12-1926

Alfalfa Investigations

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AGRICULTURAL EXPERIMENT STATION
RESEARCH BULLETIN NO. 36

ALFALFA INVESTIGATIONS

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LINCOLN, NEBRASKA
ACCEPTED FOR PUBLICATION JUNE, 1926
DECEMBER, 1926

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SUMMARY

1. Alfalfa appears to have been introduced into Nebraska in 1875. Over 200,000 acres were reported as having been grown within the State in 1902. There has been a rather gradual increase in acreage since then to over 1,300,000 acres in 1925.

2. As a 3-year average, 1923-1925, Cossack, Baltic, Grimm, and Canadian Variegated yielded 13, 10, 5, and 3 per cent, respectively, more hay per acre than Nebraska-grown Common alfalfa, whereas Sand Lucern and Turkestan yielded 8 and 7 per cent less. Peruvian alfalfa winterkilled practically 100 per cent during its third winter, and during the time that stands were comparable, it gave no indication of being superior to Common. In a parallel test including 20 regional strains of Common alfalfa, Spanish, yielding 29 per cent less than the Nebraska-grown Common used as check, and West Nebraska dry land, producing 7 per cent more than check, were the extreme yielding strains. Aside from the low yielding Spanish, differences in yield were not significant as long as stands were comparable.

3. The use of a hardy and otherwise well adapted variety is a very important factor in the maintenance of an alfalfa stand under Nebraska conditions. Wide variation exists between the various varieties and strains in ability to withstand severe winter conditions. During the winter of 1924-1925 Peruvian winter killed almost completely. Sand Lucern and Turkestan were slightly injured, while decided thinning occurred with the Argentine, Italian, and Spanish alfalfas. This winterkilling occurred in the established stands in field plats and in new seedings in the nursery. Some winterkilling was apparent with all the strains and varieties during the winter of 1925-1926, but was especially marked in the case of Sand Lucern. Nebraska-grown Common appeared to show a little more thinning than Cossack, Grimm, and Baltic. Southern-grown domestic strains showed measurably more thinning than the northern-grown domestic strains of Common alfalfa.

4. The variation in flower color of the variegated sorts was the most striking physical difference observed between varieties. As a 3-year average for all cuttings, the proportion of leaves ranged from 44.9 per cent for the Common, to 47.9 per cent for the Turkestan.

As a 3-year average for all cuttings, Common alfalfa was 23.4 inches high per cutting as compared with Turkestan with a height of 21.9 inches as the other extreme. Coarseness of stem as measured in 1925 ranged from 2.27 millimeters for Cossack to 2.49 millimeters for Sand Lucern. Detailed root and crown measurements of the Common, Cossack, and Grimm varieties did not show differences sufficient to permit of varietal classification.

5. Variations between cuttings were more striking than varietal or strain differences. As an average for the 7 varieties the yield of the first, second, third, and fourth cuttings was 43, 32, 19, and 6 per cent of the total annual yield. As an average for the same varieties the first, second, and third cuttings consisted of 39.7, 43.7, and 54.9 per cent leaves. Average stem diameters by cuttings were 2.97, 2.38, and 1.89 millimeters, respectively, for the first, second, and third cuttings. Corresponding plant heights were 27.0, 24.8, and 17.6 inches per cutting. The average protein content for the first, second, and third cuttings was found to be 16.84, 18.58, and 19.99 per cent, respectively.

6. Tillage of established stands of alfalfa with disk harrow, spring tooth harrow (alfalfa renovator), and ordinary harrow failed to increase yields. The most intensive treatment, that of the spring tooth harrow, after each cutting, reduced the yield 7 per cent as a 4-year average. When all plats were harvested uniformly without tillage treatment in the fifth year, those having had this treatment yielded but 81 per cent of the untilled plats.

7. During the 5-year period there was a 30 per cent reduction in the number of plants per square foot on the untilled plats as compared with 43 per cent reduction on the plats receiving disk and spring tooth harrow treatments. There appeared to be no relation between tillage and plant development as measured by root diameters.

8. As a 4-year average alfalfa harvested at the pre-bloom, initial bloom, one-tenth bloom, half-bloom, full bloom, seed, and new growth stages yielded 3.00, 3.03, 3.35, 3.42, 3.19, 2.82, and 3.51 tons per acre, respectively. The proportion of leaves at time of harvest for these respective stages was 57.3, 56.6, 55.8, 53.2, 49.4, 33.3, and 52.8 per cent. There was measurable seed production from the seed plats in only one year out of four.

9. Harvesting alfalfa in relatively immature stages tended to thin the stand and retard root development.

10. As a 4-year average there was a rather gradual decrease in the protein content of the hay from 21.98 per cent in the pre-bloom stage to 18.13 per cent in the full bloom stage. This decrease in protein was accompanied by an increase in crude fiber from 25.13 per

cent to 30.82 per cent. The ash content decreased from 11.24 to 9.36 per cent as maturity increased, whereas the slight variations in the nitrogen-free extract and fat contents did not appear to be associated with maturity.

11. Averaging the composition of alfalfa hay harvested at 6 stages of maturity during a 4-year period, it is found that the stems contained 75, 43, 249, 91, and 46 per cent as much ash, protein, crude fiber, nitrogen-free extract, and fat respectively, as the leaves. The ratio of the protein content of the stems to that of the leaves remained practically constant regardless of the stage of maturity.

12. The annual acre yields of protein as a 4-year average for the pre-bloom, initial bloom, one-tenth bloom, half-bloom, full bloom, and new growth stages were 0.552, 0.515, 0.541, 0.535, 0.482, and 0.546 tons per acre, respectively. Of the total protein in the hay, that contained in the leaves ranged from 75 per cent in the least mature to 70 per cent in the most mature stages.

13. The first, second, and third cuttings of the 6 maturity stages consisted of 48.7, 56.4, and 58.1 per cent leaves during the 4-year period. The respective protein contents of these cuttings were 18.96, 19.83, and 20.03 per cent. The protein percentage of the leaves of the first, second, and third cuttings was 27.80, 26.82, and 26.44 per cent as compared with 10.62, 11.29, and 11.73 per cent for that of the stems.

14. From the combined standpoints of acre yield of hay and feed constituents, quality of hay, and permanency of stand, it would seem that harvesting alfalfa approximately at the new growth stage should prove the most desirable practice. Under normal blooming conditions this commonly falls between the tenth and half-bloom stages and the time to cut may be judged by either the new growth or bloom. Frequent cutting in more immature stages is inadvisable.

15. The application of either gypsum, sulphur, lime and sulphur, or lime as top dressings to an established stand of alfalfa failed to increase the yield. The application of barnyard manure at the rate of 8 tons per acre each 4 years increased the yield 13 per cent. As a 4-year average the following yields were secured; no treatment 3.64 tons per acre, gypsum 3.58, sulphur 3.53, lime and sulphur 3.73, lime 3.68, and barnyard manure 4.11 tons.

16. The yield of alfalfa and timothy seeded in combination was not materially more than that of alfalfa seeded alone. The first cutting of the season was the only one to contain a measurable amount of timothy. This practice is not recommended unless the mixed hay is considered especially valuable.

17. Seeding practices should be adapted to local conditions. Favorable seed bed and moisture conditions at seeding time and timely seeding will greatly enhance the likelihood of securing a stand.

18. Experiment Station and cooperative tests indicate that inoculation is seldom necessary in Nebraska. Its trial is recommended, however, where repeated failures to secure a stand have been experienced.

19. Partial or complete crop failure frequently experienced following the breaking up of alfalfa is primarily due to overstimulation. Crops in semi-arid or subhumid regions commonly deplete the soil of its available moisture within the working depths of their root systems. For the common cereal crops this seldom exceeds the fourth or fifth foot, whereas with alfalfa it may be 15 feet or even deeper.

20. Under conditions where the subsoil moisture has been depleted, alfalfa should not follow alfalfa for a period of years or until a new reserve of moisture can be accumulated. It would seem, however, that alfalfa could advantageously be left growing under these conditions as long as it remains productive.

Wherever corn or small grain follows alfalfa, in regions of moisture shortage, the use of practices which counteract the tendency for too large vegetative development are desirable. These may consist in the use of somewhat smaller varieties, thinner seeding, and listing rather than surface planting corn. The use of an intertilled crop seems more desirable since it permits control of the vegetative growth to a greater extent and is less subject to lodging.

21. Clean, fine-stemmed, leafy, sweet, and green-colored hay has superior market and feeding value. The last 3 of these qualities are closely related to curing practices. The rate of hay curing is controlled by the moisture content and character of the forage, the weather conditions prevailing during the curing period, and the method of handling.

22. As a 3-day average, the moisture content of growing alfalfa was found to be 2.7 per cent lower at 5 P. M. than at 8 A. M. The moisture content at time of cutting for alfalfa harvested in the pre-bloom, initial bloom, one-tenth bloom, half bloom, full bloom, seed, and new growth stages was 76,5, 74.3, 72.8, 71.8, 70.5, 60.0, and 72.8 per cent, respectively.

23. The moisture content of thoroly air-dry hay depends primarily upon the nature of the crop and the weather conditions. It will average about 11.4 per cent for alfalfa. The moisture content of field-cured hay is more variable. Hay containing 25 per cent moisture is considered sufficiently dry for placing in the stack or mow.

24. Windrowing or cocking of relatively green or partially cured hay will materially prolong the curing period, and the time required to reduce the hay to a field-cured or air-dry condition is shortened as the period of swath curing is extended.

As an average of 4 field-curing tests, 27 hours were required to reduce the moisture content of hay curing in the swath to 30 per cent. Where hay was cured in the windrow and cock thruout, 65 and 102 hours were required to reach the same moisture content, respectively. Where swath curing to the " beginning to wilt ", " well-wilted ", and " two-thirds cured " stages preceded either windrowing or cocking, 50 and 53, 44 and 45, and 29 and 29 hours were required, respectively, to reduce the hay to a 30 per cent moisture content.

25. There was no indication in tests covering a period of 5 years that the leaves functioned materially in the withdrawal of moisture from the stems during the curing period. In 487 comparisons of comparable samples of hay curing in the field with leaves intact and detached, it was found that the moisture content of the two kinds of samples differed one per cent or less 253 times, or in 52 per cent of the comparisons. In the remaining comparisons or those wherein the difference in moisture content was greater than 1 per cent, the samples with leaves intact had a somewhat lower moisture content than the corresponding samples with leaves detached in 117 cases, and a somewhat higher moisture content in an equal number of instances.

The fact that alfalfa windrowed or cocked in a green or partially cured condition lost moisture more slowly than when cured entirely in the swath, is further evidence of the fallacy of a rather common opinion that such conditions prolong the normal transpiratory functioning of the leaves in the cut forage, thereby accelerating the rate of moisture loss from the stems.

26. Laboratory curing tests of normal hay and of hay with leaves detached indicated that the normal hay dried somewhat faster than the bare stems, but when the curing of the stems and leaves are averaged the rate is almost identical with that of normal hay.

27. A very close relation was observed between weather conditions and rate of curing. Frequently, correlated weather conditions such as high temperature, sunshine, and wind, and low humidity are very conducive to rapid curing .

28. Drying of external moisture bears, in general, the same relation to weather conditions and method of curing as that of internal moisture, but usually takes place more rapidly.

29. Prolonged curing of hay beyond the field-cured condition resulted in increased loss of dry matter. As an average of 2 tests,

90.7 per cent of the hay curing in the swath until field cured was recovered. That recovered when cured in the windrow and cock ranged from 99.9 to 94.5 and from 96.3 to 95.0 per cent, respectively depending upon the period of swath curing preceding windrowing and cocking. If swath cured hay were properly handled from the time it became about "two-thirds cured", it would seem that the loss should not exceed 5 per cent as measured by these tests.

30. In regions where damage from rains may be expected, the best practice would seem to be to reduce the moisture content of the hay to a field-cured condition as rapidly as possible, without undue loss in quality and dry matter. In no case, however, should swath curing continue after the hay approaches a field-cured condition. Partial swath curing followed by windrowing before the leaves shatter may be regarded as the most effective and desirable procedure in general farm practice.

ALFALFA INVESTIGATIONS

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The purpose of these alfalfa investigations has been to determine the relation of variety, source of seed, and cultural practice to the yield and quality of hay produced. Due to the high initial cost of seeding, the inconvenience and wastefulness of losing a stand prematurely, and the superiority of properly-made hay, an understanding of these relationships is very important.

IMPORTANCE OF ALFALFA IN NEBRASKA

Nebraska ranks first among all states in the acreage grown to alfalfa as reported in the 1924 Agricultural Yearbook of the United States Department of Agriculture.[1] The annual crop in this State during the 5-year period 1920-1924 has averaged 1,193,000 acres as compared with 9,599,000 acres for the entire United States. The production of alfalfa within the State has had a rather gradual growth during the last 25 years. In 1902, 207,000 acres were reported in the Annual Report of the Nebraska State Board of Agriculture. The average annual acreages for 5-year periods since then as compiled from similar reports in 1905 and 1908, and from Bulletin 123 of the Nebraska Department of Agriculture, have been 322,000 for 1903-1907, 687,000 for 1908-1912, 1,043,000 for 1913-1917, and 1,188,000 acres for 1918-1922.

The great economic importance of alfalfa in regions where it is adapted lies in its large and unequaled yield of palatable, high-protein forage, and in its soil-building qualities. No combination of crops could be better suited for the extensive production of livestock than alfalfa, sweet clover, and corn, where these can be grown successfully.

It is generally considered that alfalfa is better adapted to irrigated districts and to subhumid regions than to the more humid or arid localities. Thus in Nebraska approximately three-fourths of the acreage is found in the eastern one-half of the State. Nevertheless, the subirrigated valleys and irrigated districts in western Nebraska where the rainfall is relatively low are well suited to the growing of alfalfa. Without question the conditions in regions of relatively low rainfall are most favorable for the handling and curing of the hay crop.

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[1] Complete reference to all papers cited may be found on pp. 117-125.

INTRODUCTION OF ALFALFA

According to Bassett (1916), alfalfa was first introduced into Nebraska in 1875 from Utah and during the early eighties it was being grown in several counties in the southwestern part of the State. Bessey (1886) stated that "It has been sown repeatedly in many parts of the country east of the Rocky Mountains, but for some reason it has not come into general use even in those portions where the winters are not too severe for it." Bessey further stated at that time, before Nebraska conditions were fully understood, that much of Nebraska might be irrigated and that then red clover, alfalfa, and the grasses would flourish as in the irrigated districts of Colorado. Smith (1888) concludes from field tests by the Nebraska Experiment Station that "It is the best of the 'clovers' tried by us." Bessey (1890) lists it as one of the 12 most prominent grasses and clovers for Nebraska and in 1896 quotes S. P. Baker of Curtis, Nebraska, who stated that he had received his first seed directly from San Francisco 17 years previous and that the field seeded at that time was still in vigorous condition.

From a review of the literature it is apparent that alfalfa spread in this country from the West to the East. Altho it had been introduced into the Atlantic Coast States in earlier days, it did not maintain a recognized foothold in the United States until about 1850, when it was brought into California from South America.

Early History.—According to Hendry, (1923), alfalfa is native to Mesopotamia. From there it was taken south into Arabia during the remote epochs of antiquity. The first written reference to alfalfa was found in a Babylonian text of about 700 B. C. In the fourth century B. C., it was found in Greece. From there it was carried to Italy in about the second century B. C. At the same time it was taken from that part of Asia which has since become Russian Turkestan, into northern China. In the meantime it was being carried out from the Roman Empire into southern Spain and to the Lucerne Lake region of Switzerland. In its subsequent dispersion thru Europe it was known as 'Lucern.' According to some authorities it entirely disappeared from Italy in the fifth century and was reintroduced from Spain in the sixteenth century from where it spread to France and to

Germany in about 1573 and soon thereafter to England. Alfalfa was carried to South America during the fifteenth century, whence it was introduced to the United States.

CLASSIFICATION OF VARIETIES

The commercially grown alfalfas are commonly classified in four groups. In case of the Common and Turkestan alfalfa, the group and variety names are synonymous, while in the variegated and non-hardy groups several rather widely recognized varieties are found.

The Common Group includes the ordinary purple-flowered nonpubescent sorts. The alfalfa first brought under cultivation was probably of this type. Much of the alfalfa in the United States is of the Common variety, having spread from the Western States after its introduction into California from South America. According to Oakley and Westover (1916) "the term 'Common Alfalfa' has been used to include all of the alfalfas that are not clearly of hybrid origin or that do not have fairly distinct and uniform varietal characteristics, even though within this group, what are known as regional strains are coming to be recognized."

The Variegated Group includes the alfalfas that are commonly believed to have originated from a natural cross between common alfalfa *(Medicago sativa)* and the yellow-flowered alfalfa *(Medicago falcata)*. They are considered intermediate in form between these two varieties and they may always be distinguished by more or less variegation in the blossom. They are generally regarded as more resistant to low temperatures than Common alfalfa due to their inheritance from the yellow-flowered parent. Grimm, Cossack, Baltic, Canadian Variegated, and Sand Lucern are representatives of this group.

The Turkestan Group includes all the alfalfa of Turkestan origin. The original importations were thought to be hardy, due to the adverse conditions under which they had been grown for many seed generations. Within recent years, however, the importations have included miscellaneous lots of seed, much of which has been produced under relatively favorable conditions, so that now Turkestan seed is generally considered inferior.

The Non-Hardy Group includes alfalfas of southern origin, generally believed to be more susceptible to low temperatures than any of the other sorts. In the more temperate climates they may be characterized by long periods of growth and quick recovery after cutting. Peruvian and Arabian are the only two varieties of this group grown commercially to any great extent in this country.

FIELD PLAT TECHNIQUE OF THESE EXPERIMENTS

Plat Size.—All yields determined in connection with these investigations are from one-twentieth acre field plats, being either 14 or 28 feet in width. For certain cultural studies, related only to the question of securing a stand and for which yield determinations were not desired, the plats were in a few instances reduced to a single drill swath, 7 feet wide. Fallow strips 1 foot wide have been maintained between plats, and the roadways at the ends of the plats were seeded to alfalfa or brome grass.

Duration of Tests.—The plats dealing with tillage, top dressing, and stages of maturity were laid out in the spring of 1921 in a field of alfalfa which had been seeded in the fall of 1918. The plats comparing varieties and regional strains were seeded in the spring of 1922 (Fig. 1). Seedings for the miscellaneous cultural studies were first made in 1922 and continued since then according to the plan of the test.

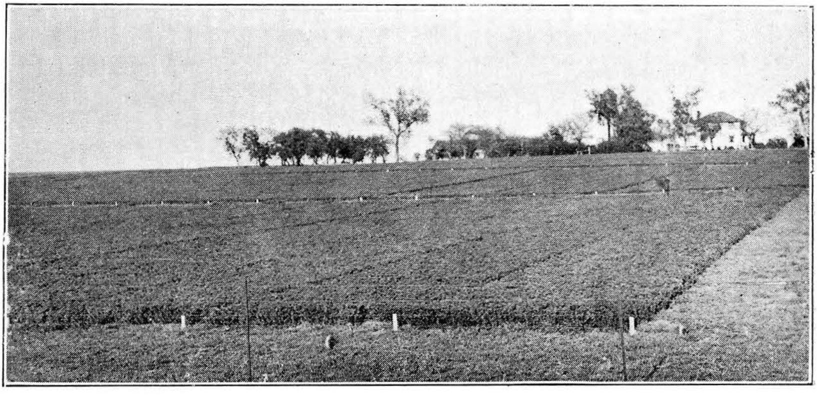

FIG. 1.—General view of field containing the varieties and regional strains of Common alfalfa seeded in the spring of 1922. Photographed May 25, 1925.

Replication and Check Plats.—In tests where yield determinations were desired, the plats have always been in duplicate. In the variety tests, three of the more common sorts were replicated five times and the other varieties, excepting Peruvian, three times. Every fifth plat was used as a check, being seeded to Common alfalfa the seed of which was produced in west central Nebraska under dry-land conditions. Seedings were usually made in the spring of the year without nurse crops. Except in the method-of-seeding test, an ordinary press wheel grain drill with an alfalfa seeder attachment was used and seeding was at the rate of 20 pounds per acre, unless otherwise specified. Clippings were made as found necessary but yields were not determined during the first season.

Except where otherwise required by the nature of the experiment, the alfalfa plats were ordinarily harvested at the new growth stage. This stage was determined by the rather definite appearance of new growth or shoots at the crown and usually occurred between one-tenth and one-half bloom.

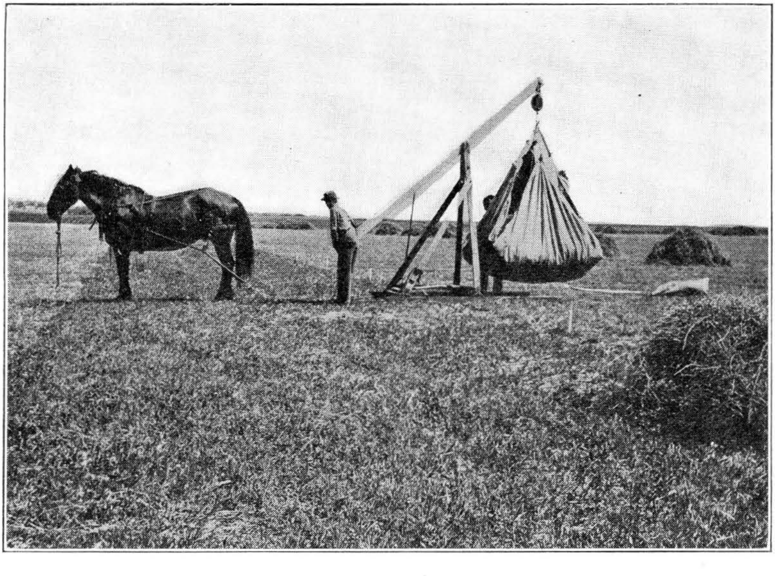

FIG. 2.—Field weighings are made with a spring dial scale. As soon after weighing as possible a composite sample of hay is taken for moisture determination. Field weights are converted on the basis of this sample to hay containing 15 per cent moisture.

Yields on Uniform Moisture and Weed-Free Basis.—All yields reported are on an equal moisture content basis. Plat weights were taken in the field with a spring dial scale (Fig. 2). At the time of weighing, a composite sample of hay (a 2-bushel bag was usually filled) was taken from each variety, strain, or treatment. These samples were run thru a small hand feed cutter, were well mixed, and then reduced in quantity (usually to 500 grams). These samples were placed in small cotton bags and dried in an electric oven to a moisture free basis. The plat yields have been converted to a 15 per cent moisture content on the basis of these samples.

In those cases where the forage contained any considerable amount of weed growth due to thinning as a result of winterkilling or other causes, the percentage of weeds was determined by weight and indicated as in Table 3.

VARIETIES AND REGIONAL STRAINS

COMPARATIVE VARIETY TESTS

Eight varieties, representing the four commercial groups, were seeded at the Nebraska Experiment Station under comparable conditions in the spring of 1922 in order to measure their relative hardiness, productiveness, and the quality of forage produced. The seed of Common alfalfa had been produced in west central Nebraska under dry land conditions, and was seeded in every fifth plat as a check. The seed of the other seven varieties was secured thru the Office of Forage Crop Investigations of the United States Department of Agriculture. The Cossack, Grimm, and Turkestan varieties were replicated five times; the Baltic, Canadian Variegated, and Sand Lucern were seeded in triplicate, and the Peruvian in duplicate. The results from 1923 to 1925 are recorded in Table 1 and Chart 1.

YIELD OF HAY PER ACRE

The yields reported in Table 1 are weighted on a percentage basis in accordance with the average of the two nearest checks. Three cuttings were harvested in 1923 and 1924 and four cuttings in 1925. As a 3-year average, 1923-1925, the following yields of hay in tons per acre were secured: Common, 5.36; Cossack, 6.08; Baltic, 5.92; Grimm, 5.62; Canadian Variegated, 5.53; Sand Lucern, 4.94; and Turkestan, 5.00 tons per acre. Corresponding relative yields were 100, 113, 110, 105, 103, 92, and 93 per cent. With the exception of the Canadian Variegated in 1923, the yields have been

TABLE 1.—*Comparative yields, physical characteristics, and chemical composition of alfalfa varieties, 1923-1925*

	Common	Cossack	Baltic	Grimm	Canadian Var.	Sand Lucern	Turkestan	Peruvian
YIELD OF HAY PER ACRE WITH 15 PER CENT MOISTURE CONTENT								
Annual yields								
Actual (tons per acre)								
1923	4.33	4.83	4.76	4.37	4.08	3.94	4.24	4.45
1924	6.83	7.77	7.49	7.44	7.09	6.48	6.41	6.11
1925	4.92	5.64	5.51	5.05	5.42	4.41	4.35	...
Average	5.36	6.08	5.92	5.62	5.53	4.94	5.00	...
Relative (Pct.)–								
1923	100	112	110	101	94	91	98	103
1924	100	114	110	109	104	95	94	89
1925	100	115	112	103	110	90	88	...
Average	100	113	110	105	103	92	93	...
Yield by cuttings, 3-yr. av.								
Actual (tons per acre)								
1st cutting	2.15	2.72	2.60	2.37	2.37	2.05	2.14	...
2nd cutting	1.73	1.95	1.92	1.83	1.75	1.60	1.55	...
3rd cutting	1.11	1.05	1.04	1.05	1.08	0.96	1.00	...
4th cutting	0.37	0.36	0.36	0.37	0.33	0.33	0.31	...
Relative, inter-var.								
1st cutting	100	127	121	110	110	95	100	...
2nd cutting	100	113	111	106	101	92	90	...
3rd cutting	100	95	94	95	97	86	90	...
4th cutting	100	97	97	100	89	89	84	...
Relative, inter-crop								
All cuttings	100	100	100	100	100	100	100	...
1st cutting	40	45	44	42	43	42	43	...
2nd cutting	32	32	32	32	32	32	31	...
3rd cutting	21	17	18	19	19	19	20	...
4th cutting	7	6	6	7	6	7	6	...
PHYSICAL CHARACTERISTICS								
Per cent leaves, 3-year av.								
1st cutting	39.6	40.5	37.6	40.2	38.1	41.0	40.9	...
2nd cutting	42.8	43.2	43.2	44.9	43.6	43.3	44.9	...
3rd cutting	51.7	55.5	54.6	56.0	54.8	54.0	57.6	...
All cuttings	44.9	46.6	45.3	47.2	46.0	46.1	47.9	...
Stem diam., 1925 (mm.)								
1st cutting	2.67	2.81	3.17	3.13	2.90	3.12	3.00	...
2nd cutting	2.22	2.29	2.54	2.38	2.39	2.46	2.38	...
3rd cutting	1.86	1.71	1.87	1.92	1.90	2.03	1.93	...
All cuttings	2.29	2.27	2.47	2.45	2.40	2.49	2.40	...
Plant height, 3-yr. av. (in.)								
1st cutting	27.5	27.0	27.1	26.8	27.3	26.7	26.9	...
2nd cutting	25.4	24.5	24.8	24.8	24.7	25.5	24.2	...
3rd cutting	18.6	17.1	17.5	17.3	18.0	18.2	16.3	...
All cuttings	23.4	22.4	22.7	22.5	22.8	23.1	21.9	...
Variegated flowers (Pct.)	0	55.3	50.4	48.0	41.7	35.0	0	0
CHEMICAL COMPOSITION (MOISTURE-FREE BASIS)[1]								
Crude protein content (Pct.)								
Annual								
1923	15.60	17.15	17.50	17.95	17.60	17.60	18.15	15.80
1924	17.10	17.70	17.60	17.37	17.90	17.93	18.53	18.77
1925	19.10	19.93	19.27	20.20	20.00	19.00	19.30	...
Average	17.27	18.26	18.12	18.51	18.50	18.18	18.66	...
By cuttings, 3-yr. av.								
1st cutting	16.03	16.47	16.30	17.57	17.43	17.27	16.83	...
2nd cutting	17.60	18.18	18.43	18.55	19.57	18.83	18.93	...
3rd cutting	18.67	20.90	20.47	19.83	19.93	19.00	21.13	...
Fodder analyses, 3-year average (Pct.)								
Ash	10.16	9.86	10.21	10.39	10.48	10.02	10.15	...
Crude protein	17.27	18.26	18.12	18.51	18.50	18.18	18.66	...
Crude fiber	33.68	32.49	32.87	31.91	32.00	32.27	31.57	...
Nitrogen-free extract	36.36	36.75	36.22	36.54	36.41	36.72	36.62	...
Fat	2.53	2.64	2.58	2.65	2.61	2.81	3.00	...

[1]All chemical analyses reported in these investigations were made for the Agronomy Department under the direction of Dr. M. J. Blish, Station Chemist.

fairly consistent thruout the period. Further confidence is had in these results when the actual average yields during the 3-year period are compared with the corrected yields as presented in Table 1. The greatest variation of the actual from the corrected yield was 3.8 per cent, while the average variation for the 7 varieties was found to be 1.8 per cent.

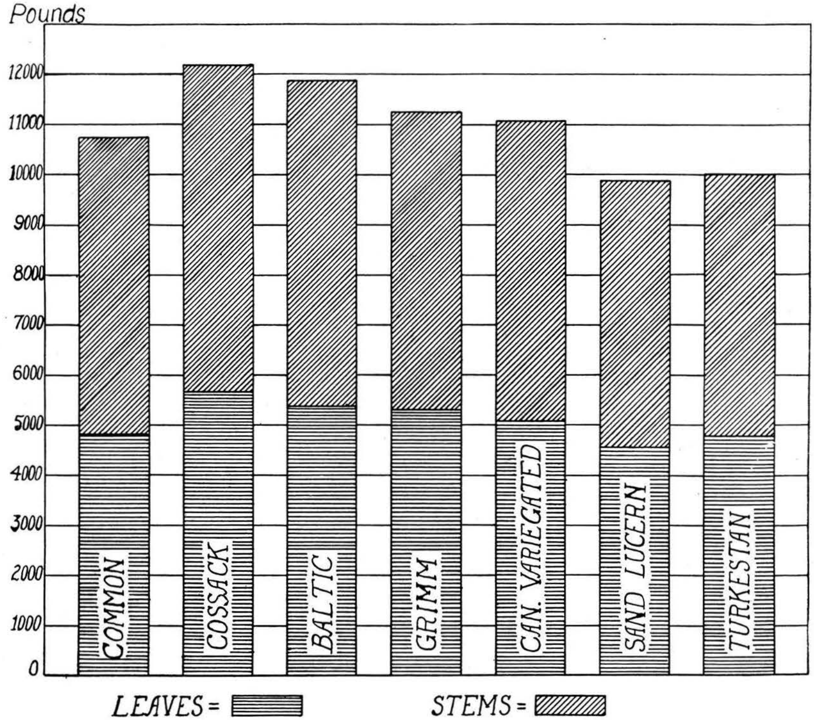

CHART 1.—Comparative hay yields of alfalfa varieties together with their proportionate yields of leaves and stems, 3-year average, 1923-1925. (Table 1.)

It should be borne in mind, however, that in this experiment only one strain of each variety was grown; and even tho care was taken to use alfalfa typical of the variety, these results should not be considered as an absolute measure of varietal differences. Attention is called to Table 3, where an extreme variation of 11 per cent in yield was found between domestic strains of Common alfalfa. As a group the 5 variegated varieties averaged 5 per cent more in yield than Common.

With the exception of three varieties Sand Lucern, Turkestan, and Peruvian, the stands have been quite comparable during the period for which yields have been reported. Peruvian was entirely winterkilled during the winter of 1924-1925 (Fig. 3); but during the preceding 2-year period when stands were comparable, it gave no indication of being superior to Common. Sand Lucern and Turkestan were

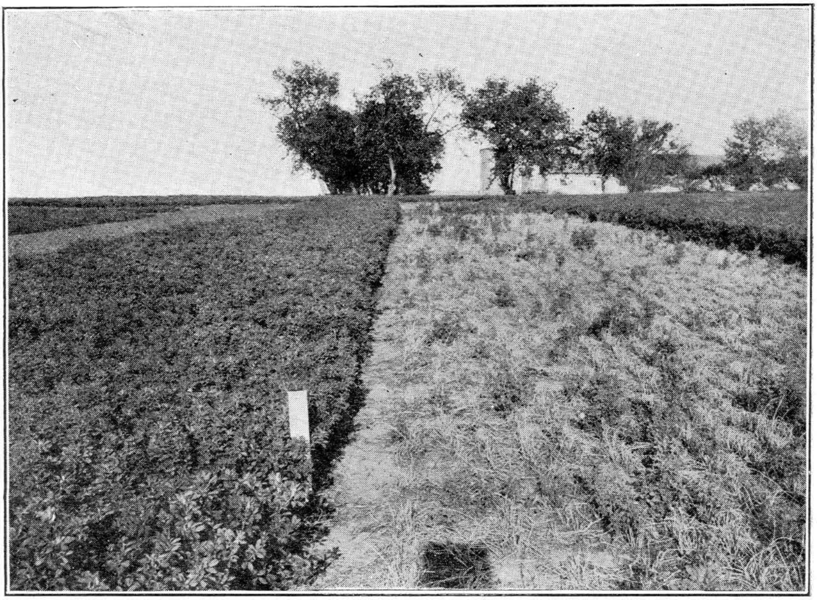

FIG. 3.—Nebraska-grown Common alfalfa at left and Peruvian alfalfa at right, seeded May 16, 1922. Both varieties seemed equally good during 1923 and 1924, but the Peruvian winterkilled almost completely in the winter of 1924 to 1925, while the Nebraska Common was uninjured. Photographed May 25, 1925.

slightly thinner at the outset, but the difference was not considered great enough to affect the yield. The stand of Turkestan was slightly reduced and that of Sand Lucern was materially reduced, however, during the winter of 1924-25, and in 1925 the stand of the latter was only 73 per cent of the average for the other six varieties. Again during the winter of 1925-26 the stand of Sand Lucern was further reduced and in 1926 averaged less than one-third of that of the other varieties (Fig. 4). Some winterkilling during the winter of 1925-26 was also observed on all other plats but appeared somewhat more marked with the Common and Canadian Variegated than with the other varieties. Good stands remain, however, and differences in yield due to this thinning are not anticipated except in the case of Sand Lucern.

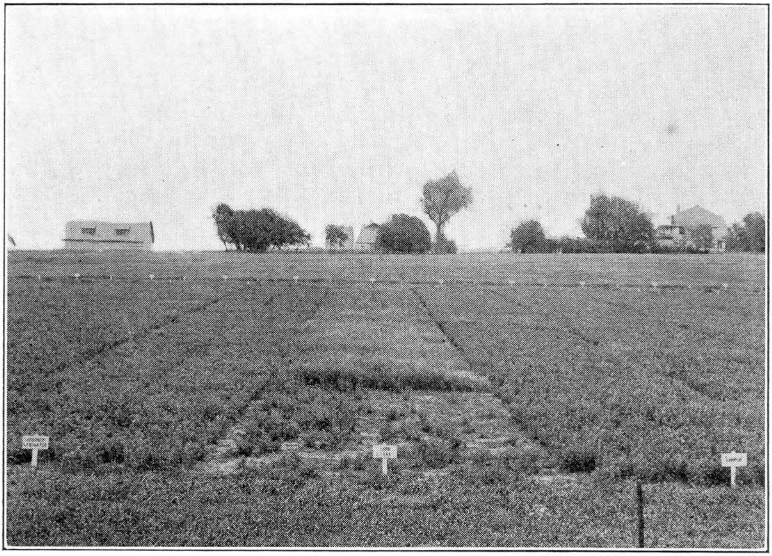

FIG. 4.—Canadian Variegated alfalfa on the left, Sand Lucern in the center, and Common alfalfa on the right. Seeded May 16, 1922, and photographed September 2, 1926. The stand of Sand Lucern was materially thinned during the winter of 1924-1925 and again during 1925-1926. The weeds in the foreground of the Sand Lucern plat have been pulled in order to show the actual stand of alfalfa in contrast with the adjacent plats.

A further comparison of Common and the 4 variegated varieties, Cossack, Baltic, Grimm, and Canadian Variegated, which averaged 8 per cent more than the Common, show their average yield by cuttings to be 117, 108, 95, and 96 per cent of the Common for the first, second, third, and fourth cuttings, respectively. When the yield of the different cuttings is compared with the total yield, it is found in the case of the

Common that the first, second, third, and fourth cuttings have produced 40, 32, 21, and 7 per cent, respectively, of the total yield, whereas with the 4 variegated varieties the first, second, third, and fourth cuttings have yielded 44, 32, 18, and 6 per cent of the total. This would suggest that since there was no apparent varietal difference in time of maturity the variegated sorts are slightly better adapted to and make more of their growth during the early part of the growing season.

PHYSICAL CHARACTERISTICS

Flower Color.—No very striking individuality in appearance or physical characteristics was observed among the 8 varieties studied. The most pronounced difference between groups was the limited fall growth of Turkestan (Fig. 5) and the variation in flower color of the variegated sorts.

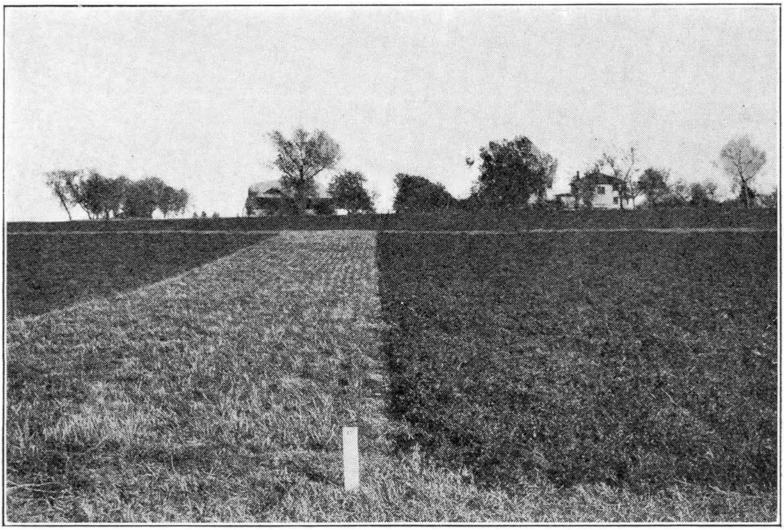

FIG. 5.—Cossack alfalfa on the extreme left, Turkestan in center, and Common on right. Turkestan is slower to recover and makes much less growth after the removal of the last cutting in the fall. Photographed October 23, 1924.

Altho the purple flower is the predominating type in variegated alfalfa, light colors including greenish or yellowish tints and even pure white or yellow make up a considerable per cent of the total. The amount of variegation varies with the variety, the cutting, and weather conditions. Ordinarily it is much more apparent with second and third cuttings. Counts made from these two cuttings of the variegated sorts showed Sand Lucern to have 35 per cent variegation and Cossack 55 per cent as the two extremes.

Proportion of Leaves.—The proportion of leaves by weight was determined on a moisture-free basis for all cuttings of each of the varieties. As a 3-year average, it was found at time of harvest that Common had 44.9; Cossack, 46.6; Baltic, 45.3; Grimm, 47.2; Canadian Variegated, 46.0; Sand Lucern, 46.1; and Turkestan, 47.9 per cent leaves, respectively. These varieties were always harvested and sampled on the same day. With the exception of Turkestan, which was a number of days later blossoming, they usually appeared to be in comparable stages of maturity when harvested. The difference in maturity will account in part at least for the higher proportion of leaves in the Turkestan. As an average of all varieties the first, second, and third cuttings consisted of 39.7, 43.7, and 54.9 per cent of leaves, respectively.

Coarseness and Length of Stem.—Measurement of stem diameters was made for the 7 varieties in 1925. One hundred random selected stems from which the leaves had been stripped in the above test were used. The extreme difference in the average stem diameters between the varieties was 0.22 millimeters or approximately 10 per cent. As an average of all cuttings for the 7 varieties, the uncured forage had an average stem diameter of 2.40 millimeters. Average stem diameter by cuttings for all varieties was 2.97, 2.38, and 1.89 millimeters for the first, second, and third crops, respectively.

The extreme difference in average plant height per cutting between the varieties at the time of harvesting was 1.5 inches as a 3-year average. The average plant height for all cuttings and varieties was 22.7 inches. Average plant height for all varieties by cuttings was 27.0, 24.8, and 17.6 inches for the first, second, and third cutting, respectively. Tendency to lodge in the case of heavy first cuttings was more apparent with the variegated varieties than with the other sorts.

Altho these data fail to show any marked or consistant varietal differences with respect to leafiness, coarseness of stem, and plant height, they do show an increase in the leafiness and a decrease in coarseness and length of stem with successive cuttings.

CHEMICAL COMPOSITION

Complete fodder analyses of the hay were made during the three-year period, 1923 to 1925, for each cutting of all varieties. A summary of these determinations on a moisture-free basis is included in Table 1. No very striking varietal differences were found. The 5 variegated sorts averaged 18.31 per cent protein compared with 17.27 per cent for Common and 18.66 per cent for Turkestan. As an average of all varieties, the protein of the first, second, and third cuttings was 16.84, 18.58, and 19.99 per cent, respectively. These variations in protein percentage are in the main associated with differences in the proportion of leaves.

As a 3-year average for all varieties and cuttings the hay contained 10.18 per cent ash, 18.21 per cent protein, 32.40 per cent fiber, 36.52 per cent nitrogen-free extract, and 2.69 per cent fat.

COMPARATIVE CROWN AND ROOT DEVELOPMENT

A comparative study was made of the crown and roots of Common, Grimm, and Cossack alfalfa. Approximately 300 3-year-old plants of each variety taken from 4 replicate plats of the foregoing variety tests were measured in each case. Most excavations and measurements were made to a depth of 1 foot below the crown. In one case, however, a trench 42 feet long and 5 feet deep, across 3 adjacent plats seeded to these varieties, was opened for measuring and photographing to a greater depth (Figs. 6, 7, 8, and 9). Typical roots of plants one year old and of seedling plants are shown in Figs. 10 and 11 for Common, Grimm, and Cossack alfalfa.

In a number of instances, the root systems were very carefully worked out to a depth of 18 inches in order to show the great abundance of small fibrous roots. (Fig. 12).

The measurements and observations reported in Table 2 fail to show any very striking differences in the character of the crowns or root systems. The Cossack variety made the greatest departure from the Common, which it exceeded 22 per cent in number of crown branches, 13 per cent in width of crown, 5 per cent in depth of crown, and 12 per cent in the number of forage stems per crown.

The Grimm variety surpassed the Common 9 per cent in the number of crown branches and 8 per cent in width of crown; but did not exceed it in crown depth or number of stems produced.

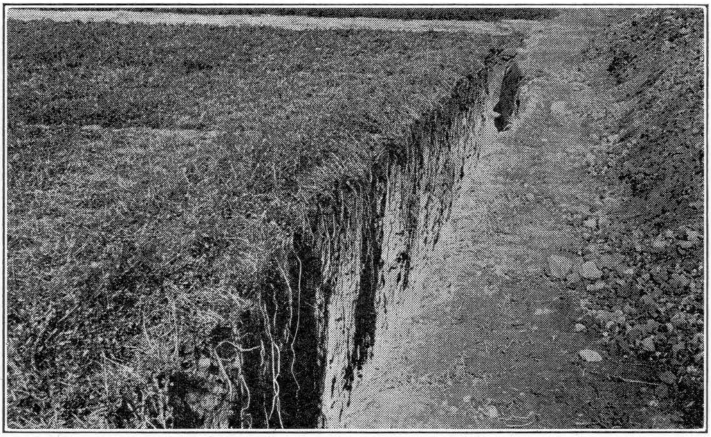

FIG. 6.—The trench which was opened across adjacent plats of Common, Grimm, and Cossack alfalfa for measuring and photographing their roots to a depth of 5 feet as shown in Figs. 7, 8, and 9. Photographed October 23, 1924.

FIG. 7.—Exposed roots in a trench 5 feet deep within a plat of Common alfalfa seeded May 16, 1922. Photographed November 11, 1924.

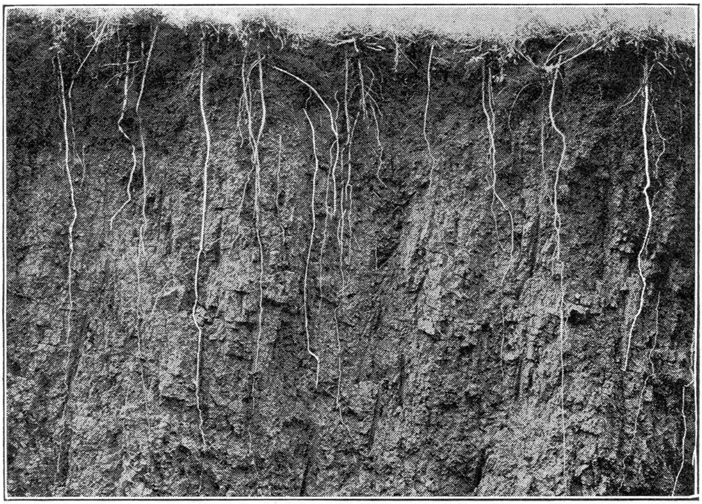

FIG. 8.—Exposed roots in a trench 5 feet deep within a plat of Grimm alfalfa seeded May 16, 1922. Photographed November 11, 1924.

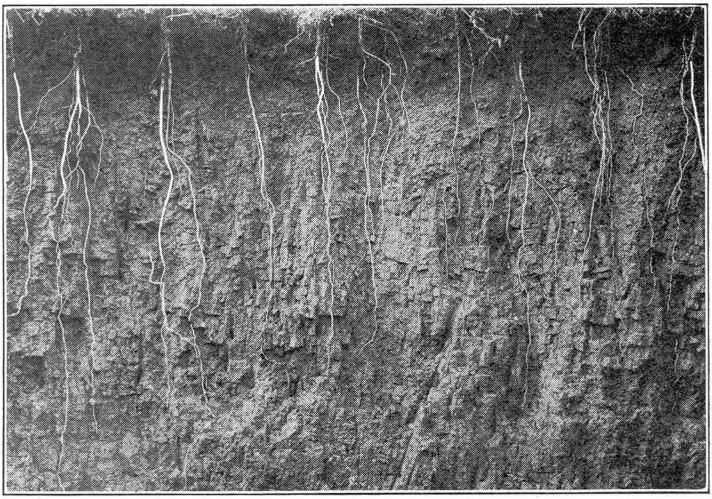

FIG. 9.—Exposed roots in a trench 5 feet deep within a plat of Cossack alfalfa seeded May 16, 1922. Photographed November 11, 1924.

These 2 variegated varieties had slightly finer tap and branch roots and about 8 per cent more of the roots were branched than with the Common. In the case of the Grimm and Cossack, however, the roots that were branched had measurably more branches per root. Very few of the taproots of any variety were forked, and it is doubtful if the small differences in favor of the Common is very significant.

TABLE 2.—*Comparative crown and root development of Common, Grimm, and Cossack alfalfa*[1]

Measurement	Variety and average number of plants measured					
	Common-316		Grimm-334		Cossack-294	
		Relative		*Relative*		*Relative*
Crown						
Number of crown branches	2.46	100	2.69	109	3.01	122
Depth of crown (inches)	1.34	100	1.32	99	1.41	105
Width of crown (inches)	1.57	100	1.70	108	1.77	113
Stems per crown[2]	3.72	100	3.59	97	4.16	112
Root[3]						
Diameter (inches)						
At base of crown–	0.343	100	0.320	93	0.337	98
1 foot below crown	0.165	100	0.151	92	0.152	92
2 feet below crown[4]	0.123	100	0.114	93	0.118	96
3 feet below crown	0.101	100	0.096	95	0.090	89
4 feet below crown	0.080	100	0.074	93	0.071	89
Depth to first fork or root branch (inches)	2.83	100	2.27	80	2.11	75
Forked roots per 100 plants	9.29	...	3.36	...	6.21	...
Maximum diameter of forked roots (inches)	0.367	100	0.355	97	0.330	90
Maximum diameter of root forks (inches)	0.186	100	0.189	102	0.177	95
Branched roots per 100 plants	20.59	...	27.49	...	28.85	...
Root branches per plant	0.32	100	0.48	150	0.52	163
Diameter of root branches (inches)	0.105	100	0.094	90	0.088	84
Relative fibrousness of roots[5]						

[1]3-year-old plants. Seeded in spring of 1922.
[2]Stems per plant produced during last crop of season.
[3]Unless otherwise stated, root measurements are for the upper 12 inches. In case of root branches, only those .05 inch or over in diameter were counted. Roots approximately equally divided were classed as forked.
[4]Root diameters taken below 1 foot in depth are for fewer numbers.
[5]Accurate measurements and counts of the smaller and more fibrous root branches was not undertaken because of the difficulty in extracting the root system in its entirety. Close observation, however, of the above roots as excavated and of a few carefully worked out root systems failed to show a measurable varietal difference in relative root fibrousness.

While the fibrousness of the various root systems was striking, there was no apparent difference in this regard for the various varieties. An abundance of nodules were found on the roots of all sorts.

COMPARATIVE TEST OF REGIONAL STRAINS OF COMMON ALFALFA

A test including Common alfalfa from 20 different sources was run parallel with the preceding variety test for comparison as to growth characteristics and possible differences

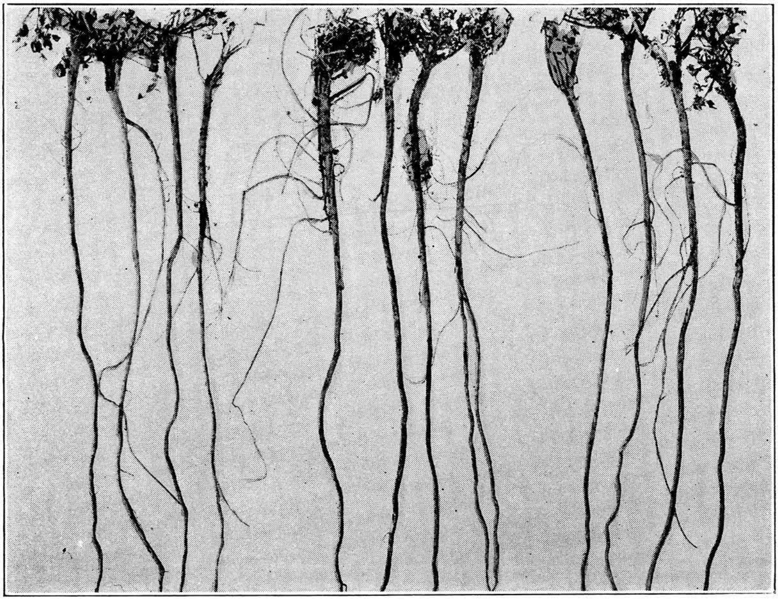

FIG. 10.—Typical plants of Common alfalfa (left), Grimm (center), and Cossack (right). Seeded September 6, 1924, and photographed November 30, 1925.

in hardiness and productiveness. The same strain of Common alfalfa as used in the variety tests was seeded every fifth plat for checking results. The other nineteen strains were grown in duplicate plats. Five of these strains were of foreign origin. The domestic strains included local seed from each of the series of states extending from North Dakota to Texas and from Montana to New Mexico inclusive. Four of the strains in addition to the check were from Nebraska. Two of these were from Dawson County where they were thought locally to have special merit, while the other two were produced respectively under dry land and irrigated conditions of extreme western Nebraska. Both dry land and irrigated seed was included from Wyoming and the one strain from New Mexico had been produced under irrigation. Otherwise the domestic strains were all of dry land origin. Seed of these regional strains of alfalfa was secured either from the Office of Forage Crops Investigations of the United States Department of Agriculture or thru Experiment Stations in the states concerned. Effort was made to

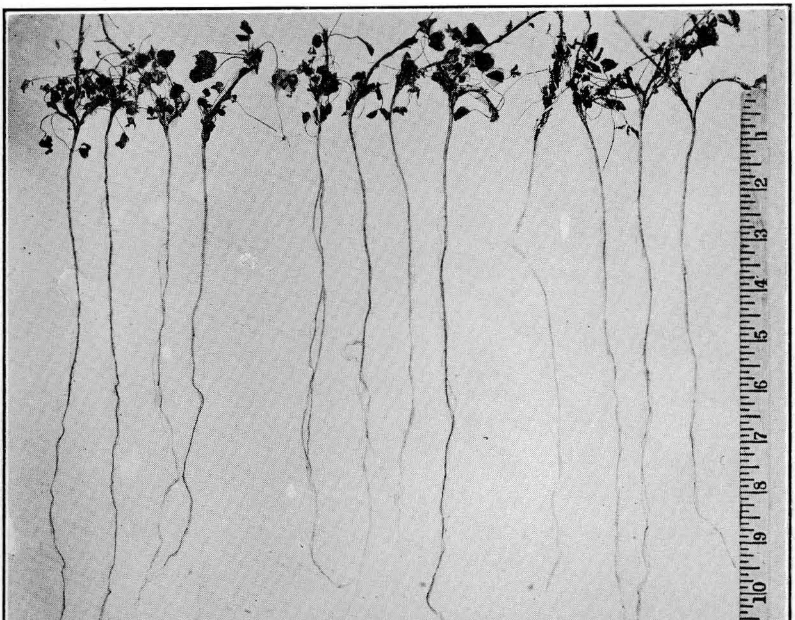

FIG. 11.—Typical seedling plants of Common alfalfa (left), Grimm (center), and Cossack (right). The plants above were from seedings made August 24, 1925, and those below from seedings made September 15, 1925. Photographed November 30, 1925.

secure seed of known origin and which had been grown for a number of seed generations under the specified environmental conditions. The yields, weighted by check plats, are shown in Table 3.

TABLE 3.—*Comparative yields of regional strains of Common alfalfa, 1923-1925*

Source of Seed	Average height per cutting	Yield of hay per acre with 15 per cent moisture content							
		1923		1924		1925		Average	
	Inches	*Tons*	*Relative*	*Tons*	*Relative*	*Tons*	*Relative*	*Tons*	*Relative*
Nebraska (Lincoln Co.)	23.7	4.76	100	7.18	100	4.90	100	5.61	100
Russia	23.1	5.14	108	7.31	102	5.32	109	5.92	106
Italy[1]	24.1	5.30	111	7.30	102	3.75	77	5.45	97
France (Provence)	22.0	4.71	99	6.67	93	4.83	99	5.40	96
Spain[1]	22.2	3.45	72	4.87	68	3.72	76	4.01	71
Argentina[1]	23.2	5.02	105	7.36	103	3.37	69	5.25	94
North Dakota	23.8	4.69	99	7.33	102	4.84	99	5.62	100
South Dakota	23.5	4.90	103	7.28	101	4.98	102	5.72	102
Nebraska (Dawson Co.)	23.6	4.76	100	6.90	96	4.73	97	5.46	97
Nebraska (Dawson Co.)[2]	23.4	5.04	106	6.98	97	5.09	104	5.70	102
West Nebr. Dry Land	23.7	5.19	109	7.59	106	5.15	105	5.98	107
West Nebr. Irrigated	23.9	5.21	109	7.56	105	5.02	102	5.93	106
Kansas	23.5	5.34	112	7.53	105	4.87	99	5.91	105
Oklahoma	23.8	4.27	90	7.15	100	5.61	114	5.68	101
Texas	23.5	4.29	90	7.17	100	5.59	114	5.68	101
Montana	23.5	4.83	101	7.12	99	5.13	105	5.69	101
Wyoming, Dry Land	23.5	4.73	99	7.38	103	5.12	104	5.74	102
Wyoming, Irrigated	23.5	5.02	105	6.65	93	5.07	103	5.58	99
Colorado	23.0	4.65	98	6.87	96	4.72	96	5.41	96
New Mexico, Irrigated	23.4	5.30	111	7.53	105	4.86	99	5.90	105

[1]Due to considerable thinning thru winterkilling (1924-1925), the fourth crop of the Italian, Spanish, and Argentine alfalfas contained a high percentage of weeds in 1925. This cutting comprised 29, 23, and 30 per cent respectively of the season's yield for these 3 strains and consisted of 40, 37, and 58 per cent weeds. Stand counts made in the fall of 1925 showed the Italian, Spanish, and Argentine alfalfas to have but 48, 70, and 51 per cent as many plants per square foot as the adjacent check plats of Nebraska Common. There was no apparent winterkilling with the other strains.

[2]Grown in Dawson County as Turkestan. In these tests it could not be distinguished from Common Alfalfa.

YIELD OF HAY PER ACRE

The comparable forage yields of these regional strains as reported in Table 3 are on a basis of 15 per cent moisture content. As an average of the 3-year period 1923-1925, the yields ranged from approximately 4 tons per acre for Spanish to 6 tons for Western Nebraska seed. If we allow 5 per cent deviation from the check for the experimental error of the test, little dependable difference in productivity of the strains has yet been indicated by these experiments aside from the inferior production of Spanish, Italian, and Argentine seed. Even these strains, except the Spanish, yielded satisfactorily

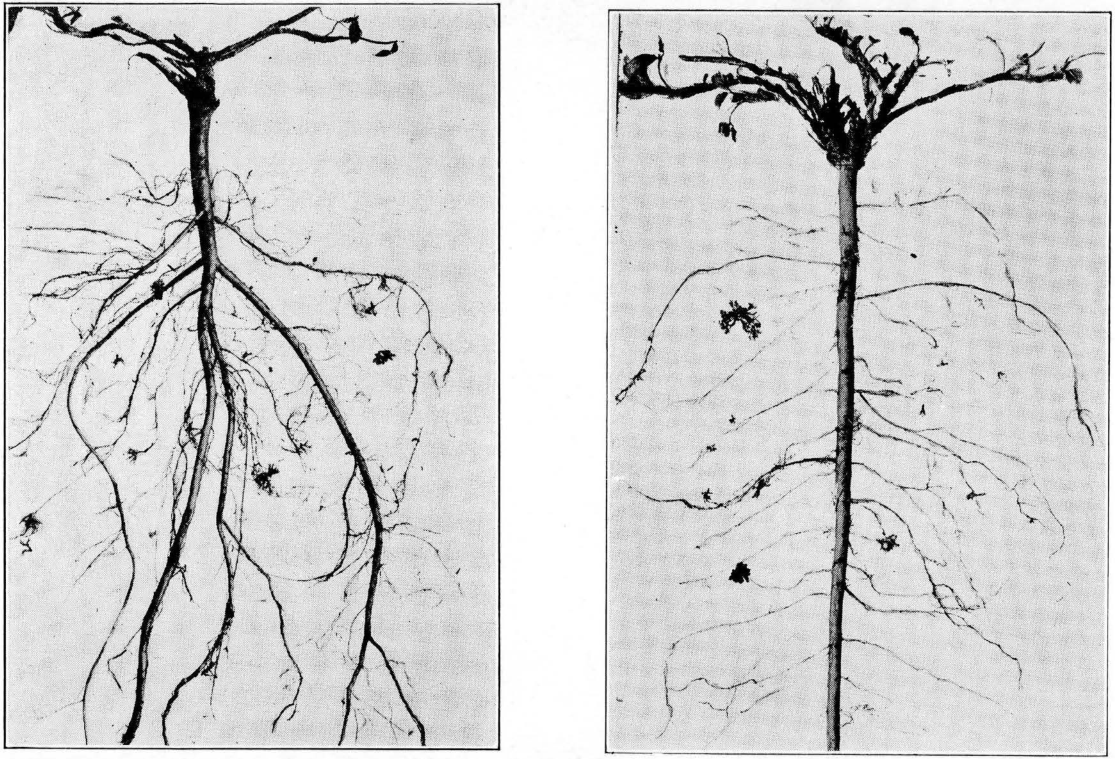

FIG. 12.—Extreme types of alfalfa roots. It was found that 21, 28, and 29 per cent, respectively, of the Common, Grimm, and Cossack plants had branched roots. Note the large numbers of finer branches and nodules obtained by careful excavation.

until the last year, when thinning out by winterkilling resulted in a material reduction in their yield and in rather weedy hay during the latter part of the season (Figs. 13, 14, and 15). During the winter of 1925-26 further winterkilling occurred in these 3 strains as well as in all others. This thinning of stand was sufficiently greater on the plats seeded to alfalfa from Colorado, New Mexico, Oklahoma, and Texas, that a reduction in their yield is expected in 1926 as well as a further reduction in yield for that from Argentina, Spain, and Italy. Based on the results of this test to date and on experiences in more northern states, it is to be expected that winterkilling in these southern and less hardy strains will increase and that they will lower relatively in yield as time goes on or as more severe winter conditions arise. It appears from the data at hand that, aside from the factor of winterkilling, all of these strains, except Spanish, possess nearly equal producing capacity.

Yields from Irrigated and Non-Irrigated Seed.—Comparable samples of seed grown under dry land and irrigated conditions in Nebraska and Wyoming were tested. There was practically no difference between the seed from either State and as an average for both States the dry land seed yielded 2 per cent more hay than the irrigated seed.

PHYSICAL CHARACTERISTICS

There were no striking differences in the appearance of these 20 strains of Common alfalfa. Those from Italy, Spain, Argentina, and France usually appeared somewhat lighter green in color. The strains from Russia, Argentina, Italy, and France made a somewhat slower and shorter growth after the last cutting of the season was removed. This difference was not so apparent at other times of the season. On the other hand, the strain from Spain was quicker to start after each cutting and usually made more late fall growth. There was no material difference in average height per cutting except in the case of the French and Spanish alfalfas, which averaged 1.7 and 1.5 inches shorter per cutting than checks.

VARIATION IN WINTER HARDINESS

Winter killing in these tests has ranged from a very slight to a complete loss of stand. Where winter injury has occurred, some of the affected plants may start growing in the spring but show weakness and continue to die thruout the season. Such results may sometimes be confused with the effects of drought and disease.

That there is a difference between varieties and regional strains of Common alfalfa in winter hardiness has been borne out by the results from the field plats previously discussed, and by similar results from comparable seedings of the same alfalfas in nursery plats in the fall of 1924 and again in 1925 (Fig. 16). In 1925 these nursery seedings were made at 2 dates — normal and later than normal. In comparison with the more hardy sorts, the less hardy winterkilled relatively much more at the later seeding date.

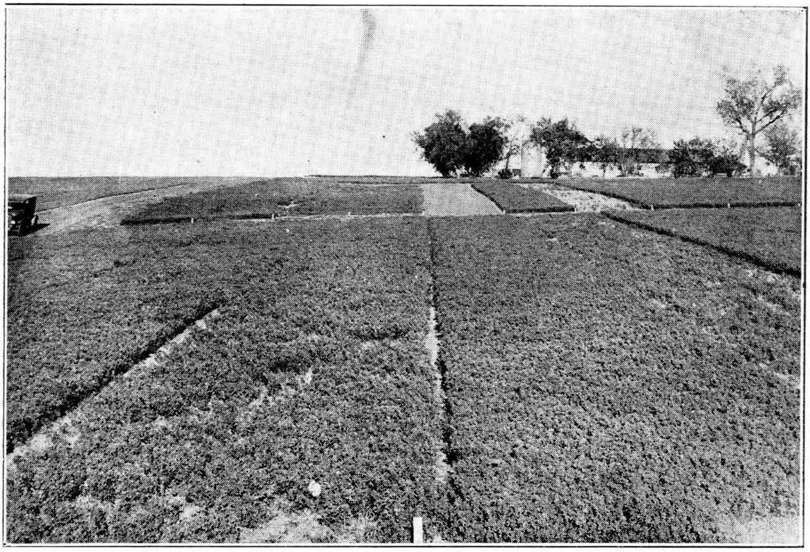

FIG. 13.—Left to right: (1) Spanish-grown, (2) French-grown (Provence), and (3) Italian-grown seed of Common alfalfa; seeded May 16, 1922. The Spanish and Italian strains winterkilled severely in the winter of 1924 to 1925. Photographed May 25, 1925.

Since the same 4 alfalfas winterkilled severely during the winter of 1924-25 and again in 1925-26, whether in new seedings or established two-year and three-year old stands, and since a number of other sorts winterkilled materially in 1925-26, it would appear that more severe conditions in the future may indicate a further difference in the relative winter hardiness of the varieties and strains. All of these established plats as well as new duplicate seedings of the same seed are being continued in a further effort to measure inherent differences in hardiness as well as in production. A new series of field plats has also been seeded to Grimm alfalfa obtained from various sources for similar observation.

Waldron (1919) has shown that natural cross-fertilization in alfalfa is rather frequent. This fact suggests that a variety or strain will not remain constant for any great number of seed generations. Thus alfalfa of the same origin, when subjected for a number of generations to two widely different environments, may develop into two distinct regional strains thru the principle of survival of the fittest.

There are no data available to show the occurrence of such changes but it is probable that natural as well as control selection following hybridization have been very potent factors in variety and strain differentiation. Such differences are largely a matter of degree.

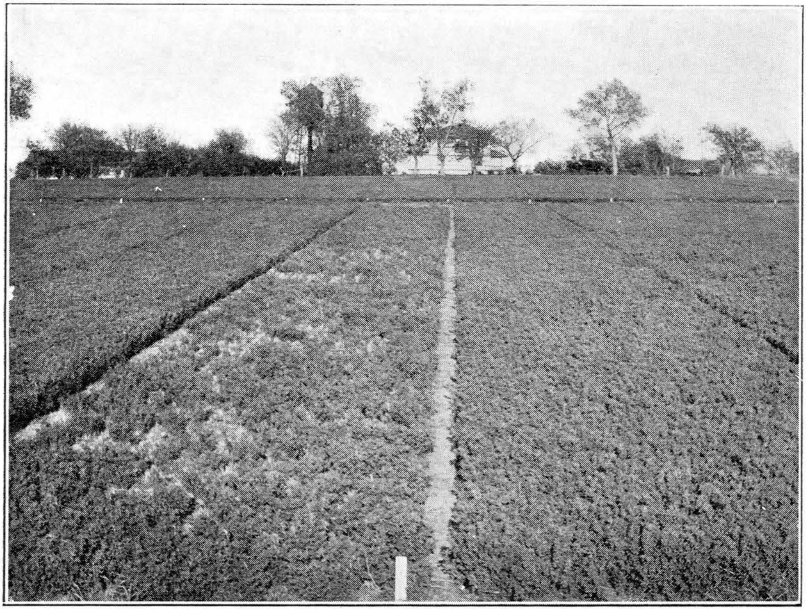

FIG. 14.—Argentine seed of Common alfalfa at left and Nebraska Common at right, seeded May 16, 1922. The Argentine seed has proved unhardy for Nebraska conditions, winterkilling severely in the winter of 1924 to 1925. Photographed May 25, 1925.

Just to what extent and how rapidly such natural selection may effect the hardiness of a strain of alfalfa has not been determined. In view of all available information, it would seem advisable to use seed that has been grown for at least several seed generations under climatic conditions fully as severe as where it is to be planted.

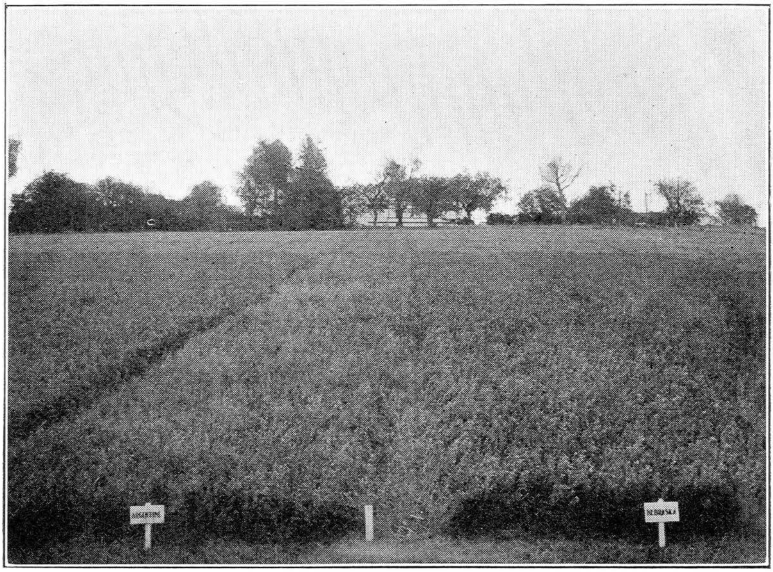

FIG. 15.—Argentine seed of Common alfalfa at left and Nebraska-grown Common at right, seeded May 16, 1922. The same plats as shown in Fig. 14. Photographed September 21, 1925, to show the weed growth in the fourth cutting of the Argentine.

Since the better established variegated varieties such as Grimm and Cossack have originated and passed thru the natural selection of climatic conditions more severe than those obtaining in Nebraska, it seems reasonable that they should be among the hardiest alfalfas suitable for our conditions. They have been unsurpassed in hardiness and yield in these tests, and general observations point to some superiority under the more severe winter conditions. On the other hand, the data available indicate that the local and more northern strains of Common alfalfa are also relatively hardy and productive for average Nebraska conditions, and it may be questioned whether one would be justified in paying a large premium for seed of the variegated sorts when seed of the former is available. Since an extensive demand exists for recognized hardy alfalfa seed, especially of several variegated varieties such as Grimm and Cossack, and since their seed yield is satisfactory, more extensive use of these sorts seems advisable where seed is grown.

FIG. 16.—Nursery test of alfalfa varieties and regional strains showing winterkilling in winter of 1924 to 1925. Seeded September 6, 1924. Extreme left to right: (1) North Dakota-grown Common, (2) Argentine, (3) Spanish, (4) Nebraska-grown Common, (5) French (Provence), (6) Italian, (7) Russian, and (8) extreme right, Peruvian. The winterkilling results in this nursery test were identical with those of the field plats seeded in 1922. Photographed May 25, 1925.

SUMMARY OF VARIETAL AND STRAIN DIFFERENCES

The results obtained at this station are in the main in accord with those reported elsewhere. Based on all information, the following broad conclusions seem justified.

Alfalfa is being grown in large areas where severe winterkilling is frequently experienced. Wide variation exists in the ability of the various groups, varieties, and regional strains to survive these adverse environmental conditions. The inherent physiological differences associated with this varietal variation in winter resistance have not been established.

It has been shown conclusively that alfalfas of the nonhardy group are unadapted to regions having severe winters. On the other hand, these non-hardy sorts can be expected to yield most wherever they are adapted. It is also apparent that there is a wide range in the hardiness of regional strains of Common alfalfa which becomes progressively more hardy thru acclimatization as conditions become more severe. The exact comparative winter resistance of the various hardy strains has not been fully determined. There seems to be no question but that the most hardy alfalfas available commercially are found within the variegated group. All variegated alfalfas, however, cannot be considered hardier than some strains of the Common. Grimm and Cossack appear to be among the hardiest commercially available. Indications are that there may be some slight difference in the plant characteristics and hardiness between strains of these varieties. It is also apparent that yellow-flowered alfalfa *(Medicago falcata)* is able to survive even more severe winters than the hardiest variegated sorts.

Such varieties as Grimm and Cossack will produce as much or more hay per acre than most strains of Common alfalfa. Whenever winterkilling becomes a serious factor the varieties or strains best able to survive such conditions will prove most productive.

Data as to physical characteristics are somewhat conflicting. The variegated alfalfas, however, can be readily recognized by the variation in their flower color. Varieties and strains may also differ somewhat in the amount of early spring and late fall growth and in their renewal of growth after cutting. The differences in crown and root development of the various commercial varieties is too small to permit classification in this respect.

HISTORICAL REVIEW [1] — VARIETIES AND REGIONAL STRAINS

COMPARATIVE YIELDS AND HARDINESS

Lyon and Hitchcock (1904) seeded alfalfa from Arizona, California, Colorado, Kansas, Utah, and Nebraska at the Nebraska Experiment Station in 1898. The alfalfa from Arizona and California killed out almost entirely during the winter of 1898-1899, that from Colorado was severely injured, whereas that from Utah and Kansas suffered more loss than that from Nebraska-grown seed. There was no further loss until 1902-1903, when that from Arizona and California

[1] Due to the extensive literature concerning alfalfa production, a review is herewith included of only three phases of the problem, namely: (1) Varieties and regional strains, (2) maturity stages, and (3) curing practices. The literature reviews immediately follow the related subject matter of these investigations.

entirely disappeared and the Colorado, Utah, and Kansas alfalfa suffered further injury. Conclusions drawn were "not to bring alfalfa seed from a southern to a more northern region or from an irrigated to a non-irrigated soil."

Wheeler and Balz (1907) report that seedings made at Highmore, South Dakota, in 1905 of Montana, Oasis, Arabian, Turkestan, and Tripoli alfalfas winterkilled during the following winter 5, 100, 75, 5, and 100 per cent, respectively. The Montana, Arabian, and Turkestan yielded 2960, 2560, and 3060 pounds per acre, respectively, in 1906.

Mackay (1909) reports yields secured at Indian Head, Saskatchewan, Canada, in 1905 as follows: Turkestan 8,840 pounds, Utah 8,080, and Common 7,122 pounds per acre. During the following winter the Utah alfalfa was entirely killed out and the other two were considerably thinned. Six crops were harvested from 1906 to 1909 from these latter two, the Turkestan yielding 2,895 pounds per cutting and the Common 2,508 pounds.

A seeding was made in May, 1905, of Utah, Southern Montana, Commercial, Grimm, Peru, New York, Turkestan, Nebraska, and Northern Montana seed. The Utah, Southern Montana, Commercial, Peru, and Northern Montana alfalfas were entirely killed out in the spring of 1906. The New York, Turkestan, and Nebraska alfalfas were greatly injured, whereas the Grimm came thru perfectly.

A third seeding was made in the spring of 1908 of Grimm, Idaho, Montana, dry land, French, and Turkestan alfalfas. The following respective yields were reported for 1909: 5,308, 5,400, 5,830, 7,303, 5,480, and 7,388 pounds per acre.

Westgate (1909) reports acre yields for 1907 and 1908 at Pullman, Washington, as follows: Sand Lucern 6,163 pounds, Turkestan 5,358 pounds, and ordinary 5,783 pounds. The following yields produced without irrigation are also reported for 1908 at Great Falls, Montana: Canadian 7,505 pounds, Sand Lucern 6,425 pounds, Turkestan 5,490 pounds, Kansas Variegated 5,430 pounds, and Nebraska dry land 4,700 pounds. At Dickinson, North Dakota, in 1909 the first cutting of Sand Lucern yielded 1,826 pounds as compared with 1,411 for Grimm, 1,179 for Turkestan, and 1,173 pounds for Utah.

Brand and Waldron (1910) concluded from a series of tests begun at Dickinson, North Dakota in 1906 "that employment of good tillage, the use of a suitable strain of seed, and the character of the winter weather are the controlling factors in successful alfalfa production in the Northwest." Early dormancy in the fall, deeply set crowns, and the ability to put out new roots and reestablish after breaking of the taproot seemed correlated with winter hardiness.

Westgate (1910) in summarization of all available information to date, with reference to variegated alfalfas concludes: " The studies of the somewhat isolated instances of especially hardy alfalfa fields have shown that these relatively hardy strains agree quite closely among themselves in their botanical characters and differ noticeably in a number of characters from the ordinary western grown alfalfa.

" The investigations recorded in this bulletin have indicated that the primary explanation of the hardiness of these strains is that they possess a small percentage of the blood of *Medicago falcata* in their ancestry.

" The preliminary comparative field tests of the different variegated alfalfas are of too short a duration to make definite conclusions possible as to their relative value. The tests indicate, however, that under very severe conditions the Sand Lucern, while much hardier than ordinary alfalfa, is somewhat less hardy than Grimm alfalfa which has been successfully produced in Minnesota for fifty years."

Brand (1911) found a marked difference in winterkilling between Grimm and Commercial or ordinary alfalfa from seedings made in 1901, 1902, 1905, 1906, and 1907 at St. Anthony Park, Minnesota. When these results are averaged for the 5 seedings, it is found that the winter loss in the Grimm during the 2 following winters was 13.9 per cent whereas that for the commercial and ordinary alfalfa was 69.3 per cent.

Sixteen strains were seeded at Tappen, North Dakota, in 1905. At the close of the fifth season, in 1909, the per cent of stand as estimated for Montana, Nebraska, Kansas, Colorado, Utah, Texas, and Grimm seed was 90, 85, 85, 60, 20, 5, and 90 per cent respectively. Many of the same strains were also seeded at Dickinson, North Dakota, where the same general results were obtained.

Snyder and Burr (1911) concluded from a series of tests comparing 18 strains and varieties of alfalfa at the North Platte, Nebraska, Substation during the period 1906 to 1910 that " under conditions that have prevailed during the past six seasons no one regional variety has shown any great superiority over others. Nebraska-grown seed has produced the most alfalfa. The varieties behave differently as regards freezing and recovery after cutting, but, as noted, the yields thus far have been quite uniform."

Hume and Garver (1912) concluded from 3 series of tests conducted at Brookings, South Dakota, in 1908-1911, 1909-1911, and 1910-1911: "For the conditions of this test, Turkestan, Utah, French, Montana, Texas, Nebraska, New York, (Non-irrigated), Grimm, or Sand Lucern proved equally productive of hay."

At the Highmore, South Dakota, Substation during the 6-year period 1905-1911, two strains of Turkestan averaged 2,684 pounds per acre as compared with 1,938 pounds for Arabian. Oasis and Tripoli winterkilled in 1905-1906. During a 4-year period, 1908-1911, at the same station, Turkestan averaged 1,910 pounds per acre as compared with 1,472 pounds for an average from 3 plats of Baltic. During a 3-year period, 1909-1911, Kansas alfalfa averaged 1,460 pounds per acre as compared with 1,017 for Turkestan, 1,220 for German, and 960 pounds for Grimm.

Cook (1916) states that in West Virginia "the Grimm, Baltic, and other hardy strains of alfalfa have not proved superior to the Common northern-grown seed except in respect to seed production."

Hume and Champlin (1916) obtained the following acre yields as a 3-year average, 1913-1915, for the 4 South Dakota Stations: Vale (S. D. 22) 2565 pounds, Grimm 2532 pounds, and Turkestan 2527 pounds.

Kansas Non-irrigated, Turkestan, Vale, Montana, and Nebraska proved to be the most productive varieties as determined in several variety tests at Brookings. Turkestan, Kansas, and Grimm each ranked first in hay production in a series of 3 tests at the Highmore Substation, whereas at the Eureka Substation Vale was the most productive of hay, from 1913-1915, and Turkestan at the Cottonwood Substation during the same period.

Parsons (1916) reports average yields (1911-1915), for alfalfa grown under irrigation in Wyoming as follows: Turkestan 3.90 tons per acre; Sand Lucern 3.67; Grimm 5.25; Provence, France, 3.31; Utah seed 3.10; German seed 3.90; Dry-grown seed 3.53; Montana seed 4.56; and Native seed 4.38 tons per acre. "It will be noticed that the Turkestan, Sand Lucern, Grimm, and Montana varieties stood nearly the same for the first two years. The winter of 1912-1913 was very severe on alfalfa, and all of the varieties except the Grimm were winterkilled in varying degrees."

Voelcker (1916) found at the Woburn (England) Experiment Station that as a 4-year average (1912-1916) Russian (Europe) alfalfa gave the highest yield of hay followed in order by Provence, Canadian, North American, Russian (Asia), American (Arizona), and Turkestan.

Brooks and Gaskill (1917) (Massachusetts) state, "It has not been our experience that the Grimm variety is any more hardy than the common alfalfa produced from good northern-grown seed."

Hughes (1917) states for Iowa conditions that "there is practically no difference in the yield of hay secured from Dakota, Nebraska, and Kansas seed. The Oklahoma seed did not yield quite so well as that produced farther north while the irrigated seed from Utah made a considerably lower yield." Dakota and Montana alfalfas have withstood severe winters better than Nebraska and Kansas grown, whereas under these more severe conditions alfalfas from Oklahoma and Utah have almost entirely killed out. The Grimm and Baltic varieties, while not appearing superior to the imported alfalfas in hardiness, are deemed superior to them because of their high-yielding qualities.

Jenkins (1917) reported 4-year average yields (1913-1916) in Connecticut of 4.39, 3.76, 3.92, 3.84, 3.65, and 3.40 tons per acre respectively, for Grimm, Sand Lucern, Kansas, Provence, Utah, and Turkestan alfalfas.

Miller (1917) at the Morris (Minnesota) Station reports the following average yields during a period of 4-years: Kansas 2.89 tons per acre, Baltic 3.10, Grimm 3.35, Nebraska 2.57, Dakota 2.40, and Improved Turkestan 2.78. Winterkilling as an average of 3 seasons was reported as 15.9, 3.04, 1.66, 30.97, 26.39, and 0 per cent, respectively.

It is stated in the Wisconsin Agricultural Experiment Station Report (1917) that during the winter of 1915-1916 nine plats of different strains of northern-grown alfalfa showed on the average 55 per cent winterkilling and yielded 3,840 pounds of cured hay per acre in 2 cuttings in 1916, as compared with 2 southern-grown strains which winterkilled 52 per cent and yielded 4,470 pounds; one Turkestan winterkilled 31 per cent and yielded 5,540 pounds, while 4 variegated strains (Grimm and Baltic) winterkilled 27 per cent and yielded 6,045 pounds. It is further reported; "The so-called 'hardy alfalfas,' the seed of which was derived from 25 to 35 year old fields in Montana and Dakota, did not show any more resistance toward winterkilling or superiority in yields to the common strains from these states."

Blair (1918) reports hay yields (when averaged for 1915-1917) for the Yuma Experiment Farm as follows: Peruvian, 3.70; Chilian (Common), 3.14; Arabian, 2.17; and Grimm, 2.12 tons per acre.

Holden (1918) at the Scottsbluff (Nebraska) Reclamation Project Experiment Farm obtained total yields under irrigation during the 2-year period 1916-1917 of 9.39, 9.07, 8.92, 8.71, 8.45, 8.08, and 6.93 tons per acre, respectively, for Baltic, Grimm, Kansas, Black Hills, Canadian, Turkestan, and Native alfalfa. "All seemed to withstand the winters equally well."

Kiesselbach (1918) reports 2-year average yields at the Nebraska Experiment Station of 5.4, 5.5, and 5.5 tons per acre, respectively, for Nebraska Common, Grimm, and Turkestan alfalfa.

Boss (1919) in Minnesota stated that "Plats sown to Grimm alfalfa in 1914 yielded three crops during the season of 1918. Common alfalfa sown on adjacent plats was entirely killed out."

Knight (1919) as an average for 1917-1918 in Nevada obtained yields of 5.99, 5.85, 5.07, 4.99, 4.88, 4.87, and 4.86 tons per acre, respectively, for North Dakota, Australian, Baltic, Nevada 38, France, Grimm, and Nevada (check) alfalfas.

Moore and Graber (1919) conducted tests in Wisconsin with 16 samples of common seed from growers in New Mexico, Arizona, and California and showed that Common seed produced in these states was less hardy and more subject to winterkilling when grown in Wisconsin than Kansas seed or Common seed produced farther north. On the other hand, trials made with 40 samples of Kansas and Nebraska-grown Common, in comparison with 20 samples of Montana and South Dakota-grown seed, showed practically no difference in hardiness. It was evident, however, that variations in hardiness of different alfalfas from the same region are to be expected. The most winter resistant alfalfas thus far found for Wisconsin conditions are the Grimm, Baltic, and Cossack.

The Wisconsin Agricultural Experiment Station Annual Report (1920) states that the total yields secured during the 6-year period, 1915-1920, from Grimm alfalfa were 20.8 to 22.5 tons per acre, and the yields from Montana Common were 13.1 to 18.7 tons.

Miller (1920) reports from the Morris (Minnesota) Station: " There was no winterkilling in any of the varieties of alfalfa in the winter of 1919-1920. * * * In 1917 and 1918, winterkilling was very severe with most varieties, Minnesota Grimm, Baltic, and Turkestan coming thru with the best records. Grimm alfalfa and Turkestan also showed highest yields for 1920. The results of these tests tend to show that permanent fields of alfalfa, even with hardiest varieties, are not yet a reality."

Zavitz (1920) of Ontario reports average acre yields in tons for a ten-year period (1910-1919) as follows: 3 Grimms, 3.60; 2 Ontario Variegateds, 3.20; 1 Baltic, 3.12; 9 European Variegateds, 3.11; 1 Mongolian (violet-flowered) 3.04; 1 Turkestan, 2.97; 10 Sand (Variegated) 2.87; 1 Ontario Common, 1.81; 1 Montana Common, 1.68; 4 Commons (Utah, Colorado, Nebraska, and Kansas) 1.11; and 1 Texas Common, 1.00.

These same alfalfas were space-planted at the time they were seeded in field plats and the following counts made: Per cent of plants living in 1914 (5 years after seeding) was found to be 68, 82, 72, 42, 92, 39, 42, and 22 per cent respectively for the Grimm, Ontario Variegated, Baltic, European Variegated, Mongolian, Turkestan, Sand, and Common as compared with 25, 16, 11, 4, 64, 10, 3, and 0 per cent in 1919 or 10 years after seeding.

In another test (1911-1918) Grimm, Sand, and Common averaged 4.3, 4.1, and 1.4 tons per acre. During the first year of the test Grimm yielded 5.3 tons per acre as compared with 4.1 for the Common whereas during the last year the respective yields were 2.9 and .03 tons per acre.

In still another seeding made in 1912 and replicated 7 times, average yields (1913-1919) for Sand (Germany), Ontario Variegated (Ontario), and Grimm (Minnesota) were reported as 3.27, 3.46, and 3.68 tons per acre, respectively.

Damon (1921) obtained yields of 3.05, 3.55, and 3.49 tons per acre for Grimm, Canadian, and Montana Dryland alfalfa as a 2-year average, 1914-1915, in Rhode Island.

Getty (1921) reports yields as a 4-year average (1916-1919) for western Kansas as follows: Canadian Variegated, 1.12; Kansas Common (3 plats averaged), 1.06; Baltic, 1.19; Grimm, 1.08; Utah non-irrigated, .97; Utah irrigated, .92; and Black Hills (South Dakota), 1.01 tons per acre. "The stands of all varieties were excellent and remained so during the tests."

In the Iowa Agricultural Experiment Station Report (1921), it is stated that "A large number of varieties and strains have been compared. Turkestan alfalfa has been found to be as hardy as Grimm, but gives much lower yields. It has been found possible to make four cuttings of Grimm alfalfa in an average season, while not more than three can be made safely with Common varieties, because of the greater winter hardiness of the Grimm. There seems to be little difference in the value of alfalfa strains from the Dakotas, Nebraska, and Kansas. Seed from Utah, Mexico, and Oklahoma is of much lower value than that from the Dakotas, Nebraska, and Kansas."

The Kentucky Agricultural Experiment Station (1921) reports that "In the fall of 1920, a number of strains of varieties of alfalfa were sown in order to determine their relative value for Kentucky. The hardy strains, Grimm, Dakota, etc., yielded much more heavily than the common strains in 1921. This was due to the severe freezes in late March and early April, which injured the Common alfalfa very greatly but scarcely injured the hardy strains. As such freezes as this do not often occur, it is not safe, of course, to conclude that the hardy strains are decidedly superior for Kentucky."

Miller (1921) states that at the Morris (Minnesota) Station "Twenty-three varieties have now been growing continuously for seven years in the trial grounds. * * * During the seven years these varieties and strains have shown a wide variation in hardiness. Not a single strain has been immune from winterkilling in severe seasons."

Bean (1922) obtained the following yields of hay per acre in 3 cuttings from a 1-year-old stand produced under irrigation in Washington: Kansas Common 7.6 tons, Dakota Common 7.2 tons, Canadian Variegated 6.6 tons, Peruvian 6.6 tons, Baltic 6.5 tons, Grimm 6.2 tons, and Turkestan 4.2 tons. In a 2-year comparison Dakota Common yielded 7.1 and Turkestan 5.3 tons per acre.

Forbell (1922) found as an average of counts made in October, 1916, on 20 newly seeded fields of Grimm alfalfa and 21 of Common alfalfa in northern Minnesota, 91.8 plants per square yard for the former and 111.6 for the latter. Counts made in May, 1917, showed 91.6 plants per square yard for the Grimm, as compared with 69.0 for the Common.

Megee (1922) found in Michigan that "Plats seeded to Arizona grown Common alfalfa and Hairy Peruvian alfalfa also winterkilled badly and the yield was much lower than that secured from Hardigan, Grimm, and the Common from Idaho, Montana, and Dakota."

Noble (1922) states that during 1919 and 1920 a number of varieties tested at the Yuma Reclamation Project ranked approximately in the following order as to yield per acre and adaptability: Hairy Peruvian, Smooth Peruvian, India, Arizona Common, Kansas Common, Turkestan, Grimm, and Baltic. The last four failed to make satisfactory growth during the hot summer months and the plats soon became infested with Bermuda grass and sand burs.

The Oregon Agricultural Experiment Station (Umatilla Branch Station) (1922) reports that "Grimm, which yielded 6.66 tons, was the highest yielding variety. Common-grown from local seed producing 6.49 tons, was next." The growing of Grimm, except for seed production, was not advised.

The Pennsylvania Agricultural Experiment Station (1922) reports that "The stands on many of the plats of alfalfa varieties seeded in June, 1918, are becoming quite thin and blue-grass is rapidly crowding out the alfalfa. The strains of the hardy group have maintained their stands better than the common alfalfas with the exception of the common strains from Kansas and California.

"All of the hardy strains have yielded better than the common strain used for check, while only the California- and Kansas-grown strains of Common have yielded better than check."

During 1919-1921, Baltic, Cossack, Grimm, and California-grown Common averaged annually about 1,000, 800, 600, and 500 pounds more hay per acre than the check.

Anderson (1923) obtained the following average acre yields in Virginia during the period of 1917-1919: Common alfalfa, 4,267 pounds; Grimm, 4,540 pounds; Turkestan, 3,500 pounds; and Baltic, 4,417 pounds.

The Turkestan plats soon became infested with weeds and grass. The other varieties remained comparatively free from foreign material until the end of the third season.

King (1923) states that at Sacaton, Arizona, "Over 100 varieties from all parts of the world have been tested and repeated experiments have demonstrated the superiority of the Hairy Peruvian for hay production."

Quesenberry (1923) reports average yields of 6.541, 4.918, 5.091, and 4.429 tons per acre, respectively, for Hairy Peruvian, Native, Grimm, and Turkestan alfalfa grown under irrigation in New Mexico during 1921 and 1922.

The Wisconsin Agricultural Experiment Station (1923) reports tests by Graber and Nelson indicating significant differences in the killing of greenhouse alfalfa plants of the Grimm, Turkestan, and Common varieties, when exposed to a -4° F. temperature in December and January. Common winterkilled to a much greater extent than either Grimm or Turkestan, 84 per cent of the Common being killed as compared with 18 per cent for the Grimm. Winterkilling in the field was very severe for all strains, being 100 per cent for the Common and 84 per cent for the Grimm.

Numerous tests have shown that new seedings of alfalfa are much hardier than old stands and that late fall cutting under adverse conditions increases winterkilling.

Woodward (1923) reports the following 9-year average acre yields obtained at the Judith Basin, Montana, Substation during 1913-1921: Northern-grown 2,228 pounds, Grimm 2,099 pounds, Kansas Irrigated 2,050 pounds, Utah Irrigated 2,028 pounds, Turkestan 2,002 pounds, and Sand Lucerne 1,857 pounds. Results for the 4-year period, 1918-1921 were as follows: Grimm 2,110 pounds, Montana Common, 2,092 pounds, Canadian Variegated 2,011 pounds, Liscomb 1,960 pounds, Baltic 1,944 pounds, Black Hills 1,937 pounds, Utah non-irrigated 1,839 pounds, Utah Irrigated 1,781 pounds, and Kansas 1,772 pounds per acre. He concludes: "Results obtained * * * indicate that there is not sufficient difference in yield between the variegated alfalfa and the hardier strains of the common group to make this a factor of any considerable importance in selecting alfalfa for this region.

"In localities where alfalfa is subject to winterkilling, preference should be given to variegated alfalfas such as

Grimm. As a rule alfalfas belonging to the variegated group are more resistant to cold and drought than the common alfalfas."

Dalton (1924) states for New York conditions that: " Not until the Grimm variety was produced was there any sort of alfalfa known that was not greatly affected by the cold and unfavorable winters of this state. * * * There are other introduced and selected varieties, such as Baltic, Cossack, and Ontario variegated, that are hardy but in tests none have proved superior to Grimm for the cold humid climate of New York State."

The Kansas Agricultural Experiment Station (1924) reports that " Eighteen varieties and regional strains were sown in duplicate in one-twentieth acre plats on the Agronomy Farm. Good stands were secured in most cases and no winter injury occurred. In 1923 Grimm produced 3.95 tons per acre, the highest yield of any variety. Cossack produced 3.80 tons per acre, Italian 3.69 and Kansas Common 3.27."

Kirk (1924) reports the following average yields (1916-1924) for alfalfa grown in cultivated rows in Saskatchewan, Canada: Grimm 5643 pounds per acre; Baltic 5892, Cossack 4885, Canadian Variegated 3247, Turkestan (5 strains) 4923, and Falcata (8 strains) 4494 pounds per acre.

Oakley and Westover (1924) have reported average yields as follows: 1913 to 1922 at Moccasin, Montana, Grimm 2,132 pounds per acre; Northern-grown Common 2,249, Kansas 2,070, and Turkestan 2,035; 1917 to 1922 at Havre, Montana, Grimm 426 pounds per acre, Northern-grown Common 327, Kansas 285, and Turkestan 304; 1918 to 1922 at Sheridan, Wyoming, Grimm 2.274 pounds per acre, Northern-grown Common 1,948, and Kansas 2,044; and 1916 to 1922 at Redfield, South Dakota, Grimm 3,685 pounds per acre, Northern-grown Common 3,101, Kansas 2,993, and Turkestan 3,187.

Piper (1924) compares the yields of 2 variegated alfalfas, 1 Turkestan and 4 common alfalfas when grown from 4 to 9 years in from 2 to 6 locations. When the results from 5 stations (Redfield, South Dakota; Moccasin, Montana; Sheridan, Wyoming; Hays, Kansas; Connecticut Experiment Station or Wyoming Experiment Station) averaging 5 years per station are averaged together it is found that Grimm yielded 4379 pounds per acre compared with 4017 for Northern Common; 3924 pounds per acre as compared with 3540 for Kansas Common, and 5680 pounds per acre as compared with 4169 for Utah alfalfa.

Piper also reports the reduction in stand from 1916 to 1920 at Redfield, South Dakota, as follows: Grimm 21.1 per cent, Baltic 34.9, Kansas 83.6, Utah Irrigated 95.3, Utah non-irrigated 95.2, Dakota 66.9, Dakota 49.3, and Canadian Variegated 52.6. Reduction in stand by years ranged as follows: 1916-17, from 0 to 5 per cent; 1917-18, 1.2 to 27.5 per cent; 1918-19, none; 1919-20, 19.0 to 94.2 per cent.

Aune (1925) compared 3 strains of common alfalfa, 4 variegated sorts, and a selection of Turkestan, when grown under irrigation during 1916-1918 at Belle Fourche, South Dakota. No obvious difference occurred in winterkilling and there was no material difference in yield. The 3 strains of common averaged 3.62 tons per acre, whereas the 4 variegated varieties averaged 3.80 tons. The 3 strains of common alfalfa seemed a little later in starting in the spring and the yield of the first cutting was somewhat less.

Georgeson (1925) states for Alaska conditions that: " The yellow-flowered sort *(Medicago falcata)* is the only hardy alfalfa that so far has been found."

" In 1919 for example, the varieties Grimm, Cherno, North Swedish, and Semipalatinsk were tried at the Fairbanks Station, but either died or so deteriorated in vigor as no longer to justify their occupation of the ground. *M. falcata*, on the other hand, has maintained itself, and is ripening seed."

" The stations have repeatedly experimented with common alfalfa but since it invariably winterkills, no further trials will be made with it."

Kiesselbach and Anderson (1925) found Peruvian, Argentine, Italian, and Spanish alfalfa to be especially unhardy under Nebraska conditions.

Miller (1925) at the Morris Substation (Minnesota) obtained the following yields in 1925 from a series of seedings made in 1924: Grimm, 3.77 tons per acre; Cossack, 3.65; Hardigan, 3.25; Ontario Variegated, 3.05; Baltic, 3.46; and Northern-grown Common, 3.07 tons. Even, uniform stands were secured in all cases.

Tinline (1925) in Canada reports the results of 3 separate tests as follows: (1) Average yields for 1924 and 1925, as obtained from 1923 seedings, were,—Canadian Variegated, 5.23 tons per acre; Cossack, 5.23; Macsel, 4.85; Grimms, 4.65; Liscomb, 4.79; Turkestan, 4.35; Common, 4.79; Canadian Variegated, 4.51; and Baltic, 4.49. Per cent stands in 1925 were 87, 88, 70, 80, 93, 75, 90, 85, and 77 per cent, respectively. (2) Results for 1925 secured from 1924 seedings were: Canadian Variegated, 3.28 tons per acre; Cossack 3.50; Macsel, 3.65; Grimms, 3.72; Grimms, 3.55; Liscomb, 2.69; Turkestan, 3.47; Canadian Variegated, 3.62; Baltic, 3.55; and Montana, 3.10. Per cent stands in 1925 were 90, 90, 83, 98, 88, 90, 95, 97, 99, and 92 per cent, respectively. (3) The following yields were reported as a 4-year average: Baltic, 5.06 tons per acre; Grimms, 4.85; Macsel, 4.80; Montana, 4.53; Liscomb, 4.51; Turkestan, 4.43; Cossack, 3.50; and Canadian Variegated, 3.32.

Towle (1925) reports the following 6-year average (1918-1923) acre yields at the Sheridan (Wyoming) Field Station: Grimm, 2,386 pounds; locally-grown seed, 1,972 pounds; and Kansas-grown seed, 2,122 pounds. There was no material difference in winterkilling or drought resistance.

Sylven (1925) states that in Sweden, Ultuna, a selection of a blue and yellow alfalfa cross, has shown itself to be the most winter-resistant of several varieties in different localities. In central Sweden it compares favorably in production with Grimm, but in southern Sweden it cannot compete with French Blue (common), Grimm, Cossack, and other varieties.

Grimm alfalfa obtained from various sources showed wide variations in yield.

Arny (1926) reports average yields in tons per acre for 5 separate tests in Minnesota as follows: 1913-1916, Minnesota Grimm, 5.42 tons; Montana Grimm, 5.19; and Turkestan Common, 4.74; 1914-1917, Minnesota Grimm, 4.77 tons; Montana Grimm, 4.52; Turkestan Common, 3.76; Kansas Common, 3.90; and Nebraska Common, 4.17; 1915-1919, Minnesota Grimm, 4.03 tons; Montana Grimm, 3.90; Turkestan Common, 2.14; Kansas Common, 2.38; and Nebraska Common, 2.76; 1923-1925 (tests conducted at University Farm, Waseca, and Crookston averaged),—Grimm 3.74 tons; Cossack, 3.82; and Northern Grown Common, 3.80; and total yields for 1924 and 1925 as follows: Grimm, 7.60; and Common alfalfas as follows: Idaho, 7.28; New Mexico, 7.64; Kansas, 5.93; and Argentine (S. A.), 6.26.

Cox and Megee (1926) report as a 4-year average (1922-1925) the following yields in Michigan: Hardigan (Michigan), 5.95 tons; Grimm (Idaho), 5.75; Grimm (South Dakota), 5.53; and Common alfalfas from Montana, Kansas, North California, Utah, and Idaho, 5.34, 5.29, 5.23, 5.05, and

4.69 tons per acre respectively, and Spanish (Spain), 3.55, Hairy Peruvian (Arizona), 1.75, and Common (Arizona), 1.69 tons per acre. About the same results are reported for somewhat similar tests for the years 1923-1925 and 1924-1925. The variegated sorts in still another seeding in 1924 withstood the winter in excellent condition with stands of 95 to 100 per cent whereas the South American alfalfas suffered so heavily from winterkilling that they were not worth leaving.

Overpeck and Conway (1926) report relative yields of 100, 71, 70, and 60 per cent, respectively, for Hairy Peruvian, Common, Grimm, and Turkestan alfalfa tested during the period 1921 to 1925 in New Mexico.

PLANT CHARACTERISTICS

Blinn (1911) of Colorado observed differences in root, crown, and stooling habits of hardy and non-hardy strains. He concludes: " The fact is the hardy strains of alfalfa have spreading crowns with underground root stocks and shoots with buds which are protected by soil from winter freezing.

" The non-hardy strains of alfalfa have more upright stooling crowns with the bud areas very near the surface exposed to winter freezing, thawing and drying out."

The Wisconsin Agricultural Experiment Station (1917) states: " The common strains of alfalfa usually make a succulent fall growth, whereas the variegated strains become dormant earlier in the fall after the third cutting. The imported Turkestan also possess this characteristic even to a more marked extent.

" Comparative tests of 34 different strains have been made on two and three year old growths, and it does not seem possible to connect any very direct relation between the hardiness of the branched root plants in comparison with those which possess a taproot system. The observations made show that all of the principal varieties or strains of American grown alfalfa have both types of root systems."

Cox (1919) (Michigan) states that " The variegated strains such as Grimm, Baltic, and Cossack are characterized by closely set and branching crowns, and by greater development of roots with a tendency toward branching. This type of crown and root does not heave or winterkill as badly as the straighter rooted and higher crowned common alfalfa."

Knight (1919) found that North Dakota, Australian, Baltic, Nevada 38, France, Grimm, and Nevada (check) strains of alfalfa consisted of 38.0, 32.2, 39.9, 37.4, 40.6, 40.0, and 38.8 per cent leaves, respectively.

Zavitz (1920) compared Grimm, Ontario Variegated, Baltic, European Variegated, Mongolian, Turkestan, Sand, and Common alfalfa grown in Ontario. As a 6-year average 34, 19, 36, 29, 3, 1, 29, and 1 per cent variegation was observed for these varieties, respectively. The respective comparative early spring growth during 7 years was as follows: 96, 94, 91, 93, 48, 84, 100, and 64 per cent.

Southworth (1921) concluded from observations and investigations that the capacity of alfalfa to withstand severe winter conditions depends very largely on its root system. Plants possessing a branched root withstand winter heaving much better than those having only single taproots of whatever length.

Garver (1922) conducted field studies at various times between 1914 and 1920 of the root systems of Peruvian, Poona, southern- and northern-grown Common, Turkestan, Grimm, and yellow-flowered alfalfas when grown in rows at Redfield, South Dakota. Difficulty was found in obtaining comparable data in the older fields whenever there was a marked difference in hardiness, since it is believed that the more susceptible plants were winterkilled and those remaining were unduly favored. Factors tending to produce modifications of taproots in alfalfa are soil, climate, cultural treatments, and injuries.

The root systems of the Peruvian and Poona of one season's growth are characterized by small, upright crowns and distinct taproots with few branches and fibrous roots.

All common alfalfas have distinct taproots. The northern grown strains have somewhat broader crowns and exhibit more of a tendency to throw out branches and fibrous roots but in both instances this difference is more pronounced than in the Peruvian and Poona varieties.

Grimm alfalfa is characterized by broad, deep set crowns and numerous branch and fibrous roots. Rooting rhizomes are well-developed. Turkestan alfalfa has a root system very similar to that of Grimm.

The yellow alfalfas exceed all others in having a broad, deep-set crown and an abundance of branch and fibrous roots.

Dalton (1924) states that " Common alfalfa has a long tap root from which the lateral roots branch out, while Grimm alfalfa has a more spreading root system, similar to that of an elm tree, which helps to prevent heaving."

The Iowa Agricultural Experiment Station (1924) states that " During the past year extensive studies were made on alfalfa roots, giving special attention to comparisons of different varieties * * * Our studies indicate that under Iowa conditions there is very little difference in the character of the root of the common alfalfa as compared with Grimm, Baltic, and Cossack. The hardy varieties showed a slightly greater percentage of plants with divided taproots, but the difference was not sufficient to be used in variety identification."

Carlson (1925) in New York, studied the effect of soil structure on the development of alfalfa root systems. Grimm, South Dakota and Kansas Common, Siberian, and Baltic were compared. The field plat experiments were of 29 months' duration, the tank experiment 12 months' and water culture 6 weeks'.

" The results show that in compact soil all varieties and strains developed branch roots, while in open soil the tap roots predominate; that Grimm alfalfa is characterized by broad deep-set crowns, and numerous fibrous roots; that the northern and southern grown common alfalfas have similar root features, small high set crowns and few fibrous roots; that the Baltic and Siberian compare favorably with the characteristics of the Grimm alfalfa; that the distinctive characteristics of alfalfa roots do not develop until after three to four months of normal growth; and that the results of water culture experiment substantiate those obtained under field conditions.

" This would seem to indicate that Grimm and common as representatives of the hardy and non-hardy alfalfas, respectively, have inherent root characteristics and that the nature of the soil structure determines the degree of root branching."

McCool (Michigan) (1926) as an average of 7 determinations in 1924 and 1925 found the tops of Grimm, Cossack, and Common alfalfa to contain 4.23, 3.99, and 3.86 per cent nitrogen, respectively, as compared with 2.38, 2.10, and 2.03 per cent nitrogen in the roots (average of 9 determinations).

CULTIVATION OF ALFALFA

Tillage of an established stand of alfalfa has been frequently advocated as a means to stimulate growth of the crop and to destroy weeds. A series of comparative tests was started in 1921 to determine the effects upon stand and yield from cultivation by means of a disk harrow, a spring tooth harrow (alfalfa renovator), and an ordinary smoothing harrow. The details of treatment and the results for the 5-year period, 1921 to 1925, are shown in Tables 4 and 5. All treatments were in duplicate on twentieth-acre plats in a field of well-established alfalfa seeded in 1918 and having an almost perfect and uniform stand. Production from 1922 to 1925 was relatively low, due to moisture shortage. This condition was intensified by the rainfall being below normal much of the time, by considerable run-off due to the gently sloping character of the field, and by the heavy production of hay during 1919-1921.

Yield of Hay per Acre.—As a 4-year average, 1921-1924, the plats receiving no cultivation averaged 3.39 tons per acre. In comparison, 3 different disk harrow treatments averaged 3.22 tons, the 3 spring tooth harrow treatments averaged 3.31 tons, and the ordinary harrow treatment 3.37 tons. No manner of tillage increased the production. Different results might, perhaps, be secured in an old field where the stand has become thinned and where weeds are a factor.

When all the plats were harvested uniformly in 1925 without further treatment, there was no marked difference in yield excepting that where the spring tooth harrow had been used after each crop the yield was but 81 per cent of the untilled plats.

Effect on Plant Development.—It is of interest to note the effect of disk and spring tooth harrow cultivation upon the stand and root development of the alfalfa (Table 5). Quadrat counts and measurements were made in 1925 for 12 representative locations within each plot. Comparable observations had been made in 1921. The plants were counted after being cut off just below the crown, and the root diameters were measured at the point of severance. The number of plants per square foot has been calculated and they have been classified into several groups according to their root diameters.

TABLE 4.—*The effect of tillage treatments upon the yield of alfalfa hay, 1921-1925*

Treatment	Yield of hay per acre with 15 per cent moisture content						
	1921	1922	1923	1924	Average 1921-1924		1925[1]
	Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Relative*	*Tons*
No treatment	5.23	2.59	2.71	3.02	3.39	100	2.23
Disk harrow							
In spring and ordinary harrow after 2nd crop	5.00	2.26	2.63	2.48	3.09	91	2.16
In spring	5.26	2.38	2.79	2.55	3.25	96	2.15
After 2nd crop	5.57	2.36	2.55	2.78	3.32	98	2.10
Average	5.28	2.33	2.66	2.60	3.22	95	2.14
Spring tooth harrow							
In spring	5.39	2.47	2.85	2.69	3.35	99	2.11
After 2nd crop	5.39	2.58	2.81	2.99	3.44	101	2.20
After each crop	5.19	2.34	2.53	2.48	3.14	93	1.80
Average	5.32	2.46	2.73	2.72	3.31	98	2.04
Ordinary harrow							
In spring	5.24	2.54	2.85	2.85	3.37	99	2.30

[1]Harvested uniformly and without tillage treatments in 1925.

The number of plants per square foot in the no treatment plats was reduced about 30 per cent during the 5-year period, whereas there was about 43 per cent reduction in the plats where the disk and spring tooth harrow were used. It seems probable that if the tests were continued the difference in stand resulting from such practices would become more marked.

TABLE 5.—*Stand and root development of alfalfa in relation to tillage practices, 1921-1925*

Year	Plants per square foot	Plants grouped according to diameter of roots (inches)[1]				
		0-¼	¼-½	½-¾	¾-1	1-1¼
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*
NO TREATMENT						
1921	11.4	22.2	69.4	8.4	...	...
1925	7.9	14.0	50.2	23.4	9.2	3.2
DISK HARROW IN SPRING AND ORDINARY HARROW AFTER SECOND CROP						
1921	11.0	16.5	79.2	4.3	...	...
1925	6.3	16.3	44.0	32.9	5.8	1.0
SPRING TOOTH HARROW IN SPRING AND AFTER EACH CROP						
1921	11.9	13.7	76.8	9.5	...	...
1925	6.8	14.5	34.1	32.6	15.6	3.2

[1] Root diameters measured just below the crown.

Root measurements in 1921, when 3 years old, showed about three-fourths of the plants to have taproots ranging from one-fourth to one-half inch in diameter. Of the remaining one-fourth, about two-thirds of the plants measured one-fourth inch or less in root diameter. Measurements in 1925 still showed about the same relative number of plants falling in the group of the smaller root size but with a much reduced percentage in the one-fourth to one-half inch group while the groups of still larger size had increasingly larger numbers of plants. There appeared to be no relation between tillage treatment and plant development as measured by root diameters.

EFFECT OF THE TIME OF CUTTING UPON THE YIELD AND QUALITY OF ALFALFA HAY

Knowledge as to the relation of the time of cutting to stand survival, yield, and quality of hay produced is of material importance. The results and recommendations of different investigators are not all in agreement. It is possible that climatic effects have been largely responsible for these differences.

FIRST EXPERIMENT, 1915-1918

Two separate experiments pertaining to the time of harvesting alfalfa have been conducted at the Nebraska Experiment Station. The first experiment 1915-1918 (Table 6) has been previously reported in Nebraska Experiment Station Bulletin 169. The results of the second test, 1921-1925, are reported in Tables 7 to 12.

SECOND EXPERIMENT, 1921-1925

This latter test was run parallel with the tillage experiments just reported and the yields were likewise affected to some extent by the abnormal growth conditions resulting from a moisture shortage during the period 1922 to 1925. Continuous harvesting of alfalfa at 7 stages of maturity was practiced. The tests were made in duplicate field plats during 1921 to 1924. In 1925 all plats were harvested uniformly at the " new growth " stage to determine the carry-over effects of previous treatments.

Cutting Stages.—Five of these cutting stages were determined by the state of bloom as follows: (1) pre-bloom, (2)

TABLE 6.—*Effect of time of cutting upon the yield of alfalfa hay, 1915-1918*[1]

Stage of maturity[2]	Av. no. times cut 1915-1917	Number of plats averaged	Yield of hay per acre with 15 per cent moisture content					
			1915	1916	1917	Average 1915–1917		1918[3]
			Tons	*Tons*	*Tons*	*Tons*	*Relative*	*Tons*
Before normal.....	5	3	3.72	4.17	3.61	3.83	100	2.24
Normal...........	3	3	5.01	6.42	5.86	5.76	150	3.52
Later than normal	2	3	3.49	3.73	3.55	3.59	94	3.22

[1]Recalculated from Table 6, Nebraska Agricultural Experiment Station Bulletin No. 169.
[2]Each frequency of cutting was made on the same plats during the three consecutive years 1915-1917, in order to determine the accumulative effect. The stage of maturity when cut was arbitrary and not determined by the bloom or new growth at the crown except in case of the normal cutting. In 1918 all plats which had been previously cut at different stages were cut at the same time at normal maturity to determine the effect of the previous differences in treatment.
[3]Only three cuttings were made in 1918. A light fourth cutting was lost by the erection of buildings upon the land. There was a very marked weakening of plants and thinning of stand where alfalfa was cut too frequently.

initial bloom, (3) one-tenth bloom, (4) one-half bloom and (5) full bloom. In a sixth practice the second cutting was left each year to mature a seed crop while the other cuttings were made at the normal or new growth stage. The yields as reported are inclusive of all cuttings. The seventh or new growth stage, also designated as normal or check in these tests, was determined by the rather definite appearance of new growth or shoots at the crown. Ordinarily this stage fell between the tenth and half bloom stages, but several times it preceded or followed them. A modified new growth stage was included, comparable to the other except that the second cutting was harvested each year in the initial bloom stage. Quite frequently under Nebraska conditions the second cutting of alfalfa and the small grain crop are ready for harvest at the same time and this test was planned to indicate the effect of cutting the second crop early so as not to interfere with the small grain harvest. All of these specified maturity stages were adhered to as nearly as conditions permitted. Owing to irregularity in blooming and growth associated with season and weather, some of the cuttings were at times more or less arbitrary. Any appreciable growth at the end of the season was harvested regardless of maturity and included in the yield.

Yield of Hay per Acre.—The acre yield of hay and the proportion of leaves for these various stages of maturity are recorded in Table 7. As an average for the 4-year period 1921-1924, these yields were as follows: pre-bloom, 3.00 tons; initial bloom, 3.04 tons; one-tenth bloom; 3.35 tons; one-half bloom, 3.43 tons; full bloom, 3.19 tons; and the new growth stage, 3.51 tons per acre. Corresponding relative yields were 100, 101, 112, 114, 106, and 117 per cent.

The relatively unfavorable soil moisture conditions during the greater part of the period have doubtless caused the annual results to be somewhat inconsistent but it is believed that the yields as a 4-year average are fairly indicative of the normal tendency.

The one-tenth and one-half bloom and new growth stages averaged 14 per cent higher yield than the pre-bloom and initial bloom stages. The full bloom stage yielded 6 per cent more than pre-bloom, whereas the seed stage yielded 6 per cent less. These data indicate that the annual yield per acre can be expected to increase until the half bloom stage or slightly past, and then decrease somewhat with further maturity.

These differences in yield are in the main consistent with those of the earlier test reported in Table 6, tho the effects

TABLE 7.—*Effect of time of cutting upon the yield of alfalfa hay, 1921-1925*

Stage of maturity	Average 1921-1924		Yield of hay per acre with 15 per cent moisture content						
	Date of cutting first crop	Proportion of leaves	1921	1922	1923	1924	Average 1921-1924		1925[1]
		Per cent	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Relative*	*Tons*
CUTTING DETERMINED BY STAGE OF BLOOM									
Pre-bloom	May 23	57.3	3.90	2.87	2.88	2.35	3.00	100	2.47
Initial bloom	May 29	56.6	4.34	2.62	2.60	2.59	3.04	101	2.23
One-tenth bloom	June 2	55.8	4.51	2.76	2.71	3.43	3.35	112	2.09
One-half bloom	June 6	53.2	4.58	3.02	2.90	3.20	3.43	114	2.20
Full bloom	June 13	49.4	3.96	3.41	2.96	2.44	3.19	106	2.72
Seed stage[2]	....	33.3	3.54	2.56	2.57	2.61	2.82	94	2.57
CUTTING DETERMINED BY APPEARANCE OF NEW GROWTH AT CROWN									
New growth	June 3	52.8	4.67	3.34	2.86	3.15	3.51	117	2.36
New growth[3]	....	....	3.97	3.37	2.67	3.33	3.34	111	2.37
Average	....	....	4.18	2.99	2.77	2.89	3.21	....	2.38

[1]All stages harvested uniformly at the new growth stage in 1925.

[2]The proportion of leaves includes pods and blossoms and is for the seed crop only. The yields include a first crop cut at the new growth stage, the seed crop and usually a light, third crop.

[3]All crops cut at new growth stage excepting the second which was cut in initial bloom stage.

are not so marked. No marked decrease in yield may be expected when only one cutting per year is harvested earlier than normal. No other differences were observed to result from such a practice.

Proportion of Leaves.—The proportion of leaves at harvest was found to be very closely correlated with maturity. As a 4-year average for all cuttings the pre-bloom, initial bloom, one-tenth bloom, one-half bloom, full bloom, seed and new growth stages consisted of 57.3, 56.6, 55.8, 53.2, 49.4, 33.3, and 52.8 per cent leaves respectively. This was an extreme difference of 24.0 per cent, and a variation of 7.9 per cent among the stages ordinarily harvested for hay.

Yield of Seed per Acre.—Under Nebraska conditions the second cutting is usually considered the most desirable to leave for seed production. It will ordinarily blossom and set seed pods more freely than the first cutting, whereas later cuttings seldom mature seed. Leaving the second cutting for seed in these tests has reduced the yield of forage materially as well as resulting in feed of lower quality. There was measurable seed production during this test in only one year out of four, the seed plats yielding at the rate of 1.2 bushels per acre in 1921. It is recognized that seed production in eastern Nebraska is uncertain and seldom profitable.

Effect on Plant Development.—Stand and root measurements comparable to those in Table 5 were made for the pre-bloom, new growth and full bloom stages of harvest. The data are recorded in Table 8. In 1925, 58, 78, and 64 per cent as many plants survived per square foot for the pre-bloom, new growth, and full bloom stages, respectively, as in 1921. There was a tendency for more rapid thinning out of the stand in the case of the most frequent cutting, tho even here a satisfactory stand still remained after 4 years of continuous pre-bloom cutting. This difference in thinning out was not as marked as that indicated in the earlier test, 1915-1918, which is reported in Table 6. The incoming of blue-grass, the annual grasses, and other weeds was not noticeable in this last experiment, whereas in the earlier experiment this condition was very marked. The difference in location of the plats may have been a factor in the relative amounts of weed growth. In the first test the plats, tho protected by a narrow border of alfalfa, were located adjacent to a roadway and the College campus where the conditions were rather favorable for the ingress of blue-grass, dandelions and other weeds. The second test was located in the center of a larger field of alfalfa which in turn was surrounded by cultivated fields. It is probable that when such weeds once obtain a foothold they will compete with the alfalfa. When the roots of these 3 maturity stages are classified according to their diameters, a slight tendency is apparent for the most frequent cutting to retard root development somewhat.

TABLE 8.—*Stand and root development of alfalfa in relation to time of cutting, 1921-1925*

Year	Plants per square foot	Plants grouped according to diameter of roots (inches)[1]			
		0-¼	¼-½	½-¾	¾-1
		Per cent	*Per cent*	*Per cent*	*Per cent*
		PRE-BLOOM			
1921	11.3	11.4	77.2	11.4	....
1925	6.6	9.7	45.2	43.5	1.6
		NEW GROWTH			
1921	11.3	18.9	75.7	5.4	....
1925	8.8	4.2	50.0	45.1	2.5
		FULL BLOOM			
1921	10.6	16.7	71.4	11.9	....
1925	6.8	4.8	38.1	52.4	4.7

[1]Root diameters measured just below the crown.

Chemical Composition of Hay.—Fodder analyses were made of the leaves and stems from all cuttings of each maturity stage during the 4-year period, 1921-1924. In case of the seed stage, the second or seed cutting only was analyzed. The composition of the whole hay has been calculated from that of the leaves and stems on the basis of their constituent proportion. The ash, protein, fiber, nitrogen-free extract, and fat contents are reported in Table 9 for 1921 to 1924. As a 4-year average, there is a rather gradual reduction in the ash content from 11.24 per cent in the pre-bloom stage to 9.36 per cent in the full bloom stage. The protein content for the pre-bloom, initial bloom, one-tenth bloom, one-half bloom, full bloom, and new growth stages was 21.98, 20.03, 19.24, 18.84, 18.13, and 18.38 per cent, respectively. This decrease in protein content of 3.85 per cent between extremes was rather parallel with increase in maturity of the plant and was accompanied by an increase of crude fiber content of 5.69 per cent from the pre-bloom to the full bloom stage. No consistent variation was found in the percentage of nitrogen-free extract. Of the 6 stages harvested for hay, the initial bloom stage contained 40.67 per cent nitrogen-free extract and the full bloom 38.70 per cent, as the two extremes. The average fat content for the 6 stages was 2.93 per cent, with an extreme variation of 0.34 per cent. The crop harvested for seed as compared with the new growth stage was

TABLE 9.—*Effect of the time of cutting upon the chemical composition of alfalfa hay, 1921-1924*

Constituents	Stage of maturity						
	Pre-bloom	Initial bloom	One-tenth bloom	One-half bloom	Full bloom	Seed stage	New growth
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1921							
Ash	10.35	9.74	9.83	10.33	8.64	6.59	9.78
Protein	20.11	19.24	18.19	18.53	16.41	13.11	18.25
Fiber	25.29	25.25	28.97	30.22	31.99	41.97	29.13
Nitrogen-free extract	40.68	41.87	39.49	37.54	39.69	35.51	39.57
Fat	3.57	3.90	3.52	3.38	3.27	2.82	3.27
1922							
Ash	11.61	10.66	10.51	11.18	9.89	7.26	9.50
Protein	22.23	20.77	20.58	20.61	19.25	13.51	20.13
Fiber	24.84	24.53	24.71	23.01	27.59	33.93	26.42
Nitrogen-free extract	38.49	40.74	40.80	41.75	39.57	42.36	41.05
Fat	2.83	3.30	3.40	3.45	3.70	2.94	2.90
1923							
Ash	11.45	10.34	9.26	9.71	8.85	6.41	8.99
Protein	21.47	19.05	18.51	18.08	16.81	13.55	17.21
Fiber	26.85	27.29	28.69	30.77	34.27	39.54	30.26
Nitrogen-free extract	37.93	41.17	41.36	39.29	37.80	39.13	41.37
Fat	2.30	2.15	2.18	2.15	2.27	1.37	2.17
1924							
Ash	11.53	11.32	11.49	11.54	10.06	9.04	10.56
Protein	24.12	21.05	19.67	18.13	20.06	16.07	17.93
Fiber	23.55	25.94	25.99	28.50	29.41	30.99	30.49
Nitrogen-free extract	37.77	38.92	39.88	39.22	37.76	41.46	38.60
Fat	3.03	2.77	2.97	2.61	2.71	2.44	2.42
AVERAGE 1921-1924							
Ash	11.24	10.52	10.27	10.69	9.36	7.33	9.71
Protein	21.98	20.03	19.24	18.84	18.13	14.06	18.38
Fiber	25.13	25.75	27.09	28.12	30.82	36.61	29.08
Nitrogen-free extract	38.72	40.67	40.38	39.45	38.70	39.61	40.14
Fat	2.93	3.03	3.02	2.90	2.99	2.39	2.69

2.38 per cent lower in percentage of ash, 4.32 per cent lower in protein, 7.53 per cent higher in fiber, 0.53 per cent lower in nitrogen-free extract, and 0.30 per cent lower in fat content.

The average physical and chemical composition of the whole hay, leaves, and stems, during the 4-year period, 1921-1924, is recorded in Table 10 and Chart 2 for each of the 7 stages of maturity. As an average of the 6 stages of matur-

TABLE 10.—*Effect of the time of cutting upon the chemical composition of alfalfa hay,*[1] *leaves, and stems. Average for 4 years, 1921-1924*

Stage of maturity and portion of hay	Proportion of parts	Constituents				
		Ash	Protein	Fiber	Nitrogen-free extract	Fat
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Pre-bloom						
Hay	100	11.24	21.98	25.13	38.72	2.93
Leaves	57.3	12.16	29.04	14.97	40.05	3.78
Stems	42.7	10.10	12.90	37.11	38.07	1.82
Initial bloom						
Hay	100	10.52	20.03	25.75	40.67	3.03
Leaves	56.6	11.70	26.82	14.95	42.66	3.87
Stems	43.4	9.09	11.56	39.38	38.02	1.95
One-tenth bloom						
Hay	100	10.27	19.24	27.09	40.38	3.02
Leaves	55.8	11.59	26.02	15.91	42.48	4.00
Stems	44.2	8.73	11.31	39.37	38.75	1.84
One-half bloom						
Hay	100	10.69	18.84	28.12	39.45	2.90
Leaves	53.2	12.29	25.74	16.30	41.78	3.89
Stems	46.8	8.98	11.33	40.99	36.88	1.82
Full bloom						
Hay	100	9.36	18.13	30.82	38.70	2.99
Leaves	49.4	11.24	25.92	18.00	40.55	4.29
Stems	50.6	7.71	10.79	42.75	36.95	1.80
Seed stage[2]						
Hay	100	7.33	14.06	36.61	39.61	2.39
Leaves	33.3	9.00	22.20	22.10	43.53	3.17
Stems	66.7	6.53	10.19	43.59	37.71	1.98
New growth						
Hay	100	9.71	18.38	29.08	40.14	2.69
Leaves	52.8	11.14	25.45	16.86	42.89	3.66
Stems	47.2	8.19	10.87	42.12	37.18	1.64

[1]The composition of the hay for each crop calculated from that of the leaves and stems on a percentage basis. The four-year average obtained from the seasonal averages.
[2]Analyses from the second or seed crop only. The pods and blossoms were included with the leaves.

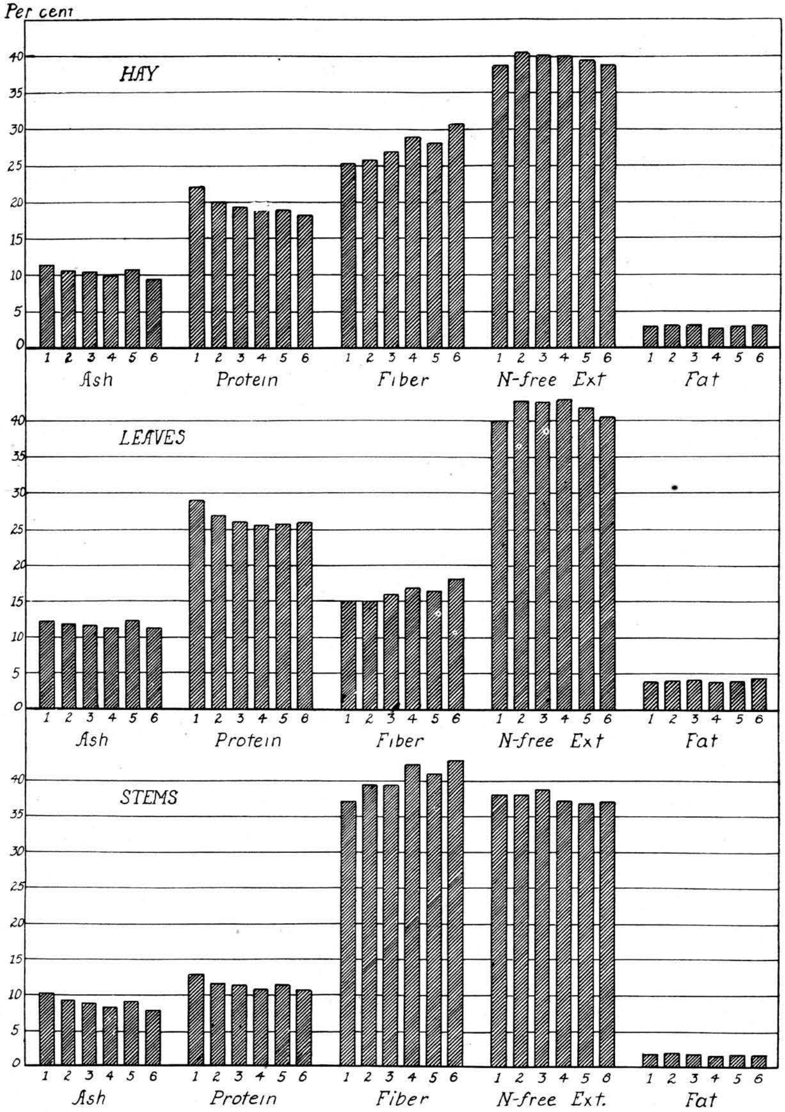

CHART 2.—Effect of the time of cutting upon the composition of alfalfa hay (above), leaves (center), and stems (below). The stages of maturity are designated as follows: (1) pre-bloom, (2) initial bloom, (3) one-tenth bloom, (4) new growth, (5) one-half bloom, and (6) full bloom. Average for 4 years, 1921-1924. (Table 10.)

ity harvested solely for hay, the stems comprised 45.8 per cent of the total crop. There was an increase of 7.9 per cent in proportion of stems from the least mature stage to the most mature stage. When the analyses of hay harvested at these 6 stages are averaged for the 4-year period it is found that the stems contained 75, 43, 249, 90, and 46 per cent as much ash, protein, fiber, nitrogen-free extract, and fat, respectively, as the leaves. The ratio of the protein percentage of the stems to that of the leaves remained practically constant regardless of the stage of maturity. The gradual decrease in the protein of the leaves and stems, accompanied by a decrease in the proportion of leaves, results in hay of lower protein content as the crop becomes more mature.

It is of further interest to compare the physical and chemical composition of the whole hay, leaves, and stems, by cuttings. Such data have been averaged for the first, second, and third cuttings of the above 6 stages of maturity for the 4-year period, 1921-1924, and recorded in Table 11. The first, second, and third cuttings consisted respectively of 48.7, 56.4, and 58.1 per cent leaves. There was a slight increase,

TABLE 11.—*Relative chemical composition of first, second, and third cuttings of alfalfa hay as obtained from an average of 6 stages of maturity. Average for 4 years, 1921-1924*

Cutting	Proportion of leaves	Constituents				
		Ash	Protein	Fiber	Nitrogen-free extract	Fat
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
HAY						
First	48.7	10.29	18.96	29.35	38.55	2.85
Second	56.4	10.35	19.83	27.31	39.62	2.89
Third	58.1	10.12	20.03	27.06	39.84	2.95
LEAVES						
First	....	12.24	27.80	15.82	40.03	4.11
Second	....	11.52	26.82	15.98	41.85	3.83
Third	....	11.13	26.44	16.21	42.41	3.81
STEMS						
First	....	8.51	10.62	41.97	37.25	1.65
Second	....	8.98	11.29	40.95	37.04	1.74
Third	....	8.89	11.73	41.10	36.49	1.79

1.07 per cent, in the protein content of the whole hay from the first to the third cutting. The leaves decreased 1.36 per cent in protein content from the first to the third cuttings, whereas the stems increased 1.11 per cent. Since the leaves contain a much higher per cent of protein than the stems, these changes would result in lower protein content for the whole hay in the second and third cuttings if it were not for their respective increases of 7.7 and 9.4 per cent in the proportion of leaves.

Yield of Feed Constituents.—The 4-year average annual acre yields of moisture-free hay, leaves, and stems together with their yields of feed constituents are given in Table 12

TABLE 12.—*Effect of the time of cutting upon the yield of moisture-free alfalfa hay, and of its principal food elements. Average for 4 years, 1921-1924*[1]

Stage of maturity and portion of hay	Acre yield on a moisture-free basis					
	Hay	Ash	Protein	Fiber	Nitrogen-free extract	Fat
	Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
Pre-bloom						
Hay	2.548	0.287	0.552	0.648	0.987	0.074
Leaves	1.430	0.174	0.414	0.214	0.574	0.054
Stems	1.118	0.113	0.138	0.434	0.413	0.020
Initial bloom						
Hay	2.578	0.267	0.515	0.680	1.036	0.080
Leaves	1.428	0.166	0.386	0.214	0.604	0.058
Stems	1.150	0.101	0.129	0.466	0.432	0.022
One-tenth bloom						
Hay	2.848	0.287	0.541	0.797	1.132	0.091
Leaves	1.534	0.176	0.404	0.243	0.644	0.067
Stems	1.314	0.111	0.137	0.554	0.488	0.024
One-half bloom						
Hay	2.909	0.304	0.535	0.847	1.138	0.085
Leaves	1.493	0.180	0.387	0.240	0.625	0.061
Stems	1.416	0.124	0.148	0.607	0.513	0.024
Full bloom						
Hay	2.712	0.252	0.482	0.854	1.042	0.082
Leaves	1.295	0.145	0.337	0.227	0.528	0.058
Stems	1.417	0.107	0.145	0.627	0.514	0.024
New growth						
Hay	2.978	0.289	0.546	0.885	1.175	0.083
Leaves	1.518	0.170	0.395	0.252	0.642	0.059
Stems	1.460	0.119	0.151	0.633	0.533	0.024

[1]The annual yields of the various food elements were calculated from the composition and yield of each cutting.

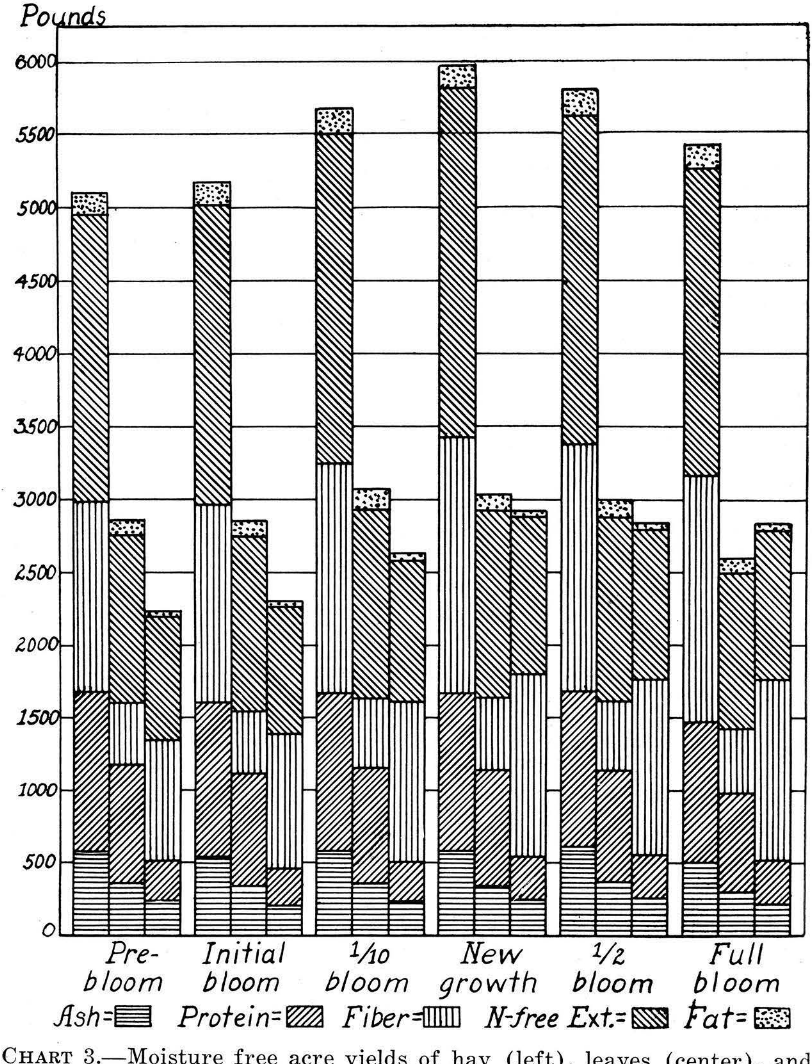

CHART 3.—Moisture free acre yields of hay (left), leaves (center), and stems (right), for each of the stages of maturity designated at the base of the chart, together with their proportionate content of ash, protein, fiber, nitrogen-free extract and fat. Average for 4 years, 1921-1924. (Table 12.)

and Chart 3 for each of the 6 maturity stages. The average annual acre yields of protein for the pre-bloom, initial bloom, one-tenth bloom, one-half bloom, full bloom, and new growth stages were 0.552, 0.515, 0.541, 0.535, 0.482, and 0.546 tons, respectively. The proportion of this total protein that was borne in the leaves ranged from 75 per cent in the least mature stages to 70 per cent in the full bloom stage. Due to the higher percentage of protein in the hay from the more immature stages, there was no marked difference in the acre yield of protein until the stage of maturity producing the highest acre yield of hay had been passed. The full bloom stage, due to its lower acre yield of hay and lower percentage of protein, yielded decidedly less protein per acre than the new growth stage. From the combined standpoints of acre yields of hay and feed constituents, quality of hay, and permanency of stand, it would seem that harvesting alfalfa at approximately the new growth stage should prove the most desirable practice. This stage usually occurs under average Nebraska conditions during the period from one-tenth to one-half bloom, and for practical purposes harvesting may ordinarily extend over this period without materially affecting results, using either the new growth or bloom development as an index. A modification of this practice to fit local conditions may often prove desirable, but frequent cutting of alfalfa in more immature stages should be avoided.

HISTORICAL REVIEW — MATURITY STAGES

EFFECT OF TIME OF CUTTING UPON YIELD

Sanborn (1893) reports one year's results from Utah with harvesting alfalfa at different stages of maturity as follows: early cutting (before coming into bloom) 7182 pounds per acre, medium cutting (early bloom) 7158 pounds, and late cutting (out of bloom) 7122 pounds per acre.

Mills (1896), in continuation of the work reported by Sanborn (1893), reports yields for 3 years (1893-1895) on a 12 per cent moisture basis, for early, medium, and late cutting, of 9,061, 8,396. and 8,166 pounds per acre respectively.

Foster and Merrill (1899), in continuation of the work reported by Sanborn (1893) and Mills (1896) reports a 5-year average (1893-1895 and 1897-1898) of early (first bloom), medium (full bloom), and late (half of bloom gone) cutting of 10,719, 9,829, and 9,100 pounds per acre, respectively.

Harcourt (1900) reports yields of 2,714, 3,525, and 3,142 pounds of dry matter per acre as an average of 3 cuttings in 1897 and 1898 made in Ontario in bud, one-third bloom, and little past full bloom stages.

In tests at Ottawa, Canada, Shutt (1904) in 1901 obtained 8742 pounds dry matter and 1411 pounds crude protein per acre for alfalfa cut twice as compared with 8545 pounds dry matter and 1658 pounds protein for alfalfa cut 4 times.

Ten Eyck (1908) reports yields for a 1-year period in Kansas of 4.69, 5.35, 4.52, and 5.99 tons per acre, respectively, when harvested in first bloom, one-tenth bloom, one-half bloom and full bloom.

As an average for 1903-1907, Hansen (1909) in Denmark reports yields of 7,720, 8,897, and 8,456 pounds per acre from cuttings made 4, 3, and 2 times annually.

Hansen (1914, 1915, and 1916), at the Huntley (Montana) Reclamation Project Farm, harvested alfalfa at the appearance of the first basal shoots and at 4 successive 5-day intervals, the last harvest of each cutting being made 20 days after the first harvest of that cutting. When the yields for 1913, 1914, and 1915 are averaged the following results are obtained,— 5.87, 5.81, 5.64, 5.29, and 5.72 tons per acre respectively from the least to the most mature stage.

Bean (1922) reports yields from the Washington Agricultural Experiment Station (Irrigation Branch Station), of 6.7, 7.8, and 8.1 tons per acre as a 2-year average when harvested just before bloom, one-half bloom, and three-fourths full bloom stages.

Moore and Graber (1925) obtained 1.9, 2.7, and 3.4 tons per acre in Wisconsin for bud, one-tenth bloom, and full bloom stages.

Salmon, Swanson, and McCampbell (1925) of Kansas report 8-year average yields, 1914-1921, (10 per cent moisture basis) of 3.24, 3.41, 3.51, and 2.93 tons per acre for the bud, tenth bloom, full bloom, and seed stages, respectively. When harvested uniformly in 1923, yields of 2.47, 2.61, 3.11, and 2.99 tons per acre were obtained from the plats which had previously received these respective cutting treatments.

RELATION OF TIME OF CUTTING TO PHYSICAL COMPOSITION

Foster and Merrill (1899) of Utah, as an average of first and second crops, found early cutting (first bloom) to consist of 41.07 per cent leaves, medium cutting (full bloom)

37.07 per cent, and late cutting (half bloom gone) 30.21 per cent.

Salmon, Swanson, and McCampbell (1925) found in Kansas as an 8-year average (1914-1921) that alfalfa harvested in the bud, one-tenth bloom, full bloom, and seed stages consisted of 53.4, 51.1, 48.4, and 41.6 per cent leaves, respectively. During this same period the weight of grasses within the hay averaged 18.2, 5.9, 2.3, and 0.8 per cent, respectively, of the total yield.

RELATION OF TIME OF CUTTING TO CHEMICAL COMPOSITION AND DIGESTIBILITY

The Colorado Agricultural Experiment Station (1889) reports a decrease of albuminoid nitrogen from 18.19 per cent from the bud stage to 11.67 per cent when seed was fully ripened.

Headden (1896) found that, as an average for all stages of development in Colorado, the first, second, and third cuttings consisted of 14.85, 14.43, and 13.05 per cent protein, respectively.

Mills (1896) reports from Utah that, as an average of 2 crops during 1 year, early, medium, and late cuttings consisted of 14.80, 12.47, and 13.41 per cent protein respectively. The leaves contained 11.92, 18.42, 20.42, 44.57, and 4.66 per cent ash, protein, fiber, nitrogen-free extract, and fat, respectively, as compared with 6.82, 7.38, 42.43, 41.33, and 2.04 per cent for the stems.

As an average for 3 crops grown in Colorado in 1896, Headden (1897) reports that the protein content in the beginning to bloom, half bloom, and full bloom stages averaged 17.69, 17.13, and 17.25 per cent, respectively, and the average protein content for the first, second, and third cuttings of all stages was 16.32, 18.46, and 17.29 per cent.

Widtsoe and Stewart (1898) for Utah conditions conclude that "The digestibility of lucern remains practically constant from budding time to the period of full bloom."

Foster and Merrill (1899) report from Utah that the annual yield of digestible matter per acre during 5 years, 1893-1895 and 1897-1898, averaged 6,413, 5.912, and 5,309 pounds for early, medium, and late cutting. The protein content for the same stages for 3 years, 1895-1897, was 14.26, 12.77, and 12.92 per cent, respectively. "The average composition of all cuttings and crops shows the leaves to contain 150 per cent more protein than the stems, 300 per cent more fats, 35 per cent more nitrogen-free extract, and 256 per cent less crude fiber."

Harcourt (1900) reports from Ontario that the protein content ranged from 25.33 per cent when 6 inches high to 14.23 per cent at the time the bloom is falling. As an average of 3 cuttings in 1897 and 1898, the protein content at the bud, one-third bloom, and a little past full bloom stages was found to be 19.11, 15.53, and 13.89 per cent, respectively. Nutrition experiments showed that 58.6, 56.2, and 51.3 per cent of the dry matter in these respective stages was digestible, whereas 73.4, 72.8, and 64.4 per cent of the protein was digestible.

Cottrell (1902) reports a protein content of 18.5, 17.2, and 14.4 per cent for the one-tenth bloom, one-half bloom, and full bloom stages, respectively, for hay grown in Kansas.

Snyder and Hummel (1903) report from Minnesota that the protein content at weekly intervals beginning June 30 and extending to July 29 was 31.25, 26.25, 22.62, 18.25, and 16.56 per cent, respectively. On June 30 the growth was about 6 inches high and on July 22 first blossoms were appearing.

Hansen (1909) of Denmark reports a nitrogen content (1903-1907) of 2.66, 2.35, and 1.96 per cent, respectively, from 4, 3, and 2 cuttings per season.

Salmon, Swanson, and McCampbell (1925) report that cuttings made in Kansas in 1923 at 10- and 20-day intervals, and in the bud, one-tenth bloom, full bloom, and seed stages, contained 26.4, 22.5, 18.5, 18.7, 18.1, and 17.7 per cent protein respectively. The latter 4 stages in the regular stage of maturity test contained 19.9, 18.9, 17.6, and 16.0 per cent protein, when sampled green. Of this total protein, 71.0, 71.0, 72.3, and 74.4 per cent, respectively, was "pure" protein. The leaves of the bud, tenth bloom, full bloom, and seed stage contained 66.5, 68.2, 66.3, and 57.8 per cent of the total protein, respectively. As an average for feeding tests carried on during 3 years, 1,628, 2,086, 2,163, and 3,910 pounds of hay harvested in the bud, one-tenth bloom, full bloom, and seed stages, respectively, were required to produce 100 pounds gain.

RELATION OF TIME OF CUTTING TO PLANT DEVELOPMENT

McKee (1916), California, found as a 2-year average that, where alfalfa was clipped twice during the first season, root diameters averaged 6.45 mm. as compared with 6.92 mm. for the unclipped.

Garver (1922) found at Redfield, South Dakota, that alfalfa clipped 3, 7, and 18 times the second season resulted in a mortality of 17, 92 and 98 per cent, respectively. The plants harvested but 3 times showed a much larger and stronger root growth.

The Wisconsin Agricultural Experiment Station (1923) found that late fall cutting or the removal of 3 crops as compared with 2 increased winterkilling from 26 to 62 per cent (average of 4 tests).

Nelson (1925) concluded from a series of cutting experiments in Wisconsin extending from 1921 to 1923 that, " frequent cutting of alfalfa in premature stages results in depleted root reserves. This causes slow recovery and rate of growth after cutting, low yields of hay, increased weed infestation, and retarded root growth. An increase in the number of crown buds, shoots, and main stems occurs as an immediate effect with frequent and early cutting, but the average height and total yields of these top growths is much less than with less frequent cuttings at a more mature stage.

" Chemical analysis of alfalfa roots and physiological observations show that stored organic foods in the roots of certain plants such as alfalfa have an important influence on their productivity. Both the nitrogen and carbohydrate reserves of the root are decreased by cutting the crop too early."

Salmon, Swanson, and McCampbell (1925) of Kansas, cutting at 4 stages of maturity, i.e., bud, tenth bloom, full bloom, and seed stage, found that the respective losses in number of plants per acre from 1914 to 1922 were 77.1, 84.1, 64.4, and 53.9 per cent of the original number; that similar losses in number of stems produced per acre were 50.8, 63.8, 46.5, and 13.0 per cent. The number of stems produced per plant from 1915 to 1921 was practically constant for the various cutting stages, but on the average increased from 3.7 to 7.0 stems per plant.

Root diameters measured 3 inches below the crown in 1923 were 241, 206, 233, and 242 per cent as large as the diameters in 1915 for the bud, one-tenth bloom, full bloom, and seed stages, respectively.

THE USE OF TOP DRESSING ON ALFALFA

It is generally recognized that profitable production of alfalfa hay may be limited on soils low in their lime and sulphur content and in general fertility. Alfalfa will not thrive on very strongly acid soils. Sulphur is a necessary plant food element and alfalfa has a high sulphur requirement. Table 13 contains the results of a 4-year test during 1921-1924, wherein gypsum (calcium sulphate), sulphur (flowers of sulphur), lime and sulphur in combination, lime, and barnyard manure were applied as top dressings in commonly recommended amounts to alfalfa growing on the Experiment Station Farm. The applications were made in duplicate in the spring of 1921 on a well-established stand of alfalfa. Gypsum was applied at the rate of 400 pounds per acre. Sulphur alone as well as in conjunction with lime was applied at the rate of 200 pounds per acre, while 2 tons of crushed limestone and 8 tons of barnyard manure were used.

TABLE 13.—*The effect of top dressings upon the yield of alfalfa hay, 1921-1924*

Treatment applied in 1921	Amount of application per acre	Yield of hay per acre with 15 per cent moisture content					
		1921	1922	1923	1924	Average	
	Pounds	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Relative*
No treatment	.....	5.22	2.97	3.00	3.38	3.64	100
Gypsum	400	5.29	2.77	2.90	3.34	3.58	98
Sulphur	200	4.98	2.63	2.95	3.54	3.53	97
Lime and sulphur	4000 200	5.35	2.94	3.14	3.48	3.73	102
Lime	4000	5.59	2.89	2.92	3.30	3.68	101
Manure[1]	16000	5.89	3.88	3.13	3.54	4.11	113
Average	.....	5.39	3.01	3.01	3.43	3.71	...

[1]The yields for the manure treatment are calculated from manurial effects in an adjacent alfalfa field.

The 4-year averages show practically no difference in the yields from either the no treatment, the gypsum, the sulphur, the lime, or the sulphur-and-lime treated plats. These results indicate that there is sufficient lime and sulphur in this soil for successful alfalfa production. The application of barnyard manure increased the yield of alfalfa hay 13 per cent over the plats receiving no treatment.

ALFALFA-TIMOTHY MIXTURE

The growing of alfalfa and timothy in combination has been occasionally advocated. Seedings were made in duplicate in 1922, comparing alfalfa seeded alone at the rate of 20 pounds per acre with an alfalfa and timothy mixture seeded at the same rate. The mixture consisted of 7 parts alfalfa and 13 parts of timothy by weight. Good uniform stands were secured on the 4 plats. The results are recorded in Table 14. The field in which these plats were located produced a heavy crop of silage corn in 1921 and was in alfalfa during the 4-year period preceding 1921. The dry condition of the subsoil due to the previous cropping, together with a rather dry series of years, resulted in relatively low yields on these plats from 1923 to 1925. As a 3-year average alfalfa alone yielded at the rate of 2.21 tons per acre, whereas alfalfa and timothy in combination yielded 2.35 tons of cured forage. This difference in yield is not considered significant. The first cutting each year was the only one to contain a measurable amount of timothy. As a 3-year average of alfalfa alone the first, second, and third cuttings comprised 54, 32, and 14 per cent of the total yield and these respective cuttings in the alfalfa-timothy mixture formed 58, 28, and 14 per cent of the total yield. The growing of such a mixture is not recommended unless the mixed hay is especially desired for feeding purposes.

TABLE 14.—*Comparative yields of alfalfa alone and alfalfa and timothy in combination, 1923-1925*

Crop	Yield of hay per acre with 15 per cent moisture content			
	1923	1924	1925	Average
	Tons	*Tons*	*Tons*	*Tons*
Alfalfa	2.20	2.51	1.91	2.21
Alfalfa and timothy	2.59	2.76	1.69	2.35

SEEDING PRACTICES

GENERAL OBSERVATIONS AND RECOMMENDATIONS

The relation of various seeding practices to the likelihood of securing satisfactory stands of alfalfa has long been under observation in this State and certain conclusions seem justified.

A high state of soil fertility aids in establishing a stand of alfalfa as well as resulting in increased production.

Thoroly prepared, finely pulverized, compact, moist seed beds are most conducive to securing a stand. Tillage operations and crop sequences should be planned with this in mind. Almost any seeding or cultural practice will prove successful when weather and soil conditions are favorable. The hazards connected with seeding increase as these conditions become less favorable. The most intensive and careful methods often fail when the weather is unfavorable. On the other hand, much can be done thru proper methods to reduce losses and to insure the likelihood of success.

Seeding should only be done when weather and soil conditions are favorable. It may preferably be either in the spring or the early fall in eastern Nebraska and in the spring or the early summer in central and western Nebraska. If fall seeding following small grain is planned, the land should be plowed as soon as possible after harvest in order to conserve moisture by reducing run-off and weed growth. Following this the land should be sufficiently disked and harrowed to prevent weed growth and to insure a compact seed bed by seeding time.

Fall seeding in eastern Nebraska can be advantageously done between August 10 and September 1. If conditions are favorable for prompt germination and continued fall growth, there is seldom danger of winterkilling, provided seed of a hardy strain or variety is planted. Chances of winterkilling are increased with more delayed seeding, altho successful stands are sometimes secured as late as September 15 in the southeastern portion of the State.

If seeding is to be done in the spring, April and May are considered good months in eastern Nebraska, the exact time depending upon the favorableness of conditions. Seeding seems most successful during May and early June in central and western Nebraska, preceded by tillage planned to conserve moisture, kill weeds, and compact the seed bed.

In those regions where seeding following a small grain crop is successful it will produce almost as much hay the following year as spring seeding. Spring seeded alfalfa seldom proves a profitable crop during the first year and must usually be clipped several times the first season to check weed growth.

Under exceptionally favorable moisture and weed-free conditions, alfalfa may be seeded directly into small grain stubble with mere disking or without any treatment. This is regarded as one of the desirable methods on sandy soils which are inclined to blow.

Except under extremely favorable conditions, drilling is more successful than broadcasting. It insures more uniform covering in moist soil and more prompt and uniform germination. The drilling should be very shallow. Broadcast seed is usually covered by a harrow.

The number of alfalfa plants necessary per acre for maximum production and the rate of seeding required to secure this stand vary with conditions. There are enough seeds in the average pound of alfalfa to average about five plants per square foot if all the seeds would grow when planted. Five and possibly 3 or 4 well established and evenly distributed plants per square foot may be as productive of forage as a much thicker stand. A thin stand which yields less the first year or two than a thicker stand will ordinarily do relatively better when it becomes well established. Thin stands, however, are invariably more or less uneven, more subject to the ingress of weeds, and usually produce a hay of lower quality.

Ten pounds or even less per acre may produce good, even stands of alfalfa when conditions are extremely favorable. The use of a somewhat larger amount of seed per acre will usually increase the chances of securing a good stand. The seeding of more than 15 pounds per acre, however, seems inadvisable and unnecessary.

The use of a small grain nurse crop is fairly successful in some localities and especially in the extreme eastern counties. Thin stands of winter wheat often prove to be good nurse crops. Short-strawed, early-maturing varieties of oats and barley, seeded at half the normal rate, make good modified nurse crops. Mowing the small grain early for hay is desirable if the season becomes very dry, or the nurse crop becomes too rank.

It is only under exceptional conditions that spring-seeded alfalfa will produce much hay the first year. If conditions are favorable and if there is but little competition from weed growth, one or two light cuttings of fair quality hay may be had the first season. Cutting in this case, however, should be delayed until the crop is fairly mature.

Ordinarily the weed growth proves a very serious factor the first season following spring seeding and the question arises as to how best to handle the situation. If the weed growth becomes quite heavy the most feasible plan appears to be clipping in order to avoid the loss of the alfalfa seedlings, due to weed competition. Under exceptional conditions 2 or 3 or even more clippings may be necessary the first season. These clippings should be made rather high and if possible during cool, damp weather. Whenever the clipped growth is very heavy, it should be removed.

It has sometimes been recommended that the growth be unclipped thruout the first season, to be followed by burning over or raking off the following spring. This practice should be governed largely by local conditions. Whenever the weed growth becomes sufficiently heavy so that there is danger of smothering out the less vigorous alfalfa plants, it should be clipped. In the Nebraska Experiment Station tests, the weed growth has been such in two years out of four as to kill out alfalfa when left unclipped during the season. Late summer or early fall seeding seldom needs further attention and fair yields of relatively weed-free hay may be expected the following season.

Seed inoculation has seldom been found necessary in this State. The proper bacteria are present in most of our soils. It has been concluded from various cooperative tests with farmers as well as by Experiment Station tests that in general inoculation is essential only in the restricted regions of rather acid soil and perhaps in a few isolated localities where alfalfa has not been previously grown. Its trial is recommended, however, for localities where failures to secure a productive stand cannot be otherwise accounted for.

It is evident that the most desirable seeding practice must be decided locally to fit the immediate conditions.

EXPERIMENT STATION SEEDING TESTS DURING 1922-1925

A number of seeding and cultural practices such as time and rate of seeding, drilling vs. broadcasting, and the use of nurse crops have been systematically investigataed on the Experiment Station Farm since 1922 in order to observe their relation to securing a stand of alfalfa. These results are summarized in Table 15. Aside from the question of securing a stand, the particular methods employed doubtless bear little relation to the productivity or longevity of the crop after it has become well established. In these tests a prescribed program has been followed regardless of weather conditions. This will partially account for the high percentage of failures.

TABLE 15.—*The securing of a stand of alfalfa in relation to various seeding practices, 1922-1925*

	1922	1923	1924	1925
Date, rate, or method	Stand secured	Stand secured	Stand secured	Stand secured
DATE OF SEEDING[1]				
April	Good	Good	Good	Good
May	Good	Good	Fair	Good
June	....	Fair to poor	Good	Fair to good
July	....	Failure	Poor	Good
August	Failure	Fair to good	Good	Good
September	Failure	Failure	Poor	Good
Early spring and late fall	....	Failure	Failure	Failure
RATES OF SEEDING[2]				
5 lbs. per acre	Failure	Poor, thin, little uneven	Very thin, uneven	Thin, little uneven
10 lbs. per acre	Failure	Poor, thin, little uneven	Fair to good	Fair to good, little uneven.
15 lbs. per acre	Failure	Fair, fairly uniform	Good	Good, little uneven
20 lbs. per acre	Failure	Good	Good	Good
NURSE CROPS AND MISCELLANEOUS PRACTICES				
Spring seeded				
Normal clipping	Good	Good	Good	Good
Unclipped-weeds burned off	Good	Failure	Failure	Good
Unclipped-weeds raked off	Good	Failure	Failure	Good
Two bushels of oats	Good	Failure	Good	Good
One bushel of oats	Good	Failure	Good	Good
Fall seeded				
Following small grain	Failure	Failure	Failure	Good
Summer fallow	Failure	Failure	Good	Good
Standing corn	Failure	Failure	Failure	Fair

[1]Drilling and broadcasting was practiced on all seeding dates from April to September. On the average, drilling resulted in securing a somewhat larger per cent and more uniform stands. Since seedings were made at prescribed times regardless of conditions, the percentage of failures was quite large in both cases. All seedings marked good considered generally satisfactory.

[2]Fall seeded in 1922 and spring seeded 1923-1925.

INOCULATION TESTS

Inoculation of the soil or seed before sowing alfalfa has been widely advocated. If the inoculating bacteria essential to alfalfa are not naturally present in the soil, they must be supplied before alfalfa will thrive. These bacteria may be supplied by scattering soil from a field known to be inoculated or by artificial cultures applied to the seed.

Frequent soil and artificial culture inoculation tests have been made at the Nebraska Experiment Station. No differences have been observed in any of these tests. The results of one test seeded in duplicate twentieth-acre plats in 1922 are shown in Table 16. There was no apparent difference in stand, vigor of growth, or yield, between the uninoculated and the soil and culture inoculated plats at any time during the 4-year period.

TABLE 16.—*The effect of inoculation upon the yield of alfalfa hay, 1923-1925*

Treatment[1]	Yield of hay per acre with 15 per cent moisture content			
	1923	1924	1925	Average
	Tons	*Tons*	*Tons*	*Tons*
Uninoculated	4.96	6.90	5.16	5.67
Soil inoculated	5.06	7.01	5.00	5.69
Culture inoculated	5.25	6.89	5.05	5.73

[1]Inoculations made at time of seeding in 1922. No differences in growth observed during the first year.

MAINTENANCE OF ALFALFA STANDS

Maintaining an alfalfa stand for a period of several years is very desirable because of the expense and time ordinarily involved in securing a stand. The premature thinning out of alfalfa may be due to a number of causes. Some of these may be controlled in a large measure by proper cultural practices.

The avoidance of (1) seed of an unhardy sort, (2) cutting too late and too close in the fall, and (3) frequent cutting in very immature stages, will prolong the life of the alfalfa and aid in maintaining effective stands. Unavoidable losses are frequently due to drought and cold, and other adverse climatic conditions beyond the endurance of the crop. Bacterial wilt (*Aplanobacter insidiosum* McCulloch) has recently come to be regarded as a factor in the premature thinning of stands and merits further investigation. Experiment Station tests have indicated the symptoms of this disease to be most prevalent in those plats seeded to non-hardy sorts in which winter injury has been severe.

Disking or otherwise cultivating an alfalfa field in an effort to thicken the stand seldom proves effective. When fields have become so badly thinned as to be unprofitable they should be plowed up rather than attempting to rehabilitate them thru tillage practices or reseeding.

ALFALFA IN THE ROTATION

Partial or complete crop failures following the growing of alfalfa are of sufficient frequency and importance to merit consideration in planning an alfalfa rotation and in giving careful study to the crops best suited to follow alfalfa. A better understanding of the situation may be had after comparing alfalfa with the common cereal crops — corn, oats, and winter wheat — in respect to the normal working depth of their root systems, their water requirement per unit of dry matter, and their total production of dry matter.

It is generally recognized that the root systems of the cereal crops seldom extend below the fifth foot and that their normal working level is somewhat less than this. Alfalfa, on the other hand, has a root system extending much deeper and from the standpoint of moisture, at least, may have a working depth of 15 feet or more. Weaver (1926) states that under normal eastern Nebraska conditions the maximum penetration of the roots of oats and winter wheat will average about 4.4 and 5.4 feet, respectively, and that their normal working level is about 3.4 and 3.8 feet. A depth of penetration of 5 to 6 feet for corn is not unusual. Alfalfa roots, on the other hand, penetrate much deeper and ultimately may extend to depths of 20 feet or even more.

A further contrast of the working depth of alfalfa as compared with brome grass and winter wheat is shown by the moisture data in Table 17 and Chart 4. These moisture data were secured from soil samples taken June 24, 1926, as follows: (1) from the alfalfa check plats for which yields are reported in Table 3; (2) from adjacent land which had been seeded to brome grass in 1922 at the time the alfalfa was seeded; and (3) from an adjacent wheat field which had been cropped to corn, oats, and wheat during the same period. Previous to 1922 these fields had been treated alike, and present differences may thus be attributed to the cropping system.

Very little difference was found in the moisture content of the soil in the upper 4 feet from the alfalfa, brome grass, or wheat ground. The soil from the sixth to fifteenth foot of the alfalfa field had been depleted of moisture content practically to the point of non-availability and averaged 7 and 8 per cent lower in moisture than that from the brome grass and wheat fields.

TABLE 17.—*Comparative moisture content of soils from alfalfa, brome grass, and winter wheat fields,*[1] *June 24, 1926*

Depth	Moisture content of soil		
	Alfalfa field	Brome grass field	Winter wheat field
Feet	*Per cent*	*Per cent*	*Per cent*
1	15.3	17.3	17.2
2	16.7	16.7	16.4
3	15.4	15.4	15.5
4	14.4	15.1	15.4
5	13.8	16.9	17.6
Average 1-5	15.1	16.3	16.4
6	13.5	18.3	18.3
7	13.1	19.1	19.8
8	13.1	19.1	20.7
9	13.5	20.3	20.7
10	13.0	20.4	21.2
Average 6-10	13.2	19.4	20.1
11	13.0	21.8	20.8
12	12.9	19.6	21.6
13	13.5	20.1	21.6
14	13.7	20.7	22.3
15	13.2	18.7	22.1
Average 11-15	13.3	20.2	21.7

[1]The moisture content was determined on dry basis from composite of 3 one-foot cores in each case. The alfalfa and wheat fields sampled are those for which yields are reported in Table 18, while the brome grass field was adjacent.

Comparable yields (total air-dry matter) of alfalfa, corn, oats, and winter wheat for the period 1923 to 1925 are reported in Table 18 and Chart 5. In total production alfalfa has yielded 239, 515, and 334 per cent as much respectively, as corn, oats, and wheat.

The water requirements per unit of dry matter for alfalfa, corn, oats, and wheat as determined in 1916 from potometers situated in the field are presented in Table 19 and Chart 5. The water consumption per unit of dry matter for alfalfa was 3.2, 2.1, and 2.7 times that of corn, oats, and wheat.

Due to the high water requirement of alfalfa, its high yield, and the nature of its root system, the depletion of the subsoil moisture to a much lower depth than that of brome grass or

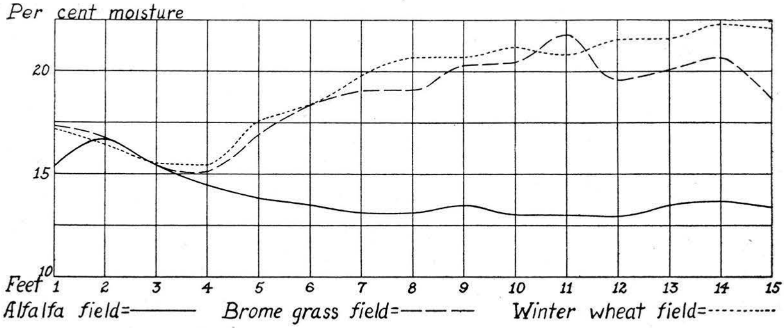

CHART 4.—Comparative moisture content of successive one-foot soil sections to a depth of 15 feet in alfalfa, brome grass, and winter wheat fields, June 24, 1926. (Table 17.)

wheat is readily understood. Because of this reduction in available soil moisture there was a marked decrease in the yield of alfalfa in 1925 as compared with that of the previous year and in 1926 the yield was only 30 per cent[1] of the 3-year average, 1923-1925. It is thus evident that the period of maximum yield in this field is past and the yields must now depend primarily on the seasonal rainfall. It is likely that the yield of alfalfa in the future will drop down to or below that of the cereals, due to its higher water requirement.

TABLE 18.—*Comparative yields of alfalfa, corn, oats, and winter wheat. 1923-1925*

Crop	Yield per acre[1]							
	1923		1924		1925		Average	
	Total	Grain	Total	Grain	Total	Grain	Total	Grain
	Pounds	*Bushels*	*Pounds*	*Bushels*	*Pounds*	*Bushels*	*Pounds*	*Bushels*
Alfalfa (Common)	9520	....	14360	......	9800	....	11227	....
Corn (Hogue)	5370	43.6	3600	25.1	5100	21.5	4690	30.1
Oats (Kherson)	3380	50.4	1890	33.7	1270	19.3	2180	34.5
Wheat (Turkey)	2810	18.6	5860	45.1	1410	10.0	3360	24.6

[1]The alfalfa yields are those of the check alfalfa as reported in Table 3 and are for hay containing 15 per cent moisture. The yields of corn, oats, and wheat were secured from adjacent fields and are based on air-dry material.

[1] This relative yield for 1926 has been supplied since the acceptance of this manuscript for publication.

TABLE 19.—*Comparative water requirement of alfalfa,*[1] *corn, oats, and winter wheat when grown in potometers under normal exposure in fields of their own respective crops, 1916*

Crop and variety	Total number of pots[2]	Dry matter per pot	Transpiration per Pot	Transpiration per Gram dry matter
		Grams	*Kgms.*	*Grams*
Alfalfa (Common)	6	201	172.4	858
Corn (Hogue)	8	513	137.0	267
Oats (Kherson)	6	188	77.9	414
Wheat (Turkey)	6	251	71.0	323

[1]Second year alfalfa.
[2]Pots 16 inches in diameter by 36 inches deep. A discussion of methods employed may be found in Research Bulletin No. 6, Nebraska Agricultural Experiment Station.

Since it is generally recognized that the common cereal crops in semi-arid or subhumid regions ordinarily use all of the available water in the upper 4 or 5 feet, it would seem that the disastrous results frequently experienced in crops following alfalfa cannot be due directly to alfalfa having left the ground in a much drier condition, as is generally thought. In common practice, however, alfalfa is usually plowed up in late fall or early spring and the time for storing moisture for the following crop is somewhat shorter than between cereal crops. It would seem that the crop failures following alfalfa are in the main due to overstimulation. Frequently as in the case of corn there is insufficient moisture to carry the crop with its increased vegetative growth thru to normal maturity. Under similar conditions the small grain crops may lodge and the grain fill imperfectly due to the increased vegetative growth.

From local experience and from a review of the literature, more especially the work of Swanson (1917) in Kansas under conditions comparable with those in Nebraska, it may be concluded that this overstimulation following alfalfa is due to a marked increase in the amount of available nitrogen. The growing of alfalfa as is ordinarily practiced does not materially increase the total nitrogen content of the soil but does tend to maintain the nitrogen content rather than deplete it as do non-legumes.

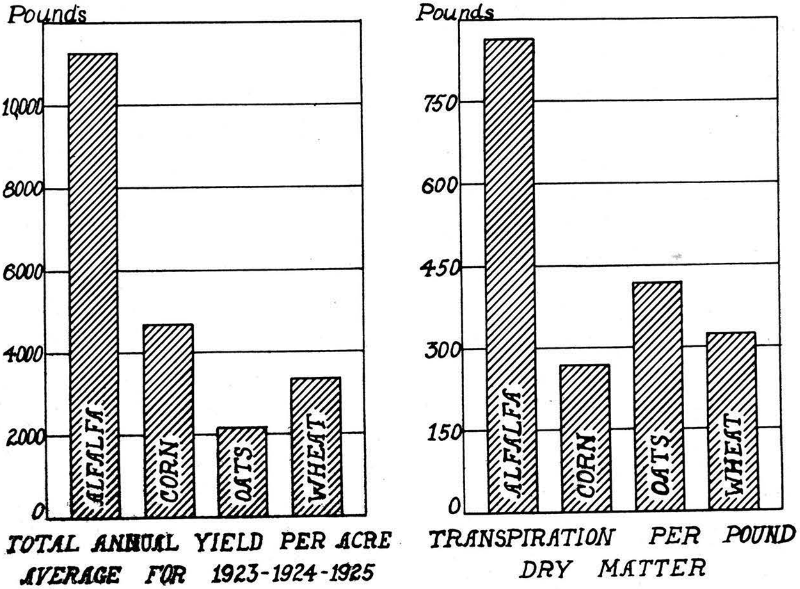

CHART 5.—Comparative acre yields (3-year average, 1923-1925) and water requirement (1916) of alfalfa, corn, oats, and winter wheat. (Tables 18 and 19.)

Whenever corn or small grain follows alfalfa, a relatively small early maturing variety should be selected and planting should be at somewhat less than the normal rate. The increased vegetative growth due to overstimulation can be overcome in part by such procedure. The use of an intertilled crop seems more desirable since it is better adapted to the storing of soil moisture and is less subject to lodging than small grain. Listing corn on such land also tends to hold the excessive vegetative growth in check.

Alfalfa should not follow alfalfa under the conditions just described, for a period of years. Whenever the available subsoil moisture has been depleted as shown in Table 17, alfalfa will not prove a productive crop, even tho good stands may be secured, until a new reserve of sub-soil moisture has been accumulated. The time required for this will of course depend on the amount and nature of the seasonal rainfall, the nature of the soil, and the system of cropping.

PRINCIPLES AND PRACTICES INVOLVED IN THE CURING OF ALFALFA HAY

The comparative market value of alfalfa hay depends more upon the curing and proper handling of this product than upon any other factor. The trade demands a clean, fine-stemmed, leafy, sweet, and green-colored hay. The last three qualities are closely related to successful curing practices.

By curing of hay is meant those practices involved in handling the forage during the time its moisture content is being reduced to a point where it will not heat, mold, or deteriorate in quality when placed in the stack or mow. Alfalfa is a very succulent plant, usually containing 70 per cent or more of moisture at the time it is harvested. Before such forage can be safely stored in bulk its moisture content must be materially reduced. The producer is interested in lowering the moisture content as rapidly as possible after cutting without undue loss of leaves, color, and other desirable qualities ordinarily associated with good hay.

The rate of drying or curing and the length of time required for hay to become sufficiently dry to stack or mow are controlled by its moisture content at time of cutting and by the character of the forage, the weather conditions prevailing during the curing period, and the method of handling. This latter factor especially can be controlled in an important degree by cultural practices.

The purpose of these investigations has been to compare the effectiveness of various curing practices, and to establish the extent to which transpiration from the leaves may be made to serve in the withdrawal of moisture from the forage during the curing process. The problem has important practical significance because of the extensive production of this crop and its high market and feeding value.

Since the moisture content of alfalfa at time of cutting under various conditions, as well as the moisture content of field-cured and air-dry hay are associated with the reduction of moisture in curing, a study of these factors is of interest in connection with these curing investigations.

VARIATION IN THE MOISTURE CONTENT OF ALFALFA AT TIME OF CUTTING

In order to determine the variation in the moisture content of growing alfalfa thruout the day, composite samples were cut at hourly intervals from 8 A. M. to 5 P. M. during the 3 days, August 5, 6, and 8, 1921. The moisture contents as calculated from the green and moisture-free weights of samples taken at specified intervals are recorded in Table 20. The composite samples of green material, ranging in weight from 300 to 500 grams, were cut from a vigorous growing third cutting which was coming well into bloom. The weather during this period was dry, mostly clear, and somewhat windy. Average maximum and minimum temperatures were 82° and 58° F, respectively. As a 3-day average there was a decrease of 2.7 per cent in moisture content from 8 A. M. to 5 P. M.

TABLE 20.—*Hourly variation in the moisture content of growing alfalfa. August, 1921*

Time of sampling	Moisture content of alfalfa			
	Aug. 5	Aug. 6	Aug. 8	Average
	Per cent	*Per cent*	*Per cent*	*Per cent*
8 A. M.	74.0	71.7	72.4	72.7
9 A. M.	73.6	72.7	71.9	72.7
10 A. M.	72.1	72.0	70.5	71.5
11 A. M.	72.3	70.6	70.2	71.0
12 M.	72.2	70.9	68.5	70.5
1 P. M.	73.6	70.7	67.9	70.7
2 P. M.	71.8	70.9	69.5	70.7
3 P. M.	70.1	70.1	69.9	70.0
4 P. M.	70.7	69.8	68.0	69.5
5 P. M.	71.0	70.0	69.1	70.0
Average	72.1	70.9	69.8	70.9

The results of this test further show a decrease in moisture content from day to day as the alfalfa increases in maturity. This decrease amounted to 2.3 per cent over the 4-day period.

The 4-year average moisture content at the time of cutting was 76.5, 74.3, 72.8, 71.8, 70.5, 60.0, and 72.8 per cent, respectively, for alfalfa harvested in the pre-bloom, initial bloom, one-tenth bloom, one-half bloom, full bloom, seed, and new growth stages which have been reported in Table 7.

Tho these data show a measurable decrease in the moisture content of growing alfalfa during the course of the day and from day to day as maturity increases, the changes are probably not of sufficient importance to be considered a very material factor in curing practices.

MOISTURE CONTENT OF FIELD-CURED AND AIR-DRY ALFALFA

The moisture content of thoroly air-dry hay depends primarily on the nature of the crop and the weather conditions. As an average of a large number of air-dry samples of alfalfa hay the moisture content was found to be 11.4 per cent. Under ordinary storage conditions hay will contain a somewhat higher moisture content than this, whereas under extremely favorable drying conditions in the field, such as result from a relatively high temperature, high wind velocity, and low humidity, it may contain less. Moisture contents as low as 5.0 per cent were obtained in field tests under prolonged curing (Table 22).

The moisture content of field-cured hay or of hay at the stage it is considered sufficiently dry for storage is less constant. There are but few data available showing the maximum amount of moisture that alfalfa may contain when placed in storage without subsequent injury. In method-of-curing studies herein reported notation was made of the time that the hay in each plat was considered sufficiently dry for stacking. As an average of 54 observations in 1922 the moisture content of the hay at this stage was found to be 23.4 per cent. In several cases the hay in this condition contained as high as 33 per cent moisture. In 1924, as an average of 48 observations, the moisture content was 23.3 per cent at the time it was considered dry enough to stack. Extremes were 30.8 and 19.1 per cent moisture content. It is believed that when the moisture content of alfalfa has been reduced to 25 per cent, it is ordinarily dry enough to stack or mow.

FIELD CURING TESTS

Experimental Procedure.—In view of the conflicting opinions and lack of experimental evidence bearing on curing practices, investigations have been made to determine the relative rates of curing, and the functioning of transpiration in reducing the moisture content of hay when cured in the swath, windrow, or cock, and when partially swath cured preceding the windrowing and cocking. The rate of curing was determined by the moisture content of samples of hay taken at stated intervals from the time it was cut until it was either field-cured or air-dry.

In all tests except that beginning June 7, 1922, two parallel methods of sampling were employed and served as a check upon each other. In one case composite samples were taken at specified intervals from forage curing under each condition. These samples approximated 225 grams of moisture-free hay. In the second method representative samples were selected at the outset of the curing test and were retained thruout in small gauze bags made from thin, white, loosely-woven material known as tarlatan. These samples were retained continuously in exposures typical of the particular curing practice which they represented. At each successive interval they were removed for weighing and were immediately returned to their normal exposure. These samples averaged approximately 75 grams of moisture-free material.

These continuous samples were of two kinds. In one case they consisted of normal hay with the leaves intact while in the other case the leaves were stripped from a comparable sample of forage. In this latter instance the detached leaves and stems were mixed and included in the same sample, so as to resemble normal hay in texture as closely as possible. It was believed that the relative curing rates of similarly exposed samples having leaves either intact or detached respectively would indicate approximately the extent to which transpiration from the leaves aids in drying the stems.

Examination of the data show that the curing rate as measured by these two methods of sampling exhibit the same tendency and in most cases practically the same results. This would suggest that no marked systematic error had been introduced by curing the continuous samples in the thin, gauze containers.

Four tests of 6-days each were conducted during 1922 and 1924 under relatively favorable weather conditions. Two of these tests, starting respectively on June 7, 1922, and July 30, 1924, were somewhat affected by rain, and are not so representative of normal curing conditions as are the two tests beginning on August 22, 1922, and August 18, 1924.

In each test, starting at 10 A. M., 24 plats one-fortieth acre in size were harvested. There was usually sufficient hay on each plat to make two average windrows about two rods in length or two cocks of normal size. In 1922 the first 12 plats were cut in the morning and the second 12 plats beginning at 1 P. M., whereas in 1924 all plats were cut in the morning. In the 1924 tests the acre yield of dry matter was determined in both the green and cured condition in order to measure the relation of the curing method to the loss of hay resulting from the shattering of leaves. As soon as the green hay weights were secured at the beginning of the test, the hay was again spread out in the swath and normal procedure followed.

These 24 plats were divided into 4 groups with 6 adjacent plats in each. The first and fourth plats in each group, or eight plats in all, were cured in the swath thruout the period. The second and fifth plats in each group were windrowed and the third and sixth were placed in the cock. The windrowed and cocked plats in the first group were cured in that condition thruout the test; whereas in the other three groups curing in the swath for various lengths of time preceded the windrowing and the cocking in which condition curing was completed. Swath curing before windrowing or cocking ranged in the second group from 3 to 6 hours; in the third group from 6 to 21 hours, and in the fourth group from 24 to 27 hours. The length of time for swath curing in each of these tests was determined by the degree of wilting or curing, which had taken place, i.e., (1) beginning to wilt, (2) well-wilted to one-half cured, and (3) about two-thirds cured to field-cured.

In the 1924 tests the first plat in each treatment was weighed out as soon as the hay was considered sufficiently dry for stacking. The second or duplicate plat was continued in the test until the hay was approximately air-dry or until the end of the curing period. Plats in the first group, however, were continued until the end of the 6-day period, since hay curing in the cock thruout seldom reached a field-cured, condition before this time.

Samples were selected and first weights taken by 10 A. M. of the first day of the test for each one of the plats in the first group. Similar samples were selected from the plats in the other three groups after they had cured the designated length of time in the swath. Thereafter moisture determinations were made daily at 7 and 10 A. M. and 1 and 4 P. M. Since all weighings could not be made at the same instant, the same sequence of sampling was followed thruout so as to provide intervals of comparable length. In order to facilitate weighing without undue delay, balances were set up in a protected shelter located near the center of the plats. The results reported in Tables 21 to 24 for the four tests are averages of the duplicate treatments. The two 1924 tests which are strictly comparable in procedure are summarized in Table 25.

TABLE 21.—*Relative rates of curing alfalfa hay in the swath, windrow, and cock. Alfalfa cut June 7, 1922*

Day and hour of test	Hourly atmometer evaporation	Moisture content of alfalfa as determined by composite samples of normal hay taken at each weighing											
		Hay cut at 10 A. M.						Hay cut at 1 P. M.					
		Windrowed and cocked immediately after cutting			Windrowed and cocked 6 hours after cutting			Windrowed and cocked 18 hours after cutting			Windrowed and cocked 24 hours after cutting		
		Swath	Windrow	Cock	Swath	Windrow	Cock	Swath	Windrow	Cock	Swath	Windrow	Cock
	Cc.	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
1– 10	....	68.0	68.0	68.0	68.0	....	....	....	....	....	....	....	....
1	6.08	60.7	63.5	66.9	60.7	....	....	67.5	....	....	67.5	....	....
4	5.62	57.6	61.4	62.6	57.6	57.6	57.6	58.7	....	....	58.7	....	....
2– 7	1.40	45.7	57.4	60.1	45.7	49.7	55.2	50.4	50.4	50.4	50.4	....	....
10	3.08	33.3	55.4	55.7	33.3	48.9	53.9	37.4	45.0	47.6	37.4	....	....
1	5.33	27.5	49.5	54.6	27.5	48.1	51.1	35.8	41.6	42.8	35.8	35.8	35.8
4	6.08	22.2	51.1	55.7	22.2	41.2	49.3	24.5	40.1	41.9	24.5	31.7	31.4
3– 7	1.62	52.6	58.4	57.8	52.6	52.5	53.1	47.0	50.8	48.1	47.0	50.4	48.7
10	2.17	45.1	52.5	55.8	45.1	44.3	47.0	37.7	43.9	44.4	37.7	43.3	44.3
1	4.67	26.0	52.8	51.1	26.0	42.5	44.9	31.0	41.7	40.5	31.0	39.4	39.3
4	6.08	22.9	48.2	49.7	22.9	42.9	44.5	27.0	41.9	38.8	27.0	36.2	36.5
4– 7	2.88	22.5	43.7	49.7	22.5	40.2	41.3	26.2	32.3	31.2	26.2	28.8	31.1
10	3.75	21.7	44.0	50.6	21.7	39.3	39.0	22.1	32.3	29.2	22.1	28.8	25.5
1	5.17	20.8	38.4	47.2	20.8	35.4	39.6	18.4	29.8	27.9	18.4	27.0	24.4
4	4.83	14.9	38.3	41.0	14.9	38.0	40.6	16.9	28.6	26.5	16.9	28.8	26.0
5– 7	1.22	34.3	32.9	37.5	34.3	30.6	33.3	27.0	38.0	26.2	27.0	23.7	24.3
10	1.67	20.7	29.9	37.7	20.7	27.9	28.7	17.4	24.2	23.9	17.4	22.2	22.1
1	3.58	11.6	29.5	38.3	11.6	27.2	26.8	13.0	26.8	22.7	13.0	22.2	19.7
4	4.25	11.4	29.6	28.5	11.4	26.5	28.5	12.3	24.2	21.6	12.3	22.9	18.9
6– 7	1.77	17.7	31.9	30.7	17.7	27.5	25.7	15.7	20.4	20.6	15.7	19.2	23.1
10	3.33	15.5	22.4	30.2	15.5	24.6	22.8	15.6	20.1	22.0	15.6	18.5	17.6
1	5.00	13.6	23.4	29.8	13.6	21.7	18.7	15.2	17.0	22.7	15.2	17.7	17.7
4	5.33	11.7	19.8	24.7	11.7	21.3	22.5	13.8	17.5	16.8	13.8	16.9	15.6

TABLE 22.—*Relative rates of curing alfalfa hay in the swath, windrow, and cock. Alfalfa cut August 22, 1922*

Day and hour of test	Hours after cutting	Hourly atmometer evaporation	Moisture content of alfalfa as determined by:								
			Composite samples of normal hay taken at each weighing			Continuous composite samples retained at normal exposure to show function of leaves in curing					
						Swath		Windrow		Cock	
			Swath	Windrow	Cock	Leaves detached	Leaves intact	Leaves detached	Leaves intact	Leaves detached	Leaves intact
		Cc.	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
WINDROWED AND COCKED IMMEDIATELY AFTER CUTTING (CUT 10 A. M.)											
1– 10	......	......	68.4	68.4	68.4	68.4	68.4	68.4	68.4	68.4	68.4
1	3	2.17	64.6	66.1	65.9	66.0	65.9	67.3	66.5	67.7	67.3
4	6	3.33	59.9	62.2	65.0	62.2	61.8	63.4	64.1	66.0	66.4
2– 7	21	0.77	57.3	61.0	60.6	59.5	59.1	62.8	63.5	65.0	65.5
10	24	4.12	39.5	53.9	60.1	51.4	51.8	60.7	61.2	61.6	62.9
1	27	3.83	26.8	54.3	61.4	41.1	42.9	55.0	57.2	55.9	59.8
4	30	9.67	14.6	53.9	60.0	31.4	30.2	44.1	45.3	45.6	48.9
3– 7	45	1.33	21.8	39.8	55.9	29.0	28.1	35.3	38.5	37.4	37.4
10	48	2.67	11.3	40.2	50.0	22.4	22.5	30.0	34.4	33.6	32.5
1	51	7.17	5.7	34.4	48.6	13.4	13.6	16.4	21.0	24.0	27.5
4	54	4.58	8.6	29.8	47.8	11.3	11.0	12.6	14.5	18.8	26.0
4– 7	69	1.36	15.8	34.7	41.3	16.4	16.2	16.8	20.1	21.2	20.1
10	72	2.33	10.7	31.8	41.0	13.0	11.8	14.6	13.6	21.0	20.4
1	75	5.00	6.3	28.9	40.8	9.9	8.9	10.0	10.1	20.5	20.0
4	78	4.00	9.3	28.7	38.5	8.5	8.3	8.5	9.0	16.7	15.8
5– 7	93	1.97	15.7	28.5	32.1	13.0	13.1	13.2	13.7	19.0	18.1
10	96	1.33	13.3	18.0	30.7	12.1	12.6	13.1	13.5	17.7	18.1
1	99	2.00	8.3	11.4	26.5	11.4	11.3	12.5	12.7	16.5	16.8
4	102	3.00	11.2	13.0	21.5	9.8	9.8	10.6	9.9	13.5	14.3
6– 4	126	1.55	10.7	16.0	20.0	7.7	7.7	9.7	9.5	8.4	9.6

TABLE 22 (Continued).—*Relative rates of curing alfalfa hay in the swath, windrow, and cock. Alfalfa cut August 22, 1922*

Day and hour of test	Hours after cutting	Hourly atmometer evaporation	Moisture content of alfalfa as determined by:								
			Composite samples of normal hay taken at each weighing			Continuous composite samples retained at normal exposure to show function of leaves in curing					
						Swath		Windrow		Cock	
			Swath	Windrow	Cock	Leaves detached	Leaves intact	Leaves detached	Leaves intact	Leaves detached	Leaves intact
		Cc.	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
WINDROWED AND COCKED 6 HOURS AFTER CUTTING (CUT 10 A. M.)											
1– 10	......	......	68.4	......	......	68.4	68.4	......	......	......	......
1	3	2.17	64.6	......	......	66.0	65.9	......	......	......	......
4	6	3.33	59.9	59.9	59.9	62.2	61.8	59.9	59.9	59.9	59.9
2– 7	21	0.77	57.3	55.9	56.8	59.5	59.1	56.1	53.2	57.3	58.2
10	24	4.12	39.5	48.6	50.0	51.4	51.8	52.0	52.9	51.3	54.3
1	27	3.83	26.8	46.9	48.3	41.1	42.9	50.5	51.0	47.0	48.4
4	30	9.67	14.6	43.1	46.6	31.4	30.2	37.5	40.5	37.3	37.4
3– 7	45	1.33	21.8	39.2	40.5	29.0	28.1	34.0	34.0	33.9	29.7
10	48	2.67	11.3	29.8	31.8	22.4	22.5	29.4	31.2	29.7	25.8
1	51	7.17	5.7	26.1	28.7	13.4	13.6	18.2	21.3	20.7	19.2
4	54	4.58	8.6	22.7	24.6	11.3	11.0	14.6	16.2	15.6	15.1
4– 7	69	1.36	15.8	31.2	37.5	16.4	16.2	15.3	18.7	18.3	17.0
10	72	2.33	10.7	30.2	35.5	13.0	11.8	13.1	16.2	16.1	14.7
1	75	5.00	6.3	23.2	30.0	9.9	8.9	11.0	12.3	12.8	12.5
4	78	4.00	9.3	18.5	25.7	8.5	8.3	9.4	10.4	10.2	11.6
5– 7	93	1.97	15.7	24.6	25.8	13.0	13.1	13.8	13.8	13.9	13.7
10	96	1.33	13.3	23.0	18.6	12.1	12.6	13.4	13.4	13.4	14.3
1	99	2.00	8.3	17.7	17.5	11.4	11.3	12.4	12.0	12.5	13.3
4	102	3.00	11.2	13.0	16.0	9.8	9.8	11.4	11.0	11.0	11.2
6– 4	126	1.55	10.7	13.3	13.7	7.7	7.7	8.5	7.8	7.7	8.3

TABLE 22 (Continued).—*Relative rates of curing alfalfa hay in the swath, windrow, and cock. Alfalfa cut August 22, 1922*

Day and hour of test	Hours after cutting	Hourly atmometer evaporation	Moisture content of alfalfa as determined by: Composite samples of normal hay taken at each weighing			Continuous composite samples retained at normal exposure to show function of leaves in curing: Swath		Windrow		Cock	
			Swath	Windrow	Cock	Leaves detached	Leaves intact	Leaves detached	Leaves intact	Leaves detached	Leaves intact
		Cc.	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
WINDROWED AND COCKED 21 HOURS AFTER CUTTING (CUT 1 P. M.)											
1– 1	......	......	68.0	......	......	68.0	68.0	......	......	......	......
4	3	3.33	64.2	......	......	65.4	65.3	......	......	......	......
2– 7	18	0.77	59.5	......	......	63.7	63.4	......	......	......	......
10	21	4.12	56.6	56.6	56.6	59.3	58.9	56.6	56.6	56.6	56.6
1	24	3.83	41.3	54.5	54.3	45.0	42.7	47.7	46.7	49.4	50.3
4	27	9.67	31.3	49.3	49.1	38.1	40.3	36.4	36.6	38.4	38.6
3– 7	42	1.33	21.6	39.0	38.8	29.6	31.9	31.1	32.4	28.8	29.7
10	45	2.67	14.2	34.8	36.1	23.7	23.2	26.5	27.5	25.8	26.3
1	48	7.17	6.3	28.6	34.6	15.4	15.0	17.3	18.2	19.6	18.1
4	51	4.58	8.0	20.3	28.1	13.3	11.7	13.6	15.9	15.6	14.5
4– 7	66	1.36	11.1	19.2	34.1	16.7	15.9	15.1	17.8	19.1	17.8
10	69	2.33	9.3	20.6	32.0	13.8	12.4	12.3	15.1	18.1	14.6
1	72	5.00	6.0	20.2	29.2	11.6	9.9	8.9	11.8	16.6	13.1
4	75	4.00	5.5	19.8	24.7	10.4	8.0	8.8	9.9	14.7	11.5
5– 7	90	1.97	14.0	21.0	25.0	14.4	13.6	12.7	13.9	14.7	14.1
10	93	1.33	13.0	20.2	20.5	14.0	13.2	12.2	13.7	14.1	13.9
1	96	2.00	7.5	13.0	18.0	12.0	10.8	9.4	10.9	12.6	13.5
4	99	3.00	11.8	12.0	16.7	11.6	10.4	8.2	10.1	11.3	12.2
6– 4	123	1.55	13.9	14.3	15.0	8.8	8.5	6.9	8.9	7.7	8.3

TABLE 22 (Concluded).—*Relative rates of curing alfalfa hay in the swath, windrow, and cock. Alfalfa cut August 22, 1922*

Day and hour of test	Hours after cutting	Hourly atmometer evaporation	Moisture content of alfalfa as determined by:								
			Composite samples of normal hay taken at each weighing			Continuous composite samples retained at normal exposure to show function of leaves in curing					
						Swath		Windrow		Cock	
			Swath	Windrow	Cock	Leaves detached	Leaves intact	Leaves detached	Leaves intact	Leaves detached	Leaves intact
		Cc.	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
WINDROWED AND COCKED 27 HOURS AFTER CUTTING (CUT 1 P. M.)											
1– 1	......	......	68.0	......	......	68.0	68.0	......	......	......	......
4	3	3.33	64.2	......	......	65.4	65.3	......	......	......	......
2– 7	18	0.77	59.5	......	......	63.7	63.4	......	......	......	......
10	21	4.12	56.6	......	......	59.3	58.9	......	......	......	......
1	24	3.83	41.3	......	......	45.0	42.7	......	......	......	......
4	27	9.67	31.3	31.3	31.3	38.1	40.3	31.3	31.3	31.3	31.3
3– 7	42	1.33	21.6	24.5	23.5	29.6	31.9	23.7	24.7	21.0	22.5
10	45	2.67	14.2	19.0	21.3	23.7	23.2	22.7	21.3	18.9	17.6
1	48	7.17	6.3	11.0	14.0	15.4	15.0	16.7	15.3	12.5	12.5
4	51	4.58	8.0	11.3	13.5	13.3	11.7	15.2	13.2	11.9	10.9
4– 7	66	1.36	11.1	11.0	17.6	16.7	15.9	15.9	14.1	14.4	13.7
10	69	2.33	9.3	9.6	15.6	13.8	12.4	14.1	11.2	12.7	11.5
1	72	5.00	6.0	8.0	13.3	11.6	9.9	11.7	9.9	11.1	9.3
4	75	4.00	5.5	5.0	5.6	10.4	8.0	10.9	9.7	10.1	9.2
5– 7	90	1.97	14.0	16.7	16.3	14.4	13.6	13.8	12.7	13.0	12.2
10	93	1.33	13.0	11.0	15.0	14.0	13.2	13.3	12.5	12.8	12.1
1	96	2.00	7.5	10.5	10.7	12.0	10.8	12.1	10.8	11.6	10.6
4	99	3.00	11.8	10.0	10.1	11.6	10.4	11.8	10.6	11.1	9.8
6– 4	123	1.55	13.9	12.6	14.3	8.8	8.5	9.2	8.0	8.7	8.1

TABLE 23.—*Relative rates of curing alfalfa hay in the swath, windrow, and cock. Alfalfa cut July 30, 1924*

Day and hour of test	Hours after cutting	Hourly atmometer evaporation	Moisture content of alfalfa as determined by:								
			Composite samples of normal hay taken at each weighing			Continuous composite samples retained at normal exposure to show function of leaves in curing					
						Swath		Windrow		Cock	
			Swath	Windrow	Cock	Leaves detached	Leaves intact	Leaves detached	Leaves intact	Leaves detached	Leaves intact
		Cc.	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
WINDROWED AND COCKED IMMEDIATELY AFTER CUTTING (CUT 10 A. M.)											
1– 10	......	......	69.6	69.6	69.6	69.6	69.6	69.6	69.6	69.6	69.6
1	3	5.17	53.7	65.9	67.0	60.6	59.0	63.4	62.8	65.4	66.1
4	6	4.00	43.7	57.6	61.3	49.4	47.5	54.7	55.8	62.4	62.8
2– 7	21	0.63	41.6	55.6	61.2	43.6	42.4	49.7	50.8	58.8	60.7
10	24	0.67	37.9	51.4	60.0	41.5	40.0	48.8	49.6	58.0	60.4
1	27	2.08	35.5	47.6	55.0	36.0	35.3	46.7	47.4	56.7	59.8
4	30	2.67	25.6	47.8	51.7	29.3	29.5	44.1	41.3	55.7	58.6
3– 7	45	0.62	40.0	53.1	60.5	33.7	33.3	44.6	42.4	54.0	57.5
10	48	0.17	36.6	46.5	60.3	32.3	32.5	44.1	42.4	53.9	57.3
1	51	1.58	28.6	42.9	48.6	28.3	29.2	44.0	42.0	53.0	55.8
4	54	0.92	29.7	42.7	48.9	28.5	28.9	40.3	40.3	52.0	55.4
4– 7	69	0.28	59.8	57.4	63.5	54.3	51.6	52.3	50.5	55.4	59.0
10	72	2.00	46.9	58.9	61.3	40.4	40.0	48.2	43.3	53.8	55.7
1	75	4.58	27.7	47.6	48.7	22.3	23.0	31.3	34.6	52.8	48.0
4	78	4.50	18.6	29.6	46.2	15.1	16.2	21.2	26.3	44.4	40.6
5– 7	93	2.40	15.6	23.0	41.1	15.0	14.5	15.4	18.4	32.4	31.7
10	96	3.08	14.3	18.7	40.7	12.6	11.6	14.6	19.2	28.4	28.2
1	99	5.42	10.1	17.0	40.8	9.1	8.6	11.5	14.2	22.4	25.7
4	102	3.83	7.9	7.8	35.3	8.0	7.8	9.1	11.8	19.2	22.1
6– 7	117	1.93	......	......	34.2	......	......	......	......	19.0	20.2
10	120	1.08	......	......	34.2	......	......	......	......	24.2	24.9
1	123	1.92	......	......	32.2	......	......	......	......	16.6	16.8
4	126	1.58	12.7	18.3	21.4	12.0	11.3	14.4	13.4	15.7	17.0

TABLE 23 (Continued).—*Relative rates of curing alfalfa hay in the swath, windrow, and cock. Alfalfa cut July 30, 1924*

Day and hour of test	Hours after cutting	Hourly atmometer evaporation	Moisture content of alfalfa as determined by:								
			Composite samples of normal hay taken at each weighing			Continuous composite samples retained at normal exposure to show function of leaves in curing					
						Swath		Windrow		Cock	
			Swath	Windrow	Cock	Leaves detached	Leaves intact	Leaves detached	Leaves intact	Leaves detached	Leaves intact
		Cc.	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
WINDROWED AND COCKED 3 HOURS AFTER CUTTING (CUT 10 A. M.)											
1– 10	......	......	69.6	......	......	69.6	69.6	......	......	......	......
1	3	5.17	53.7	53.7	53.7	60.6	59.0	53.7	53.7	53.7	53.7
4	6	4.00	43.7	42.7	43.9	49.4	47.5	42.9	42.9	44.0	42.2
2– 7	21	0.63	41.6	37.9	40.1	43.6	42.4	36.4	36.3	39.8	40.8
10	24	0.67	37.9	35.7	36.6	41.5	40.0	35.6	35.1	39.1	39.9
1	27	2.08	35.5	32.6	35.9	36.0	35.3	33.8	32.5	38.1	37.4
4	30	2.67	25.6	29.3	32.0	29.3	29.5	31.3	29.2	34.9	33.8
3– 7	45	0.62	40.0	27.2	39.8	33.7	33.3	31.1	29.9	35.1	33.1
10	48	0.17	36.6	32.9	36.3	32.3	32.5	31.0	30.0	35.0	33.1
1	51	1.58	28.6	28.6	34.0	28.3	29.2	30.9	29.6	34.3	32.1
4	54	0.92	29.7	28.2	30.8	28.5	28.9	30.1	28.4	34.3	31.4
4– 7	69	0.28	59.8	59.2	55.3	54.3	51.6	49.9	48.2	41.0	41.1
10	72	2.00	46.9	47.5	42.7	40.4	40.0	37.7	38.1	36.7	39.6
1	75	4.58	27.7	27.8	33.4	22.3	23.0	23.5	23.8	27.0	29.1
4	78	4.50	18.6	19.1	23.1	15.1	16.2	17.5	18.6	19.1	23.3
5– 7	93	2.40	15.6	15.0	25.3	15.0	14.5	19.3	16.8	19.7	17.4
10	96	3.08	14.3	14.7	16.7	12.6	11.6	16.4	15.2	15.9	14.2
1	99	5.42	10.1	9.8	16.4	9.1	8.6	12.9	11.4	12.5	10.6
4	102	3.83	7.9	7.4	11.9	8.0	7.8	9.9	10.1	10.4	9.2
6– 4	126	1.78	12.7	14.2	14.3	12.0	11.3	13.6	13.9	14.2	15.0

TABLE 23 (Continued).—*Relative rates of curing alfalfa hay in the swath, windrow, and cock. Alfalfa cut July 30, 1924*

Day and hour of test		Hours after cutting	Hourly atmometer evaporation	Moisture content of alfalfa as determined by: Composite samples of normal hay taken at each weighing			Continuous composite samples retained at normal exposure to show function of leaves in curing: Swath		Windrow		Cock	
				Swath	Windrow	Cock	Leaves detached	Leaves intact	Leaves detached	Leaves intact	Leaves detached	Leaves intact
			Cc.	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
WINDROWED AND COCKED 6 HOURS AFTER CUTTING (CUT 10 A. M.)												
1–	10	......	......	69.6	......	......	69.6	69.6	......	......	......	......
	1	3	5.17	53.7	......	......	60.6	59.0	......	......	......	......
	4	6	4.00	43.7	43.7	43.7	49.4	47.5	43.7	43.7	43.7	43.7
2–	7	21	0.63	41.6	38.0	39.4	43.6	42.4	40.1	41.4	40.4	39.9
	10	24	0.67	37.9	35.3	35.8	41.5	40.0	39.2	39.5	39.1	39.2
	1	27	2.08	35.5	31.4	34.3	36.0	35.3	36.8	37.5	37.0	38.0
	4	30	2.67	25.6	25.6	32.0	29.3	29.5	33.3	34.0	34.7	36.7
3–	7	45	0.62	40.0	35.6	38.6	33.7	33.3	33.6	33.6	34.3	35.3
	10	48	0.17	36.6	32.8	35.0	32.3	32.5	34.0	33.4	34.2	35.2
	1	51	1.58	28.6	29.3	34.3	28.3	29.2	32.1	32.1	32.7	33.7
	4	54	0.92	29.7	30.1	32.0	28.5	28.9	33.0	31.8	32.0	33.4
4–	7	69	0.28	59.8	57.6	58.3	54.3	51.6	50.3	51.0	40.6	41.6
	10	72	2.00	46.9	47.9	46.2	40.4	40.0	41.6	42.5	36.8	39.4
	1	75	4.58	27.7	29.3	32.2	22.3	23.0	25.3	28.4	27.5	24.5
	4	78	4.50	18.6	18.8	26.7	15.1	16.2	19.2	19.3	26.4	22.6
5–	7	93	2.40	15.6	15.2	19.5	15.0	14.5	17.6	15.4	16.7	17.4
	10	96	3.08	14.3	13.6	17.0	12.6	11.6	13.5	13.3	16.3	12.7
	1	99	5.42	10.1	10.0	13.5	9.1	8.6	10.5	8.1	8.8	9.9
	4	102	3.83	7.9	8.5	8.3	8.0	7.8	8.3	7.6	8.5	9.4
6–	4	126	1.78	12.7	14.6	16.7	12.0	11.3	13.5	12.6	13.4	13.4

TABLE 23 (Concluded).—*Relative rates of curing alfalfa hay in the swath, windrow, and cock. Alfalfa cut July 30, 1924*

Day and hour of test		Hours after cutting	Hourly atmometer evaporation	Moisture content of alfalfa as determined by: Composite samples of normal hay taken at each weighing — Swath	Composite samples — Windrow	Composite samples — Cock	Continuous composite samples retained at normal exposure to show function of leaves in curing: Swath — Leaves detached	Swath — Leaves intact	Windrow — Leaves detached	Windrow — Leaves intact	Cock — Leaves detached	Cock — Leaves intact
			Cc.	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
WINDROWED AND COCKED 27 HOURS AFTER CUTTING (CUT 10 A. M.)												
1–	10	......	......	69.6	......	......	69.6	69.6	......	......	......	......
	1	3	5.17	53.7	......	......	60.6	59.0	......	......	......	......
	4	6	4.00	43.7	......	......	49.4	47.5	......	......	......	......
2–	7	21	0.63	41.6	......	......	43.6	42.4	......	......	......	......
	10	24	0.67	37.9	......	......	41.5	40.0	......	......	......	......
	1	27	2.08	35.5	35.5	35.5	36.0	35.3	35.5	35.5	35.5	35.5
	4	30	2.67	25.6	30.0	31.3	29.3	29.5	30.9	32.5	30.4	33.4
3–	7	45	0.62	40.0	37.6	37.7	33.7	33.3	31.2	33.6	30.0	33.0
	10	48	0.17	36.6	34.9	33.2	32.3	32.5	31.3	33.9	31.9	33.6
	1	51	1.58	28.6	32.2	33.6	28.3	29.2	30.3	32.2	30.1	32.6
	4	54	0.92	29.7	32.4	32.4	28.5	28.9	30.4	31.4	30.0	32.2
4–	7	69	0.28	59.8	56.8	60.4	54.3	51.6	45.1	48.7	43.6	42.8
	10	72	2.00	46.9	47.7	41.3	40.4	40.0	33.3	39.3	35.2	39.2
	1	75	4.58	27.7	26.8	35.4	22.3	23.0	20.1	24.4	27.0	26.7
	4	78	4.50	18.6	20.7	24.4	15.1	16.2	15.6	18.3	20.6	24.4
5–	7	93	2.40	15.6	14.8	21.5	15.0	14.5	14.2	16.7	16.3	17.8
	10	96	3.08	14.3	13.8	21.0	12.6	11.6	12.3	13.7	14.3	16.7
	1	99	5.42	10.1	9.9	18.9	9.1	8.6	8.2	9.8	11.7	12.0
	4	102	3.83	7.9	9.1	10.7	8.0	7.8	9.6	9.1	10.4	9.7
6–	4	126	1.78	12.7	16.0	15.8	12.0	11.3	13.8	13.9	13.5	13.2

TABLE 24.—*Relative rates of curing alfalfa hay in the swath, windrow, and cock. Alfalfa cut August 18, 1924*

Day and hour of test	Hours after cutting	Hourly atmometer evaporation	Moisture content of alfalfa as determined by: Composite samples of normal hay taken at each weighing — Swath	Composite samples — Windrow	Composite samples — Cock	Continuous composite samples retained at normal exposure to show function of leaves in curing — Swath, Leaves detached	Swath, Leaves intact	Windrow, Leaves detached	Windrow, Leaves intact	Cock, Leaves detached	Cock, Leaves intact
		Cc.	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
WINDROWED AND COCKED IMMEDIATELY AFTER CUTTING (CUT 10 A. M.)											
1– 10	......	......	66.7	66.7	66.7	66.7	66.7	66.7	66.7	66.7	66.7
1	3	9.00	52.3	55.8	59.4	57.3	58.0	64.1	63.4	66.1	62.9
4	6	5.75	41.9	53.6	57.7	47.8	47.6	63.5	61.6	63.1	61.3
2– 7	21	1.85	32.6	45.1	52.7	37.7	37.1	57.8	55.8	60.3	58.6
10	24	4.67	27.4	39.6	48.2	30.8	30.5	55.0	53.3	59.5	57.8
1	27	5.67	18.8	32.5	44.9	23.7	22.6	51.6	51.3	58.5	56.8
4	30	4.33	16.2	30.4	43.2	24.7	24.3	48.1	47.2	55.4	54.8
3– 7	45	0.78	39.7	37.1	45.0	36.0	33.9	45.8	45.1	53.4	52.5
10	48	1.33	22.3	31.4	43.3	28.1	26.7	44.6	44.1	52.7	51.7
1	51	4.67	11.1	26.9	38.0	17.9	16.7	40.6	38.9	51.5	47.6
4	54	9.33	10.2	21.5	37.3	16.0	14.3	32.3	29.8	50.3	46.8
4– 7	69	3.60	14.9	18.2	39.6	18.9	17.2	30.4	26.9	46.0	44.3
10	72	3.33	12.9	17.4	33.1	15.9	15.1	28.4	25.0	40.0	43.3
1	75	5.83	9.9	13.0	32.4	12.5	12.6	23.2	20.8	34.9	39.9
4	78	5.83	9.1	13.4	30.4	10.7	10.2	20.1	18.1	34.4	37.6
5– 7	93	1.52	23.6	20.4	28.6	21.5	18.9	26.5	25.2	32.2	33.0
10	96	2.08	14.7	15.5	26.2	15.1	14.4	22.8	22.1	30.9	31.7
1	99	4.33	10.2	11.7	25.3	12.1	11.5	19.4	18.1	25.4	26.9
4	102	4.42	8.8	12.0	24.7	10.4	9.9	17.3	16.6	21.9	24.8
6– 7	117	1.03	24.3	19.7	28.9	23.8	20.7	23.8	23.0	25.0	25.1
10	120	3.50	20.8	16.7	27.0	16.6	15.1	18.3	17.9	24.2	24.1
1	123	4.50	10.7	11.0	25.3	10.2	8.7	13.7	12.5	23.0	23.1
4	126	2.18	11.0	12.3	23.4	10.2	8.7	12.7	12.5	19.8	21.8

TABLE 24 (Continued).—*Relative rates of curing alfalfa hay in the swath, windrow, and cock. Alfalfa cut August 18, 1924*

Day and hour of test	Hours after cutting	Hourly atmometer evaporation	Moisture content of alfalfa as determined by:								
			Composite samples of normal hay taken at each weighing			Continuous composite samples retained at normal exposure to show function of leaves in curing					
						Swath		Windrow		Cock	
			Swath	Windrow	Cock	Leaves detached	Leaves intact	Leaves detached	Leaves intact	Leaves detached	Leaves intact
		Cc.	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
WINDROWED AND COCKED 3 HOURS AFTER CUTTING (CUT 10 A. M.)											
1– 10	......	......	66.7	......	......	66.7	66.7	......	......	......	......
1	3	9.00	52.3	52.3	52.3	57.3	58.0	52.3	52.3	52.3	52.3
4	6	5.75	41.9	43.8	48.1	47.8	47.6	47.9	47.1	47.8	49.0
2– 7	21	1.85	32.6	35.2	38.0	37.7	37.1	38.9	38.7	42.8	42.4
10	24	4.67	27.4	31.4	37.3	30.8	30.5	36.2	35.9	41.4	40.4
1	27	5.67	18.8	25.5	35.5	23.7	22.6	31.0	31.8	38.6	37.5
4	30	4.33	16.2	22.6	28.6	24.7	24.3	27.7	28.9	37.5	36.0
3– 7	45	0.78	39.7	31.1	35.7	36.0	33.9	32.2	31.2	36.3	35.5
10	48	1.33	22.3	26.0	29.6	28.1	26.7	30.1	30.3	36.0	34.4
1	51	4.67	11.1	20.0	23.2	17.9	16.7	22.7	23.9	34.8	33.8
4	54	9.33	10.2	12.3	22.3	16.0	14.3	19.5	21.1	28.8	28.5
4– 7	69	3.60	14.9	16.7	22.3	18.9	17.2	17.1	16.8	24.9	23.2
10	72	3.33	12.9	14.5	23.0	15.9	15.1	15.7	15.1	18.9	22.0
1	75	5.83	9.9	11.9	19.8	12.5	12.6	11.9	11.8	16.9	17.0
4	78	5.83	9.1	9.0	14.6	10.7	10.2	9.7	9.4	11.9	10.7

TABLE 24 (Concluded).—*Relative rates of curing alfalfa hay in the swath, windrow, and cock. Alfalfa cut August 18, 1924*

Day and hour of test	Hours after cutting	Hourly atmometer evaporation	Moisture content of alfalfa as determined by: Composite samples of normal hay taken at each weighing			Continuous composite samples retained at normal exposure to show function of leaves in curing					
						Swath		Windrow		Cock	
			Swath	Windrow	Cock	Leaves detached	Leaves intact	Leaves detached	Leaves intact	Leaves detached	Leaves intact
		Cc.	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
WINDROWED AND COCKED 6 HOURS AFTER CUTTING (CUT 10 A. M.)											
1– 10	......	......	66.7	......	......	66.7	66.7	......	......	......	......
1	3	9.00	52.3	......	......	57.3	58.0	......	......	......	......
4	6	5.75	41.9	41.9	41.9	47.8	47.6	41.9	41.9	41.9	41.9
2– 7	21	1.85	32.6	31.7	31.3	37.7	37.1	33.7	33.4	32.6	33.7
10	24	4.67	27.4	28.2	31.2	30.8	30.5	30.1	29.2	31.1	31.3
1	27	5.67	18.8	22.5	26.8	23.7	22.6	25.0	24.1	29.7	29.1
4	30	4.33	16.2	20.8	25.3	24.7	24.3	23.3	22.7	27.9	26.9
3– 7	45	0.78	39.7	32.2	31.1	36.0	33.9	29.6	28.1	28.3	28.9
10	48	1.33	22.3	23.1	26.9	28.1	26.7	26.6	26.8	26.9	27.6
1	51	4.67	11.1	17.5	21.2	17.9	16.7	19.0	17.6	22.3	24.2
4	54	9.33	10.2	12.6	22.8	16.0	14.3	13.4	12.9	20.7	20.7
4– 7	69	3.60	14.9	15.3	19.2	18.9	17.2	17.1	14.8	17.8	17.4
10	72	3.33	12.9	12.8	16.1	15.9	15.1	13.2	12.3	16.0	17.5
1	75	5.83	9.9	11.2	14.9	12.5	12.6	8.6	10.1	14.6	11.3
4	78	5.83	9.1	8.5	9.3	10.7	10.2	8.4	8.1	9.6	11.0
WINDROWED AND COCKED 24 HOURS AFTER CUTTING (CUT 10 A. M.)											
1– 10	......	......	66.7	......	......	66.7	66.7	......	......	......	......
1	3	9.00	52.3	......	......	57.3	58.0	......	......	......	......
4	6	5.75	41.9	......	......	47.8	47.6	......	......	......	......
2– 7	21	1.85	32.6	......	......	37.7	37.1	......	......	......	......
10	24	4.67	27.4	27.4	27.4	30.8	30.5	27.4	27.4	27.4	27.4
1	27	5.67	18.8	20.7	20.8	23.7	22.6	23.6	24.9	22.8	23.6
4	30	4.33	16.2	19.7	21.8	24.7	24.3	22.0	23.7	22.2	22.2
3– 7	45	0.78	39.7	33.9	26.8	36.0	33.9	30.2	30.5	24.4	25.2
10	48	1.33	22.3	23.3	23.1	28.1	26.7	29.1	28.6	22.4	24.5
1	51	4.67	11.1	18.1	18.5	17.9	16.7	21.2	20.3	17.7	20.1
4	54	9.33	10.2	12.2	16.6	16.0	14.3	13.4	15.3	15.3	17.3
4– 7	69	3.60	14.9	15.7	14.9	18.9	17.2	16.3	15.6	12.7	13.9
10	72	3.33	12.9	14.6	13.5	15.9	15.1	13.8	13.5	12.0	13.9
1	75	5.83	9.9	12.8	11.4	12.5	12.6	11.1	12.3	10.9	10.4
4	78	5.83	9.1	10.3	10.7	10.7	10.2	8.6	8.5	7.2	8.9

TABLE 25.—*Summary*[1] *of relative rates of curing alfalfa hay in the swath, windrow, and cock.*

Day and hour of test	Hours after cutting	Hourly atmometer evaporation	Moisture content of alfalfa as determined by:								
			Composite samples of normal hay taken at each weighing			Continuous composite samples retained at normal exposure to show function of leaves in curing					
						Swath		Windrow		Cock	
			Swath	Windrow	Cock	Leaves detached	Leaves intact	Leaves detached	Leaves intact	Leaves detached	Leaves intact
		Cc.	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
WINDROWED AND COCKED IMMEDIATELY AFTER CUTTING (CUT 10 A. M.)											
1– 10	......	......	68.2	68.2	68.2	68.2	68.2	68.2	68.2	68.2	68.2
1	3	7.09	53.0	60.9	63.2	59.0	58.5	63.8	63.1	65.8	64.5
4	6	4.88	42.8	55.6	59.5	48.6	47.6	59.1	58.7	62.8	62.1
2– 7	21	1.24	37.1	50.4	57.0	40.7	39.8	53.8	53.3	59.6	59.7
10	24	2.67	32.7	45.5	54.1	36.2	35.3	51.9	51.5	58.8	59.1
1	27	3.88	27.2	40.1	50.0	29.9	29.0	49.2	49.4	57.6	58.3
4	30	3.50	20.9	39.1	47.5	27.0	26.9	46.1	45.8	55.6	56.7
3– 7	45	0.70	39.9	45.1	52.8	34.9	33.6	45.2	43.8	53.7	55.0
10	48	0.75	29.5	39.0	51.8	30.2	29.6	44.4	43.3	53.3	54.5
1	51	3.13	19.9	34.9	43.3	23.1	23.0	42.3	40.5	52.3	51.7
4	54	5.13	20.0	32.1	43.1	22.3	21.6	36.3	35.1	51.2	51.1
4– 7	69	1.94	37.4	37.8	51.6	36.6	34.4	41.4	38.7	50.7	51.7
10	72	2.67	29.9	38.2	47.2	28.2	27.6	38.3	34.2	46.9	49.5
1	75	5.21	18.8	30.3	40.6	17.4	17.8	27.3	27.7	43.9	44.0
4	78	5.17	13.9	21.5	38.3	12.9	13.2	20.7	22.2	39.4	39.1
5– 7	93	1.96	19.6	21.7	34.9	18.3	16.7	21.0	21.8	32.3	32.4
10	96	2.58	14.5	17.1	33.5	13.9	13.0	18.7	20.7	29.7	30.0
1	99	4.88	10.2	14.4	33.1	10.6	10.1	15.5	16.2	23.9	26.3
4	102	4.13	8.4	9.9	30.0	9.2	8.9	13.2	14.2	20.6	23.5
6– 4	126	1.88	11.9	15.3	22.4	11.1	10.0	13.6	13.0	17.8	19.4
WINDROWED AND COCKED 3 HOURS AFTER CUTTING (CUT 10 A. M.)											
1– 10	......	......	68.2	......	......	68.2	68.2	......	......	......	......
1	3	7.09	53.0	53.0	53.0	59.0	58.5	53.0	53.0	53.0	53.0
4	6	4.88	42.8	43.3	46.0	48.6	47.6	45.4	45.0	45.9	45.6
2– 7	21	1.24	37.1	36.6	39.1	40.7	39.8	37.7	37.5	41.3	41.6
10	24	2.67	32.7	33.6	37.0	36.2	35.3	35.9	35.5	40.3	40.2
1	27	3.88	27.2	29.1	35.7	29.9	29.0	32.4	32.2	38.4	37.5
4	30	3.50	20.9	26.0	30.3	27.0	26.9	29.5	29.1	36.2	34.9
3– 7	45	0.70	39.9	29.2	37.8	34.9	33.6	31.7	30.6	35.7	34.3
10	48	0.75	29.5	29.5	33.0	30.2	29.6	30.6	30.2	35.5	33.8
1	51	3.13	19.9	24.3	28.6	23.1	23.0	26.8	26.8	34.6	33.0
4	54	5.13	20.0	20.3	26.6	22.3	21.6	24.8	24.8	31.6	30.0
4– 7	69	1.94	37.4	38.0	38.8	36.6	34.4	33.5	32.5	33.0	32.2
10	72	2.67	29.9	31.0	32.9	28.2	27.6	26.7	26.6	27.8	30.8
1	75	5.21	18.8	19.9	26.6	17.4	17.8	17.7	17.8	22.0	23.1
4	78	5.17	13.9	14.1	18.9	12.9	13.2	13.6	14.0	15.5	17.0

TABLE 25 (Concluded).—*Summary*[1] *of relative rates of curing alfalfa hay in the swath, windrow, and cock*

Day and hour of test	Hours after cutting	Hourly atmometer evaporation	Moisture content of alfalfa as determined by:								
			Composite samples of normal hay taken at each weighing			Continuous composite samples retained at normal exposure to show function of leaves in curing					
						Swath		Windrow		Cock	
			Swath	Windrow	Cock	Leaves detached	Leaves intact	Leaves detached	Leaves intact	Leaves detached	Leaves intact
		Cc.	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
WINDROWED AND COCKED 6 HOURS AFTER CUTTING (CUT 10 A. M.)											
1– 10	......	......	68.2	......	......	68.2	68.2	......	......	......	......
1	3	7.09	53.0	......	......	59.0	58.5	......	......	......	......
4	6	4.88	42.8	42.8	42.8	48.6	47.6	42.8	42.8	42.8	42.8
2– 7	21	1.24	37.1	34.9	35.4	40.7	39.8	36.9	37.4	36.5	36.8
10	24	2.67	32.7	31.8	33.5	36.2	35.3	34.7	34.4	35.1	35.3
1	27	3.88	27.2	27.0	30.6	29.9	29.0	30.9	30.8	33.4	33.6
4	30	3.50	20.9	23.2	28.7	27.0	26.9	28.3	28.4	31.3	31.8
3– 7	45	0.70	39.9	33.9	34.9	34.9	33.6	31.6	30.9	31.3	32.1
10	48	0.75	29.5	28.0	31.0	30.2	29.6	30.3	30.1	30.6	31.4
1	51	3.13	19.9	23.4	27.8	23.1	23.0	25.6	24.9	27.5	29.0
4	54	5.13	20.0	21.4	27.4	22.3	21.6	23.2	22.4	26.4	27.1
4– 7	69	1.94	37.4	36.5	38.8	36.6	34.4	33.7	32.9	29.2	29.5
10	72	2.67	29.9	30.4	31.2	28.2	27.6	27.4	27.4	26.4	28.5
1	75	5.21	18.8	20.3	23.6	17.4	17.8	17.0	19.3	21.1	17.9
4	78	5.17	13.9	13.7	18.0	12.9	13.2	13.8	13.7	18.0	16.8
WINDROWED AND COCKED 27 HOURS AFTER CUTTING (CUT 10 A. M.)											
1– 10	......	......	68.2	......	......	68.2	68.2	......	......	......	......
1	3	7.09	53.0	......	......	59.0	58.5	......	......	......	......
4	6	4.88	42.8	......	......	48.6	47.6	......	......	......	......
2– 7	21	1.24	37.1	......	......	40.7	39.8	......	......	......	......
10	24	2.67	32.7	......	......	36.2	35.3	......	......	......	......
1	27	3.88	27.2	28.1	28.2	29.9	29.0	29.6	30.2	29.2	29.6
4	30	3.50	20.9	24.8	26.6	27.0	26.9	26.5	28.1	26.3	27.8
3– 7	45	0.70	39.9	35.8	32.3	34.9	33.6	30.7	32.1	27.2	29.1
10	48	0.75	29.5	29.1	28.2	30.2	29.6	30.2	31.3	27.2	29.1
1	51	3.13	19.9	25.2	26.1	23.1	23.0	25.8	26.3	23.9	26.4
4	54	5.13	20.0	22.3	24.5	22.3	21.6	21.9	23.4	22.7	24.8
4– 7	69	1.94	37.4	36.3	37.7	36.6	34.4	30.7	32.2	28.2	28.4
10	72	2.67	29.9	31.2	27.4	28.2	27.6	23.6	26.4	23.6	26.6
1	75	5.21	18.8	19.8	23.4	17.4	17.8	15.6	18.4	19.0	18.6
4	78	5.17	13.9	15.5	17.6	12.9	13.2	12.1	13.4	13.9	16.7

[1]Average of 1924 data reported in Tables 23 and 24.

TABLE 26.—*Recorded weather observations for the curing periods beginning June 7 and August 22, 1922, and July 30 and August 18, 1924*

Year	Month	Day	Temperature				Wind Velocity		Per cent of possible sunshine	Solar intensity	Relative Humidity				Rainfall	Dew
			24-hr. mean	12-hr. mean (7 A. M. 7 P. M.)	Maximum	Minimum	24-hr. mean	12-hr. mean (7 A. M. 7 P. M.)			7 A. M	1 P. M.	7 P. M.	Average		
			Deg. F.	*Deg. F.*	*Deg.F.*	*Deg. F.*	*Miles*	*Miles*	*Per cent*	*Gram. calor.*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*In.*	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
1922	June	7	77	83	88	65	10.3	12.2	93	...	80	39	43	54	...	...
		8	80	86	90	67	9.7	10.6	87	...	81	36	39	52	...	...
		9	78	84	89	64	16.6	17.8	51	...	89	51	50	63	.25	...
		10	80	86	92	68	16.3	15.9	86	...	73	48	66	62	...	...
		11	75	81	87	61	5.2	5.7	53	...	87	45	35	56	...	Heavy
		12	83	92	98	65	10.8	11.9	70	...	52	40	42	45	...	...
		Av.	79	85	91	65	11.5	12.4	73	...	77	43	46	55	...	...
1922	Aug.	22	76	79	84	69	7.8	8.2	48	...	88	72	53	71	...	...
		23	85	94	102	65	6.1	7.9	99	...	85	33	34	51	...	Light
		24	87	97	104	66	7.0	3.7	77	...	70	20	33	41	...	...
		25	72	80	85	56	7.3	7.8	92	...	77	21	32	43	...	...
		26	70	74	78	62	7.2	7.7	47	...	64	21	47	44	T	...
		27	75	83	90	59	7.9	9.5	100	...	79	30	26	45	...	...
		Av.	78	85	91	63	7.2	7.5	77	...	77	33	38	49	...	...
1924	July	30	78	85	89	67	7.5	11.0	99	687.5	93	65	50	69	...	Heavy
		31	73	77	81	65	5.6	5.5	69	433.9	85	65	61	70	...	Light
	Aug.	1	71	73	77	64	8.1	9.0	1	165.5	90	75	94	86	.10	Heavy
		2	83	88	94	70	15.9	18.4	89	683.6	74	45	50	56	.17	...
		3	89	94	101	78	14.3	14.0	99	684.6	54	37	38	43	...	...
		4	83	85	88	73	7.5	7.0	45	373.2	91	65	63	73	T	Light
		Av.	80	84	88	70	9.8	10.8	67	504.7	81	59	50	66	...	...
1924	Aug.	18	80	86	94	67	12.9	15.3	80	586.1	88	47	56	64	T	...
		19	83	87	92	76	10.0	9.9	90	565.5	70	49	72	64	...	...
		20	86	93	101	72	11.4	11.4	71	583.9	99	38	41	59	...	Heavy
		21	85	90	96	74	14.2	14.8	85	480.7	57	42	60	53	...	...
		22	73	78	84	60	5.8	5.1	81	564.6	79	38	47	55	...	Heavy
		23	79	85	93	71	8.1	9.0	68	501.8	83	55	70	69	T	...
		Av.	81	87	93	70	10.4	10.9	79	547.1	79	45	58	61	...	...

Data in columns 4 to 15 were compiled from the records of a nearby station of the Nebraska Section, U. S. Weather Bureau and those in columns 16 and 17 were taken adjacent to the curing test.

The average hourly evaporation data from two Livingston atmometers situated in the alfalfa field have been included in the tables to show the correlation between the rate of curing and the weather conditions as expressed by the rate of water loss from the clay cups. The daily maximum and minimum temperatures, wind velocity, relative humidity, per cent sunshine, and other weather observations for each one of the curing tests are reported in Table 26.

Results as to Rate of Curing.—The data recorded in Table 27 show the number of hours required for hay curing in the swath, windrow, or cock to reach 30 per cent moisture content. These results are based on the moisture contents of the composite samples as presented in Tables 21 to 24.

TABLE 27.—*Number of hours[1] required for hay curing in swath, windrow, and cock to reach 30 per cent moisture content as determined by composite samples taken periodically. From Tables 21 to 24*

Test Beginning 10 A. M.	Curing thruout the test in			Partial swath curing preceding winding and cocking for[2]					
				3-6 hours		6-21 hours		24-27 hours	
	Swath	Windrow	Cock	Windrow	Cock	Windrow	Cock	Windrow	Cock
TOTAL NUMBER OF HOURS FROM TIME OF HARVESTING									
June 7, 1922	27	96	102	96	96	72	69	30	30
August 22, 1922	27	54	99	48	51	48	51	30	30
July 30, 1924	30	78	126	30	33	30	33	30	33
August 18, 1924	24	33	81	27	30	24	27	24	24
Average	27	65	102	50	53	44	45	29	29
NUMBER OF HOURS FROM 7 A. M. TO 7 P. M. DURING TEST									
July 7, 1922	15	48	54	48	48	36	33	18	18
August 22, 1922	15	30	51	24	27	24	27	18	18
July 30, 1924	18	42	66	18	21	18	21	18	21
August 18, 1924	12	21	45	15	18	12	15	12	12
Average	15	35	54	26	29	23	24	17	17

[1]Hay with 30.1 to 32.0 per cent moisture content at 4 P. M. was considered as having 30 per cent or less by 7 P. M.

[2]These periods represent the approximate stages: beginning to wilt, well wilted, and about two-thirds cured.

As an average of the 4 curing tests wherein alfalfa was cut at 10 A. M. or 1 P. M., it was found in the case of swath curing that 27 hours were required to reduce its moisture content to 30 per cent. Where hay was cured thruout in the windrow or cock, 65 and 102 hours were required respectively for hay to reach this same degree of moisture content. Where swath curing to the "beginning to wilt", "well-wilted", and "two-thirds cured" stages preceded windrowing or cocking, 50 and 53, 44 and 45, and 29 and 29 hours were required, respectively, to reduce the hay to a 30 per cent moisture content. Relative curing rates of hay by these various methods as averaged for the two 1924 tests (Table 25) are shown graphically in Chart 6.

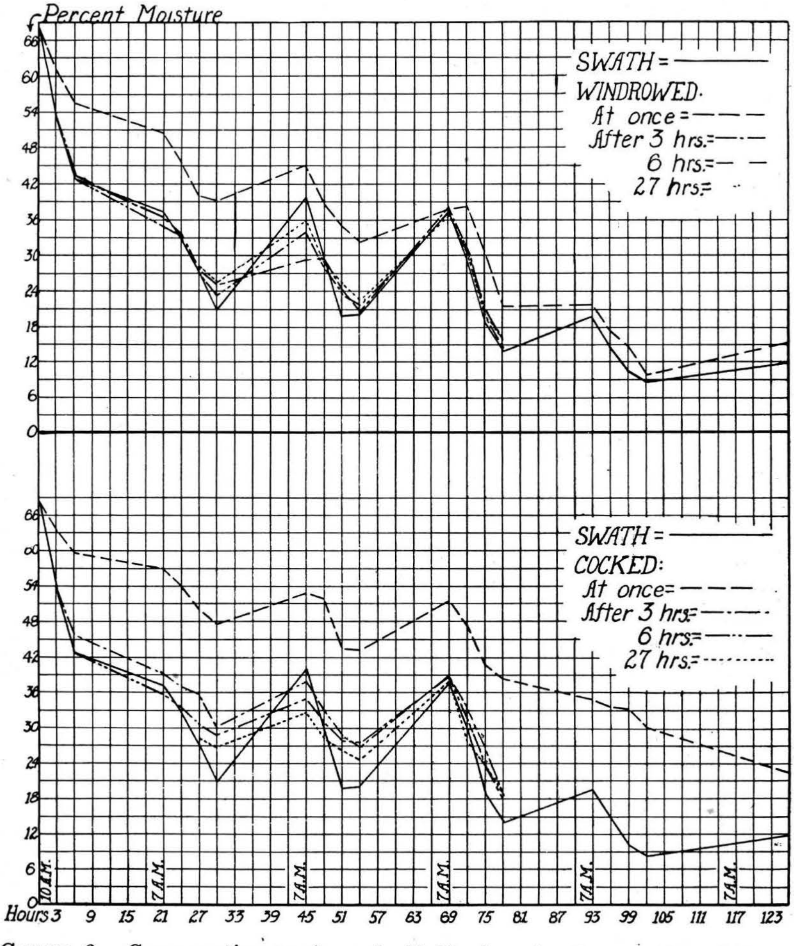

CHART 6.—Comparative curing of alfalfa hay in the swath, windrow, and cock as determined from composite samples of normal hay taken at stated intervals from time of cutting. (Table 25.)

These data show very clearly that windrowing and cocking of relatively green or slightly cured hay will materially prolong the curing period. It is further shown that the time required to reduce hay to a field-cured or air-dry condition is shortened as the period of swath-curing is extended.

Results Concerning Transpiration as a Factor in Curing. —A study of the rate of curing, as measured by the continuous samples having their leaves either intact or detached, respectively, indicates that the normal functioning of the leaves is not significantly instrumental in the withdrawal of moisture from the stems. Of the 487 comparative moisture determinations bearing on this problem, (Tables 22 to 24) it was found that the 2 kinds of samples differed as much as 1 per cent or less in moisture 253 times, or in 52 per cent of the comparisons. In the remaining comparisons or those differing more than 1 per cent in moisture content, the sample with the leaves intact had a somewhat lower moisture content than the corresponding sample with leaves detached in 117 cases, and a somewhat higher moisture content in an equal number of instances. The two comparative 1924 tests of the parallel curing rates of alfalfa with leaves intact and those with leaves detached are shown graphically in Chart 7.

The fact that alfalfa windrowed or cocked in a green or partially cured condition lost moisture more slowly than when cured entirely in the swath, is further evidence of the fallacy of a rather common opinion that such conditions prolong the normal transpiratory functioning of the leaves in the cut forage, thereby accelerating the rate of moisture from the stems.

The histological views of a typical alfalfa stem and leaf shown in Figs. 17, 18, and 19 are of some interest in this connection by way of illustrating the character of the material from which water must be evaporated in the curing process. Fig. 18 shows cross- and longi-sections of the stem with its peripheral distribution of the vascular system. The epidermis of the alfalfa stem is generally supplied with stomata as may be seen in the lower view of Fig. 19, except in the regions of collenchymatous tissue which may comprise one-fourth of the stem surface.

A comparison of Fig. 17 (center) with Fig. 18 (above) which are low power cross sections, is suggestive of the marked difference in mass of material between leaves and stems which must be dried during curing.

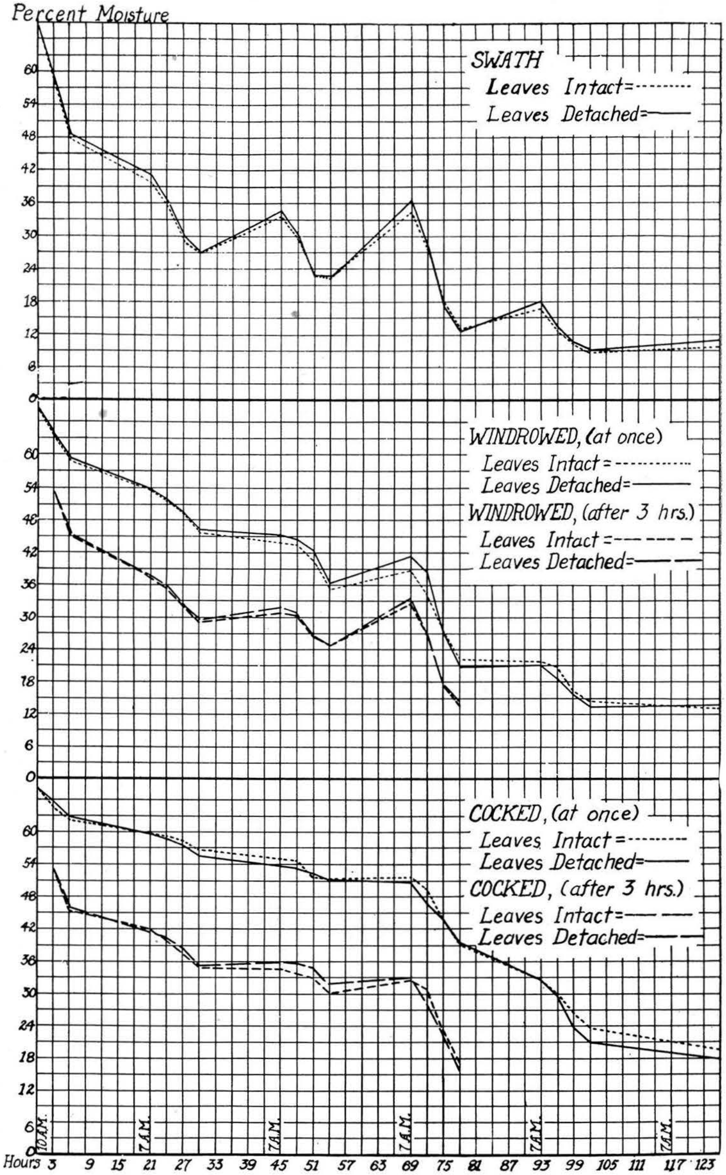

CHART 7.—Function of leaves in the field-curing of alfalfa hay. Comparative curing in the swath, windrow, and cock of hay with leaves intact and detached. (Table 25.)

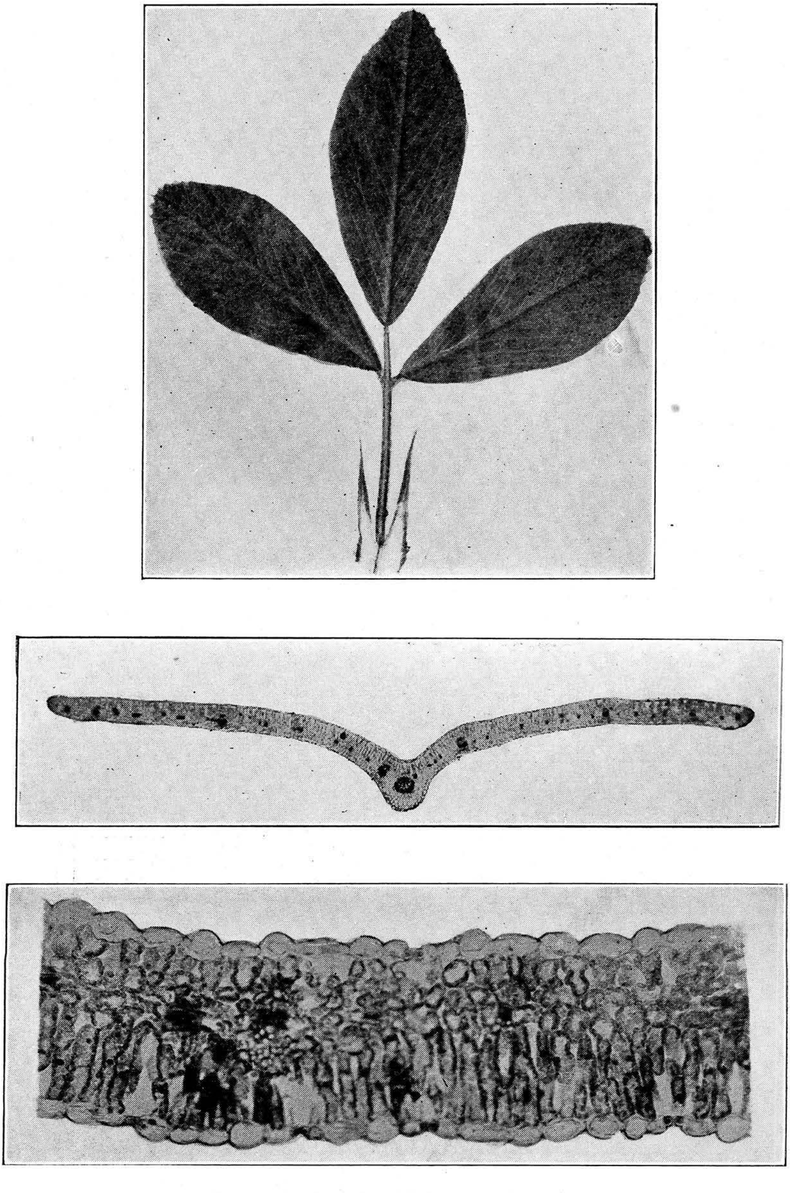

FIG. 17.—Above, photograph of alfalfa leaf (x 1.5); center, photomicrograph of a median cross-section of leaflet (x 20); and below, a portion of cross-section (x 175).

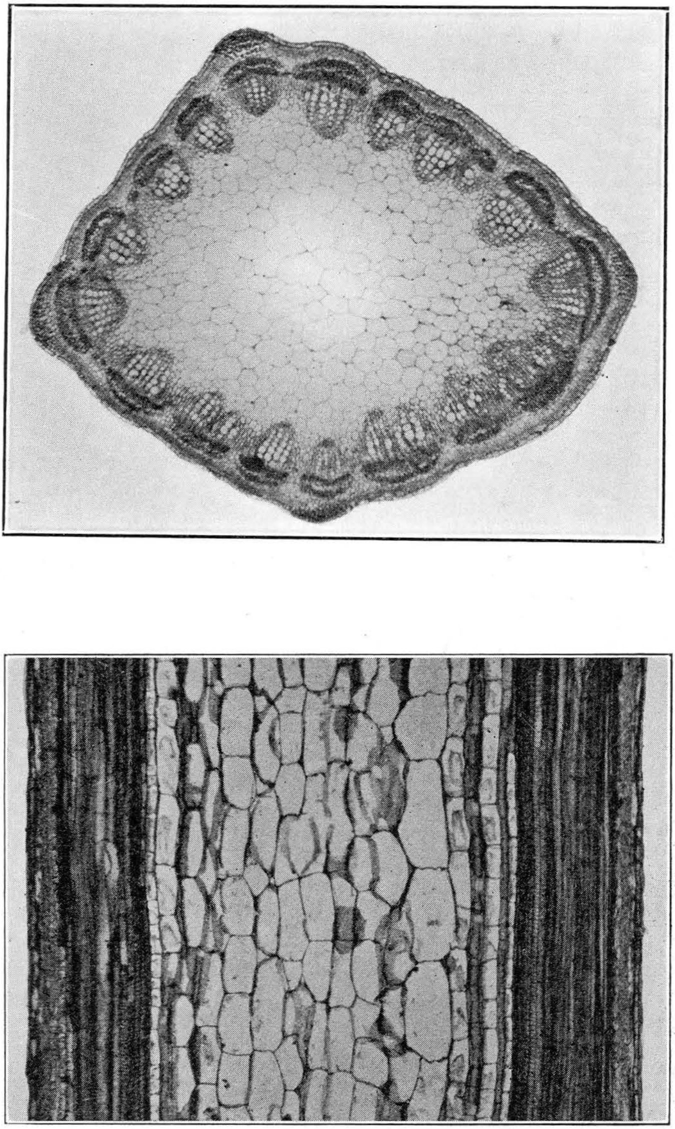

FIG. 18.—Photomicrographs of a typical alfalfa stem. Above, cross-section, and below, longi-section. (x 30).

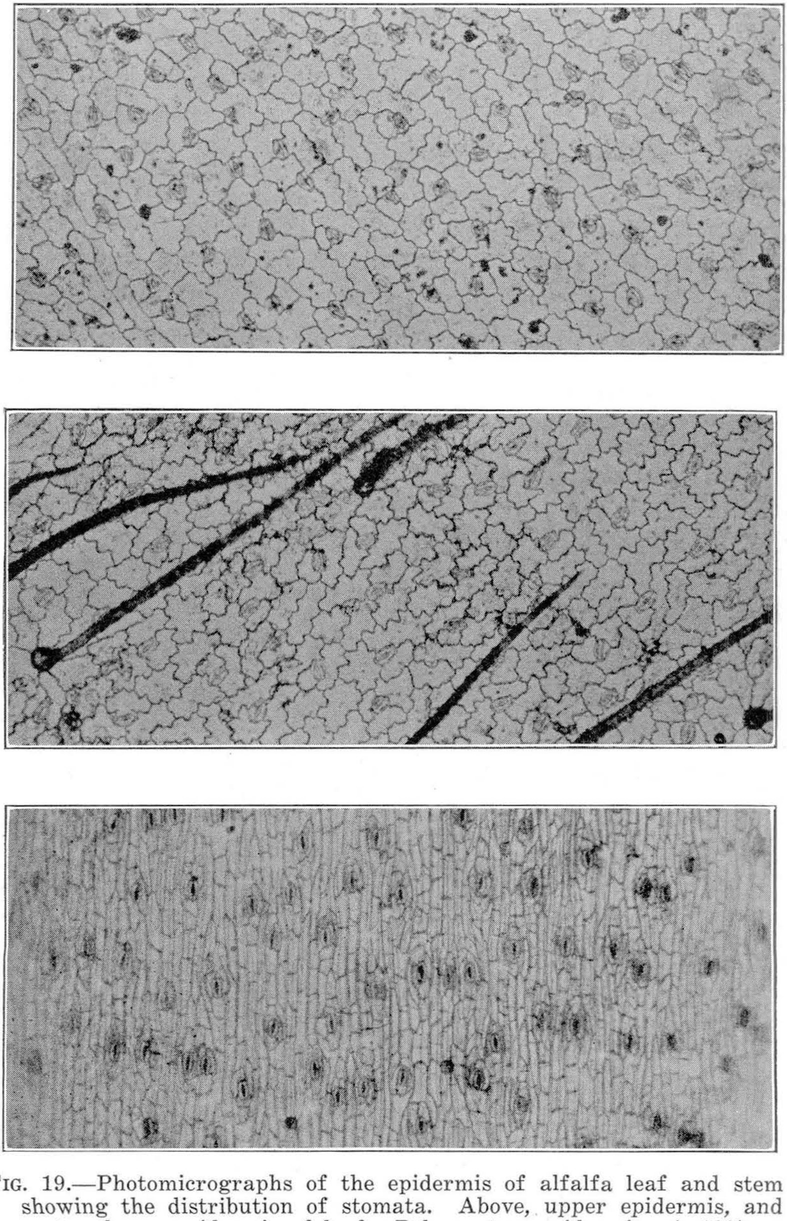

FIG. 19.—Photomicrographs of the epidermis of alfalfa leaf and stem showing the distribution of stomata. Above, upper epidermis, and center, lower epidermis of leaf. Below, stem epidermis. (x 120).

A cross section of the leaf is shown in higher magnification in Fig. 17 (below). The upper and lower epidermises with their distribution of stomata which have often been erroneously said to "pump water" from the stems under proper curing conditions, are shown in Fig. 19 (above and center).

The alfalfa examined averaged 220 stomata per square millimeter for the upper leaf epidermis and 215 for the lower. The stomatal apertures averaged 11 millimeters in length and when open comprised 0.4 per cent of the area of the leaf epidermis.

LABORATORY TESTS

A number of simple tests extending from 1921 to 1925 were conducted in the laboratory wherein the loss of moisture from the normal hay with leaves intact was compared with that from the bare stems. The samples were scattered thinly on sheets of paper and placed in a well exposed position for curing (but not in direct sunlight). The results of a typical test are shown graphically in Chart 8. These tests indicated that the normal hay dried somewhat faster than the

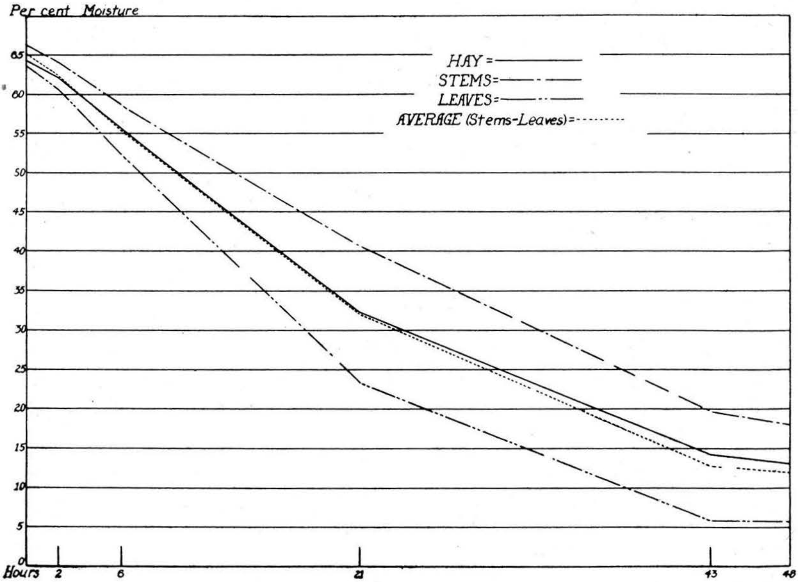

CHART 8.—Comparative drying of alfalfa hay, leaves, and stems under laboratory conditions.

stems alone, but that when the curing rates of the stems alone and leaves alone were averaged, the rates were almost identical with that of the whole hay.

RELATION OF THE RATE OF CURING TO THE WEATHER

A very striking relation was observed between weather conditions and rate of curing. Frequently, correlated weather conditions, such as high temperature, sunshine, low humidity, and high wind, are very conducive to rapid drying. During such a period differences in the curing rate resulting from the method of handling are ordinarily less marked. In attempting to correlate the rate of curing with weather conditions (Table 26) it should be borne in mind that the curing rate ordinarily becomes slower as the hay dries, even tho weather conditions may become more conducive to high evaporation.

The drying of external moisture bears the same relation to the weather conditions and method of curing as that of internal moisture but usually, especially in swath curing, it takes place more rapidly. Hay in the swath is more subject to increase in moisture content from humid weather, dews, or light rains than is hay in the windrow or cock. Heavier rains, however, can be expected to effect hay curing under all methods to practically the same extent. In the case of windrow and cock curing, danger of heating and molding from external moisture is as great, or greater, than that from internal moisture.

CURING PRACTICES IN RELATION TO QUALITY OF HAY PRODUCED

Curing practices should also be considered in relation to the quality of the resultant forage. Color and retention of leaves in alfalfa hay are of prime consideration. The dry matter yield of hay was determined in 1924 at the beginning and end of the curing period. The differences obtained were assumed to be due primarily to the curing method. Such data for 1924 indicating the per cent of dry matter recovered are shown in Table 28. In view of the fact that the dry matter contained in the stems would be largely recovered regardless of the curing method, such losses as were found must have consisted largely of shattered leaves. Prolonged curing of hay beyond the field cured condition resulted in an increased loss of dry matter. As was to be expected, the greatest loss was in the case of swath curing. This loss became greater as the air-dry condition was approached. The raking and proper handling of swath cured hay at the right time materially reduces such loss. The data in Table 28 indicate that hay should not remain in the swath after it has become about two-thirds cured. If properly handled at this time the loss should not exceed 5 per cent as measured by these tests.

TABLE 28.—*The amount of hay (per cent dry matter) recovered from the various curing methods as an average of the curing tests beginning July 30 and August 18, 1924*

Method of curing	30 per cent moisture content reached in[1]	Hay (dry matter) recovered when		
		Field cured	Test ended[2]	All plats averaged
	Hours	*Per cent*	*Per cent*	*Per cent*
Swath	27	90.7	81.5	86.1
Windrow, thruout	56	99.9	95.3	97.6
Windrow, preceded by 3 hours swath curing	29	97.8	98.3	98.1
Windrow, preceded by 6 hours swath curing	27	99.1	94.4	96.8
Windrow, preceded by 24-27 hours swath curing	27	94.5	91.4	93.0
Average	35	97.8	94.9	96.4
Cock, thruout	104	96.3	96.3	96.3
Cock, preceded by 3 hours swath curing	32	98.4	98.0	98.2
Cock, preceded by 6 hours swath curing	30	96.3	96.5	96.4
Cock, preceded by 24-27 hours swath curing	29	95.0	91.5	93.3
Average	49	96.5	95.6	96.1

[1]Number of hours required for hay to reach 30 per cent moisture content. From Table 27.
[2]When the hay became air dry or at the end of the six-day curing period.

An exact measurement of color retention in relation to curing method was not undertaken. Close observations, however, indicated that it bore practically the same relation to curing method as retention of leaves. Exposure to external moisture followed by bright sunlight was found very destructive of good color. Hay that was curing in the windrow or cock was more or less protected from moisture in the form of dew. Repeated rains, however, which necessitated the turning and opening of the windrows and cocks resulted in serious color damage as well as loss in dry matter.

APPLICATION OF CURING PRINCIPLES

These tests have indicated that under favorable weather conditions the best quality of hay and the largest per cent recovery of dry matter is obtained where most of the curing is done in the windrow or cock. By such practice, however, the curing period is materially prolonged and thus the likelihood of serious deterioration due to unfavorable weather conditions arising is increased. In regions of frequent rains the best practice would seem to be to reduce the moisture content of the hay to a field-cured condition as rapidly as possible without undue loss of quality and dry matter. In no case, however, should swath curing continue so long that material bleaching and shattering of leaves may result.

Curing practice must also be considered from an economic standpoint and from that of the individual producer. The more extensive type of hay making as is practiced on most Nebraska farms involves partial curing in the swath followed by windrowing and stacking or mowing as soon as the hay reaches a field-cured condition. Tho this method often results in a little lower quality of hay, it has a lower labor requirement, permits of the handling of a larger acreage, and is less subject to unfavorable weather conditions, due to its more rapid curing. A definite period for swath curing cannot be assigned, due to many variable factors. Under favorable curing conditions, hay cut in the morning should probably be raked in the afternoon or early the following morning, whereas under unfavorable conditions it may be advisable to extend the swath curing over a two-day period or even longer. In case swath curing has proceeded too far, undue loss of leaves may be partially overcome by delaying raking until late evening or early morning, in expectation of more humid conditions. Where a rather large acreage has been cut, raking should be started somewhat earlier. This will slow up the curing of the hay first raked, with the result that the period during which the hay reaches a field-cured condition will be extended.

Where the acreage is small and maximum quality of hay is essential, the more intensive curing practices may be followed Such practices would involve the careful cocking of the hay soon after it is well wilted and possibly one or more recockings if the curing is very slow. Canvas shock covers may be used for covering the shocks during unfavorable weather. Such practice, tho usually resulting in hay of a very good quality, is slow and involves a high labor requirement.

HISTORICAL REVIEW — CURING PRACTICES

VARIATION OF MOISTURE IN GROWING ALFALFA

The Colorado Experiment Station (1889) reports moisture contents varying from 77.7 to 49.3 per cent for hay cut at 4 stages of maturity ranging from "beginning to bud" to "seed fully ripened."

McKee (1914) found in California that the moisture content of alfalfa just preceding the pre-bloom stage was 85.8 per cent.

Hansen (1916) reported from the Huntley (Montana) Reclamation Project that the shrinkage of all cuttings in 1915, 1914, and 1913, was 76.2, 76.3, and 76.7 per cent, respectively. The shrinkage in the first, second, and third cuttings in 1915 was found to be 75.4, 75.4, and 77.4 per cent.

Vinall and McKee (1916) found that alfalfa growing at Chico, California, contained 1 per cent more moisture at 8 A. M. than at 3 P. M., and further reported a variation in moisture content of 78.9 to 73.4 per cent for alfalfa varying in maturity from very young (12 inches high) to past full bloom.

They conclude that "The moisture content of any crop at a given stage of maturity is not constant, but may vary with the conditions under which the crop is grown."

Salmon, Swanson, and McCampbell (1925) report moisture contents ranging from 71.7 to 63.8 per cent from bud to seed stages at the Kansas Experiment Station.

MOISTURE CONTENT OF FIELD-CURED AND AIR-DRY ALFALFA

Cooke (1900) found in Colorado that the moisture content in 35 samples of field-cured alfalfa ranged from 9.3 to 30.0 per cent. Hay containing from 22.0 to 24.0 per cent moisture heated somewhat when stored in bulk whereas that averaging 26.5 per cent moisture heated quite badly.

Arny (1916) found in Minnesota that the dry matter content of field-cured alfalfa in 1914 ranged from 55.0 to 96.0 per cent.

Vinall and McKee (1916) found that field-cured alfalfa at Chico, California, contained 22.3 per cent moisture, and 9.7 per cent when air-dry. They conclude "That the amount of moisture in air-dry material depends not only upon the humidity of the atmosphere but also upon the nature of the material in the sample."

Salmon, Swanson, and McCampbell (1925) (Kansas) report that the moisture content of field-cured hay varied from 20.8 per cent when cut in the bud stage to 14.0 per cent for hay harvested in the seed stage. Corresponding air-dry moisture contents ranged from 7.5 to 7.6 per cent.

RELATION OF CURING PRACTICE TO CURING RATE

Data bearing on various curing practices are very meagre. Statements and recommendations as reviewed were found somewhat conflicting and have been grouped in Table 29 under several rather general headings.

Vinall and McKee (1916) working with sorghum at Hays, Kansas, found that it lost 11.1 per cent of its weight during the first 4 hours after cutting when curing in the swath whereas in the windrow, it lost 6.6 per cent.

Piper *et al* (1924) state that " there is serious doubt as to the accuracy of the theory that the leaves of the cut plants act as pumps. Nevertheless the secret of making good, bright green hay is to reduce the water content in the plants from an average of about 70 per cent to about 15 per cent and do this fairly rapidly and without allowing any of the leaves to become brittle dry."

Willard (1926) concludes from a series of laboratory tests: " Experiments to determine whether the leaves of plants drew water from the stems in the process of curing into hay indicate that this occurs with some plants and not with others. Alfalfa stems dried at the same rate whether the leaves were attached or not."

In a paper appearing since the acceptance of this manuscript for publication, Westover (1926) concludes from a series of laboratory tests " that alfalfa in the quantities here used cures at least as rapidly with the leaves removed as with them attached."

CURING PRACTICE IN RELATION TO QUALITY OF HAY

Headden (1896) found in Colorado that hay exposed in the field to 1.76 inches of rain during a 14-day period, increased 12.37 per cent in relative amount of crude fiber, whereas the protein and nitrogen-free extract content decreased 7.70 and 5.07 per cent respectively.

Cooke (1900) found as an average of 8 tests in Colorado that the loss in dry matter under ordinary methods of field handling varied from 5.1 per cent to 26.1. The extreme represented differences in weather conditions.

Kenney (1916) states that the average loss in harvesting 41 lots of alfalfa in Kansas in 1914 was 12.43 per cent of the entire crop. The loss in leaves varied from 6 to 48 per cent.

Swanson and Latshaw (1916) found in Kansas that alfalfa

TABLE 29.—*Historical summary of statements reviewed bearing on curing practices*

Mechanical loss reduced and quality improved by windrowing and cocking soon after cutting	Windrowing or cocking advised			When properly handled leaves continue transpiration and aid materially in drying stems.	Windrowing and cocking before hay is dry will delay curing.
	As soon after cutting as possible	When hay is wilted to well wilted	When fairly well cured or before leaves begin to shatter		
Cooke (1900)	Fairfield & Hutton (1912)	Holden (1902)	Connor (1911)	Ten Eyck (1908)	Doyle (1916)
Westgate (1908)	Atkinson & Wilson (1915)	Hitchcock (1905)	Gardner (1916)	Cook (1911)	McClure (1918)
Fairfield & Hutton (1912)	Kezer (1915)	Westgate (1908)	Schmitz (1919)	Waldron (1911)	Schmitz (1919)
Jardine & Call (1914)	Adams (1925)	Waldron (1911)		Jardine & Call (1914)	Oakley & Westover (1921)
Moore & Graber (1915)	Cox (1925)	Brooks (1914)		Kezer (1915)	
Kenney (1916)		Jardine & Call (1914)		Moore & Graber (1915)	
Ames & Boltz (1917)		Moore & Graber (1915)		Kenney (1916)	
Moore & Graber (1919)		Doyle (1916)		McClure (1918)	
Stewart (1921)		Ames & Boltz (1917)		Cox (1919)	
Stewart (1926)		McClure (1918)		Stewart (1921)	
		Cox (1919)		Rather (1924)	
		Moore & Graber (1919)		Taylor (1924)	
		Beeson, Daane & Johnson (1921)		Adams (1925)	
		Damon (1921)		Ahart (1925)	
		McClure (1921)		Burger (1925)	
		Oakley & Westover (1921)		Cox (1925)	
		Rather (1924)		Stewart (1926)	

cured in the sun had a higher pure protein content as determined by Stutzer's method than that cured in the shade. This difference is so great as to more than offset the influence of the loss of leaves.

Salmon, Swanson, and McCampbell (1925) found in Kansas that as an average of 4 maturity stages, 1914-1920, 19.0 per cent of the leaves or 9.2 per cent of the dry matter was lost in harvesting.

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