting series (Page 100) was planned to study the effect of mulches on late-cut alfalfa. In addition, a small experiment with mulching was carried out at Holgate in 1931-1932. This gave no increase and suggested a slight decrease from mulching with straw.

It is very doubtful if the practice is generally practical on young or old alfalfa. The mulch must be very carefully spread, preferably by machine. One to 2 tons per acre are probably as much as it is desirable to use. Care must be used to take it off in good time in the spring, or the alfalfa will be injured both by the mulch and by its removal. The expense, on a field scale, of spreading and removing the mulch makes mulching generally impractical, except for spots which are especially prone to winterkilling.

CULTIVATION OF ESTABLISHED ALFALFA

The cultivation of established alfalfa with a disc or spring-tooth harrow has long been recommended. In the experimental studies of the practice, Etheridge and Helm (18) have found it very beneficial, while Kiesselbach and Anderson (29), Burlison *et al.* (10), Woodward (78), and several others have found it of no effect or injurious.

Established stands of alfalfa were cultivated at Wooster during the period 1907-1912, using both the disc harrow and a special spring-toothed alfalfa cultivator. A note in the Monthly Bulletin (42) says, "Yields of alfalfa hay were increased a third of a ton to the acre by harrowing in tests covering 2 years at the Ohio Agricultural Experiment Station. A disc may be used but a spring-tooth harrow is preferred. Little difference in effectiveness has been noted which cutting is followed, provided weather conditions are favorable." Observations by Director Williams, who was Station Agronomist at the time, led to the conclusion that blue grass could be eradicated by thorough cultivation during dry weather but that cultivation followed by rain was not effective and that the expense of cultivation was generally more than the value of the increase in the alfalfa crop. The practice has not been followed as a practical method in alfalfa culture on the Experiment Station farm.

Four plots in the top-dressing test at Columbus (Table 14) were cultivated with a spring-tooth harrow, two after the first cutting and two after the first and second cuttings. The yields do not suggest any significant effect nor was any visible on the plots after the crop had made a little growth. In the spring of 1932, when the test was discontinued, the four cultivated plots had 64 per cent dead plants, the untreated checks 46 per cent, and the fertilized plots 40 per cent. Sampling difficulties in making these counts were great, and even these differences may not be significant, but they are suggestive in view of the fact that this field showed a serious infestation of bacterial wilt, which may be spread by cultivation (27, 65). The first cutting yields were very low and not significantly different on any of the plots.

A cultivation experiment was conducted at Holgate in 1931 on alfalfa seeded in 1929. The treatments and results are given in Table 45. It was not possible to continue the test the next year.

There is nothing in these or in other scattered observations to recommend cultivation of alfalfa as a profitable farm practice in Ohio.

TABLE 45.—Alfalfa Cultivation Experiment—1931—Range 7A, Holgate

Plot	Treatment	Yield per acre			
		June 19	Aug. 3	Sept. 10	Total
		Lb.	*Lb.*	*Lb.*	*Lb.*
1	Spring-tooth after 1st cutting	4450	2010	1063	7478
2	Spring-tooth after 1st and 2nd cuttings	4090	2047	1313	7450
3	Disc after 1st cutting	3903	1843	1307	7053
4	Disc after 1st and 2nd cuttings	4220	1955	1180	7355
5	Untreated	4177	2387	1437	8001

CAN A THIN STAND OF ALFALFA BE THICKENED BY SOWING MORE SEED?

Additional seed has been sown on old, thin stands of alfalfa at Wooster, Columbus, and on the outlying farms. The attempt has uniformly resulted in failure, although in some instances conditions were almost ideal for success if it were possible. The established plants compete so strongly with the seedlings that they have no chance to establish themselves. An old stand should always be plowed before reseeding. It is not usually desirable to follow alfalfa directly with alfalfa, but it has been done successfully. Because of the rank growth of the companion crop after an alfalfa sod, it is usually better to sow the alfalfa alone.

At Wooster a thin stand sown the preceding year has often been successfully "patched up" by sowing more seed in the early spring with a disc drill. However, a spring seeding which is too thin is best thickened by drilling more seed under favorable soil moisture conditions the same summer.

A promising method of prolonging the usefulness of an old stand of alfalfa is to sow timothy in it in September after the third cutting. This was successful at the Belmont County Experiment Farm in 1932, and some trials in 1933 appear well at this time. At least a fairly good seedbed should be prepared, preferably with the spring-tooth harrow.

THE TIME OF CUTTING ALFALFA

No other management problem with alfalfa in humid states is comparable in importance to the time and number of cuttings. The yield and quality of hay obtained and the longevity of the stand depend primarily on the cutting system adopted. A considerable number of investigators have worked on different phases of this problem, but only a few in the central humid corn belt area. Salmon *et al.* (56) and Kiesselbach and Anderson (29) have conducted extensive experiments applicable to conditions west of the Missouri River. These workers have thoroughly reviewed the literature of the subject, and it will not be gone into here except in connection with definite problems in the discussion. Moore and Graber (37), Nelson (38), Graber *et al.* (21), Burlison *et al.* (10, 26), Damon (17), and Wiancko *et al.* (64) have conducted tests on the number of cuttings and time of cutting of alfalfa east of the Mississippi River.

EXPERIMENTAL WORK

Experiment I. Waterman Farm.—Experiments on the time of cutting alfalfa at the Ohio State University were begun in 1925. An area was selected in a large field on the Waterman farm in alfalfa sown in oats in 1924. The area was somewhat less uniform than would be most desirable for an experimental tract, but the stand was quite uniform. The area was divided into four sections, A, B, C, and D, to be cut, respectively, five times, four times, three times, and twice during the season. The last cutting for all four sections was made on the same date. Most of the time-of-cutting experiments conducted prior to 1925 had attempted to cut the alfalfa at certain stages of development, such as bud, one-tenth bloom, and full bloom. This resulted in making the last cutting in the fall on different dates, and from field observations it seemed probable that in some instances the date of making the last cutting had influenced the results more than had the number of cuttings. Cuttings were made at arbitrarily determined dates, except for the first cuttings. The date was set for the last cutting and the intervening time so divided as to secure the required number of cuttings.

TABLE 46.—Five, Four, Three, and Two Cuttings in the First Year of Cutting

Experiments I and II, Columbus

	Five cuttings	Four cuttings	Three cuttings	Two cuttings
Yield of hay per acre, average 1925-1926, pounds	8890	9060	7580	5000
Leaves in hay, average 1925-1926, per cent	53.4	50.7	44.3	36.4
Protein in hay, average 1925-1926, per cent	20.1	19.1	16.1	14.5
Yield of protein per acre, average 1925-1926, pounds	1783	1726	1219	730
Yield of hay per acre, June 7, 1926, following these treatments in 1925	3590	4470	4650	4300

The yields in Experiments I and II were obtained by harvesting selected representative square-yard areas. They were cut by hand about as a mowing machine would cut them. Then the roots were dug from these areas to a depth of approximately 1 foot and washed free of soil. The stubble was cut from the roots, and the roots counted to obtain the exact stand in the area. When feasible, the green weight of the roots was obtained. The height of the plants on each area was also noted. Any weeds present were discarded, so that the hay yields reported are of air-dry, weed-free alfalfa. The root yields are also reported on the air-dry basis. Four square-yard samples were harvested from each plot on each date in 1925, and two from each plot on each date in 1926, 1927, and 1928. Because of the shorter stubble and more complete harvesting, the yields of hay obtained by this method are usually 10 to 15 per cent higher than those from field plots but are comparable with each other. The percentage difference tends to be greater in the later (that is, smaller) cuttings.

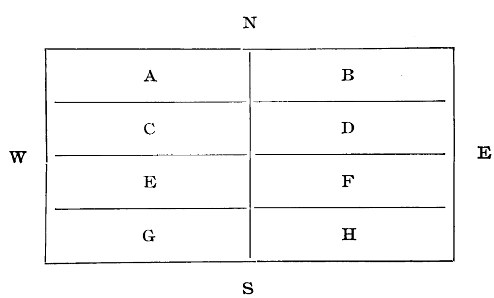
Where the indicated hay yield is below 1000 pounds per acre, the hay was so short that in field operations most of it would have been lost in raking. This should be kept in mind in studying all yield results obtained from square-yard samples.

The leaf percentage and protein determinations are of the material as it was harvested green, with no loss in curing, and, hence, are higher than would be found in field-cured hay from the same material.

The season of 1925 was very early, and the first cutting on the plot to be cut five times was made May 16, with the alfalfa in bud. The schedule for the other cuttings was then made out and followed throughout the season without a deviation of more than 2 days. The first cuttings on B, C, and D were made June 1, June 13, and June 26, respectively, and the last cutting was made September 23. Data from Experiment I are included in Tables 46, 47, 48, and 59. In addition to its lack of uniformity, this tract was somewhat inaccessible, and the only harvests in 1926 were uniform harvests in April and June made to measure the effects of the different numbers of cuttings made the year before.

Experiment II. Range 800.—In order to continue the experiment, the variety test sown in 1925 on Range 800 was cut in two and the south half divided into eight sections for the time-of-cutting study. These were lettered from A to H, according to the following plan:

Variety plots



The plots of the different varieties ran across these sections. Sections A, C, E, and G were cut five, four, three, and two times during the season as in 1925 and according to the same plan, except that it was not possible to make the first cuttings as early as in 1925. They were cut for the first time on May 28, June 7, June 14, and June 28, respectively, and the last cutting in the fall was made September 25.

It was planned to cut Section B four times on those dates which seemed for the season to be the best farm practice. Through a misunderstanding the last cutting on this plot was made 2 weeks too soon, and, as it was already weakened, the result was a very poor fall growth (Fig. 20) and very severe winterkilling. Section B had a stand of only 58 plants per square yard in the spring of 1927 and would hardly have been left for hay if a farmer had owned a field like it. However, it was left and cut three times with the adjacent variety plots. It made a surprising recovery, the weight of roots increasing from 700 pounds per acre on May 28, 1927, to 2270 pounds per acre in November 1927. The yields of hay were not taken, but they were about two-thirds of the yield of Section D. In 1928 Section B was cut three times and produced yields of hay equal to the other three-cutting plots. The results from Section B show the serious effects of premature cutting and, on the other hand, the great recuperative power of an alfalfa stand which contains as many as 50 plants per square yard.

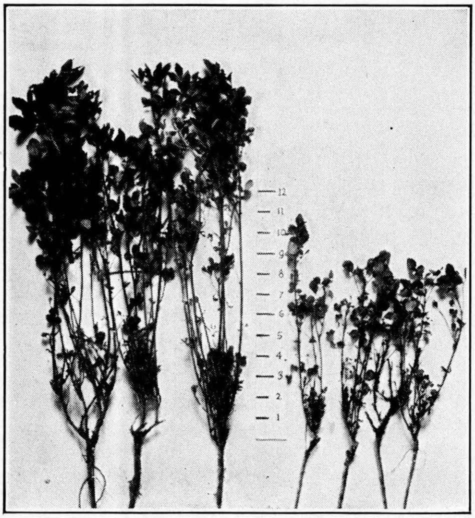


Fig. 20.—Effect of premature cutting

Recovery, October 26, 1926, of two plots cut on September 9—Left, Section D cut June 7, July 19, and September 9; right, Section B cut May 28, July 7, August 10, and September 9. Section B winterkilled more than 60 per cent in the following winter.

Sections D and F were both cut three times each season. In general, F was cut on the same dates as the adjacent variety plots, although this rule was not uniformly followed. Attacks of leafhoppers (Page 119) made the data from this section unsatisfactory. The first cutting on Section D was always made at the same time as the first cutting on Section C, the four-cutting section. The other two cuttings were made as seemed desirable. This plot was planned to study the possibility of making the first cutting early, in order to secure a high quality of hay, and then restoring the loss in root reserves, if any, by proper management of the later cuttings. Section H was cut twice each season, but at an earlier stage for both the first and second cuttings than Section G, in which two cuttings were spread over the entire growing season. The result of this system was to leave a very considerable third growth on the ground for winter.

The winter of 1926-1927 resulted in a considerable amount of winterkilling from heaving (Fig. 21), and Section A, cut five times in 1926, was almost completely killed, the average stand being 5.5 living plants per square yard. The variegated strains were only slightly better than the common strains, averaging six plants per square yard as compared with five in common alfalfas.

TABLE 47.—Time of Cutting Alfalfa—Four, Three, and Two Cuttings, Columbus

Yield per acre

No. of cuttings and approximate dates	Waterman 1925 1st year	800 1926 1st year	800 1927 2nd year	800 1928 3rd year	1400 1929 1st year	1400 1930 2nd year	400 1930 1st year	Av. 1930	400 1931 2nd year	400 1932 3rd year	600 1932 1st year	Av. 1932	Av. 1925 to 1932	Av. 1926 to 1932	Av. first years only, 1925 to 1932
4 cuttings*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
1—May 31	3840	3600	2620	2310	3740	2840	4060	3450	5490	2800	2430	2620	3460	3400	3540
2—July 3	2730	1390	1940	1590	2780	1330	2550	1940	2770	3260	3060	3160	2290	2220	2500
3—Aug. 7	1550	2080	1140	830	2030	550	500	530	1710	2440	1990	2220	1510	1500	1630
4—Sept. 10	1280	1650	780	330	1230	700	620	660	1770	1380	1030	1200	1110	1090	1160
Total	9400	8720	6480	5060	9780	5420	7730	6580	11740	9880	8510	9200	8370	8220	8830
3 cuttings, standard†															
1—June 10-14	3710	4020	4970	3640	4710	2800	3700	3250	4850	3470	3640	3560	4090	4140	3960
2—July 28	2260	1840	3200	3380	3740	1180	1380	1280	2620	4760	4480	4620	2870	2960	2740
3—Sept. 10	1380	1940	1670	1640	1960	640	920	780	3010	2050	1910	1980	1800	1850	1620
Total	7350	7800	9840	8660	10410	4620	6000	5310	10480	10280	10030	10160	8750	8950	8320
3 cuttings, 1st cutting early‡															
1—May 31	....	3900	3040	3700	3540	2970	3910	3440	5640	4000	2700	3350	....	3800	3510
2—July 21	....	1870	2480	2560	3210	1280	2150	1720	2260	3830	3850	3840	....	2560	2770
3—Sept. 10	....	2810	1570	2050	1780	820	830	820	2680	2050	1910	1980	....	1960	1830
Total	....	8580	7090	8310	8530	5070	6890	5980	10580	9880	8460	9170	....	8320	8110
2 cuttings, occupying entire season§															
1—June 27	3290	3480	5290	4910	3650	2910	3050	2980	6060	3770	3090	3430	4140	4260	3310
2—Sept. 10	1280	1940	1560	1180	2280	1220	1380	1300	2640	2940	2810	2880	1880	1970	1940
Total	4570	5420	6850	6090	5930	4130	4430	4280	8700	6710	5900	6310	6020	6230	5250
2 cuttings, better distribution‖															
1—June 20	....	3800	4550	3910	3240	3250	3770	3510	6720	3230	2920	3080	....	4120	3430
2—Aug. 25	....	2380	1720	2490	3640	1380	1710	1550	2350	3980	3530	3760	....	2550	2820
Total	....	6180	6270	6400	6880	4630	5480	5060	9070	7210	6450	6840	....	6670	6250

*Section B, 1925; Section C, 1926-1928; System 3, 1929-1932. †Section C, 1925; Section E, 1926-1928; System 9, 1929-1932.
‡Section D, 1926-1928; System 4, 1929-1932. §Section D, 1925; Section G, 1926-1928; System 14, 1929-1932.
‖Section H, 1926-1928; System 13, 1929-1932.

TABLE 48.—Time of Cutting Alfalfa—Four, Three, and Two Cuttings, Columbus

No. of cuttings and approximate dates	Leaves in hay		Protein in hay		Protein per acre		Total hay at each cutting	
	Av. 1925 to 1932	Av. first years only‡	Av. 1925 to 1932	Av. first years only‡	Av. 1925 to 1932	Av. first years only‡	Av. 1925 to 1932	Av. first years only‡
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Lb.*	*Lb.*	*Pct.*	*Pct.*
4 cuttings*								
1—May 31	45.9	44.2	19.1	18.3	661	645	41.3	40.0
2—July 3	52.7	50.9	19.3	19.8	442	496	27.3	28.3
3—Aug. 7	59.3	58.3	19.1	19.2	288	313	18.1	18.5
4—Sept. 10	62.6	60.4	21.8	23.9	242	278	13.3	13.2
Total	51.8	50.0	19.4	19.3	1633	1732	....	....
3 cuttings, standard*								
1—June 10-14	38.8	37.7	16.3	15.7	666	621	46.7	47.6
2—July 28	49.0	50.2	15.8	16.1	453	441	32.8	32.9
3—Sept. 10	54.1	55.5	20.2	21.2	363	344	20.5	19.5
Total	44.5	44.4	16.8	16.7	1482	1406	....	....
3 cuttings, 1st cutting early*†								
1—May 31	45.4	43.8	19.0	18.4	723	647	45.7	43.3
2—July 21	48.2	47.3	16.8	16.8	430	467	30.8	34.1
3—Sept. 10	53.7	54.6	19.0	19.6	372	359	23.5	22.6
Total	47.4	46.1	18.0	17.7	1526	1472	....	....
2 cuttings occupying entire season*								
1—June 27	35.9	34.1	14.9	14.8	617	490	68.7	63.1
2—Sept. 10	34.4	39.0	16.7	16.6	314	321	31.3	36.9
Total	35.4	34.9	15.5	15.2	931	811	....	....
2 cuttings, better distribution*†								
1—June 20	38.1	36.2	15.5	15.3	638	524	61.7	54.9
2—Aug. 25	39.4	43.2	15.0	15.6	348	440	38.3	45.1
Total	38.1	38.7	15.2	15.1	1022	964	....	....

*See footnote, Table 47. †The data for these two systems are for 1926-1932.
‡1925, 1926, 1929, 1930, and 1932.

TABLE 49.—Time of Cutting Alfalfa, Summary of Experiments III, IV, and V, 1929-1932

Total yield of hay per acre

System of cutting	Range 1400 1929	Range 1400 1930	Range 400 1930	Average 1930	Range 400 1931	Range 400 1932	Range 600 1932	Average 1932	Average 1929-1932
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
1—May 31, July 10, Aug. 25	7530	4730	5870	5300	11460	8270	8260	8260	8140
2—May 31, July 15, Sept. 3	7780	4330	6490	5410	11840	8890	8720	8800	8460
3—May 31, July 3, Aug. 7, Sept. 10	9780	5420	7730	6580	11740	9880	8510	9200	9320
4—May 31, July 21, Sept. 10	8530	5070	6890	5980	10580	9880	8460	9170	8560
5—June 7, July 21, Sept. 3, Nov. 1	11130	5060	6890	5980	12150	10670	10420	10550	9950
6—June 7, July 21, Sept. 3, Nov. 1	10400	4390	6660	5520	11800	10550	10030	10300	9500
7—June 7, July 21, Sept. 3, Oct. 15	10720	4890	6670	5780	12330	9230	10710	9970	9700
8—June 7, July 21, Sept. 3	10210	4640	5820	5230	9950	9430	8670	9050	8610
9—June 10, July 28, Sept. 10	10410	4620	6000	5310	10480	10280	10030	10160	9090
10—June 13, July 28, Sept. 10	10340	4900	5300	5100	10990	11130	9690	10400	9200
11—June 17, July 31, Sept. 10	8920	5120	6220	5670	11380	11260	9460	10360	9080
12—June 20, July 31, Sept. 10	7800	5240	6830	6040	12050	11100	9420	10270	9040
13—June 20, Aug. 25	6880	4630	5480	5060	9070	7210	6450	6840	6960
14—June 27, Sept. 10	5930	4130	4430	4280	8700	6710	5900	6310	6300
15—June 27, Aug. 7, Sept. 20	10110	4820	5440	5130	10380	9150	7720	8430	8510
16—June 27, Aug. 16, Sept. 30	9670	5810	5210	5510	9950	8510	6750	7630	8190
Average of all systems	9130	4860	6120	5490	10920	9500	8700	9100	8660
Leaves in the hay, average all systems, per cent	42.0	51.2	46.0	48.6	41.2	39.8	42.9	41.3	43.3
Protein in the hay, average all systems, per cent	16.7	17.4	17.0	17.2	17.2	17.8	18.8	18.3	17.4

TABLE 50.—Time of Cutting Alfalfa, Total Yield per Acre for the Year—Holgate

System of cutting	1930 7A Common	1930 7A Grimm	1931 7A Common	1931 7A Grimm	1931 14 Common	1931 14 Grimm	1931 Av.	1932 14 Common	1932 14 Grimm	1932 Av.	Average 1931-1932
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
1—May 31, July 10, Aug. 25	6820	6660	8560	8250	5680	6330	7210	6270	6080	6180	6690
2—May 31, July 15, Sept. 3......	6110	6650	8550	8060	5230	6180	7010	5880	6500	6190	6610
3—May 31, July 3, Aug. 7, Sept. 10	6780	6780	9620	8180	5860	6680	7580	6580	6410	6490	7040
4—May 31, July 21, Sept. 10	6430	5930	8650	7280	5520	6200	6920	6380	6420	6400	6660
5—June 7, July 21, Sept. 3, Nov. 1*	7330	5830	9300	9460	6510	7280	8210	7290	6640	6970	7590
6—June 7, July 21, Sept. 3, Nov. 1	6260	6790	10320	8740	6470	7110	8170	7050	6930	6990	7580
7—June 7, July 21, Sept. 3, Oct. 15	7070	6330	9770	9060	6630	7150	8150	6890	7030	6960	7560
8—June 7, July 21, Sept. 3........	5240	5890	7880	8550	5940	6520	7220	5620	6520	6070	6650
9—June 10, July 28, Sept. 10......	4650	5590	6960	7810	5180	6620	6640	5900	6500	6200	6410
10—June 12, July 28, Sept. 10......	....	....	....	....	5250	7310	6750	5990	6960	6480	6610
11—June 17, July 31, Sept. 10......	4350	4630	6290	7780	6100	7840	7010	5590	6430	6010	6510
12—June 20, July 31, Sept. 10......	4950	5070	7120	7660	6350	7340	7120	5710	6880	6300	6710
13—June 20, Aug. 25..............	4240	4140	6920	6390	4770	5560	5920	5030	5730	5380	5650
14—June 27, Sept. 10..............	3160	4610	5950	6690	4400	5580	5660	4340	5360	4850	5260
15—June 27, Aug. 7, Sept. 20	5040	5280	8370	7400	5850	6810	7110	5800	6180	5990	6550
16—June 27, Aug. 16, Sept. 30	5200	5000	7560	7440	5460	7500	6980	6160	6840	6500	6740
Average all systems	5580	5680	8120	7920	5700	6750	7100	6030	6460	6250	6680

*Cut November 1 and left as mulch, 1929-1931; mulched with 1 ton of straw per acre in 1932.

TABLE 51.—Time of Cutting Alfalfa, Experiments III, IV, and V at Columbus and Ranges 7A and 14 at Holgate

Days between cuttings, proportion of total hay at each cutting, and average growth for winter cover

System of cutting	Days 1st to 2nd cutting	Days 2nd to 3rd cutting	Days 3rd to 4th cutting	Proportion of total hay in each cutting: Columbus, average 1929-1932, Crop 1	Columbus Crop 2	Columbus Crop 3	Columbus Crop 4	Holgate, average 1931-1932, Crop 1	Holgate Crop 2	Holgate Crop 3	Holgate Crop 4	Hay left for winter cover, November: Columbus, average 1929-1932	Holgate, average 1931-1932
	No.	*No.*	*No.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Lb.*	*Lb.*
1—May 31, July 10, Aug. 25	40	46	...	43.8	32.7	23.5	...	44.5	34.0	21.5	...	1010	360
2—May 31, July 15, Sept. 3	45	50	...	43.5	34.9	21.6	...	45.4	35.3	19.3	...	1060	360
3—May 31, July 3, Aug. 7, Sept. 10	33	35	34	41.0	28.5	17.4	13.0	41.6	30.2	17.6	10.6	720	140
4—May 31, July 21, Sept. 10	51	51	...	46.6	32.2	21.2	...	46.6	37.5	15.9	...	980	280
5—June 7, July 21, Sept. 3, Nov. 1*	44	44	59	43.2	27.5	18.8	10.5	44.6	32.3	15.8	7.3	...	...
6—June 7, July 21, Sept. 3, Nov. 1	44	44	59	43.5	27.5	18.2	10.8	45.1	31.4	16.2	7.3	...	...
7—June 7, July 21, Sept. 3, Oct. 15	44	44	42	41.8	27.3	18.3	12.6	44.5	30.7	15.0	9.8	...	...
8—June 7, July 21, Sept. 3	44	44	...	46.9	32.2	20.9	...	49.6	33.8	16.6	...	990	280
9—June 10, July 28, Sept. 10	48	44	...	45.0	33.8	21.2	...	53.6	31.1	15.3	...	1060	270
10—June 13, July 28, Sept. 10	45	44	...	44.6	33.3	22.1	...	56.7	31.1	12.2	...	1130	260
11—June 17, July 31, Sept. 10	44	41	...	42.9	35.6	21.5	...	56.8	29.0	14.2	...	1150	250
12—June 20, July 31, Sept. 10	41	41	...	48.1	33.0	18.9	...	58.1	26.5	15.4	...	1000	290
13—June 20, Aug. 25	66	...	...	59.4	40.6	...	...	67.9	32.1	...	...	1120	400
14—June 27, Sept. 10	75	...	...	63.9	36.1	...	...	72.3	27.7	...	...	1060	420
15—June 27, Aug. 7, Sept. 20	41	44	...	48.3	33.2	18.5	...	58.3	26.8	14.9	...	640	110
16—June 27, Aug. 16, Sept. 30	50	45	...	48.2	32.4	19.4	...	58.2	27.9	13.9	...	220	...
Average 12 systems (5, 6, 7, 16 omitted)	...	...	...	...	...	...	...	...	...	...	...	990	280

*Cut November 1 and left as mulch, 1929-1931; mulched with 1 ton of straw per acre in 1932.

TABLE 52.—Yield per Acre, Percentage of Leaves and Protein in the Hay, and Protein per Acre from Cutting Systems at Columbus and Holgate

Ranges III, IV, and V at Columbus; Ranges 7A and 14 at Holgate

System and dates of cutting	Columbus, Av. 1929-1932				Holgate, Av. 1931-1932			
	Yield per acre	Leaves in hay	Protein in hay	Protein per acre	Yield per acre	Leaves in hay	Protein in hay	Protein per acre
	Lb.	*Pct.*	*Pct.*	*Lb.*	*Lb.*	*Pct.*	*Pct.*	*Lb.*
1-May 31	3570	43.4	18.8	....	2900	56.8	20.2	....
July 10	2660	48.8	18.2	....	2310	60.0	18.2	....
Aug. 25	1910	57.3	17.9	....	1480	66.6	18.0	....
Total	8140	48.4	18.4	1497	6690	60.0	19.0	1272
2-May 31	3680	43.4	18.8	....	2940	56.8	20.2	....
July 15	2950	46.8	17.5	....	2370	57.5	16.9	....
Sept. 3	1830	50.1	18.0	....	1300	64.3	18.2	....
Total	8460	46.0	18.2	1537	6610	58.8	18.6	1232
3-May 31	3820	43.4	18.8	....	2840	56.8	20.2	....
July 3	2660	50.9	19.4	....	2060	59.2	19.2	....
Aug. 7	1620	58.2	19.2	....	1470	64.1	19.0	....
Sept. 10	1220	59.1	23.6	....	670	77.2	25.2	....
Total	9320	50.2	19.7	1833	7040	61.0	20.1	1418
4-May 31	3990	43.4	18.8	....	3030	56.8	20.2	....
July 21	2760	44.0	15.9	....	2630	58.0	17.2	....
Sept. 10	1810	53.5	20.1	....	1000	64.4	20.8	....
Total	8560	45.7	18.1	1553	6690	58.4	19.1	1272
5-June 7	4310	39.6	17.8	....	3420	55.4	19.2	....
July 21	2730	44.6	16.8	....	2540	59.6	17.4	....
Sept. 3	1870	52.2	20.0	....	1160	66.6	19.2	....
Nov. 1*	1040	56.1	19.4	....	470	67.6	19.6	....
Total	9950	45.1	18.1	1802	7590	59.3	18.6	1414
6-June 7	4140	39.6	17.8	....	3600	55.4	19.2	....
July 21	2620	44.6	16.8	....	2380	59.6	17.4	....
Sept. 3	1720	52.2	20.0	....	1120	66.6	19.2	....
Nov. 1	1020	56.1	19.4	....	480	67.6	19.6	....
Total	9500	45.0	18.1	1719	7580	59.1	18.6	1414
7-June 7	4060	39.6	17.8	....	3420	55.4	19.2	....
July 21	2640	44.6	16.8	....	2380	59.6	17.4	....
Sept. 3	1780	52.2	20.0	....	1070	66.6	19.2	....
Oct. 15	1220	60.5	22.8	....	690	78.8	22.9	....
Total	9700	45.9	18.6	1801	7560	60.4	18.9	1431
8-June 7	4040	39.6	17.8	....	3360	55.4	19.2	....
July 21	2770	44.6	16.8	....	2260	59.6	17.4	....
Sept. 3	1800	52.2	20.0	....	1030	66.6	19.2	....
Total	8610	43.8	17.9	1544	6650	58.6	18.6	1236
9-June 10	4090	37.1	16.6	....	3540	54.4	17.8	....
July 28	3070	49.5	15.5	....	2070	57.4	16.2	....
Sept. 10	1930	53.9	21.2	....	800	74.4	21.0	....
Total	9090	44.9	17.2	1564	6410	57.9	17.7	1133

TABLE 52.—Yield per Acre, Percentage of Leaves and Protein in the Hay, and Protein per Acre from Cutting Systems at Columbus and Holgate—Continued

System and dates of cutting	Columbus, Av. 1929-1932				Holgate, Av. 1931-1932			
	Yield per acre	Leaves in hay	Protein in hay	Protein per acre	Yield per acre	Leaves in hay	Protein in hay	Protein per acre
	Lb.	*Pct.*	*Pct.*	*Lb.*	*Lb.*	*Pct.*	*Pct.*	*Lb.*
10–June 13	4110	37.1	16.2	......	3740	49.4	17.0	......
July 28	3060	49.5	16.0	......	2060	57.4	17.3	......
Sept. 10	2040	53.9	21.2	......	810	74.4	21.0	......
Total	9210	45.0	17.2	1588	6610	55.0	17.6	1162
11–June 17	3890	36.4	15.6	......	3800	48.2	16.2	......
July 31	3240	50.4	16.4	......	1980	54.8	17.4	......
Sept. 10	1950	54.6	21.7	......	730	73.0	22.8	......
Total	9080	45.3	17.2	1561	6510	53.0	17.3	1126
12–June 20	4350	34.8	15.6	......	4000	44.3	16.4	......
July 31	2980	51.3	16.6	......	1890	54.1	17.2	......
Sept. 10	1710	54.6	21.7	......	820	73.0	22.8	......
Total	9040	44.0	17.1	1545	6710	50.6	17.4	1166
13–June 20	4140	34.8	15.6	......	3870	44.3	16.4	......
Aug. 25	2820	43.0	15.6	......	1780	50.6	16.0	......
Total	6960	38.1	15.6	1086	5650	46.1	16.3	920
14–June 27	4030	33.4	15.3	......	3800	40.6	13.9	......
Sept. 10	2270	34.7	17.2	......	1460	43.8	16.6	......
Total	6300	33.9	16.0	1006	5260	41.5	14.6	770
15–June 27	4120	33.4	15.3	......	3750	40.6	13.9	......
Aug. 7	2830	49.7	16.8	......	1980	58.7	16.7	......
Sept. 20	1560	51.4	20.4	......	820	73.9	22.9	......
Total	8510	42.1	16.7	1423	6550	50.2	15.9	1040
16–June 27	3950	33.4	15.3	......	3860	40.6	14.1	......
Aug. 16	2660	47.4	16.3	......	1920	57.1	17.0	......
Sept. 20	1580	53.5	20.8	......	960	73.4	23.0	......
Total	8190	41.8	16.7	1367	6740	50.0	16.2	1091
17†–June 10	3500	38.1	18.0	......	......	......	......	......
July 15	3160	39.3	19.2	......	......	......	......	......
Sept. 2	2150	42.1	17.0	......	......	......	......	......
Total	8810	39.5	18.2	1603	......	......	......	......
18‡–May 24	2540	46.2	21.6	......	......	......	......	......
July 5	3100	50.0	17.2	......	......	......	......	......
Aug. 8	1900	55.4	18.9	......	......	......	......	......
Sept. 10	1500	54.9	22.6	......	......	......	......	......
Total	9050	50.8	19.7	1780	......	......	......	......
19†–May 24	2370	50.2	24.1	......	......	......	......	......
June 27	2880	49.2	20.1	......	......	......	......	......
Aug. 1	3170	50.0	18.4	......	......	......	......	......
Sept. 10	1560	58.5	22.2	......	......	......	......	......
Total	9980	51.2	20.8	2079	......	......	......	......

*Mulched. †1932 only; Range 600. ‡1931-1932 only; Range 400.

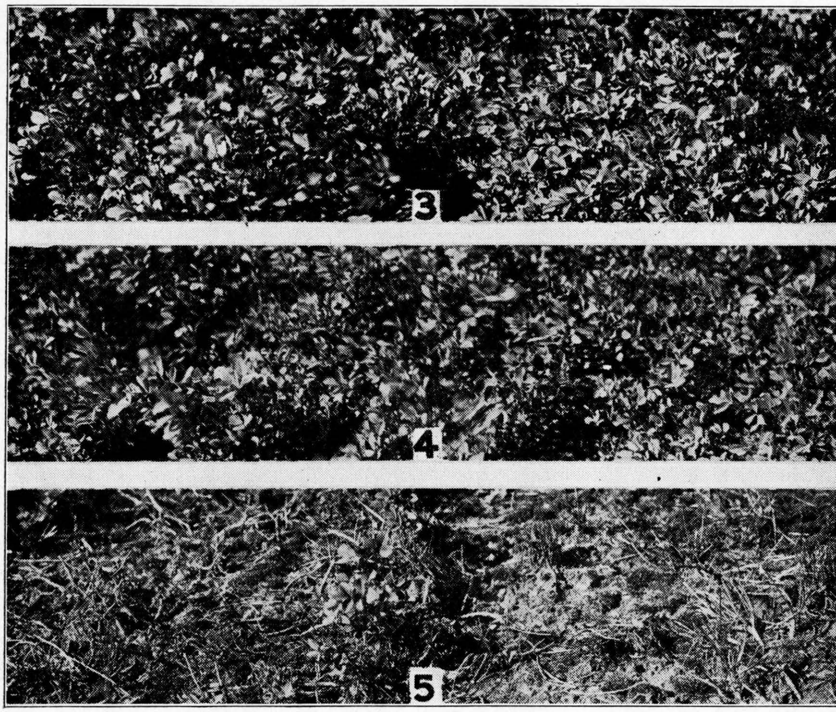


Fig. 21.—Cutting five times a season may destroy the stand

Alfalfa cut three times (top), four times (middle), and five times (bottom) in 1926; photographed April 30, 1927.

The yield harvests in 1926 had been taken from plots of the same two varieties throughout the season. It was not possible to continue the harvests in 1927 from the same two varieties because the roots on most of the plot had been dug; therefore, harvests were made on May 28-30 in all of the sections both from the varieties harvested in 1926 and from those harvested in 1927. A comparison of the harvests from the different varieties did not suggest that any important error was introduced into the experiment by the change in varieties. The sections were cut as in 1926, except that the date of making the final cutting was September 15 instead of September 25. The work of the preceding years had shown that September 25 was too late for the last cutting at Columbus. In 1928 the last cutting was made on September 11; September 10 has been the standard date since.

There was some winterkilling in the winter of 1927-1928 (Fig. 22). As determined from counts of 10 square-yard areas in each section, 48 per cent of the plants in the four-cutting section were winterkilled; in the four three-cutting sections, 12, 2, 7, and 7 per cent, averaging 7 per cent; and in the two two-cutting sections, each 2 per cent. The plots were quite weedy by this time, and there was a very noticeable difference between the plots cut four times and those cut three times in this respect. Data from Experiment II are given in Tables 46, 47, 48, and 59. The more important data from Experiments I and II have already been published (68, 69). For completeness, a portion of these data has been included in the present summaries.

Fig. 22.—Cutting four times a season may seriously injure the stand

Alfalfa cut four times (left) and three times (right) in 1926 and in 1927; photographed April 17, 1928.

Since the sections were rather small in the beginning, most of the available alfalfa had been destroyed by sampling by the spring of 1929, and the range was plowed.

Experiment III. Range 1400.—Twenty plots of Dakota common alfalfa were sown on Range 1400 in 1928. They were sown a little late (April 11), and a dry April resulted in a generally poor stand. However, there were good stands on parts of each plot, and in order to continue the experiment three square-yard areas in each plot were permanently marked. At each cutting, these areas were harvested by hand. Then the entire plot was cut and the hay removed, yields being obtained from the square-yard areas only. It was possible in this way to obtain reasonably comparable areas. The 4 years' work up to this time had indicated the feasibility of cutting alfalfa on dates definitely set in advance (68), and since that time all of the cuttings, except a few made to study the effects of unusual weather conditions, have been made by cutting schedules made out in advance to study definite problems in the cutting of alfalfa.

Sixteen of these plots were cut according to as many different systems. These systems were planned to study in some detail the following points suggested by the work of the 4 previous years:

1. The relative value of making two, three, and four cuttings of alfalfa at Columbus. (Five cuttings had been shown to be out of the question for these conditions.)

2. The effect of making the last cutting at different dates in the fall. This required making the next to the last cutting at such a time that the last cutting would not be premature, or the effect of date of cutting would be confused with that of premature cutting.

3. The effect of different dates of making the first cutting on the yield and quality of hay secured then and at later cuttings.

4. Effect of the date of cutting as related to external factors, especially rainfall and leafhoppers.

5. Cumulative effect of the treatments on root reserves. The permanent square yards were to be dug in the fall of 1930. It seemed probable that by that time the effect of the cutting treatments would largely overshadow any initial variations in stand.

Data from Experiment III are included in Tables 47, 48, 49, 51, 52, and 60.

Three of the plots were cut June 7, July 21, and September 3 and used to furnish areas for a study of the development of the roots (Table 73). The plan was to use these plots as a standard by which to estimate the effect of the other treatments when the roots in the permanent areas were harvested. In this way a maximum amount of information could be obtained with a minimum number of root harvests. In addition, one sample of roots from each plot was harvested in the fall of 1929. Two of the permanent areas in each plot were dug in November 1930 and the other in March 1931 (Table 60). Because of the dry season the root yields from the different cutting treatments were very similar.

Experiment IV. Range 400.—Another series of 22 plots of Dakota common alfalfa was sown in the spring of 1929 on Range 400, and an excellent stand was obtained. The standard series of harvests begun in 1929 was followed on these plots in 1930-1932, as given in Tables 49, 51, and 52. Two of the systems were replicated on two border plots (Table 68), while four plots were left to be used for whatever problems presented themselves during the seasons.

Yields on Range 400 in 1930 and 1931 were obtained by two methods. The plots were 14 feet x 100 feet. From these, areas 14 feet x 50 feet were cut off by hoeing strips 1½ feet wide across the plots. These areas were cut, raked, and weighed green, and a moisture sample taken to determine the yield of air-dry hay of a uniform moisture content. The first cutting was quite weedy, but the percentage of weeds was determined and the yields corrected, so that the plot yields, like the square-yard yields, are reported as weed-free, air-dry hay. From the rest of the plot, yields were determined from three representative square-yard samples harvested at the same time. Samples of roots were also taken from this part of the plot. In general, the square-yard samples indicated higher yields than the plots. Since there was opportunity for variation, not only because of differences in method but also from soil variation, the agreement has been surprisingly good. The square-yard samples were used for leaf-stem determinations and for analysis. The plot yields seemed to be somewhat more reliable and are the ones reported (Table 49) from Range 400 for 1930-1931. In 1932, as a measure of economy, plot yields were not taken, but the number of square yards taken was increased to five, obtained from the 50-foot area of the plot.

A sufficient number of root harvests were made on Range 400 to obtain a general history of the development of the stand (Table 73). One square-yard sample of roots from each treatment was harvested in November 1930 (Table 60). As with Range 1400 the differences between the treatments in amount of roots were much smaller than the errors of sampling.

Because of the exceptionally dry weather, blossoms appeared unusually early in 1930. By May 20 the plots appeared to be in full bloom. In order to investigate the effect of cutting at this early date, one plot was cut on May 24 and another on May 28. The second cutting came into bloom very soon after it started into growth; in fact, there was bloom on many plots 2 weeks after the previous cutting had been made. These two plots on Range 400 and the extra plot on Range 1400 were cut early to study the effect of consistently cutting by bloom instead of by dates (Pages 103 and 117).

As was predicted from root reserve studies (50, p. 49), 1931 was a year of large yields of alfalfa on all stands established prior to 1930. The regular cutting systems and a four-cutting system in which the first cutting was made May 24 (Table 52) were continued on Range 400 in 1931-1932.

Experiment V. Range 600.—A new series of 20 plots of Dakota common alfalfa was sown on Range 600 in 1931. Some parts of the seeding were injured by water and weeds, but a good stand was obtained on a majority of the plots. Range 600 was cut according to the standard systems and some additional ones (Tables 49, 51, 52, 60, and 68) in 1932.

Experiments at the Northwestern Experiment Farm, Holgate.—When the Northwestern Experiment Farm was started in 1929, an experiment on the time of cutting alfalfa was among the major projects planned. The first range, 7A, was sown in August 1929 and consisted of 15 plots of Kansas common alfalfa and 15 plots of Grimm. Poor stands were obtained, but the standard systems of cutting (except No. 10) were followed in 1930, yields being obtained from three selected square-yard areas in each plot. The yields are reported, but, because of the poor stands, the abnormally dry season, and the fact that no analyses were made of the samples, the 1930 results have not been included in the averages. By 1931, the dry season had so built up the stand that reliable results could be obtained, and the results from Range 7A, again obtained from square-yard samples, are included in the averages.

Sixteen plots of Utah common and 16 plots of Grimm were sown on Range 14 in 1930 and used for regular cutting systems in 1931 and 1932. Since Holgate is much further north than Columbus, it might seem reasonable to use a different series of dates there. However, data on the length of the growing season indicate little difference between the two locations, and it seemed that the practical differences, if any, would best appear by using the same dates at each place.

Yields on Range 14 in 1931 were obtained by harvesting two 50-foot strips, 1 mower-width wide, in a special pan attached to the cutter-bar of the mowing machine, which collected the green alfalfa as it was cut. Shrinkage samples were then taken from the green material and the yield expressed as air-dry hay. Square-yard samples were also taken from each plot at the same time, three in the first cutting and five in the later ones, in order to make a comparison under especially favorable conditions of the plot and square-yard methods of estimating yields. It is hoped to publish this and other comparisons of plot and square-yard yields separately. Since plot yields were taken only in 1931, the data reported here for that year are the square-yard yields, in order that the data might be more directly comparable with those of the other years.

Data obtained from the 16 systems of cutting followed at Columbus and Holgate since 1929 are given in Tables 49 to 51, but only the totals or averages for the year are given, not the data for the separate cuttings. Table 52 gives the 4-year averages at Columbus and 2-year averages at Holgate for these cutting systems by cuttings.

Data for the five systems of cutting which have been continued since 1925 and 1926 at Columbus are summarized by cuttings in Tables 47 and 48. Data from the same systems at Holgate may be obtained from Table 52.

HOW SHOULD ALFALFA BE CUT IN OHIO?

In planning a cutting system for his alfalfa, the grower should first decide how many cuttings he should try to obtain, since a definite number of cuttings must be fitted into the available growing season. Then he must decide when it is best to make this number of cuttings.

Five cuttings a year.—A five-cutting system was included during only the first 2 years of the experiments, and each of these was the first year of cutting the stand. A summary, comparing cutting alfalfa five, four, three, and two times in its first cutting year, is given in Table 46. The detailed data were published earlier (68). Five cuttings a year are entirely out of the question as a regular practice on upland soils in the latitude of Columbus. Even in the first cutting year, no more hay is obtained than from four cuttings, the hay is of only slightly better quality, and the growth is often so short that in practical operations it could not be raked. The effect upon the yields the next year was serious in 1925 and resulted in a total loss of the stand in 1926 (Fig. 21).

Four versus three cuttings.—The 8-year average yields given in Table 47 include three records for the first-cutting year and two averages between first and later years. They are also influenced greatly by the dry year 1930 (Page 117). Consequently, the average yields are probably more favorable to four cuttings than an average based on a larger number of long-time records and more normal seasons would be. Even so, three cuttings have yielded more hay than four cuttings but not as much protein. The records for 1927 and 1928 indicate that under normal rainfall conditions, four cuttings at Columbus are too many. On the other hand, four cuttings in dry seasons, such as 1925 and 1930, do not injure vigor of the stand, as is indicated by the yields of the first cutting in 1926 (Table 46) and 1931 (Table 47) following four cuttings in the previous year. Two other plots on Range 400 were cut four times in 1930 without injuring the stand or yield in 1931.

Alfalfa may profitably be used in the rotation as a one-year crop (Pages 49 to 50), and the yields for the first year of cutting (Table 47) suggest that, where this is done, four cuttings may prove profitable in seasons which permit all of the four crops to be raked up cleanly. Four cuttings in the first year yielded 23 per cent more protein per acre than three cuttings (Table 48). In every test thus far, alfalfa has permitted 2 years of cutting four times before the stand was seriously reduced. However, the expense of making an extra cutting and the greater loss of short alfalfa in raking should be considered before planning to make four cuttings regularly.

Two cuttings a year.—Making only two cuttings is as completely out of the question at Columbus as making five. Two cuttings have produced more than a ton less hay than three cuttings, and the hay is of much poorer quality—the average total protein for the season being only about 60 per cent of that from three cuttings. The second cutting in this system is really a seed crop, but seed worth harvesting was obtained only in 1930. There is nothing to recommend the two-cutting system for the central and southern part of the State.

Making two cuttings earlier.—Since 1926, a two-cutting plot has been harvested somewhat earlier, both for the first and second cuttings, than the regular two-cutting plot. This system is superior to one occupying the entire season, since it uniformly gives larger yields of hay, but it is still markedly inferior to any three-cutting system. The fact that the late-cut hay has averaged a higher protein content at the second cutting than that cut earlier seems to be due to new growth coming up in the old growth. This has been noted in the field rather frequently both at the June 27 and the September 10 cuttings.

WHEN SHOULD CUTTINGS BE MADE?

It seems clear that for ordinary farm conditions, three cuttings before September 10 constitute the best number in the latitude of Columbus. The next problem is the distribution of these cuttings.

What is the best date for making the first cutting?—In Table 53 are brought together the data for the 8 years of the experiment on the effect of making the first cutting at different dates on the yield, the percentage of leaves, and the percentage and yield of protein. In some of the earlier years data for all the dates given were not available and were obtained by straight-line interpolation. As an average, the yield increases rapidly up to June 7, slightly to June 14, and changes little after that. As alfalfa reaches this point of maximum vegetative growth, it seems to "stand still". This condition has been noted earlier (68; 77, p. 293) as an excellent criterion of the best stage at which to cut. However, the weather modifies this general rule, as is evident from the data for individual years. A wet June, such as was experienced in 1927 and 1928, tends to make the yields on the later dates heavier than on the early dates; whereas dry Junes, such as 1925, 1930, and 1931, have the reverse effect. The years 1926, 1929, and 1932 represent relatively normal seasons. At Holgate in 1931, the season was very dry until June 9, when a heavy rain started new growth and produced a much larger yield in the later cuttings. The large yield of June 21, 1931, at Columbus seems to represent plot variability.

Insofar as can be judged from Systems 12, 15, and 16, the effect of delaying the first cutting on the total yield for the season is slight. In fact, the similarity of the yields in all of the three-cutting systems is rather outstanding.

The percentage of leaves in the hay drops from week to week but most rapidly from June 1-7. In each year a week can be noted in which there is an especially sharp drop in the percentage of leaves. This can also be noted in the field. The percentage of protein in the hay drops about 0.2 per cent per day from June 1 to 14 and about 0.1 per cent per day after that. The total protein per acre is at a maximum on June 7 and drops sharply after June 14.

These data indicate clearly that the best time to make the first cutting of alfalfa in central Ohio is the week of June 7-14—a little earlier in dry seasons and a little later in wet seasons.

TABLE 53.—Effect of Different Dates of Making the First Cutting on the Yield and Composition of Alfalfa Hay

Date of first cutting	Year: Columbus 1925	1926	1927	1928	1929	1930	1931	1932	Average	Holgate 1931	1932	Average
Yield of hay, pounds per acre												
May 31	3840	3060	2830	3020	3470	3300	5510	2770	3470	2290	2860	2920
June 7	3780	3750	4140	2960	4815	3200	5740	3030	3930	3660	3200	3430
June 14	3710	4270	4970	3640	4820	3010	5370	3460	4160	3640	3750	3700
June 21	3450	3800	4550	3910	3365	3480	6650	3460	4080	4120	3740	3930
June 28	3230	3480	5290	4910	4330	2990	5430	3380	4130	4010	3590	3800
Percentage of protein in the hay												
May 31	17.6	19.0	20.0	22.0	17.2	17.2	19.0	22.0	19.2	20.6	19.6	20.1
June 7	16.2	16.9	18.8	19.2	16.8	16.0	18.0	20.2	17.8	19.3	19.2	19.2
June 14	14.6	14.6	16.7	18.2	15.2	14.0	17.4	18.1	16.1	17.1	17.0	17.0
June 21	13.4	14.8	15.4	16.5	15.1	13.6	15.8	18.1	15.3	16.4	16.4	16.4
June 28	12.2	13.9	13.8	17.9	14.8	14.0	14.8	17.6	14.9	13.6	14.6	14.1
Percentage of leaves in the hay												
May 31	45.6	48.9	49.7	51.8	40.8	44.8	43.6	44.5	46.2	57.8	55.9	56.8
June 7	39.9	45.0	41.7	49.0	40.1	40.5	36.9	40.8	41.7	53.8	56.9	55.4
June 14	34.1	39.0	42.4	45.8	34.7	38.5	34.4	38.9	38.5	48.1	53.2	50.6
June 21	31.3	41.7	41.1	45.1	30.4	38.0	33.7	36.9	37.3	43.2	45.4	44.3
June 28	28.8	39.9	40.9	42.7	29.4	34.6	31.4	38.1	35.7	39.3	41.8	40.6
Pounds of protein per acre												
May 31	676	581	566	664	597	568	1047	609	667	616	561	588
June 7	612	634	778	568	809	512	1034	612	700	706	614	658
June 14	542	623	830	662	733	421	934	626	670	622	638	629
June 21	462	562	701	645	508	473	1051	626	624	676	613	644
June 28	394	484	719	879	641	419	804	595	615	545	524	536

What is the effect of making the first cutting early in a three-cutting system?—Since the quality of hay from the first cutting decreases very rapidly as cutting is delayed (Table 53), the effect of making the first cutting early is an important practical question. Tables 47 and 48 compare the normal three-cutting system with Section D in Range 800 and System 4 in Experiments III, IV, and V. System 4 was used because it was longest continued, but there are no significant differences in the three "first-cutting-early" plans, Systems 1, 2, and 4. Apparently, the general effect of making the first cutting early has been to reduce somewhat the total yield for the season. The protein per acre for the year is substantially the same, but the hay is of more uniform quality. Thus far, no injury to the stand has resulted from this system.

TABLE 54.—Development of Second Crop of Alfalfa, Columbus

Date of first cutting	Date of second cutting				
	July 7	July 14	July 21	July 28	August 3
Protein in second-crop hay, per cent					
June 12, 1928	21.0	20.6	16.7	18.0	......
June 6, 1930	19.7	19.4	17.6	......	......
June 10, 1932	......	19.2	......	15.4	......
June 17, 1933	......	19.9	19.4	16.7	16.6
Average	20.4	19.8	17.9	16.7	16.6
Leaves in second-crop hay, per cent					
June 12, 1928	54.6	45.5	52.6	52.1	......
June 10, 1929	49.7	50.9	50.2	51.1	49.4
June 10, 1932	......	39.3	......	42.8	......
June 17, 1933	......	53.4	55.4	49.3	52.4

What is the best date for the second cutting?—Unfortunately, the available data do not answer this question directly when the first cutting is made on the recommended dates. In Systems 8 to 11 the first cutting is made during, or just after, the recommended period, but they all involve 44 to 48 days between cuttings. Some data on the changes in the second cutting, obtained from other experiments, are given in Table 54. Data on the development of the second cutting when the first cutting is made May 31 and June 27 are given in Table 52 (Systems 1 to 4 and 14 to 16). The yield data indicate little increase in yield after 33 days of growth, reflecting the frequent dry periods which stunt growth in July. The percentage of leaves does not decrease as rapidly in the second cutting as in the first. The percentage of protein in the hay decreases from 0.1 to 0.2 per cent per day during its last 3 weeks of growth, which is similar to the first cutting. The fact that the protein percentage drops more, proportionately, than the leaf percentage is due to leafhopper attacks (Page 123).

The present recommendation (Page 128) is to make the second cutting July 20 to 27. The weather and leafhopper attacks largely determine, in practice, the best date for making the second cutting (Page 125).

When should the last cutting be made?—Systems 5, 6, 7, 15, and 16 were planned especially to study this question. The entire series includes August 25, September 3, September 10, September 20, September 30, October 15, and November 1 as dates of making the last cutting. Because of the prevailing dry seasons and lack of winterkilling since these systems were started, the data are not as conclusive as would be expected under other conditions. No reduction in yield the next year has been experienced from making the last cutting as late as September 10. Systems 15 and 16, cut September 20 and September 30, decreased in yield and increased in weediness on Range 400 until in 1933 they made only about half the yield of the standard systems at the first cutting. This was also true at Holgate, where there was some winterkilling in 1932-1933. Systems 15 and 16 were the poorest of the group, with the October 15 cutting, System 7, next. On Range 1400 at Columbus cutting September 20 and 30 did not decrease the yield nor did it in one year on Range 600. The last cutting on all plots in Experiment I and in the first year of Experiment II was made September 25. Although there were no plots for comparison, the results in Experiment II seemed quite unfavorable. They were not unfavorable in Experiment I, but 1925 was a dry season (Pages 115 to 118).

Some preliminary studies of very late cutting were made both at Wooster and Columbus (Table 55, Fig. 23). Clearly some late cuttings are disastrous. In the studies since 1929, the plots cut October 15 have always been inferior in recovery in the spring to those cut November 1, but the effect on yield has been slight. It is clear from these fairly extensive tests that late cuttings are frequently not seriously injurious. Since the preceding cutting for both Systems 6 and 7 is September 3, it may be that the October 15 cutting is somewhat immature, even though 42 days have elapsed between the cuttings. Systems 5 and 6 have not been inferior to System 8 in the yield of the first cutting the next year, and, since they have yielded an appreciable and often considerable fourth cutting, the system is worth consideration. The outstanding practical difficulty is making hay at that time of year, but, if some practical form of utilization, such as silage or artificial curing, could be devised, it might be important.

TABLE 55.—Effect of Cutting Established Alfalfa About November 1

	Cut about November 1	Not cut
Columbus		
1926-1927—No. plants per square yard in November	129	115
No. plants per square yard in April	49	75
Winterkilling, per cent	62	32
Yield, pounds per acre, June 7	2860	3060
1927-1928—No. plants per square yard in November	48	49
No. plants per square yard in April	31	39
Winterkilling, per cent	37	27
Yield, pounds per acre, June 12	2580	2820
Wooster		
1927-1928—Total yield, 1928, pounds per acre, 9 varieties	3235	8284
Average reduction in yield, 9 varieties, per cent	61	....
Average reduction in yield, 5 variegated varieties, per cent	57	....
Average reduction in yield, 3 common varieties, per cent	66	....

There has been so little winterkilling since these tests were started that there has been little opportunity to contrast Systems 5 and 6. In 1929 and 1930 at Columbus and in 1930 and 1931 at Holgate the hay on System 5 was cut and left on the ground, the idea being to separate its value as a mulch from the effects of possible further growth after November 1. However, the cut material was so short that it had little mulch value after it was cut, and there was no real difference in the two systems. Thus, after the above mentioned years, one ton of wheat straw was applied to System 5 as a mulch some time after Thanksgiving. This straw has had no opportunity to benefit the alfalfa at Columbus (no winterkilling) and seemed rather a detriment in the spring of 1932. However, at Holgate in the spring of 1933 the mulched plot had heaved and been killed very notably less than System 6. There is no possible doubt but that the "good growth for winter protection" is sometimes valuable directly as a mulch.

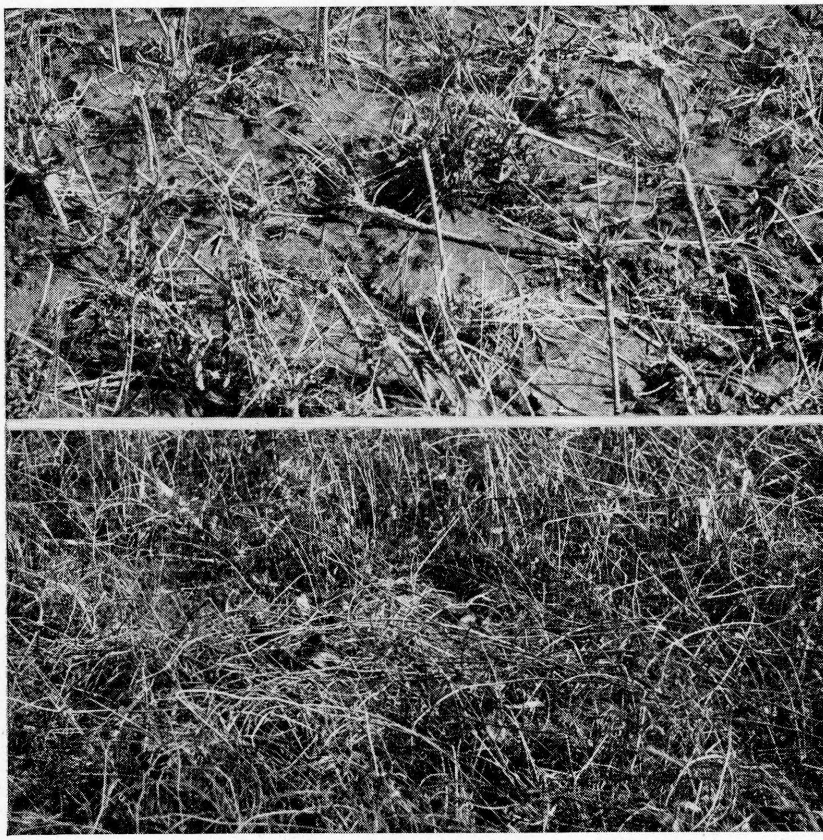


Fig. 23.—Late fall cutting may be disastrous

Wooster, March 16, 1927. Alfalfa sown in 1925—Lower, cut June 17 and August 6, 1926; upper, also cut October 18, 1926.

What cutting systems are adapted to other sections of the State?—The Holgate data have been given with the Columbus data. The results are very similar to those at Columbus. There were no indications of any differences in the date for making the first cutting or the second. However, the third cutting was distinctly smaller, on the average (Tables 51 and 52), than at Columbus. In practice, there have been seasons in which it has not paid to remove the third crop, and it has been left uncut. This method of making two cuttings is superior to either of the two-cutting systems in the regular series, since it produces more and better hay than either of them. It is noticeable from Table 51 that the growth for winter cover was very much less at Holgate than at Columbus. The reason for this difference is not clear. Temperature differences do not seem to be sufficient to account for it.

Experiments at the Paulding County Experiment Farm are reported in Table 56. The results were quite similar to those at Holgate, in favoring three cuttings over two occupying the entire season, but here, also, in practice, the third cutting is sometimes not removed. Unlike Columbus, there have been indications at Holgate and Paulding that the two-cutting systems maintained their vigor better than the three-cutting systems. Thus far, however, this has not been serious, and three cuttings are recommended for this section whenever it is profitable to remove them.

TABLE 56.—Time of Cutting Alfalfa, Paulding County Experiment Farm

Dates of cutting	Yield of hay per acre 1929-1931	Leaves in hay 1929-1931	Roots per acre October 1930	Yield of hay per acre* 1932
	Lb.	*Pct.*	*Lb.*	*Lb.*
June 9-17	3380	55.7	....	2020
July 11-25	2080	55.7	....	1440
Aug. 26-Sept. 8	930	59.1	....	740
Total	6390	56.0	3480	4200
June 25-July 2	4040	50.3	....	1900
Aug. 26-Sept. 8	1750	41.5	....	1070
Total	5790	46.8	3580	2970

* New range.

Systematic time-of-cutting tests were first started at Wooster in 1932. The results are typical of others in northern Ohio (Table 57). No injurious effects of three cuttings in 1932 were observable in 1933. In practice, it has often happened that only two cuttings have been made on the Experiment Station farm. If the first cutting is at all delayed, it is more difficult to get in three cuttings than at Columbus. Further northeast in the State two cuttings may be generally desirable.

TABLE 57.—Time of Cutting Alfalfa, Wooster, 1932

Dates of cutting	Yield of hay per acre	Leaves in hay	Protein in hay	Protein per acre
	Lb.	*Pct.*	*Pct.*	*Lb.*
Cut June 10, July 20, Sept. 1	8770	49.6	17.2	1502
Cut June 20, July 28	7220	40.9	15.2	1097

Time-of-cutting tests have also been conducted on upland soil at the Hamilton County Experiment Farm and the Southeastern Experiment Farm, but the data are incomplete and inconclusive. Although it might be anticipated that four cuttings would be preferable as far south as these two farms, the general indications were in favor of three (Page 107). In practice, four, or even more, are taken on bottom lands in that latitude.

OTHER FACTORS IN CUTTING ALFALFA

The most desirable number of days between cuttings.—The data are not well adapted to a critical study of the most desirable number of days between cuttings, but it may be significant that most of the desirable systems of cutting given in Table 51 range from 40 to 45 days between cuttings. This checks very well with the conclusions of Salmon *et al.* (56) but suggests that alfalfa develops a little more slowly in Ohio upon Miami-Brookston upland soils than it does in Kansas, since Salmon secured his maximum yield at 40 days between cuttings. It can be safely said that in ordinary seasons 38 to 45 days should be allowed between cuttings in this State.

The relation of bloom to the proper time of cutting.—In the states west of the Missouri River the stage at which to cut alfalfa is almost entirely designated by the stage of bloom. The bloom is also an important indication in Ohio, but weather and other conditions modify the bloom to such an extent that it is more difficult to use in this State than in the western states. In ordinary, humid weather in Ohio the bloom of alfalfa, especially the common varieties, is not normal. The variegated varieties bloom much better than the common strains, and the stage of bloom can be more readily determined on them than on common alfalfa. In the dry year of 1930 there was, for almost the first time in these experiments, the sort of bloom to which the western grower is accustomed. Blossoms here often drop off before they have shown color, and, consequently, a field which should be in full bloom may show only a small amount of bloom. Also, when continued rains come during the bloom period, alfalfa continues to grow and bloom, so that it may show about the same amount of bloom for a period of 2, 3, or even 4 weeks. On July 1, 1928, an uncut field of Grimm alfalfa had been in apparently continuous full bloom for over 2 weeks. At this time there were ripe seed pods and new branches bearing flowers in the axils of some of the lower leaves. This field continued to bloom for another 10 days.

Alfalfa in Ohio should never be cut before there is at least some bloom. Beyond that, it is difficult to use bloom as an indication of maturity. As nearly as it can be determined, the most favorable stage at which to make the first cutting is one-fourth to one-half in bloom. The later cuttings may be allowed to go to the one-half to full-bloom stage. Continued wet weather at any season will cause continued growth and will mask the bloom, but this continued growth also makes it advantageous to delay cutting (Table 53, 1927 and 1928). In a very dry season the combination of intense sunlight and low moisture supply in the soil results in the alfalfa coming into bloom very soon after the previous cutting and while very short. In 1930 it was a common occurrence over the State and in these experiments for the second cutting to come into bloom 2 weeks after the previous cutting had been taken off, with the alfalfa less than 6 inches high. Cutting at this stage did not injure the alfalfa, but it was too small from which to harvest any hay, and the only result of cutting under these conditions was to bring on another equally short crop which, because of continued dry weather, bloomed equally early (Page 117).

Recovery after dry weather and its bearing on time of cutting.—It is notable that alfalfa that has completely ceased growing at the bloom stage does not ordinarily resume growth at the top of the plant. At the same time, the stunted growth often seems to inhibit growth from the base for some time, so that, after conditions become favorable for growth, failure to cut stands which have reached the bloom stage and have definitely stopped growing may seriously reduce the total yield of hay for the season (Fig. 24).

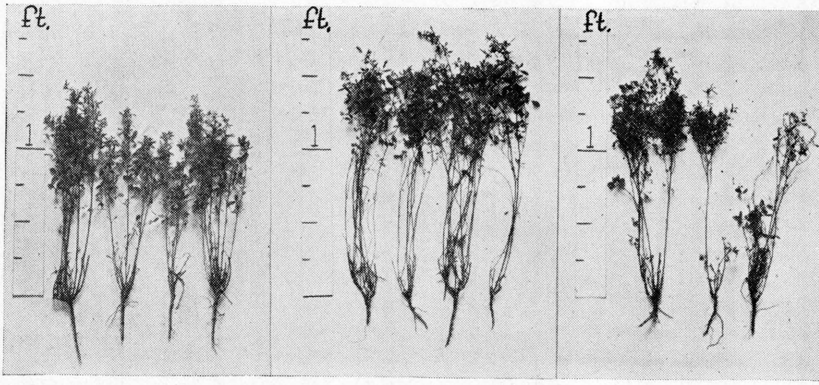


Fig. 24.—Effect of cutting on development of alfalfa, 1926

When the short, stunted growth at the left was cut July 19, the growth shown in the center was produced by September 10. When the stunted growth was not removed, little additional growth resulted, as shown at the right.

The season of 1931 furnished an illustration of the extent to which recovery at the top of the plant depends upon whether or not the plant has completely ceased growth. From July 16 to 21, 1931, nearly 4 inches of rain were received in well-distributed amounts, the first rains of consequence since 0.65 inch on June 21, with a deficiency of total rainfall in June. Plots were standing on Range 400 on which the previous cutting had been made June 8, June 10, June 13, June 17, June 27, and July 3. After these rains the growth on the plots cut July 3, which had not stopped growing, was greatly accelerated. The plots which had been cut on June 27 started a very vigorous growth from the upper parts of the shoots. The plots which had been cut on June 20 had been showing a few blooms when the rains came, but a considerable new growth started on these plots from among the flower heads. A week later the green of new growth was quite visible among the yellowed and stunted older growth (Fig. 25). The plots cut on June 13 and before were quite yellow when the rains came and were in the full-bloom stage or beyond. These plots produced no new growth from the tops of the plant. The plot cut June 17 produced only a few new shoots. The difference between it and the plot cut June 20 was quite pronounced, although there was only 3 days' difference in the age of the growth.

The relation of the shoots at the crown to the proper stage of harvesting.—Fifteen years ago the standard recommendation for cutting alfalfa in humid regions was to cut it when the shoots of the next crop could be found at the crown of the plant. Moore and Graber of the Wisconsin Agricultural Experiment Station (36, 37) were apparently the first to challenge with experimental data this almost universal recommendation. No specific attention has been paid to the shoots at the crown in planning these experiments, but their presence or absence has been noted when the various cuttings have been made. No single point is more evident from these experiments than that the presence or absence of shoots at the crown is of absolutely no value in deciding when to cut alfalfa in Ohio. In a dry season, shoots do not ordinarily form at the crown, regardless of the maturity of the alfalfa. In a wet season, they may form while the alfalfa is in the bud stage. It is true that in an ordinary, humid season there will frequently be shoots at the base when alfalfa is one-fourth to one-third in bloom and at the dates for cutting recommended in this bulletin. However, neither their presence nor their absence is important. A uniform growth of shoots, such as would be necessary to be of any value as an indicator of when to cut the crop, does not appear except when a prolonged drouth is broken by a heavy rain. An instance of this occurred in September 1925 on the two-cutting plot (Fig. 26). The old growth was very thin and yellow, in the seed stage, although almost no seed was present. A rain of 1.61 inches fell on September 12-15, the first rain of any consequence since an inch on August 13. The result was a prompt and uniform crop of shoots.

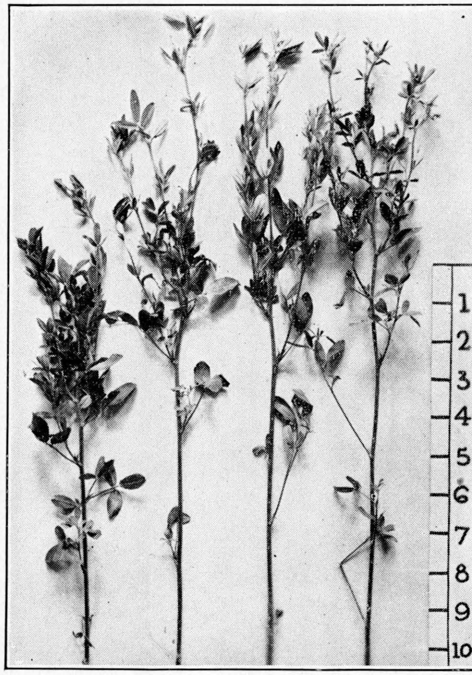


Fig. 25.—Vegetative growth following rains

Columbus, July 27, 1931. Four stems from a plot cut June 20, 1931. Good rains July 16-21, following a month's dry weather.

In irrigated regions, alfalfa is often irrigated several days before cutting in order to produce this development of new shoots and to bring the new crop on more promptly than would occur if irrigation was delayed until after the hay was removed. Since the crop is usually in need of water, the result is often a quick and uniform growth of new shoots. It seems possible that the idea of using the shoots as a sign of the time to cut originated from this practice.

Older articles and textbooks on alfalfa frequently make the statement that if these shoots at the crown become tall enough to be cut by the mower the next cutting will be injured. This has never proved to be true in these experiments. New shoots 6, 8, 10, and 12 inches high have repeatedly been cut in those systems where cutting is delayed beyond full bloom, and there has never been an instance in which the next growth has shown signs of being set back.

While moisture in the soil seems to be the most important stimulus in bringing on new shoots, observations suggest that light is also an important factor, if, indeed, it is not necessary to their starting. The new growth is usually much more extensive where the crowns have been exposed to light through lodging than where the alfalfa is not lodged or where the crowns have not been exposed. An extreme example was a Grimm alfalfa field in which the first cutting had not been made on July 1, 1928. One part of the field had lodged, and on this part the new growth was from 10 to 14 inches high. Another part of the field had not lodged and showed almost no new growth at the base.

Fig. 26.—Shoots at the crown

Plants from the 2-cutting plot, September 21, 1925, showing uniform vigorous growth of shoots at the crowns. 1.61 inches of rain fell September 12-15—no previous rain of consequence since 0.99 inch on August 13.

Another factor which sometimes modifies the appearance of shoots is the variety of alfalfa. On June 28, 1926, there were abundant shoots at the crown in the plot of Kansas common alfalfa, while Grimm alfalfa immediately adjacent showed no shoots whatever.

Relation of lodging to proper cutting of alfalfa.—The recommendation has been made (6, 55) that alfalfa should be cut promptly when it lodges. This is true insofar as the quality of hay is concerned (Fig. 27), but it does not seem to be true for yield of hay or for the benefit of the stand. The first cutting in these experiments lodged in 1925, 1928, 1929, and 1931, usually in the first week of June. There was more or less lodging at other times. Lodging is always associated with a vigorous, vegetative growth, and the general conclusion from these experiments would be to cut later than usual, rather than earlier, under such conditions (Table 53; Page 97). The rapid growth at such times often insures a fair proportion of leaves despite their dying off from the lower part of the stem. In the wet season of 1928, a sample of first-cutting hay on July 17 contained 32 per cent of leaves and 14.9 per cent of protein. Lodging is a decided detriment to the quality of alfalfa hay, but it is not clear that cutting early is a satisfactory answer to it. Nevertheless, situations have arisen in which practical growers have felt that it was essential that their alfalfa be cut on account of severe lodging, sometimes involving decay of considerable masses of material in the bottom of the swath.

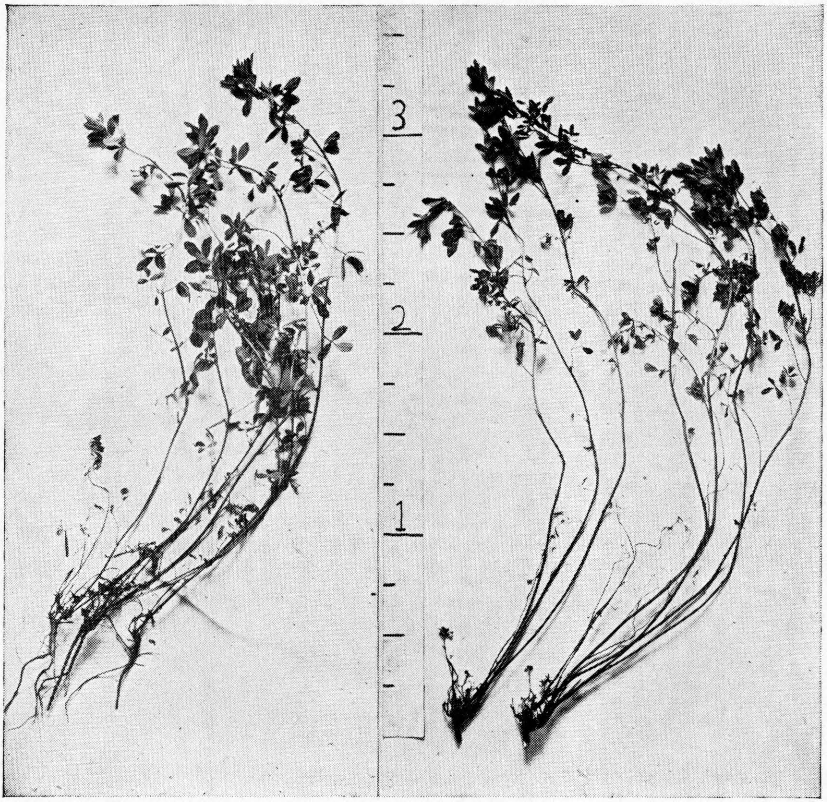


Fig. 27.—Lodging causes rapid loss of leaves

Left, alfalfa which has just lodged, June 4; right, alfalfa from the same locality 13 days later. Note that while the plants are nearly a foot taller there are no more leaves than earlier, so that the hay is very inferior.

What is the relation of the productivity of the soil to time and number of cuttings?—These experiments do not furnish any definite data on this question. They have been conducted on soil types of more than average value for alfalfa but rather uniform in their productivity for that crop. Farm experience indicates that on river bottoms, and perhaps on other unusually well adapted soils, alfalfa can be cut somewhat more often than these experiments indicate. Experiences in cutting alfalfa at the Southeastern Experiment Farm, on soils which are poorly adapted to the crop, indicate that, where alfalfa recovers slowly because of soil limitations, it cannot be cut as frequently as would be expected from the latitude in which the field is located. It seems likely, therefore, as might be expected, that the better the soil, the more frequently alfalfa on it can be cut.

Effect of time of cutting on height of growth.—While the height of the plants has been recorded for all the cuttings reported in these experiments, the point is of so little significance that it does not seem worth while to reproduce even a summary of the data. They agree with those of Salmon *et al.* (56); namely, that frequent cutting results in a greater total height growth for the season.

Relation of time of cutting to percentage of dry matter in the green alfalfa.—An objection frequently offered to early cutting of alfalfa is that it contains a high percentage of moisture at this time. Data on the percentage of dry matter in first-cutting green alfalfa at different stages are given in Table 58. Data from the second cutting are given in an earlier publication (72).

Since, immediately after cutting, alfalfa will lose at least 2 per cent of moisture per hour in any curing weather, the alfalfa cut May 23 would not take more than 6 hours longer to cure than that cut June 27, insofar as this one factor is concerned. Usually the difference in time of curing for alfalfa of different ages would be much less than this—it may lose from 6 to 8 per cent or more of moisture per hour.

TABLE 58.—Dry Matter in Green Alfalfa

Date	Dry matter in green alfalfa		
	Columbus		Holgate 1931
	1930	1931	
	Pct.	*Pct.*	*Pct.*
May 23	21.0	13.9	....
May 30	27.0	17.3	21.8
June 6	28.9	18.1	23.1
June 8	....	18.8	....
June 10	32.0	21.1	23.8
June 13	30.7	22.6	26.6
June 17	27.7	24.6	27.6
June 20	28.8	24.0	27.2
June 27	30.9	27.2	30.4

Effect of time of cutting on the market grade of the hay.—The time of cutting has a very important relation to the market grade; in fact, the U. S. standards for hay are to a large extent based on the stage of maturity of the hay. In the U. S. standards for alfalfa the factors affected directly by the time of cutting are the percentage of leaves and the percentage of green color. U. S. Extra Leafy Alfalfa must contain 50 per cent or more of leaves; U. S. No. 1 Alfalfa, 40 per cent or more; U. S. No. 2 Alfalfa, 25 per cent or more. The relation of time of cutting to this factor may be seen directly from Tables 46, 48, 52, and 53. However, in applying the figures in these tables it should be noted that they are for the amount of leaves in the alfalfa as cut, with no harvesting and curing losses. It was not feasible to base the tables on cured hay, because the effect of time of cutting would then be obscured by the particular curing weather which that sample experienced.

Salmon *et al.* (56) have estimated the loss of leaves in the curing process at 9.2 per cent of the total hay, or 19 per cent of the leaves in the hay. This figure seems a little high for hay cured by proper methods in Ohio. Kiesselbach and Anderson (31, p. 16) found that hay cured indoors contained 52 per cent of leaves, while that cured by the best field methods contained 48 per cent of leaves, a loss of 4 per cent. The same authors (29, p. 111; 30, p. 125) report losses amounting to 20 per cent where the hay was cured entirely in the swath but an average of only 5 per cent when the curing was conducted in the windrow or cock.

From these data it seems clear that the figures for leaf percentages in the tables in this bulletin should be reduced at least 5 per cent and, in some instances, up to 10 per cent to arrive at the leaf content of the hay which would have been made from the material by field curing. The data in Tables 46, 48, 52, and 53, interpreted in this way, show that it is only when the first cutting is made before June 7 that there is any likelihood of obtaining leaves enough in the hay for U. S. No. 1 Alfalfa. On the average, the recommended systems of cutting will produce U. S. No. 2 Alfalfa in the first cutting. The second cutting will make U. S. No. 1 in leaf percentage, unless excessive loss in curing is permitted; whereas there is an excellent chance of producing U. S. Extra Leafy in the third cutting and the third and fourth cuttings in a four-cutting system. A four-cutting system will also often produce U. S. No. 1 hay in the first cutting.

Attempts were made to measure the effect of time of cutting on the other grading factor, color. However, the loss in color which alfalfa undergoes before cutting is primarily due to attacks of diseases and insects, especially the potato leafhopper in Ohio. It soon became evident that the effect of time of cutting on color was to a considerable extent a measure of the effect of time of cutting on leafhoppers. This and other insects, as well as diseases, frequently reduce the color of Ohio alfalfa to a point where no curing method will make "U. S. Extra Green", or even "U. S. No. 1", hay of it.

Effect of time of cutting on the encroachment of weeds.—When an alfalfa stand is weakened or thinned in any way, weeds occupy the vacant spaces. Consequently, a common effect of too frequent cutting is excessively weedy hay. The four-cutting plots in 1928 and on Range 400 in 1932 and 1933 were decidedly weedier than the two- and three-cutting plots. One important reason for this in the first cutting is that the weak fall growth on the frequently-cut plots is not sufficient to smother out seedlings of winter annuals.

The relation of variety to proper time of cutting.—It is sometimes claimed that the variegated alfalfas will stand earlier and more frequent cutting than the common alfalfas. It is true that the variegated strains are, in general, more vigorous than the common strains in this section, and, consequently, they are likely to appear better than the common strains under any set of conditions. Thus, where two series of plots—one of variegated alfalfa and the other of common—are subjected to identical cutting treatments, as has been done at Holgate, some plots will be found in which the effect of cutting treatment was just severe enough to injure the common alfalfa severely, or to an unprofitable point, while the corresponding variegated plot, though markedly injured, survived. However, Grimm alfalfa at Holgate was no more outstandingly superior to Utah common alfalfa in the time-of-cutting plots than in many other comparisons on the farm which have received normal cutting treatments. Different varieties made up the time-of-cutting plots in 1926-1927-1928, as well as the Holgate comparisons, and at no time has there been an indication that there is any fundamental difference in the responses of varieties to cutting at different stages. Ladak (Page 44) may be an exception, but no data are available at this time.

Comparative value of different cuttings.—Much alfalfa hay is sold merely by the cutting—"First-cutting hay", "Third-cutting hay", etc. It is evident from these studies that such designations have only a very limited value. Some first-cutting hay is better than some second-cutting, and vice versa. In Ohio, because of the winter and spring rainfall, the first crop tends to be coarser stemmed than the later ones, although there have been years, 1931 for example, when the second crop was coarser than the first. The comparative protein content of the first and second crops is largely a matter of the relative time of making the two cuttings. The second crop is usually leafier, stage for stage, than the first. If the second cutting is made on July 28 or later, the third-cutting hay, or any crop that grows after July 28, is almost certain to be higher in leaves and protein than the two preceding. The high value of this late-cut hay is sometimes overlooked in deciding whether or not to make a third cutting. Such hay is especially valuable for swine and poultry.

Percentage of the total hay obtained at different cuttings.—In planning the year's operations, it is desirable to know what proportion of the hay may be expected in each crop (Tables 48 and 51). When three normal cuttings are made, about half the hay is obtained at the first cutting, from 25 to 35 per cent at the second, and from 20 to 25 per cent at the third. About two-fifths of the total yield for the year is obtained at the first cutting when four cuttings are made, and about two-thirds when only two are made. The relative size of the second and third crops depends quite considerably upon the distribution of the rainfall. A larger proportion of the year's hay is obtained in the first cutting of variegated than of common alfalfa (Table 25).

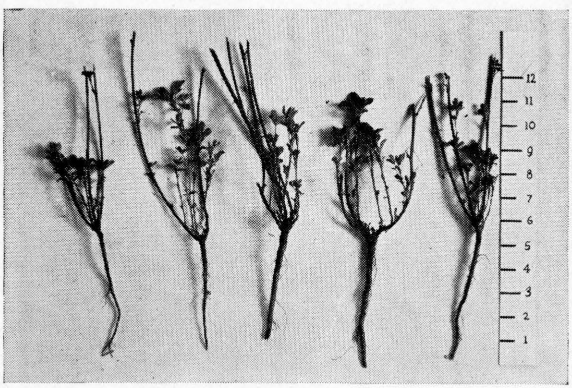


Fig. 28.—Effect of cutting alfalfa with a high stubble

Note that only very weak shoots appear near the tips of the high stubble and that where more than one shoot starts on the same branch the most vigorous is the one nearest the crown.

The effect of the height of cutting on alfalfa.—While no specific experiments in which the height of cutting has been varied have been conducted, in the course of the experiments observations bearing on the question have been made. In the course of taking hundreds of square-yard samples it has happened that they have been cut considerably closer to the ground than the mowing machine would do. No injurious effect of this close cutting has ever been seen on alfalfa, although at Holgate in 1930 red clover was almost killed in this way but was not seriously injured by the ordinary height of cutting with the mowing machine. At all times in the time-of-cutting work the mowing machine has been set at its normal height, practically as low as it could be set. At no time in the 8 years' work has there been the slightest injury apparent, despite the fact that cuttings have been made at many stages of growth and under many conditions. Where alfalfa has been accidentally cut with a long stubble (Fig. 28), either no shoots whatever start along the stem or those which do start are soon outgrown by those starting at the crown. The strongest shoot is always the one nearest the crown.

THE EFFECT OF TIME OF CUTTING ON THE STORAGE OF ORGANIC RESERVES IN THE ROOTS

The fact that cutting alfalfa at immature stages reduces its root reserves has been shown by several previous writers, including McKee (35), Nelson (38), Garver (19), Graber *et al.* (21), and Salmon *et al.* (56).

Yields of roots following different cutting systems.—In the first 4 years of this study samples of roots were taken at every cutting of the alfalfa. The data on yield of roots from these 4 years have been published (68, 69), but for completeness these data are given with additional data in Table 59. This table shows clearly the rapid loss in stand and amount of root reserves from making five cuttings, and the slower but serious loss from making four cuttings a year, except in 1925, which was a dry year.

The most significant single measure of the effect of a cutting system on the roots in a stand of alfalfa is the weight of roots with which the stand goes into the winter. Since 1928 most of the root samples from the different cutting systems have been taken in November, or in March before growth started; however, some others have been taken, as indicated in Table 60. The data on the amount of roots in November in the five longest continued cutting systems are collected in Table 61. These data indicate that all the two-cutting and three-cutting systems have maintained root reserves at least moderately well. There is a very distinct tendency for the four-cutting plot to give a lower yield of roots than the others, although there are exceptions.

It is noticeable that the two-cutting plots show no consistent tendency to give greater root yields than the three-cutting plots. In 1925-1928, samples were taken in the two-cutting plots about a month before the final harvest, approximately at full bloom, as well as on the date of cutting. An average of six such comparisons indicated 2190 pounds of roots per acre at full bloom and 2080 pounds a month later. Insofar as these figures go, there is no indication of additional root storage after the full-bloom stage. However, it should be emphasized that these data were secured in plots which were yellowed and had lost a considerable proportion of their leaves through diseases and leafhopper attacks, so that they constitute no criterion of what might happen in a region where the leaves remained healthy. Even under these conditions no injury to the stand has ever resulted from failure to cut alfalfa. In some instances the two-cutting plots have recovered after cutting with a "punch" and vigor which indicated that they acually had stored more reserves than the other plots. It is reasonable to suppose that they would store additional reserves, if any considerable proportion of healthy, green leaves remained on the stems for some weeks, without producing vegetative growth. If photosynthesis continued beyond the needs of respiration, the product must have gone to the roots.

The objection to two cuttings at Columbus is not in its effect on root reserves or stand; it is simply that the amount and quality of hay harvested are greatly reduced by making so few cuttings.

TABLE 59.—Effect of Number of Cuttings of Alfalfa on Amount and Composition of Roots

Experiments I and II, Columbus

	Yield of air-dry roots per acre				Plants per square yard				Nitrogen in roots			
	1925 1st year	1926 1st year	1927 2nd year	1928 3rd year	1925 1st year	1926 1st year	1927 2nd year	1928 3rd year	1925 1st year	1926 1st year	1927 2nd year	1928 3rd year
	Lb.	*Lb.*	*Lb.*	*Lb.*	*No.*	*No.*	*No.*	*No.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Cut 5 times												
1st cutting	1600	1080	....	....	235	199	6	....	1.88	2.18	....	....
2nd cutting	1390	990	....	....	192	184	....	....	2.04	1.86	....	....
3rd cutting	1490	1480	....	....	188	178	....	....	1.80	1.98	....	....
4th cutting	1750	1400	....	....	174	195	....	....	1.75	1.92	....	....
5th cutting	1680	1040	....	....	185	138	....	....	1.70	1.80	....	....
Early November	1900	1250	....	....	170	129	....	....	1.96	1.92	....	....
Cut 4 times												
1st cutting	1510	....	1130	1520	182	....	96	52	1.92	....	1.73	2.08
2nd cutting	1890	1490	1050	1120	211	161	90	51	2.21	1.86	1.97	1.83
3rd cutting	2400	1740	1170	1010	199	250	96	41	1.86	1.97	1.76	1.56
4th cutting	2540	1660	1300	1020	200	126	91	32	1.75	2.00	1.71	1.68
Early November	2710	1890	2090	1240	210	185	70	27	1.98	1.79	2.11	1.79
Cut 3 times												
1st cutting	1630	1750	1820	1770	197	174	124	52	2.73	2.27	2.25	2.14
2nd cutting	2220	2120	1620	2070	161	145	96	63	2.26	2.00	1.94	2.04
3rd cutting	2700	2400	2340	2820	165	167	93	73	2.02	2.45	1.92	2.17
Early November	2840	2150	2740	3040	172	151	92	67	1.97	2.22	2.16	2.14
Cut 2 times												
1st cutting	2010	1590	2150	2430	198	171	141	70	2.63	2.44	2.18	2.26
2nd cutting	2420	2070	1700	1800	173	116	102	52	2.21	2.29	1.95	2.11
Early November	2740	2200	2040	2170	206	181	83	60	2.21	2.26	2.00	2.07

TABLE 60.—Yields of Roots per Acre from Different Systems of Cutting. Experiments III, IV, and V, Columbus; Range 14, Holgate

Based on one square-yard sample from each plot, except Range 1400, 1930, two samples

System of cutting	Range 1400, sown 1928			Range 400, sown 1929										Range 600, sown 1931		Holgate 1932		
	1929 Nov.	1930 Nov.	1931 Mar.	1930 Nov.	1931 Mar.	1931 1st cutting	1931 2nd cutting	1931 3rd cutting	1931 4th cutting	1931 Nov.	1932 Mar.	1932 Sept.	1932 Nov.	1932 Sept.	1932 Nov.	Grimm	Common	Av.
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
1—May 31, July 10, Aug. 25	2460	3460	3770	3660	3730	2980	2560	2490	....	3620	3470	......	......	1950	2700	4220	3780	4000
2—May 31, July 15, Sept. 3	2330	3400	3150	4870	3690	2860	3040	3310	....	3410	3170	3590	4320	1830	1810	5170	4350	4760
3—May 31, July 3, Aug. 7, Sept. 10	1780	3340	4380	3160	3090	3330	2740	2660	2270	2920	3020	2440	2890	1810	1600	3040	3520	3280
4—May 31, July 21, Sept. 10	2350	4480	3480	3480	3250	3240	3050	2490	....	3500	3670	......	......	2380	2800	3680	4800	4240
5—June 7, July 21, Sept. 3, Nov. 1	3290	4260	3930	3700	3320	3230	3090	3130	3780	3780	3350	......	......	3140	3040	4280	3820	4050
6—June 7, July 21, Sept. 3, Nov. 1	2940	3460	3100	4320	3590	3470	3480	3420	3730	3730	3470	3480	4200	2820	3550	5070	4900	4980
7—June 7, July 21, Sept. 3, Oct. 15	1960	3830	2810	3500	3300	3060	3430	4020	3740	3660	3010	2920	3890	2420	2320	4360	4340	4350
8—June 7, July 21, Sept. 3	2190	5240	4740	3800	3650	3250	2860	3070	....	3270	3130	2890	3980	2520	2590	4370	2980	3680
9—June 10, July 28, Sept. 10	2740	4990	4120	3320	2900	3340	2760	2590	....	3070	3420	2830	3970	1760	2900	5100	3590	4340
10—June 13, July 28, Sept. 10	3450	4560	4270	3300	3630	3190	2670	2580	....	3950	3350	3470	4930	......	......	4530	4070	4300
11—June 17, July 31, Sept. 10	3190	4610	4310	3210	3170	2880	3050	3330	....	3510	3810	3620	3970	......	......	3970	2900	3440
12—June 20, July 31, Sept. 10	2900	4260	3860	2850	3830	3050	2700	3100	....	4620	3170	3430	3380	......	......	4590	3840	4220
13—June 20, Aug. 25	3130	4360	5800	2820	3960	3220	2460	....	....	3330	3470	......	......	......	......	4320	3110	3720
14—June 27, Sept. 10	2530	4550	4380	3130	4030	3370	2910	....	....	3380	3370	3240	3430	......	......	4530	5150	4840
15—June 27, Aug. 7, Sept. 20	2620	4640	4180	3560	3340	2800	2420	3630	....	3130	3490	3580	3540	......	......	4420	2790	3600
16—June 27, Aug. 16, Sept. 30	2990	3470	4260	2910	2820	3220	2540	2510	....	3140	2150	2940	3270	......	......	4370	3910	4140
Average	2660	4160	4060	3350	3370	3090	....	....	....	3360	3260	3120	3660	2230	2480	4380	3870	4120
Nitrogen in roots, average, per cent	2.40[12]	2.40[12]	2.94[6]	2.59[10]	3.35[5]	2.25[3]	2.03[3]	2.24[1]	1.90[1]	2.27[3]	3.04[4]	2.50[3]	2.39[3]	2.52[3]	2.52[3]	......	......	......

Superscript figures=number of samples averaged.

TABLE 61.—Effect of Different Cutting Systems on Storage of Root Reserves

Year and range	Yield per acre of roots in November				
	(1)	(2)	(3)	(4)	(5)
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*
1926 (800)	1890	2150	1820	1840	2200
1927 (800)	2090	2740	2790	2520	2040
1928 (800)	1240	3040	2140	3180	2170
1929 (1400)	1780	2740	2350	3130	2530
1930 (1400)	3340	4990	4480	4360	4550
1930 (400)	3160	3320	3480	2820	3130
1930 Average	3250	4160	3980	3590	3840
1931 (400)	2920	3070	3500	3330	3380
Average 6 years	2200	2980	2760	2930	2690
1932 (400)	2890	3970	....	....	3430
1932 (600)	1600	2900	2800	....	....
1932 Holgate, Av. Grimm and common	3280	4300	4240	3720	4840

(1)=4 cuttings, approximately May 31, July 3, August 7, September 10.
(2)=3 cuttings, approximately June 10-14, July 28, September 10.
(3)=3 cuttings, approximately May 31, July 21, September 3.
(4)=2 cuttings, approximately June 21, August 25.
(5)=2 cuttings, approximately June 28, September 10.

Changes in alfalfa roots during recovery from cutting.—In 1925, 1926, and 1927, samples were taken approximately 2 weeks after cutting, as well as on the date of cutting, in order to measure the effect of the recovery after cutting on the roots. The data from 35 comparisons indicated an average loss in air-dry weight of roots of 177 pounds per acre during recovery after cutting. As an average of 23 comparisons, the dry weight of the roots was 33.4 per cent of the green weight on the date of cutting and only 28.7 per cent 2 weeks later, a difference of 4.7 per cent. Thus, as an average, the water taken up more than replaced the dry matter lost, so that the green weight of the roots did not usually decrease during recovery after cutting. The percentage of nitrogen in the roots averaged 2.06 per cent on the date of cutting and 1.89 per cent 2 weeks later, a difference of 0.17 per cent as an average of 35 comparisons. This indicates, as would be expected, that the protein reserves are drawn on to a greater extent than the carbohydrate reserves in starting new growth.

The effect of the time of making the last cutting in the fall on root storage.—A tendency to use the products of photosynthesis for storage, rather than for growth, as cool weather comes on is present in many plants, notably in sweet clover (67). Presumably, reduced respiration at the lower temperatures is one factor in this greater root storage. Although the plants have never bloomed, considerable root storage in alfalfa has always occurred between the date of making the last cutting and freezing weather. It seems reasonable to suppose that, if the last cutting is made early so that the alfalfa stand reaches October 1 with a large area of healthy leaves, a greater root storage will result than if the last cutting is made late. In this case, the root reserves are reduced to start the new growth, and there is only a short time in which to manufacture reserve foods with a comparatively small leaf area. This expectation is borne out by the data in Table 62, showing that some storage takes place in the fall, even when the last cutting is made late, but that when the last cutting is made early much greater storage takes place. This was true even in 1930, when an unusual amount of storage had taken place in the summer. The 1930 data from the Hamilton County Experiment Farm (Table 64) also indicate considerable fall storage.

For many years practical growers have recognized that making the last cutting late was likely to result in winterkilling, but this was usually attributed to the need of a "good growth" to act as a mulch. There is no possible question but that the mulch is important in reducing winterkilling, but these data suggest that the necessity for root storage is a more important reason for making the last cutting early.

If this suggestion is true, taking off the late growth on November 1 or after, when root storage is completed and there is no opportunity for exhaustive new growth, should not be as injurious as cutting September 20 to October 15. In theory, it should not cause any injury except as the removal of the growth deprived the stand of the protection of that much mulch material. The yield data from Systems 5-8, already discussed (Page 100), support this theory.

TABLE 62.—Storage in Alfalfa Roots After Last Cutting in Fall, Columbus

Year	Date of last cutting	Number of comparisons	Yield of roots per acre		
			Last cutting Lb.	Early November Lb.	Gain Lb.
	Last cutting made late				
1925	Sept. 23	16	2340	2550	210
1926	Sept. 25	16	1750	1820	70
1931	Sept. 20 to Oct. 15	3	3290	3310	20
1932	Sept. 20 to Oct. 11	4	3260	3400	140
	Weighted average	39	2260	2390	130
	Last cutting made early				
1927	Sept. 15	12	1770	2410	640
1928	Sept. 11	14	2030	2360	330
1929	Sept. 3	3	1330	2580	1250
1930	Sept. 3-8	33	2630	3280	650
1931	Aug. 25 to Sept. 10	16	2780	3460	680
1932	Aug. 25 to Sept. 10	22	2730	3130	400
	Weighted average	100	2450	3020	570

Sylven (60), in discussing the date of making the last cutting in the fall, reports a series of experiments in which "the later the third cut was taken—the better was the yield in the following year". However, Sylven made the second cutting on the same date on all of his plots, so that the earliest of the third cuttings was made only 18 days after the second. The later cuttings were made at 2-week intervals and thus were of increasingly mature alfalfa. Under these conditions it is to be expected that the later cuttings would be increasingly favorable (Fig. 20). Nevertheless, it is significant that at Svalof, Sweden (Lat. about 56° N.), it was possible to cut alfalfa, as Sylven did, on July 6, August 23, and October 24 without apparent injury to the stand.

The relation of the time of cutting alfalfa to the weather.—It was noted in an earlier paper (69) that the storage of reserve materials in the roots was favored by dry weather. The unprecedented drouth of 1930 gave an opportunity to confirm these observations and show their wider significance.

From April 1 to June 15, 1930, the total rainfall on the University Farm at Columbus was 2.74 inches, as compared with a normal rainfall of 8.08 inches for this period. As a result, alfalfa hay made a very short growth and a much lower yield than normal, the average of all first cuttings on Range 1400 in 1930 being only 68 per cent of those on the same range in 1929. However, when alfalfa roots were dug in June, it was evident at once that the roots were much larger than a month earlier—so much so that the men digging the roots commented on it.

TABLE 63.—Yields of Alfalfa Hay and Roots in 1930, Columbus

Range	Samples averaged	Yield per acre				Gain per acre		Gain per acre per day	
		May 2		June 5–14					
		Hay	Roots	Hay	Roots	Hay	Roots	Hay	Roots
	No.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
1400, sown 1928.........	3	2360	1860	3110	3220	750	1360	22.1	40.0
400, sown 1929.........	2	2860	1130	3620	1960	760	830	22.3	24.4
500, sown 1929.........	1	1590	1140	3060	2650	1470	1510	34.2	35.1
Weighted average....	6	2400	1500	3270	2700	870	1200	24.2	33.7

Comparisons based on six square-yard areas in three ranges are reported in Table 63. These data indicated an average gain in weight of roots from May 2 to early June of approximately 34 pounds per acre per day. The highest previous gain during this period of which there is any record in these experiments was 22 pounds per acre per day, while the average gain in 15 records covering approximately this period in previous years was 6.7 pounds per acre per day. From May 2 to early June, alfalfa in 1930 put almost half again as much material into the roots as into hay.

TABLE 64.—Weight of Alfalfa Roots per Acre in November 1930, with Yields at Earlier Dates Where Available, Showing Effect of Dry Season on Root Storage

Source of samples	Samples averaged			Yield of roots per acre		
	Nov. 1929	Sept. 1930	Nov. 1930	Nov. 1929	Sept. 1930	Nov. 1930
	No.	*No.*	*No.*	*Lb.*	*Lb.*	*Lb.*
O. S. U. Range 1400, sown 1928....................	19	3	38	2660	3150	4160
O. S. U. Range 400, sown 1929.....................	2	4	24	1850	2760	3350
O. S. U. Variety range, 800 S, sown 1929 (Adapted strains)............................	4	16	16	1560	2720	3220
O. S. U. Variety range, 800 S (Non-adapted strains)................................	4	8	8	1020	2170	2680
O. S. U. Variety range, 800 N, sown 1925.........	2	....	4	3640	....	3890
O. S. U. Range 1500, sown 1929....................	2	2	2	1860	2490†	2810‡
O. S. U. Range 500, sown 1929.....................	1	2	2	1450	2660	3980
Paulding County Expt. Farm, sown 1927.........	....	....	20	....	....	3520
Hamilton County Expt. Farm, sown 1928 (Variety series)................................	10	5	10	2450*	3040	3700
Hamilton County Expt. Farm, sown 1928 (Date of cutting series).......................	....	8	6	....	3360	3970
Southeastern Expt. Farm, sown 1929............	....	....	6	....	....	2450
Northwestern Expt. Farm, sown 1929............	....	12	....	....	2660	....
Weighted average, November 1930...........	....	....	136	....	....	3580

*April 1930. †August 19, 1930. ‡October 21, 1930.

Table 73 indicates that this storage continued, although not at such a rapid rate, throughout the summer, which continued to be abnormally dry. A large number of samples was taken in the late fall of 1930. These are summarized, together with comparable earlier data, in Table 64. These data from 196 square-yard samples from Columbus and four of the outlying farms in September and November of 1930 show that alfalfa went into the winter of 1930-1931 with unprecedentedly high reserves. The average of 136 early November samples is 3580 pounds of roots per acre. In the Columbus experiments the average weight of roots in November has been about 2500 pounds per acre in plots cut three times or less. Consequently, in November 1930, alfalfa sown before 1930 went into the winter with an average of about 1000 pounds per acre more roots than normal. This situation was at least partly responsible for the very high yields of alfalfa in 1931, reported in this bulletin.

It should, perhaps, be pointed out that dry weather cannot induce larger root storage unless the root system is established before the drouth. Seedings made in small grain in 1930 did not go into the winter with as large root reserves as usual (Table 81).

The hay yields in 1930 were in marked contrast to the root yields. On Range 1400 the 1930 hay yields were only 53 per cent of the 1929 yields; whereas on the variety ranges the yields were less than half of those in 1929. The average hay production of all 20 plots on Range 1400 was 5070 pounds per acre. The increase in roots from November 1929 to November 1930 on Range 1400 was 1500 pounds per acre, nearly one-third the hay yield. At Wooster, alfalfa yielded as much in 1930 as the 11-year average, while red clover and timothy did not (50, p. 48).

The effect of frequent cutting in 1930.—It was quite evident in the field that in 1930 frequent cutting did not exhaust the plots as it does in normal seasons. There were no plots which were cut five times, but several plots were cut four times at widely varying intervals, and they were indistinguishable from the three-cutting plots in vigor of recovery. Even the four-cutting plot on Range 1400, which was severely weakened in 1929, gained strength and vigor throughout 1930 and was nearly as good as its neighbors by November 1930.

This conclusion from observation of the plots is supported by comparing the yields of roots from the two-, three-, and four-cutting systems in dry seasons and in normal seasons (Tables 59 and 60). In 1930 and in the previous dry season, 1925, the roots were nearly equal in three and four cuttings, especially when not previously weakened as they had been on Range 1400. In the normal seasons, there is usually a decided contrast in the amount of roots.

Correlation of gains in root reserves with rainfall.—Since this general relation between root storage and dry weather had been found to hold more or less throughout the study, an attempt was made to correlate root storage with rainfall. In order to have comparable measures, root storage was reduced to average daily gain and rainfall to average daily rainfall. It is obvious that rainfall coming just before cutting a crop influences the next crop rather than the one on which it falls. The writer knows of no way of accurately determining how far this effect extends. Based on field observations, the gain in roots during one period was correlated with the rainfall for the same number of days, beginning, however, 5 days before the first cutting or record and ending 5 days before the plot was cut. As specific examples, a root gain during a second crop, in which the first cutting was made June 11 and the second July 19, was correlated with the rainfall from June 6 to July 13, both dates inclusive, and a root gain during the growth of the first crop, in which a root sample was taken May 6 and the plot cut June 11, was correlated with the rainfall from May 1 to June 5, inclusive. Since very immature alfalfa has little opportunity to store reserves (Page 114) even in dry weather, only those records which covered 34 days or more were included. The gains from the last cutting to November were also omitted, since cool weather has been favorable to storage in wet seasons as well as in dry. All available records were included, whether from the specific time-of-cutting experiments or not.

Altogether there were 61 records selected as described above. The correlation between the average daily gain in roots and the average daily rainfall was —0.44±.07. When one considers the assumptions made above and the very large possibility of sampling errors (inasmuch as most of the gains or losses from one date to the next were based on averages of only two square-yard samples for each date), this correlation seems fairly significant.

Practical importance of the relation of root storage and rainfall.—It has long been recognized in practice that stands of alfalfa west of the Missouri River live longer and can be cut more frequently with less injury than those east of the Mississippi. Manhattan, Kansas, for example, is only about 60 miles farther south than Columbus, and yet Salmon *et al.* (56) cut alfalfa four times a season for 8 years without serious loss of stand; whereas four cuttings completely killed plots at Columbus in 3 years. In fact, Salmon cut alfalfa five times every year but two for 8 years without as serious weakening and loss of stand as was produced here in 3 years of making four cuttings.

It seems clear from the preceding discussion that during a dry season alfalfa uses a smaller proportion of the materials produced by photosynthesis in top growth and a larger proportion in root growth. This is, indeed, a general phenomenon in root-top ratio studies. As a consequence, the western farmer in a dry climate can cut his alfalfa rather carelessly, and the climate will prevent the exhaustion of root reserves, as it did here in 1930. The eastern farmer, on the other hand, is in a climate which favors exhausting the last bit of reserve material from the roots into the tops. If he does not take special precautions in cutting, his alfalfa may be weakened and killed by cutting at intervals which would not be injurious farther west.

The relation of root storage and climate helps to explain the decidedly conflicting results which have been secured by eastern and western Stations on the time of cutting alfalfa. It also explains the conflicting results secured in different years here; for example, the results in 1925 and 1926. In 1925 four cuttings, the last one late, produced no injury, and five cuttings, only moderately severe injury; in 1926, four cuttings injured, and five cuttings destroyed, the stand.

How can the eastern farmer overcome this climatic handicap in alfalfa production?—Obviously, this climatic handicap cannot be entirely overcome. The Ohio farmer cannot hold alfalfa stands as long as the western farmer, even with the best of treatment. Indeed, he can hold them for 3 or 4 years only by cutting, on the average, at somewhat later stage of maturity and, hence, obtaining a somewhat lower quality of hay than the western farmer.

However, an excellent quality of hay can be made and still maintain root reserves at a satisfactory point if the last cutting is made early enough in the fall so that there is a healthy growth present in October to put reserves into the roots when the cool weather favors such translocation. This growth seems to be standing still in October, but it is not. It is adding reserve materials to the roots which will enable them to resist winterkilling and to make growth next year.

THE EFFECT OF LEAFHOPPERS ON ALFALFA

Observations of alfalfa yellowing.—For as long as alfalfa has been grown in the east, a mysterious "yellowing" has troubled growers. In 1927, Section F was cut June 8, the same day that the variety range was cut. The variety range made a normal recovery; Section F became intensely yellow in early July, was stunted and somewhat low-yielding, and did not recover well after the second cutting. On asking for an explanation, the writer was told of the recent papers of Jones and Granovsky (28) and Hollowell, Monteith, and Flint (25) proving the potato leafhopper to be the cause of such yellowing. The case was then perfectly clear; Section F immediately adjoined Section H, which was cut June 21. When Section H was cut the leafhoppers moved over to Section F, causing an abnormal infestation and damage. The side next to Section H had been noted as more stunted and yellow than the opposite side, but the plot was only 20 feet wide and most of it was affected. The variety range, while distinctly yellowed as the second cutting usually is, did not have this abnormal load.

Fig. 29.—"Border Effect" of leafhoppers on alfalfa

Third growth, August 29, 1932. Foreground, cut July 14; center rectangle, cut July 25. Note excessively yellowed and stunted border surrounding the later-cut area.

The same thing happened to a less degree several other times in the 1926-1927-1928 experiments on Range 800. The results from Section F have been partially discarded because of their abnormality. Sections G and H, the two-cutting areas, were the outside sections of the range. It may be that the poor showing made by the two-cutting sections in 1926-1927-1928 was in part due to this unfavorable position in the range (Page 127).

In 1928 sweet clover adjacent to a field of alfalfa was cut July 12. Soon after this, the alfalfa next to the sweet clover became very yellow. This alfalfa was cut July 28, and samples of hay from the middle of the field and from the yellowed part were cured carefully to prevent change in color. These samples were sent to the Hay, Feed, and Seed Division of the U. S. Department of Agriculture for color analysis. The hay from the center of the field had 84 per cent green color, enough for U. S. Extra Green Alfalfa; whereas that from the yellowed border had only 54 per cent green color, so that it could not have made hay of a higher grade than U. S. No. 2 Alfalfa.

On July 17-18, 1928, four swaths were mowed along the edge of another alfalfa field. The main field was cut July 28. The first cutting had been made June 12, and the sudden yellowing of the new growth on the early-cut strip was so conspicuous that the effect was certainly due to leafhopper invasion. By September, the early-cut strip was completely overgrown with weeds. The combination of leafhoppers and weeds damaged this strip so that it never recovered.

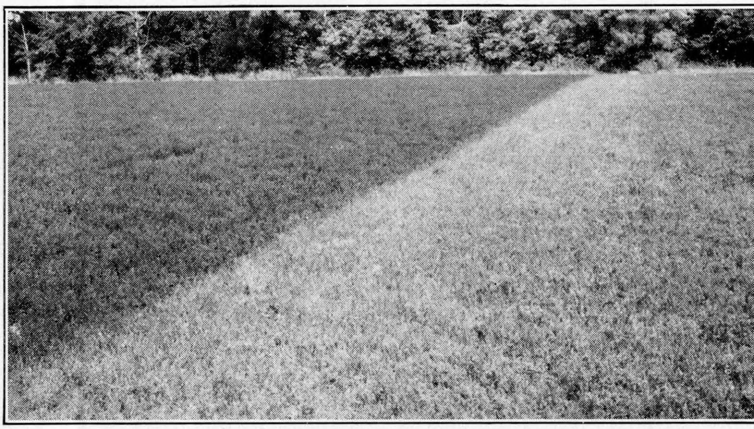


Fig. 30.—Making the second cutting early results in yellowing by leafhoppers

Third growth, August 29, 1932—Left, cut July 25; right, cut July 14. Note extremely stunted and yellowed border between the areas.

The same "border effect" has been noted many times since, but it is not worthwhile to multiply instances. A particularly striking example is shown in Figures 29, 30, and 31, taken on a farm near Columbus. However, it should be pointed out that this serious injury to the alfalfa in a few swaths cut several days before the remainder of the field has often been erroneously attributed to the weakening effect of too early cutting.

Experimental studies of leafhoppers on alfalfa.—Studies of the relation of leafhoppers to time of cutting and other alfalfa problems have been continued since 1928. In addition to taking notes on this aspect of the regular experimental work, considerable work has been done directly on this problem. An attempt in 1929 to measure the effect of leafhoppers in reducing the yield of the third crop failed because no leafhopper damage developed in the check.

In 1930, Paul E. King, a graduate student in Entomology at the Ohio State University, studied alfalfa leafhopper problems under the joint direction of Dr. Herbert Osborn[11] and the senior author. Mr. King attempted to produce hopper-free alfalfa by a combination of cheesecloth barriers and occasional spraying. He put cheesecloth barriers around two 7 x 15-foot plots—one barrier 3 feet high, the other 5 feet. In addition, the plots were sprayed five times with pyrethrum spray.

[11]Associate in Entomology, the Ohio Agricultural Experiment Station; Research Professor of Zoology and Entomology, The Ohio State University.

Unfortunately for the experiment, the hot, dry season of 1930 killed most of the leafhoppers, and there was very little leafhopper damage. The barriers caused or permitted the alfalfa to grow decidedly taller than that outside, but the yields, given in Table 65, were not different. This lack of leafhopper damage and the actual dying out of the populations in the hot, dry weather was the most significant feature of the 1930 study of the leafhopper problem.

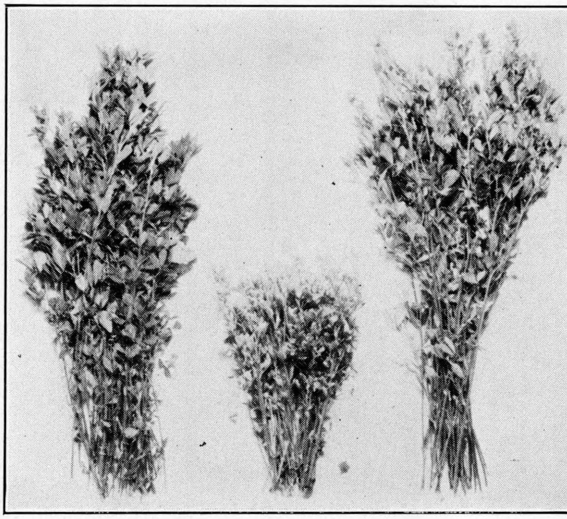


Fig. 31.—Quality of third-cutting hay as affected by date of making the second cutting

Typical bunches from each section of area illustrated in Figure 30. August 29, 1932—Left, cut July 25; right, cut July 14; center, border between the two areas, cut July 14.

In 1931, 1932, and 1933, leafhopper studies were conducted in cooperation with Dr. F. W. Poos and Mr. M. V. Anthony of the Division of Cereal and Forage Insects, Bureau of Entomology, United States Department of Agriculture. Mr. Anthony has done the field work.

TABLE 65.—Effect of Spraying with Pyrethrum on Yield of Alfalfa

Year and crop	Yield per acre	
	Sprayed	Not sprayed
	Lb.	*Lb.*
Range 400		
1930—2nd	1430	1430
1931—2nd	3310	3250
1931—3rd	2910	2390
1932—2nd	3540	3510
1932—3rd	2260	2090
Range 800		
1932—2nd	4000	4100
1932—3rd	2420	2220

Spraying with pyrethrum to avoid border effect of leafhoppers.—In order to avoid the abnormal border effect from migrating leafhoppers and still use small plots for time-of-cutting studies, the plan was developed of spraying each plot with a pyrethrum-oil spray just before it was cut. This was done by using one ounce of a standard pyrethrum-oil spray and one ounce of a potash – coconut oil soap to 3 gallons of water. Although this solution is about twice as strong as that recommended by the manufacturers, it did not injure the alfalfa, and it was thought desirable to be reasonably sure of killing most of the leafhoppers. The spray was applied with several types of hand sprayers, making as fine a mist as possible with such equipment.

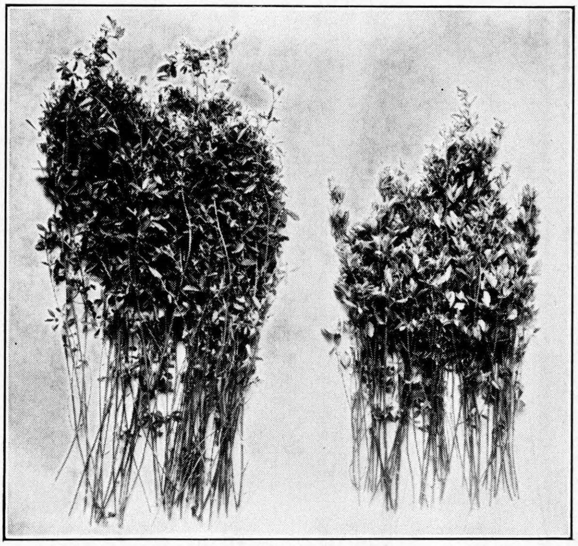


Fig. 32.—Spraying prevents leafhopper yellowing

Columbus, July 24, 1931—Left, sprayed with pyrethrum-oil spray; right, not sprayed. Previous cutting, June 8. Both samples came from the border of the plot so that the unsprayed sample is much more yellowed than the average of the plot, but, since the sprayed sample had the same exposure, the protective effect of spraying, under extreme conditions, is not exaggerated. Extreme height of left-hand sample, 27 inches.

This treatment killed most of the leafhoppers on the plots at the time they were cut, so that there was less migration to adjacent plots. This plan was followed in 1929, 1931, and 1932 and appeared to be largely successful in preventing the serious border effect which had interfered so much with the work in 1927 and 1928. However, since the hoppers leave old alfalfa even before it is cut, this was not a complete protection. Moreover, it should be noted that, if large areas of alfalfa are nearby, leafhopper migration from them may seriously influence blocks of an acre or more. While this migration is an important difficulty in using small plots for time-of-cutting work, there is reason to believe, from comparisons with farm fields cut on the same dates as the small experimental plots, that the yields presented in this bulletin are not materially affected by this source of error and the composition only slightly so. The plots at Holgate have not been sprayed.

Varietal resistance to yellowing.—The variegated varieties, in general, and the variety Hardigan, in particular, have shown less yellowing from leafhoppers than common alfalfa on adjacent plots. Possibly part of the advantage of variegated over common alfalfa in seasons of little or no winterkilling and of Hardigan over other variegated strains is due to this greater resistance to leafhopper injury.

Effect of leafhoppers on yield and composition of the hay and roots.—Mr. Anthony sprayed plots of alfalfa with pyrethrum in 1931 and 1932 in order to measure on a field scale the loss in yield due to normal leafhopper infestation. The spraying prevented yellowing and stunting of the second crop (Fig. 32), although the effect was not as noticeable in 1932 as in 1931. The immediate effect on the yield, as given in Table 65, was at least not significant, but the third crop started off stronger on the sprayed plots and yielded more in 1931.

TABLE 66.—Effect of Spraying with Pyrethrum on Composition of Alfalfa

	Sprayed	Not sprayed
	Pct.	*Pct.*
1931—2nd crop		
Protein in leaves	25.4[4]	19.8[2]
Protein in stems	10.1[4]	10.0[2]
Protein in hay	17.4[4]	14.9[2]
Leaves in hay	47.6[6]	49.7[6]
1932		
Range 400, 2nd crop		
Protein in hay	16.4[2]	16.4
3rd crop		
Protein in hay	19.2[2]	21.9*
Range 800, 2nd crop		
Protein in hay	19.3[2]	17.3[2]
3rd crop		
Protein in hay	18.9[2]	18.4[2]

*One sample only; out of line not only with these samples but also with others taken on the same date.
[2], [4], and [6] =number of samples averaged.

As in 1929 (Table 75), leafhopper yellowing in 1931 resulted in a decreased protein content of the yellowed leaves (Table 66). The protein content of the stems was not affected nor was the percentage of leaves in the hay. In 1932, because of shortage of help and the small apparent effect of spraying, the samples were not sorted into leaves and stems. The differences are in the same general direction as in 1931 but are hardly significant. This decrease in protein content is probably due to an accumulation of starch in the yellowed leaves, since Smith and Poos (58) have shown that *Empoasca fabae* Harr. injures the phloem elements of the vascular bundles in its feeding punctures. This decrease in protein content is one of the most convenient and definite measures of the degree of injury which is available.

To obtain a measure of the effect on storage of root reserves of excessive stunting and yellowing, triplicate root samples were harvested September 7 in each part of the field illustrated in Figure 30. As an average of closely agreeing triplicates, the roots in the part cut July 25 amounted to 3220 pounds per acre; in the main part cut July 14, to 2780 pounds; and in the yellowed and stunted border of the part cut July 14, 2190 pounds. The nitrogen content of these samples was, respectively, 2.24, 2.41, and 1.90 per cent.

Relation of leafhoppers to time of cutting.—Leafhoppers are present in injurious numbers at Columbus during June, July, and August. The first crop of alfalfa is never materially affected by them. The peak of their injury seems to come in July. The second crop is always, and the third crop often, more or less affected by them. Field observations have shown that usually the later the first crop is cut, the more the second growth is yellowed and that always the later the second growth is cut, the less the yellowing in the third growth. The only exceptions to the first observation were in 1930, when there was no yellowing, and in 1933, when the second growth following early-cut alfalfa was yellowed more than that following late-cut. Since the degree of yellowing is fairly well indicated by the protein content (of alfalfa of the same age), the protein content of alfalfa in which the first and second cuttings were made at different dates is significant (Table 67). It appears from this table that there is at least some tendency for the protein content of second-cutting alfalfa of the same age to decrease as the first cutting is made later. This is also borne out by a comparison of the protein content of the second crop in the "first-cutting-early" system (Table 48) and the standard system. Although the latter was 3 to 6 days younger when cut, the second crop averaged one per cent less protein, as an 8-year average, than in the early-cut system. Table 67 shows almost conclusively, as do other scattered data, that the quality of the third crop increases as the second cutting is delayed.

TABLE 67.—Yield and Composition of the Second and Third Crops of Alfalfa as Related to the Dates of Making the First and Second Cuttings

System	Date of		Days between cuttings	Yield per acre		Protein in hay	
	1st cutting	2nd cutting	No.	4-year av. Columbus Lb.	2-year av. Holgate Lb.	4-year av. Columbus Pct.	2-year av. Holgate Pct.
			Second crop				
2	May 31	July 15	45	2950	2370	17.5	16.9
8	June 7	July 21	44	2770	2260	16.8	17.4
10	June 13	July 28	45	3060	2060	16.0	17.3
11	June 17	July 31	44	3240	1980	16.4	17.4
12	June 21	July 31	41	2980	1890	16.6	17.2
15	June 27	Aug. 7	41	2830	1980	16.8	16.7
			Third crop				
	2nd cutting	3rd cutting					
1	July 10	Aug. 25	40	1910	1480	17.9	18.0
2	July 15	Sept. 3	45	1830	1300	18.0	18.2
5-8	July 21	Sept. 3	44	1790	1090	20.0	19.2
9-10	July 28	Sept. 10	44	1980	800	21.2	21.0
11-12	July 31	Sept. 10	41	1820	780	21.7	22.8
15	Aug. 7	Sept. 20	44	1560	820	20.4	22.9
16	Aug. 16	Sept. 30	45	1580	960	20.8	23.0

The standard systems of cutting (Experiments III, IV, and V) have given an excellent opportunity to study the relation of the time of making the second cutting to the yellowing of the third crop. In each year from 1929 to 1933, except 1930, the alfalfa on the ranges September 3 showed the following characteristics (Fig. 33):

1. The third crop was increasingly tall and green as the date of the second cutting advanced from July 15 to August 1. In 1929, the alfalfa on System 2, cut July 15, was only 11 inches tall, while that on System 9, cut July

26, was 19 inches tall. The alfalfa in System 8, cut July 19, was 17 inches tall but much more yellow than that on System 9. The stems of the stunted growth on System 2 were rough with leafhopper punctures. The difference in yield was not as great as was suggested by the difference in height. The stunted growth of System 2 made 1450 pounds per acre and System 9, 1960 pounds, in the third cutting in 1929.

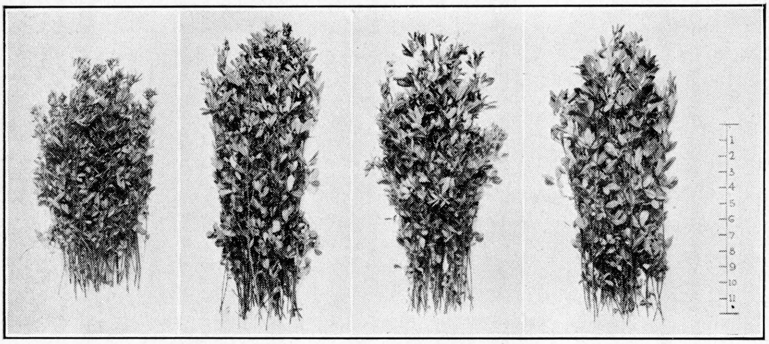


Fig. 33.—Effect of date of making the second cutting on the third growth. (Left to right)

Typical samples from Systems 2, 8, 10, and 11, Columbus, September 2, 1933. Second cutting made July 15, 21, 28, and August 1, respectively.

2. These differences in recovery were not due to root reserves, as was evidenced by the following: (a) The plots which were cut on the same date had the same appearance, although the number of days since the preceding cutting was quite different; (b) System 2, on which 44 days had elapsed from the first to the second cutting, made a much smaller third growth than System 11, on which only 38 days had elapsed from the first to the second cutting.

3. An actual root reserve effect could be seen by comparing Systems 3 and 15, both cut on August 7. These plots had made the same character of growth, but System 3, cut the third time on August 7, was 2 to 4 inches shorter than System 15, on which the August 7 cutting was the second for the season.

4. The protein content of the leaves in these crops in 1929 (Table 75) indicated that these yellowed leaves were lower in protein than the normal leaves. The stems showed no consistent difference. The leaves and stems were not analyzed separately in 1931-1933.

These differences, while present every year, were most extreme in 1929. The appearance in 1933 (Fig. 33) was perhaps most nearly typical of the 4 years.

When should the second cutting be made?—Obviously, leafhoppers have an important bearing on the best date to make the second cutting. The crops which develop under leafhopper infestation suffer considerably in quality and somewhat in yield. Since there is, as yet, no practical control for the leafhopper (except, perhaps, resistant varieties), it is necessary to avoid injury as much as possible. Making the first cutting at least as early as the standard recommendations usually gets the second growth off to a good start. The later in July the second cutting is made, the better, in general, is the quality and yield of the third crop; but, if the second crop stands too long, its quality is too greatly injured. Consequently, it seems wise to favor whichever crop seems, in the given season, to be most important. If the second crop is large and developing well, as for example in 1932 (Table 47), cut before the quality of that crop is seriously injured; if, however, the second cutting is small and stunted, as in 1926 and 1930, it is wise to leave it until near the end of July, unless sufficient rainfall to bring on a large third growth comes earlier.

This differs from the suggestion usually made for control of yellowing, which has been to cut the yellowed alfalfa at once in the hope that the next cutting will not be yellowed.

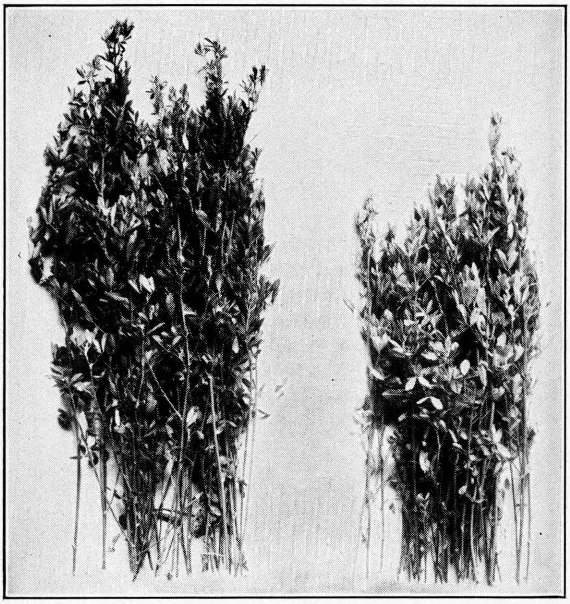


Fig. 34.—Border versus interior of alfalfa field

Columbus, July 27, 1931. Previous cutting, June 17—Left, interior of field (sample taken 50 feet from border); right, border of field (sample taken 8 feet from edge) (Plots 15 and 12, Table 68). A potato patch in a garden was immediately adjacent to this range of alfalfa and furnished an especially severe border infestation.

Graber and Sprague have recently reported (22) that making the first cutting late is an almost complete control for leafhopper yellowing in Wisconsin. As indicated in the preceding discussion, this is not at all the case at Columbus. However, the yellowing of the third crop here can be reduced as greatly and as surely by delaying the second cutting, as Graber and Sprague report for the second crop by delaying the first cutting at Madison. It may be that the shorter season at Madison is responsible for this difference in the time of appearance of an entirely similar effect.

Practical importance of leafhoppers.—The leafhopper has been studied for too short a time to express more than very tentative opinions as to its seriousness in Ohio. All the data thus far obtained, although not conclusive, indicate that, under field conditions, the immediate effect of leafhoppers on yield is small. They distinctly decrease both the feeding and the market value of the second, and sometimes the third, crop of alfalfa. They seem to be responsible for decreased root storage and vigor of recovery of the next growth, and so they constitute one factor in the gradual weakening and dying out of stands in this State. With proper cutting, this loss tends to be made up by root storage in October.

TABLE 68.—Yields of Border Plots Compared to Interior Plots Otherwise Treated Alike

Experiments IV and V, Columbus

	Total yield per acre	
	Interior plot	Border plot
	Lb.	*Lb.*
Range 400		
1930		
Plots 13 and 1, June 10, July 28, Sept. 10	6,000	4,510
Plots 15 and 12, June 17, July 31, Sept. 10	6,220	4,740
1931		
Plots 13 and 1, June 10, July 28, Sept. 10	10,480	9,160
Plots 15 and 12, June 17, July 31, Sept. 10	11,380	10,520
1932		
Plots 13 and 1, June 10, July 28, Sept. 10	10,280	7,830
Plots 15 and 12, June 17, July 31, Sept. 10	11,260	10,440
1933		
Plots 13 and 1, June 10, July 28, Sept. 10	7,130	5,760
Plots 15 and 12, June 17, July 28, Sept. 10	8,100	6,890
Range 600		
1932		
Plots 12 and 1, June 10, July 28, Sept. 10	10,030	8,630
Plots 14 and 20, June 17, July 31, Sept. 10	9,460	8,060
1933		
Plots 12 and 1, June 10, July 28, Sept. 10	7,110	6,320
Plots 14 and 20, June 17, July 31, Sept. 10	8,110	6,060
Average 4 years	8,800	7,410

The "border effect" between parts of a field cut at different dates is conspicuous but not often practically important. However, the effect of the constant excessive yellowing at the edges of the field is important both practically and experimentally. The writer has noticed repeatedly in farm fields of alfalfa that the border dies out much sooner than the rest of the field. The potato leafhopper may not be the only factor in this, but it is an important one. For experimental work, this effect requires that a border at least a plot wide (Fig. 34) surround experimental areas of alfalfa of any kind. Table 68 gives some evidence of this, and the fertilizer test at Wooster (Table 11) offers another example. The practice of having check plots only at each end of a series of alfalfa plots is likely to give large apparent increases for treatment in later years.

An apparently important effect of leafhoppers is the stunting of new seedings. It seems probable that some, or perhaps much, of the injury to new seedings of alfalfa, which has been vaguely called "injury from drouth" or "injury from exposure to sun after removal of the nurse crop", is really due to this insect.

RECOMMENDATIONS FOR CUTTING ALFALFA IN OHIO

The value of calendar dates as a guide for cutting alfalfa.—The experiments reported in this bulletin have led to a system of recommended dates for cutting alfalfa (Table 69) (33). The first cutting is made from June 7-14 to obtain the maximum protein per acre; the last cutting is made September 3-10 to allow ample opportunity for a growth to replenish root reserves; and the second cutting divides the time between the first and third and is regulated, as just described, by the weather and leafhopper attacks. Unreasonable as it appears at first, when all the variables involved are considered, the fact remains that such a system, modified to meet seasonal conditions as suggested in some of the preceding paragraphs, has been more satisfactory in practice than any other system of determining when to cut alfalfa. The variety plots at Columbus have been cut almost slavishly on this schedule for many years—years about as variable in weather conditions as could be imagined. A "date" system might not be so satisfactory in practice where more than three cuttings were involved, because of the accumulated effects of getting "off schedule". In practice, with considerable areas to be cut, many things will happen to upset the schedule, and the more completely the principles involved are understood, the better the grower can make these seasonal adjustments.

TABLE 69.—Cut Alfalfa by This Calendar

Section of Ohio	First cutting	Second cutting	Third cutting	Fourth cutting
Southern third—1st and 2nd "bottoms"...	May 28–June 4	June 28–July 5	Aug. 3-10	Sept. 8-15
Southern third—uplands..................	June 3-10	July 20-27	Sept. 3-15	....
Middle third..............................	June 7-14	July 20-27	Sept. 3-10	....
Northwest.................................	June 7-14	July 20-27	Sept. 1- 7	....
Northeast.................................	June 9-16	July 20-27	Sept. 1- 7	....

THE NORMAL DEVELOPMENT OF ALFALFA

Although studying the development of alfalfa was not a separate project in the alfalfa work at Columbus, the variety, time-of-cutting, and first-year clipping studies together gave excellent material for such a study.

DEVELOPMENT UP TO THE TIME OF MAKING THE FIRST CUTTING OF HAY

Tables 70 to 72 have been compiled to show the normal development of alfalfa, sown in the spring in early oats as a companion crop, up to the time of making the first cutting of hay. Table 70, except as noted, is made up from samples taken in the clipping test on the dates given. Tables 71 and 72 are made up from a number of sources from harvests made on such dates as it was possible to make them. In order to average the different years, interpolations were made from the original data to obtain the yields on the dates given in these tables. These interpolations have all been made on a straight line basis, which is quite satisfactory for the short periods involved. A few estimates beyond the limits of the data were made, as indicated, to complete the table.

Yields of tops and roots.—The weight of alfalfa tops increased steadily after the oats were cut until about October 1, then it decreased slowly, probably due largely to leaf fall. The roots increased in weight steadily as long as there was growing weather. In the spring the roots continued to grow until the first cutting was made. The yield of tops increased regularly and very rapidly from April 15 to May 30 of the first cutting year. Then the rate of increase slowed very decidedly, the maximum point being passed before June 15 in some instances.

TABLE 70.—Development of Alfalfa Sown in Early Oats in the Spring, Columbus

Oats left for grain, usually cut July 17-21. Stubble not clipped

Date harvested	1927	1928	1929	1930	4-year av.	1927	1928	1929	1930	4-year av.
	Lb.	Lb.	Lb.	Lb.	Lb.	Pct.	Pct.	Pct.	Pct.	Pct.
	Yield of tops per acre					Protein in tops				
July 17	600*	840	610	270	580	14.7	18.6	16.4	19.1	17.2
Aug. 1	450*	560	1030	320†	590	....	16.3	15.5	....	15.9‡
Aug. 15	560	990	1300	370	810	16.7	16.8	16.6	16.7	16.7
Sept. 1	900	1440	1600	190	1030	17.7	17.8	17.5	17.1	17.5
Sept. 15	1480	940	2000	860	1320	17.6	18.6	19.2	20.2	18.9
Oct. 1	1140	1780	2060	880	1470	16.6	18.4	18.7	19.4	18.3
Oct. 15	1510	1240	1920	730	1350	18.1	18.5	17.1	18.4	18.0
Nov. 1	1330	1200	1760	1410	1430	18.3	19.2	15.8	14.2	16.9
Nov. 9	1280	1280	1540	970	1270	18.2	17.0	15.9	16.7	17.0
	Yield of roots per acre					Nitrogen in roots				
July 17	200*	120	110	100†	130	2.84	2.34	2.34	....	2.51§
Aug. 1	200*	150	240	150†	190	....	2.00	2.29	....	2.14‡
Aug. 15	240	360	350	200†	290	2.16	2.64	2.39	....	2.40§
Sept. 1	320	700	560	220	450	2.73	2.84	2.63	2.39	2.65
Sept. 15	670	690	780	580	680	2.77	2.95	2.76	2.32	2.70
Oct. 1	740	1320	900	700	920	2.80	2.94	2.67	2.38	2.70
Oct. 15	1020	760	1360	900	1010	2.31	2.92	2.77	2.74	2.68
Nov. 1	920	890	1640	1040	1120	2.59	2.84	2.77	2.84	2.76
Nov. 9	1070	1090	1860	880	1230	2.60	3.01	3.01	3.12	2.94
	Plants per square yard									
	No.	No.	No.	No.	No.					
Average, July to November	348	141	213	396	274					

*Estimated from harvest July 22. †Estimated. ‡Two-year average.
§Three-year average.

Composition of tops and roots.—The protein in the fall growth of tops did not change greatly. In the spring the protein dropped rapidly, as one would expect. The data here are very incomplete. Some of the analyses are of "hay" rather than of "tops". ("Tops" are the entire above-ground portion of the plant.)

The young roots in the fall of the first year contained a higher percentage of nitrogen than they usually do in the fall of later years. The nitrogen content of the roots in early August was slightly lower than later in the fall.

In the spring of the first cutting year, the roots decreased in nitrogen content very rapidly until about May 15 and then gradually increased until the date of making the first cutting. This tendency appears in several incomplete records, as well as in those given here.

TABLE 71.—Development of Alfalfa Tops and Roots in the First Season of Cutting, One Year After Seeding in Oats

Data interpolated from a number of sources

Date	1923 Lb.	1925 Lb.	1925 Lb.	1926 Lb.	1927 Lb.	1928 Lb.	1929 Lb.	1929 Lb.	1930 Lb.	Average 9 records, 7 years Lb.
					Tops					
April 15	1250	1760	1420*	780*	360	450*	2140	1590	1840	1290
April 30	2040	2820	2840*	1550*	1140	890*	3020	2270	3100	2190
May 15	3500	3560	4260	2580	1920	1610	4280	3120	3910	3190
May 30	4660	3800	4940	3690	2700	2870	4750	4110	4100	3960
June 15	4870	3780	4490	4840	3530	3470	5300	5030	3970	4360
					Roots					
April 15	1140	1080	1360*	700†	540	620	880	750	1040	900
April 30	1060	1220	1360*	710†	660	640	1090	820	1120	960
May 15	1150	1320	1440	880	770	740	1380	890	1540	1120
May 30	1370	1310	1520	1120	890	1020	1480	940	1850	1280
June 15	1410	1440	1740	1570	1010	1350	1450	1070	4020	1450
					Plants per square yard					
	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.
Average, April to June	123	237	203	167	96	200	142	115	334	180

*Estimated from the later data.
†Estimated from samples of November 1925 and May 4, 1926.

TABLE 72.—Nitrogen in Alfalfa, Spring of First Cutting Year

Date harvested	1923 Pct.	1925 Pct.	1928 Pct.	1929 Pct.	1930 Pct.	Average Pct.
			Nitrogen in tops			
April 15	4.05	3.23	....	3.23	4.03	3.64‡
April 30	3.65	3.01	....	3.00*	3.64	3.32‡
May 15	3.22	2.76	3.45	2.85*	3.16	3.09
May 30	2.76	2.49	3.17*	2.81*	2.70	2.79
			Protein in tops			
April 15	25.3	20.2	....	20.2	25.2	22.7‡
April 30	22.8	18.8	....	18.8*	22.8	20.8‡
May 15	20.1	17.2	21.6	17.8*	19.8	19.3
May 30	17.2	15.6	19.8*	17.6*	16.9	17.4
			Nitrogen in roots			
Late March	3.23	....	3.80	....	....	3.51§
April 15	3.03	2.34	3.00	2.02	2.60	2.60
April 30	2.61	2.19	2.40	1.70	2.11	2.20
May 15	2.03	2.14	2.05	1.79	2.47	2.10
May 30	1.99	2.27	2.20	2.16	2.71	2.27
June 15†	2.23	2.33	2.40	2.35	2.80	2.42

*Hay. †Or date of making the first cutting. ‡Four-year average. §Two years only.

DEVELOPMENT OF STANDS AFTER THE FIRST CUTTING

Table 73 gives data on the development of the roots, their nitrogen content, and the number of plants per square yard for three fairly typical alfalfa stands. Two of them, however, involve the year 1930, which was not typical. Additional data on composition are given in the last line of Table 60.

Number of plants per square yard.—The best measure of stand is the number of plants per unit area, reported here as the number per square yard. Stands of alfalfa, as determined by counts of plants in the soil, will almost always be lower than those determined by counting the roots dug from a representative area. The stands in Table 24 were obtained by field counts, but the other stand data in this bulletin came from square-yard areas in which the roots were dug and counted.

The extent to which young stands vary in density is indicated by the data in Tables 70 and 71. These variations do not by any means cause an equal variation in yield. (See also Table 40.) A new seeding which has 150 plants or more per square yard has a sufficient stand. A stand of less than 100 plants is not a full young stand and will not yield its maximum until the plants have had opportunity to occupy the ground.

With the best of cutting treatments, an alfalfa stand steadily grows thinner as it grows older. (See also Tables 42 and 59.) This is a necessary result of competition, just as the growth of a forest results in the death of most of the initial stand. Winterkilling and disease may at times only serve to kill plants already so weakened by competition that they would die anyway. Almost certainly this is the explanation of the occasional slight effect of apparently severe winterkilling, as, for example, in 1926-1927 in Table 55. In instances like this, the smallest and weakest roots are killed.

Table 73 brings out the fact that as the stand becomes thinner, the individual plants become much larger. Just how thin an alfalfa stand can be and give maximum or nearly maximum production is not clear.

Summer mortality in alfalfa stands.—Tables 24 and 73 show that there is a distinct dying out of plants in summer, as well as in winter, and that the variegated alfalfas, which suffer the least winterkilling, suffer the most "summerkilling", if it may be so called. Besides competition, disease and insect attacks are obvious factors in summer mortality. Leaf spot is prevalent but does not seem to be a serious factor. Scattered single plants affected by bacterial wilt are often present in Ohio alfalfa fields (Page 138), but there are not many indications that bacterial wilt is an important factor in reducing stand or yield. Grasshoppers are frequently locally important, but they have not been thus far in the work here. Leafhopper yellowing has appeared to be a decidedly important factor. The writer has seen no indication that humid heat, as such, is unfavorable to alfalfa, as was suggested by Piper (53, p. 353). On the contrary, alfalfa has made its thriftiest growth in wet, hot periods. Probably the fact that such weather does not favor root storage (Pages 115 to 118) and is favorable to many diseases accounts for and justifies Piper's observation.

Yields of roots.—Table 73 suggests that the weight of roots per acre in a well-treated stand of alfalfa tends to increase until at least its second or third year, possibly longer, the increasing size of the individual roots somewhat more than making up for the steady decrease in the number of plants per square yard. (See also Table 60.)

TABLE 73.—Summary Showing Development of Alfalfa Roots and Density of Stands

Weights to a depth of approximately one foot

Year	Year, range, and dates of sampling	Yield of air-dry roots per acre (Lb.)	Nitrogen in roots (Pct.)	Plants per square yard (No.)	Average weight of each root (Grams)
	Variety test, Range 800, sown 1925				
1925	November 9	790	2.41	160	0.45
1926	May 28, June 2	1120	2.06	196	0.53
	June 14	1560	2.23	172	0.85
	July 29, August 4	2070	2.03	176	1.10
	September 25	2170	2.23	156	1.31
	November 5	2060	2.04	152	1.27
1927	June 14	1820	2.25	124	1.38
	July 26	1620	1.94	96	1.58
	September 14	2340	1.92	93	2.37
	November 4	2740	2.16	92	2.79
1928	April 28	2070	2.24	68	2.85
	June 2	2200	2.18	62	3.32
	June 14	1770	2.14	52	3.19
	July 28	2070	2.04	63	3.08
	September 11	2820	2.17	73	3.63
	November 8	3040	2.14	67	4.25
1929	November 9	3640	2.20	31	10.29
1930	October 22	3890	2.28	28	12.18
	Experiment III, Range 1400, sown 1928				
1928	September 8	1040	....	150	0.61
1929	April 6	720	2.25	141	0.45
	April 27	800	1.71	126	0.56
	May 11	900	1.69	113	0.70
	May 25	860	2.03	84	0.89
	June 6	1050	2.35	112	0.82
	July 18	1140	2.08	88	1.14
	September 3	1330	2.29	75	1.56
	November 2	2580	2.32	99	2.28
1930	May 2	1860	2.18	104	1.57
	June 6	3220	2.55	100	2.82
	July 21	3460	2.25	85	3.56
	September 3	3150	2.45	77	3.58
	November 1	4010	2.44	103	3.42
1931	March 23	4440	2.97	91	4.27
	Experiment IV, Range 400, sown 1929				
1929	November 11	1850	2.84	256	0.63
1930	April 16	1040	2.60	322	0.28
	May 2	1130	2.04	358	0.28
	May 17	1600	2.53	355	0.39
	June 5	1960	2.80	293	0.59
	July 5	2190	2.32	221	0.87
	July 21	2420	2.38	220	0.96
	September 3	2760	2.46	292	0.83
	November 13*	3410	2.65	272	1.10
1931*	March 26	3340	3.35	203	1.44
	June 7-17	3160	2.38	270	1.03
	July 21-31	2840	1.91	156	1.60
	September 3-10	2890	2.24	144	1.76
	November	3450	2.30	152	1.99
1932*	March 30	3430	3.04	141	2.13
	September 3-10	3200	2.53	65	4.31
	November	4210	2.49	72	5.12

*On November 13, 1930, and after, average Systems 8, 9, 10, 11.

Composition of roots.—It has already been noted (Page 114) that the nitrogen content of the roots tends to decrease during the recovery after cutting. Tables 60 and 73 both indicate definitely that the nitrogen content of alfalfa roots tends to decrease sharply from early spring to midsummer. The data are not sufficient to indicate whether in established alfalfa the nitrogen content increases from the middle of May until the date of the first cutting, as in the first year, but several observations in 1927 indicate that this usually occurs. The nitrogen content of the roots slowly rises again during the fall. In every instance in which we have a record (including the only two records for first-year alfalfa, 1923 and 1928, Table 72), there is a very large increase in the percentage of nitrogen from November to March. This has been noted for sweet clover (50, p. 45; 59; 66; 67) and attributed to the using up of carbohydrate reserves by respiration, leaving a higher percentage of nitrogen, which would not be so used. In sweet clover a loss in weight of roots from fall to spring has been repeatedly demonstrated. The change in the composition of alfalfa roots may be due to the same cause, but every attempt to demonstrate a loss in dry weight of alfalfa roots, measurable on a field scale, has resulted in indicating no loss whatever (Table 60). However, if there is no loss in weight, there must be a very considerable gain in total nitrogen in the roots from November 1 to late March. Since it is difficult to account for any such gain, the question remains unsettled.

In general, a high yield per acre of roots is associated with a high percentage of nitrogen, and vice versa. To illustrate this point, the percentage of nitrogen in the roots was averaged for all the instances in the 1925-1930 records in which the roots amounted to less than 1500 pounds per acre (omitting records from the first cutting of the first year of cutting the stand) and also for all the similar instances where the roots amount to more than 2000 pounds per acre. There were 23 of the former, averaging 1260 pounds of roots containing 1.83 per cent of nitrogen, and 47 of the latter, averaging 2530 pounds of roots containing 2.17 per cent of nitrogen—a difference of 0.34 per cent of nitrogen. In 1931 and 1932 there were no plots in which the yield of roots per acre in established stands dropped below 2000 pounds, but a tendency for low yields and low nitrogen content to go together was still observable. In the data averaged for the last line of Table 60, the roots from System 3 (4 cuttings) always had the lowest percentage of nitrogen.

MISCELLANEOUS ALFALFA STUDIES

EFFECT OF SEASON AND AGE OF STAND ON PERCENTAGE OF LEAVES AND PROTEIN IN HAY

It is frequently stated that hay from a new stand is leafier and presumably higher in protein than that from an old stand. Usually, the stems in a first-year stand are finer than those in an old stand, and this naturally suggests a higher percentage of leaves in the hay from the new stand. The years in the time-of-cutting studies when old and new stands were cut on the same days throughout the season gave an excellent opportunity for studying this point. These data, with some other scattered observations, are brought together in Table 74. The figures are inconclusive, and one can only say that other factors than age of stand seem to have affected the composition more than that did.

TABLE 74.—Composition of Hay from Old and Young Stands

Sources of hays compared	Dates of seeding	Crops compared	Samples of each averaged	Protein in hay from		Leaves in hay from	
				Old stand	Young stand	Old stand	Young stand
			No.	*Pct.*	*Pct.*	*Pct.*	*Pct.*
1930							
Range 1400, Columbus	1928	First	7	14.8	14.7	41.7	36.4
Range 400, Columbus	1929	Second	13	18.4	17.9	60.2	55.7
		Third	7	23.5	22.8	64.9	62.9
		Late	4	21.5	21.5	67.3	63.2
1930							
Range 800, Columbus	1925						
Range 700, Columbus	1929, summer	First	3	....	....	45.3	42.1
1931							
Range 400, Columbus	1929						
Range 1800, Columbus	1930	First	3	18.1	15.0	....	....
1931							
Range 7A, Holgate	1929	First	4–8	18.6	20.0	44.4	55.8
Range 14, Holgate	1930	Second	1–2	16.6	19.1	53.0	62.3
1932							
Range 400, Columbus	1929	First	7	18.6	19.2	39.1	41.2
Range 600, Columbus	1931	Second	13	16.2	16.7	36.6	40.1
		Third	7	18.7	20.3	47.0	48.9
		Late	4	23.6	23.6	52.7	57.3
1932							
Range 14, Holgate	1930	First	2–4	19.2	20.4	55.1	55.0
Range 15, Holgate	1931	Second	2–4	15.8	17.0	53.3	58.0

PROTEIN CONTENT OF LEAVES AND STEMS

In 2 years, 1925 and 1929, the leaves and stems in the hay from the time-of-cutting test were analyzed separately, Table 75. (See also Table 41.) Some of the analyses were used more than once in Table 75, but the grand average of 51 different analyses of each was 23.4 per cent of protein in the leaves and 12.2 per cent of protein in the stems. The detailed data do not show any very important general trends, except that immature leaves and stems are distinctly higher in protein than mature ones and that the effect of leafhopper yellowing has been to reduce the amount of protein in the leaves. Although the percentage of protein in the stems increased distinctly in the third and fourth cuttings, the larger protein content of the later cuttings seems to be due more to the higher percentage of leaves in the hay than to a higher percentage of protein in either the leaves or stems.

The upper and lower parts of the alfalfa plant differ widely in protein content. Mr. Thatcher divided stems of alfalfa (leaves attached) on June 10 into three portions. Their composition was as follows:

	Per cent of total	Nitrogen, per cent
Upper part	41.1	3.63
Middle part	30.8	2.53
Bottom part	28.1	1.50
Total hay	100.0	2.78

TABLE 75.—Protein Content of Leaves and Stems

System	Dates of cutting	Protein in 1st crop Pct.	2nd crop Pct.	3rd crop Pct.	4th crop Pct.	5th crop Pct.
	Leaves					
	1925					
	May 16, June 17, July 17, Aug. 19, Sept. 23	25.8	23.6	23.7	26.7	24.9
	June 1, July 7, Aug. 17, Sept. 23	23.7	20.9	21.1	25.8	......
	June 13, Aug. 3, Sept. 23	21.2	22.4	24.9	......	......
	June 26, Sept. 23	20.1	24.7	......	......	......
	1929					
1	May 31, July 6, Aug. 23	24.9	28.7	19.6	......	......
2	May 31, July 15, Sept. 3	24.9	25.6	19.9	......	......
3	May 31, July 3, Aug. 7, Sept. 23	24.9	27.6	22.4	26.1	......
4	May 31, July 19, Sept. 10	24.9	24.1	21.3	......	......
6	June 7, July 19, Sept. 3, Nov. 1	24.0	24.2	22.5	21.1	......
7	June 7, July 19, Sept. 3, Oct. 15	24.0	24.2	22.5	26.1	......
8	June 7, July 19, Sept. 3	24.0	24.2	22.5	......	......
9	June 10, July 26, Sept. 10	23.9	22.1	23.6	......	......
10	June 14, July 26, Sept. 10	22.6	23.2	23.6	......	......
11	June 18, July 26, Sept. 10	25.2	24.6	23.6	......	......
12	June 20, July 31, Sept. 10	24.2	21.3	24.1	......	......
13	June 20, Aug. 23	24.2	19.4	......	......	......
14	June 27, Sept. 10	23.9	24.2	......	......	......
15	June 27, Aug. 7, Sept. 20	23.9	20.4	25.4	......	......
16	June 27, Aug. 16, Sept. 30	23.9	18.1	24.1	......	......
	Av. standard 3-cutting plots (Systems 8, 9, 10, 11)	23.9	23.5	23.3	......	......
	Av. 51 different analyses 23.4	......	......	......	......	......
	Stems					
	1925	16.3	12.4	12.2	13.6	14.1
	May 16, June 17, July 17, Aug. 19, Sept. 23	12.4	12.1	12.9	13.0	......
	June 1, July 7, Aug. 17, Sept. 23	10.8	9.3	12.2	......	......
	June 13, Aug. 3, Sept. 23	9.3	11.2	......	......	......
	June 26, Sept. 23					
	1929					
1	May 31, July 6, Aug. 23	11.8	12.0	14.0	......	......
2	May 31, July 15, Sept. 3	11.8	11.9	14.2	......	......
3	May 31, July 3, Aug. 7, Sept. 10	11.8	13.1	12.5	15.9	......
4	May 31, July 19, Sept. 10	11.8	12.6	11.8	......	......
6	June 7, July 19, Sept. 3, Nov. 1	12.0	12.3	14.0	12.8	......
7	June 7, July 19, Sept. 3, Oct. 15	12.0	12.3	14.0	14.4	......
8	June 7, July 19, Sept. 3	12.0	12.3	14.0	......	......
9	June 10, July 26, Sept. 10	11.7	11.0	13.0	......	......
10	June 14, July 26, Sept. 10	11.4	11.1	13.0	......	......
11	June 18, July 26, Sept. 10	11.0	11.4	13.0	......	......
12	June 20, July 31, Sept. 10	11.1	11.0	14.1	......	......
13	June 20, Aug. 23	11.1	11.2	......	......	......
14	June 27, Sept. 10	11.1	10.6	......	......	......
15	June 27, Aug. 7, Sept. 20	11.1	10.2	13.3	......	......
16	June 27, Aug. 16, Sept. 30	11.1	10.9	11.4	......	......
	Av. standard 3-cutting plots (Systems 8, 9, 10, 11)	11.5	11.4	13.2	......	......
	Av. 51 different analyses 12.2	......	......	......	......	......

CORRELATION BETWEEN PERCENTAGE OF LEAVES AND PERCENTAGE OF PROTEIN

It is evident from the most casual study of the data of the time-of-cutting experiments that there is a very high correlation between the percentage of protein and the percentage of leaves, the two usually moving together. To study this mathematically all of the samples for the 6 years 1925-1930, for which both the leaf percentage and the protein content were available, were grouped in three correlation tables: (a) All samples from all cuttings;

TABLE 76.—Correlation Between Percentage of Leaves and Percentage of Protein in Alfalfa

	Samples in table	Means		Coefficient of correlation	Regression coefficient, leaves on protein	Regression coefficient, protein on leaves
		Leaves	Protein			
	No.	*Pct.*	*Pct.*	r	$reg._{l \cdot p}$	$reg._{p \cdot l}$
All cuttings	251	51.1	18.2	0.73 ± 0.02	2.50 ± 0.14	0.21 ± 0.01
First cutting	81	40.3	16.1	0.77 ± 0.03	2.03 ± 0.13	0.29 ± 0.02
Later cuttings	170	56.3	19.1	0.63 ± 0.03	1.80 ± 0.08	0.22 ± 0.01

(b) samples from the first cutting; (c) samples from the later cuttings. The constants obtained are given in Table 76. The first cutting gives a much higher correlation between percentage of leaves and percentage of protein than the later cuttings (0.77 ± 0.03 and 0.63 ± 0.03, respectively). From the means and regression coefficients given, one can make a fair estimate of the protein content if he has the percentage of leaves, or vice versa. The correlation coefficient for all cuttings, 0.73 ± 0.02, checks remarkably with the coefficient obtained by Kiesselbach and Anderson (31) in their study of alfalfa hay curing in Nebraska; namely, 0.721 ± 0.026 for 253 samples.

ALFALFA STUBBLE

In all the forage crop work in which yields of roots have been secured by harvesting square-yard samples, the hay has been cut as nearly as possible at the height at which the mowing machine would cut it, and, after the roots have been dug, the stubble has been cut off and recorded separately. The figure has not seemed important and, consequently, has not been reported. The 152 records from the time-of-cutting work in 1925-1928 average 800 pounds per acre of stubble. This is probably less than would be left, on the average, by the mowing machine.

Composition of stubble.—Several analyses of alfalfa stubble were made in the early legume studies (67). Seven samples were analyzed in 1925, and, then, since the part was not important, none were made until 1930 (Table 77). These latter samples were remarkable in that the stubble on June 5 in both ranges contained a higher percentage of nitrogen than either the hay or roots on the same date. Additional samples from this date were analyzed and confirmed those analyses first made. The June 13, 1925, sample was somewhat similar. Additional samples were analyzed in 1931 and gave similar results. Apparently, enough buds and young growth were present in the stubble at this time to bring its nitrogen content to these high figures.

THE COMPARATIVE PROTEIN CONTENT OF ALFALFA AND RED CLOVER

A brief paper under this title was published in 1931 (71), and the observations have been continued since. The conclusion reached in this paper was that at least a large share of the reputed difference in protein content and in digestibility of protein between alfalfa and red clover was due to the fact that, ever since its introduction to American agriculture, alfalfa has regularly been harvested at an earlier stage of maturity than red clover.

TABLE 77.—Analyses of Alfalfa Stubble

Year, range, date	Nitrogen in Stubble	Nitrogen in Hay	Year, range, date	Nitrogen in Stubble	Nitrogen in Hay
	Pct.	*Pct.*		*Pct.*	*Pct.*
1923—Series 1			1930—Range 1400		
June 14	1.86	2.22	May 2	2.30	3.78
July 2	1.59	2.63	June 6	2.49	2.32
July 19	1.39	2.51	July 21	1.83	2.66
Series 2			Range 400		
July 12	1.29	3.27	May 2	2.32	3.77
July 30	1.60	2.54	May 17	2.35	3.28
			June 5	3.08	2.44
1925—Cut 5 times			July 5	1.97	3.16
May 16	2.07	3.34	July 21	1.82	2.91
August 19	1.67	3.53			
September 23	1.98	3.43	1931—Range 400		
			May 23	1.92	3.22
Cut 4 times			May 30	2.21	3.03
July 7	1.72	2.58	June 6	2.27	3.00
			June 10	2.46	2.66
Cut 3 times			June 13	2.18	2.79
June 13	2.20	2.29	June 20	2.38	2.60
August 3	1.92	2.51	June 27	2.18	2.41
September 23	1.95	3.16			

In 1931, six samples each of alfalfa and red clover, harvested on three different dates, indicated a higher protein content for red clover (Table 78). In 1932 a series of samples from several different methods of seeding and dates of cutting indicated a higher protein content of alfalfa in every comparison. The same was true in 1933, with a still larger average difference in percentage of protein. It was notable that in these last 2 years, in which alfalfa was comparatively high in protein, sweet clover was also decidedly higher in protein than usual under the particular conditions of harvest. This suggested that seasonal factors influenced the protein content of different species differently, so that the season, rather than the sample, should be taken as the unit in comparing the protein content of the crops. Table 78 was prepared accordingly. Although further data are needed, it seems probable that, even on the same date of harvesting, there is a real difference in the average protein content of red clover and alfalfa in favor of the latter. This conclusion is especially supported by the average data in the time-of-cutting studies. [Compare Table 53 in this bulletin with Table 1 in (73).]

TABLE 78.—Protein Content of Red Clover and Alfalfa

Comparisons of samples from adjacent plots sown under the same conditions and cut on the same dates in late May and June of the year after seeding

Year	Samples averaged	Protein in Red clover	Protein in Alfalfa
	No.	*Pct.*	*Pct.*
1923	1	13.1	13.9
1925	1	14.8	15.3
1928	3	20.7	20.5
1929	3	15.5	16.4
1930	9	16.1	16.0
1931	6	15.6	15.0
1932	12	15.1	17.4
1933	11	14.1	16.8
Average 1923-1933, each year as a unit		15.6	16.4

Nevertheless, the basic conclusion of the earlier paper, that time of cutting is a more important source of differences in quality and feeding value of clover and alfalfa hay than the kind of hay, remains valid. This fact is particularly important in feeding trials intended to determine the relative feeding value of the two forages. Obviously, such experiments are valid only for hay of the same maturity and quality as that fed in the experiment; nevertheless, it is the exception, rather than the rule, to find data on the harvesting of the forage in connection with such experiments.

BACTERIAL WILT OF ALFALFA IN OHIO

The disease known as bacterial wilt has made serious inroads on alfalfa growing in the west, but, insofar as is at present known, it is not a serious factor in this State. The disease is very generally present over the State, and occasional serious attacks have been noted. The only one which has appeared in any experimental fields was in a large field on the Ohio State University farm, a small part of which was being used for alfalfa topdressing experiments (Page 26). This field developed a serious, typical attack of wilt in its fourth cutting year, 1932, following an unfavorable late cutting September 29 in 1931. This field did not pay for cutting in 1932 and was plowed up in the summer. The writer also noticed a severe attack of wilt in another field near Columbus in 1932.

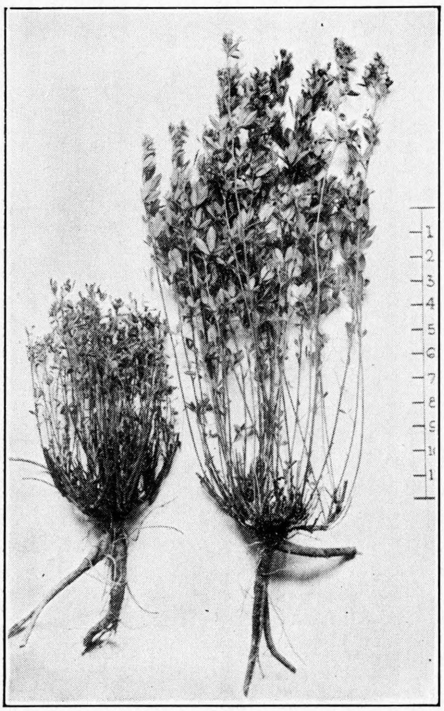


Fig. 35.—Bacterial wilt of alfalfa

Columbus, September 9, 1933—Left, typical alfalfa plant affected by bacterial wilt, from stand sown in 1926; right, normal plant dug less than one foot from the diseased plant. Wilt-infected plants were fairly common in the field but were always single plants like the above, not in patches.

Scattered plants infected with wilt can be found in many of the older alfalfa fields in the State. Such scattered plants were found in the fall of 1929 in a range sown in 1925. Part of this area had been plowed in the spring of 1929 and at once reseeded to alfalfa. This seeding is still (1933) alive, and it required careful search to find a very few typical wilt-infested plants this fall. The stand of adapted varieties is still fairly good after 9 years continuously in alfalfa (two seedings).

In 1933 a considerable number of scattered plants infected with wilt appeared in an area sown in 1926. The stand had been unprofitably thin for 2 years at least. Even here only single plants were affected. Adjacent plants with crowns at times even interlaced with infected plants were perfectly healthy (Fig. 35).

It is quite possible that infections of bacterial wilt are more important in the rapid thinning out and weakening of alfalfa stands in Ohio than has yet been demonstrated. Unless this is true, it does not seem that wilt is an important problem to the Ohio grower.

ALFALFA SEED PRODUCTION

Ordinarily, in Ohio, alfalfa does not produce sufficient seed to be worth harvesting. In 1930, however, the extremely dry weather furnished a season similar to those of the alfalfa seed-producing sections of the west. All alfalfa fields set seed freely, and there was a considerable amount of alfalfa seed harvested by farmers in the western half of the State. There were no plots available which were planted especially to study alfalfa seed production, but the opportunity was so unusual that portions of several tests were left for seed in order to have some measure of seed production under these unusual conditions. All the yields were obtained by harvesting representative square-yard samples and threshing them by hand. The data obtained are reported in Table 79. The yields are similar to those obtained under similar conditions by farmers.

TABLE 79.—Alfalfa Seed Yields, Columbus, 1930

Date, range, plot, variety, crop	Samples averaged	Yield per acre		
		Straw and seed	Seed	Seed
	No.	*Lb.*	*Lb.*	*Bu.*
August 25				
Range 800 N, sown 1925				
Plot 12, Cossack, 2nd crop	2	2780	479	8.0
Range 800 S, sown 1929, 2nd crop				
Plot 6, Utah Common	2	1470	163	2.7
Plot 7, Grimm	2	1580	240	4.0
Plot 8, Dakota Common	2	1470	171	2.9
Plots 6, 7, 8, Average	6	1510	191	3.2
September 8				
Range 500, sown 1929, common				
Plot 1, 2nd crop	1	1550	148	2.5
September 30				
Range 400, sown 1929, common				
Plot 18, 2nd crop	3	1920	209	3.5
Range 800 N, sown 1925, common				
East end, 3rd crop	4	1220	217	3.6

Home-grown seed has been an important factor in increasing the alfalfa acreage in Ohio since 1930. Some seed has been produced each year since and considerable in 1933. Although it is not yet to be anticipated that a consistently important seed production can be built up, the possibility of a seed crop is always worth keeping in mind in a dry season. There is no reason why Ohio-grown seed should not be at least as good as the seed used to sow the seed plot, and any change through natural selection would improve it. Preliminary tests of Ohio seed at Wooster were entirely favorable (Tables 19 and 21).

Time of cutting for seed.—At Holgate in 1932 an area was left for seed and used in a study of time of cutting for seed. Yields were obtained at intervals of one week, beginning when 10 to 15 per cent of the pods were dry and apparently ripe. The stand gave a very poor yield of seed, as indicated in Table 80, but the difference in the quality of the seed as cuttings were made later was very great. The last date gave both the best yield and the best quality of seed. There was no evidence of shattering at any time, either before or after cutting, except from handling. This small test suggests that it would be well in Ohio to leave the seed crop until at least three-fourths of the pods are brown or black.

TABLE 80.—Time of Harvesting Alfalfa for Seed, Holgate, 1932

Date of cutting	Yield* of seed per acre	Plump seed, estimated
	Lb.	*Pct.*
September 1	6	20
September 8	17	25
September 15	18	60
September 21	25	75

*Yields obtained by harvesting 10 square-yard samples on each date.

Other problems of seed production.—Many other important problems are involved in seed production in Ohio. It is difficult to estimate probable seed production, although not as difficult as with red clover. Ohio experience is identical with that of other states in that old, thin stands are more likely to produce seed than good, thick hay stands (Table 79).

Variegated alfalfas bloom much more freely in Ohio than common alfalfa and set more seed (Table 79). Despite the fact that much more common than variegated alfalfa is grown in northwestern Ohio, it was easier to find seed of variegated alfalfa in the fall of 1930 than of common.

In order to avoid shattering, the crop should be handled as little as possible; thus, the use of the clover buncher is advisable in cutting. The crop should be threshed or stored as soon as it is dry enough. A serious problem in this State is the sprouting of alfalfa seed in the windrow or bunch, if a rain comes during the curing period. Rains which would injure red clover only slightly will cause much sprouting of alfalfa seed, since it does not contain anything like as large a proportion of hard seed as red clover.

Another problem of seed production in humid regions is the coming up of new growth in fields left for seed before the seed can be harvested. An area of alfalfa at Columbus, cut July 14, 1933, made an excellent set of seed, but wet weather in September produced such an abundance of new growth, as tall as the seed stalks, as to make curing extremely difficult or practically impossible.

MISCELLANEOUS STUDIES OF ALFALFA ROOTS

In addition to the various quantitative studies of alfalfa roots (Pages 13, 46, 65, 75-79, 111-118, 123, 128-133), a number of other root studies have been made.

Dry/green ratios of roots.—Both green weights and dry weights of roots have been taken in these experiments since 1926, from which the dry/green ratios, here expressed as percentages of dry matter in the green roots, have been calculated. This percentage varied considerably at different times of the year. In November of the seeding year, the oven-dry weight averaged from

30 to 35 per cent of the green weight (Table 44). By April of the next year, the water content of the roots had increased until the dry weight was only about 20 per cent of the green weight. After April 15 this percentage tended to increase.

The dry/green ratios of the roots of older stands followed somewhat a similar course, but the differences were not so great. As reported by Graber *et al.* (21), there was a tendency for plots cut frequently to have a lower percentage of dry matter in the roots than normally cut plots, but the differences were not great with the only moderately excessive cutting used in these experiments.

Effect of different soil types on the development of alfalfa roots.—Since at Columbus light-colored soils low in organic matter (Miami series) are often in the same range, or even the same plot, with dark-colored soils high in organic matter (Brookston and Clyde series), observations of the effect of soil type on root development were very readily made. The writer found (55), as did Carlson (12), that soil type had a very marked influence on the type of root system developed by alfalfa. In 1928 and since, alfalfa has been grown and its root systems studied on most of the outlying farms and, consequently, on a wide variety of soil types. In general, mellow soils and soils high in organic matter have resulted in the development of roots in which the enlarged storage portion is long and nearly unbranched; hard, clayey soils low in organic matter have resulted in the storage portion of the roots being much branched and not extending very deep into the soil (Fig. 36). The vegetable gardening manuals testify that the same effect has long been known for parsnips and other similar root crops. It should be noted that the fact that the storage portion of the root is shallow and much branched does not necessarily mean that the actual depth of penetration of the roots is shallow. The total depth reached by the roots may be very similar in the different types. It is not clear just what causes these differences in root structure in different soil types, but these observations indicate almost certainly that they are not due to differences in pH. In Figure 36, for example, the soil was alkaline to at least 7 inches. Recent observations in the laboratory of Dr. Richard Bradfield, of the Department of Agronomy, suggest that the abnormal branching is associated with a low oxidation-reduction potential.

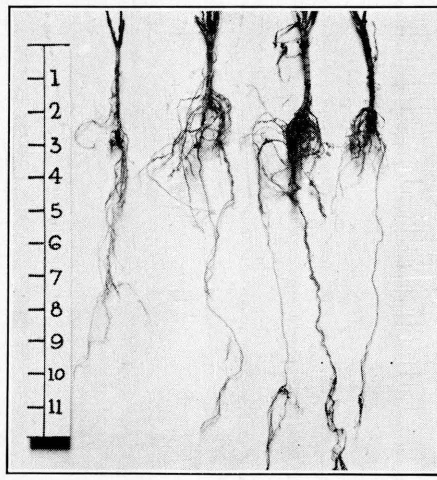


Fig. 36.—Soil type affects root development

Young alfalfa roots from Clermont silt loam on Clermont County Experiment Farm, October 25, 1928. Note sudden breaking up of the tap root at uniform depth of about 3 inches. The soil was alkaline to at least 7 inches; consequently the effect could not be due to pH.

A condition was present in alfalfa roots in a spring seeding on the Paulding clay at the Paulding County Experiment Farm in October 1928 that the writer has not seen elsewhere. A good stand had been obtained, and the roots had made a good growth in depth. They were traced to a depth of 45 inches, and probably they went deeper. September had been moderately dry, and this soil had dried so hard around the young roots that they had not been able to grow normally. Many had the appearance of having been squeezed into abnormal, flattened shapes. Others had enlarged only in the upper 2 inches of soil, where alternate wetting and drying had made the soil somewhat granular. Others had deposited reserve materials in the top 2 inches; then there was a space where the pressure of the soil around the roots had apparently prevented growth; and then there was an enlargement, where apparently for some reason less soil pressure had been developed. These enlarged areas were sometimes short and repeated (like a string of beads) and sometimes were several inches long below constricted areas ranging from one or 2 to as much as 7 or 8 inches in length. It must have required very large pressures to produce these effects.

Effect of acid and poorly drained soils on alfalfa roots.—It is a common opinion that alfalfa roots do not penetrate acid subsoils. No subsoil which has been observed in these studies has been sufficiently acid to prevent the entrance and apparently normal growth of alfalfa roots, if the top soil was limed enough to permit the growth of the crop. In 1926 alfalfa was observed on Muskingum silt loam a few miles west of Zanesville. This field had been heavily limed and supported a good crop of alfalfa. Roots were followed to 20 inches (they obviously went much deeper, but there was not time to dig deeper) and appeared entirely normal. This soil had a pH of 4.6 at 12 inches and of 4.4 at 20 inches.

In April 1927, there was a stand of alfalfa on Block R of the Trumbull County Experiment Farm, seeded in 1924 on Trumbull silty clay loam soil. It had largely been killed out except over the tile, but there were scattered plants throughout the essentially undrained areas between the tiles. An area was selected at least 15 feet from a tile line, and the roots dug out. They were followed to 45 inches without reaching their greatest depth. The soil was mottled below 9 inches. A layer containing fragments of stone was encountered at 20 inches. Below 20 inches the mottling was of blue-gray streaks in a yellow-brown soil, the blue-gray color being confined to the surface of the soil granules. Below 20 inches the roots were entirely in the blue-gray part and had followed old root traces. The appearance strongly suggested that the color of the blue-gray material had been produced by the reducing action, under poorly drained conditions, of the decaying organic matter (roots). The pH of the blue-gray part of this soil at 30 to 35 inches was 7.63; that of the brown part was 7.05.

The surface soil had been heavily limed, and there were abundant nodules in the top soil. From 9 inches to 30 inches the soil was acid, and no nodules were found; below 30 inches, with a pH above 7, nodules were abundant again to the greatest depth reached. There was no sign of abnormality in the growth or structure of the roots themselves in the acid layer. This observation has also been made on the Mahoning County Experiment Farm, the Clermont County Experiment Farm, the Main Farm at Wooster, and the Northeastern Experiment Farm at Strongsville and is supported by more extensive observations on sweet clover. However, no nodules have ever been noted on either alfalfa or sweet clover in acid subsoils.

The Trumbull soil was not only acid but poorly drained, and yet these roots had lived to a depth of at least 4 feet in such a soil for 3 years. There was no indication that the tap roots had died and sent out new branches in that period. The writer has also dug old alfalfa plants in Mahoning silty clay loam at the Northeastern Experiment Farm and found the same conditions.

Depth reached by alfalfa roots the first season.—In connection with studies of sweet clover roots a number of observations have been made on the depth of alfalfa roots during the first season of growth. It does not seem necessary to record the data in detail. However, under all normal conditions, alfalfa roots in spring seedings reach a depth of at least 3 feet, usually 4 feet, and occasionally greater depths in the first year's growth. This is true on all of the common soil types on which alfalfa can be grown, either with or without liming.

In 1925, June was extremely dry, and the rainfall later in the summer came in rather light showers which did not penetrate deeply. Actual digging of roots during June and July showed that the small grain roots had outgrown the alfalfa and sweet clover roots. Early in July the latter were only 12 to 15 inches long and were apparently unable to penetrate deeper because the small grain had used the available moisture in the soil to a depth of 3 feet or more.

After the small grain was removed, the larger part of the new alfalfa seedings grew very slowly, although a few spots grew very well. These latter areas were always slightly depressed and, hence, received a certain amount of surface run-off from surrounding areas. Roots from the two types of growth were dug September 16. The roots of the stunted plants were still only 15 to 18 inches deep, with dry soil beneath preventing deeper penetration. In the good spots the extra run-off water had enabled the roots to grow through this dry layer, and they went deeper than 3 feet into moist soil. Their total depth was not determined.

TABLE 81.—Summary of Yields of Alfalfa Roots in the Late Fall

Sown in oats in April, various clipping treatments

Year	Samples averaged	Yield per acre of roots	June rainfall
	No.	*Lb.*	*In.*
1922	2	1380	3.14
1924	2	1430	5.37
1925	6	790	1.67
1926	4	880	0.96
1927	8	1100	3.63
1928	9	1240	6.94
1929	11	1380	4.76
1930	10	810	1.25
1931	5	1180	2.30
1932*	6	1060	6.26
1933	2	1420	1.71

*September 14; undoubtedly made much larger yield by November.

Relation between June rainfall and root development in new seedings.—This stunting of the root growth of legumes sown in small grain when June rainfall is below normal would seem to be at least one reason why years in which June has been dry have often been years of small total root growth the first season (Table 81). Obviously, small root growth is associated with dry subsoil and shallow roots, and not with dry Junes as such; in 1931, for example, June and early July were very dry, but after July 15 conditions were more favorable for growth than they had been for several years. In 1933, June was very dry, but there were 6.95 inches of rain in May, and growing conditions in August and September were good—excellent for root storage.

LITERATURE CITED*

1. Agronomy Department. 1930. Field work. Ohio Agr. Exp. Sta. Spec. Cir. 27.
2. ————. 1932. Field experiments in agronomy. Ohio Agr. Exp. Sta. Spec. Cir. 38.
3. Ames, J. W. 1931. Factors affecting nitrates in soils. Ohio Agr. Exp. Sta. Bimo. Bull. 153, 232-244.
4. ———— and Geo. E. Boltz. 1912. Nitrogen and mineral constituents of the alfalfa plant. Ohio Agr. Exp. Sta. Bull. 247.
5. ———— and ————. 1917. Handling alfalfa hay. Ohio Agr. Exp. Sta. Mo. Bull. 18, 178-180.
6. Arny, A. C. 1926. Alfalfa aids progress in Minnesota. Univ. of Minn. Agr. Ext. Div. Spec. Bull. 104.
7. Borst, H. L. and G. M. McClure. 1933. Cultivation oi corn. Ohio Agr. Exp. Sta. Bimo. Bull. 162, 75.
8. ———— and L. E. Thatcher. 1931. Life history and composition of the soybean plant. Ohio Agr. Exp. Sta. Bull. 494.
9. Brown, B. A. 1928. Effect of fertilizers on maintaining stands of alfalfa. Jour. Amer. Soc. Agron. **20**: 109-117.
10. Burlison, W. L., O. H. Sears, and J. C. Hackleman. 1930. Growing alfalfa in Illinois. Ill. Agr. Exp. Sta. Bull. 349.
11. Call, L. E., R. I. Throckmorton, C. C. Cunningham, and B. S. Wilson. 1921. Fertilizers for alfalfa in eastern Kansas. Kan. Agr. Exp. Sta. Bull. 226.
12. Carlson, F. A. 1925. The effect of soil structure on the character of alfalfa root systems. Jour. Amer. Soc. Agron. **17**: 336-345.
13. Coburn, F. D. 1901. Alfalfa. 161 pp. Orange Judd Co., New York.
14. Cocke, R. P. 1926. Experiments with alfalfa in eastern Virginia. Va. Agr. Exp. Sta. Bull. 247.
15. Connecticut (Storrs) Agr. Exp. Sta. Rept. for 1929. 1929. Bull. 162.
16. Cook, W. M. 1911. Alfalfa in Ohio—a field study. Ohio Agr. Exp. Sta. Cir. 113.
17. Damon, S. C. 1921. Experiences with alfalfa. R. I. Agr. Exp. Sta. Bull. 184.
18. Etheridge, W. C. and C. A. Helm. 1933. Better methods for growing alfalfa. Mo. Agr. Exp. Sta. Bull. 326.
19. Garver, Samuel. 1922. Alfalfa root studies. U. S. Dept. Agr. Bull. 1087.
20. Gearhart, C. A. 1916. Winter injury of alfalfa and clover. Ohio Agr. Exp. Sta. Mo. Bull. 7, 199-201.
21. Graber, L. F., N. T. Nelson, W. A. Luekel, and W. B. Albert. 1927. Organic food reserves in relation to the growth of alfalfa and other perennial herbaceous plants. Wisc. Agr. Exp. Sta. Res. Bull. 80.
22. ———— and V. G. Sprague. 1933. Alfalfa yellows. Science **78**: 385-386.
23. Grantham, George M. 1930. Fertilizer aids alfalfa on sandy soil. Mich. Quart. Bull. **12**: 150-151.
24. Hickman, J. Fremont. 1896. Forage crops. Ohio Agr. Exp. Sta. Bull. 70.

*This list is intended to include all previous publications of the Department of Agronomy on alfalfa; hence, the preponderance of citations from the Ohio Agricultural Experiment Station.

25. Hollowell, E. A., John Monteith, Jr., and W. P. Flint. 1927. Leafhopper injury to clover. Phytopath. 17: 58; 399-404.

26. Illinois Agr. Exp. Sta. 1926. A year's progress in solving some farm problems of Illinois. 39th Annual Report for 1925-26.

27. Iowa Agr. Exp. Sta. 1932. Report of agricultural research for 1932.

28. Jones, Fred R. and A. A. Granovsky. 1927. Yellowing of alfalfa caused by leafhoppers. (Abst.) Phytopath. 17: 39.

29. Kiesselbach, T. A. and A. Anderson. 1926. Alfalfa investigations. Neb. Agr. Exp. Sta. Res. Bull. 36.

30. ———— and ————. 1927. Curing alfalfa hay. Jour. Amer. Soc. Agron. 19: 116-126.

31. ———— and ————. 1931. Quality of alfalfa hay in relation to curing practice. U. S. D. A. Tech. Bull. 235.

32. Leukel, W. A. 1927. Deposition and utilization of reserve foods in alfalfa plants. Jour. Amer. Soc. Agron. 19: 596-623.

33. Lewis, R. D., J. A. Slipher, and C. J. Willard. 1933. Alfalfa in Ohio farming. Ohio State Univ. Agr. Ext. Bull. 137.

34. Lloyd, W. A. 1910. A successful alfalfa and truck farm in southeastern Ohio. Ohio Agr. Exp. Sta. Cir. 107.

35. McKee, Roland. 1916. The effect of clipping on the root development of alfalfa. Jour. Amer. Soc. Agron. 8: 329-332.

36. Moore, R. A. and L. F. Graber. 1922. Make alfalfa a sure crop. Wisc. Agr. Exp. Sta. Bull. 349.

37. ———— and ————. 1925. Wisconsin's opportunity with alfalfa. Wisc. Agr. Exp. Sta. Bull. 374.

38. Nelson, N. T. 1925. The effects of frequent cutting on the production, root reserves, and behavior of alfalfa. Jour. Amer. Soc. Agron. 17: 100-113.

39. Oakley, R. A. and Samuel Garver. 1917. *Medicago falcata,* a yellow-flowered alfalfa. U. S. D. A. Bull. 428.

40. ———— and H. L. Westover. 1922 (Revised 1928). How to grow alfalfa. U. S. D. A. Farmers' Bull. 1283.

41. ———— and ————. 1926 (Revised 1927). Commercial varieties of alfalfa. U. S. D. A. Farmers' Bull. 1467.

42. Ohio Agr. Exp. Sta. 1917. Cultivating alfalfa increases hay crop. Ohio Agr. Exp. Sta. Mo. Bull. 21, 314.

43. ————, 42nd An. Rept. 1923. Bull. 373.

44. ————, 43rd An. Rept. 1924. Bull. 382.

45. ————, 44th An. Rept. 1926. Bull. 392.

46. ————, 45th An. Rept. 1927. Bull. 402.

47. ————, 46th An. Rept. 1928. Bull. 417.

48. ————, 47th An. Rept. 1929. Bull. 431.

49. ————, 48th An. Rept. 1930. Bull. 446.

50. ————, 49th An. Rept. 1931. Bull. 470.

51. ————, 50th An. Rept. 1932. Bull. 497.

52. ————, 51st An. Rept. 1933. Bull. 516.

53. Piper, C. V. 1924. Forage Plants and Their Culture. Rev. Ed. Macmillan, New York.

54. Prince, Ford S., Paul T. Blood, T. G. Phillips, and G. P. Percival. 1933. Fertilizer experiments on "run-out" hay land. N. H. Agr. Exp. Sta. Bull. 271.

55. Reed, E. P. and C. J. Willard. 1927. Alfalfa. Ohio State Univ. Ext. Bull. 58.
56. Salmon, S. C., C. O. Swanson, and C. W. McCampbell. 1925. Experiments relating to the time of cutting alfalfa. Kan. Agr. Exp. Sta. Tech. Bull. 15.
57. Schuster, G. L. and H. C. Harris. 1932. Alfalfa fertility tests. Del. Agr. Exp. Sta. An. Rept., Bull. 179, 14.
58. Smith, Floyd F. and F. W. Poos. 1931. Feeding habits of some leafhoppers of the genus Empoasca. Jour. Agr. Res. 43: 267-285.
59. Snider, H. J. and M. A. Hein. 1926. The nitrogen and dry matter content of sweet clover tops and roots at various stages of growth. Jour. Amer. Soc. Agron. 18: 273-280.
60. Sylven, Nils. 1931. Avverkningsförsök i blåluzern (Time of cutting experiments in lucerne). Sv. Utsädesf. Tidskr., sid. 9-57.
61. Thorne, C. E., C. G. Williams, and Chas. McIntire. 1912. County experiment farms in Ohio. Ohio Agr. Exp. Sta. Bull. 241.
62. Timmons, F. L. and S. C. Salmon. 1932. The resistance of certain varieties and regional strains of alfalfa to controlled low temperatures. Jour. Amer. Soc. Agron. 24: 642-655.
63. Westover, H. L. 1927. Alfalfa of Ladak variety is promising for northern states. U. S. D. A. Yearbook, pp. 94-95.
64. Wiancko, A. T., G. P. Walker, and Arthur Goss. 1933. Purdue-Vincennes Farm soils and crops experiments. Report of progress, 1925-1932.
65. Wiant, J. S. 1931. Bacterial wilt of alfalfa. Wyo. Agr. Exp. Sta. Bull. 177.
66. Wilkins, F. S. and E. V. Collins. 1933. Effect of time, depth and method of plowing upon yield and eradication of biennial sweet clovers. Iowa Agr. Exp. Sta. Res. Bull. 162.
67. Willard, C. J. 1927. An experimental study of sweet clover. Ohio Agr. Exp. Sta. Bull. 405.
68. ————. 1929. How many cuttings of alfalfa? Ohio Agr. Exp. Sta. Bimo. Bull. 138, 74-81.
69. ————. 1930. Root reserves of alfalfa with special reference to time of cutting and yield. Jour. Amer. Soc. Agron. 22: 595-602.
70. ————. 1931. The correlation between stand and yield of alfalfa and sweetclover. Jour. Agr. Res. 43: 461-464.
71. ————. 1931. The comparative protein content of alfalfa and red clover. Jour. Amer. Soc. Agron. 23: 754-756.
72. ————. 1931. The moisture content of forage at different times in the day. Jour. Amer. Soc. Agron. 23: 853-859.
73. ————, J. S. Cutler, and J. B. McLaughlin. 1934. The time of cutting the true clovers. Ohio Agr. Exp. Sta. Bimo. Bull. 167, 39-43.
74. Williams, C. G. 1909. Alfalfa culture. Ohio Agr. Exp. Sta. Cir. 91.
75. ————. 1917. Alfalfa culture. Ohio Agr. Exp. Sta. Mo. Bull. 18, 173-177.
76. ———— and C. H. Kyle. 1907. Alfalfa in Ohio. Ohio Agr. Exp. Sta. Bull. 181.
77. Wing, Joseph E. 1916. Alfalfa Farming in America. Sanders Pub. Co., Chicago.
78. Woodward, N. F. 1923. Experiments with alfalfa and grasses at Judith Basin Substation. Mont. Agr. Exp. Sta. Bull. 152.