1) Colorado

THE STATE AGRICULTURAL COLLEGE.

THE AGRICULTURAL EXPERIMENT STATION.

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ALFALFA.

Approved by the Station Council,
ALSTON ELLIS, President.

FORT COLLINS, COLORADO.

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THE AGRICULTURAL EXPERIMENT STATION,

FORT COLLINS, COLORADO.

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ALFALFA.

WILLIAM P. HEADDEN, A. M., PH. D.

No one can feel the incompleteness of the work presented in this bulletin more keenly than the writer, or regret it more than he does. The original purpose was to make a somewhat extended investigation of the effects of alfalfa growing upon different soils, particularly upon such as had been sown to wheat for a number of successive years until the yield had fallen to an unremunerative point. The results presented are confessedly those of work preliminary to the study proper, but we deem them of sufficient interest to justify their issuance in this bulletin, as they include the composition of the plant at different stages of development for each of the three cuttings—the usual number in this locality—together with the amount and composition of the ash of the whole plant above ground at different degrees of maturity, and also of the separate parts of the plant from the roots to the seed inclusive.

In two instances the soils have been analyzed, and in one the ground water also. This is the approachment made to the original object of the bulletin.

DESCRIPTION AND HISTORY.

The history of this plant has been outlined in previous bulletins published by this and other stations. The following is taken mainly from Miller's Gardener's Dictionary: The root of the cultivated Medick, or Lucern, is perennial, with annual stalks one and one-half to two feet and even almost three feet in height in good ground. The common color of the flower is a fine violet purple, but pale blue and variegated flowers are mentioned as arising accidentally from seeds. Villars affirms that the flowers are white—seldom greenish. Its native place is variously given, it being assigned to Spain and France, the Palatinate, and other portions of Europe. He adds: It may possibly have been originally a native of Europe, continuing to be disregarded until it was imported into Greece from the East after Darius had discovered it in Media, whence its name. It has been culivated "time immemorial" in the southern countries of Europe, and French Lucern seed was imported into England about 1650, but it was entirely neglected for many years, and in 1765 the fact that a farmer in Kent had fourteen acres of it was a matter worthy of mention. Lucern, he continues, has been greatly celebrated for increasing the milk of kine, but Haller, who certainly knew it well, asserts that cattle are apt to grow tired of it and that they are subject to be blown by it.

The culture of this plant by the Greeks is mentioned in their literature for about four and a half centuries, from the time of Theophrastus, 381 B. C., to that of Dioscorides, in the first century of the Christian era, and by the Roman writers through a period of about two and a half centuries from the time of Virgil, to that of Palladius, at the end of the second century, A. D. If the Persians, under Darius, introduced the Medick into Greece from Media, it would fix its date of introduction at about 490 B. C. I have not found any date given for its introduction into the Roman provinces. Its culture in Italy, however, has not been continuous down to the present time. Matthioli, writing in 1558, states that he had never seen it growing (in Italy), but adds: "It is related that it is abundantly cultivated in Spain where it is known by the Arabic name, Alfalfa." This name came with the Spaniards to this continent and has been borrowed by us directly from the Chilians, who, according to Prof. Hilgard, introduced it into California in the early fifties (1854). It was first introduced into this State in 1862 ,the seed being imported from California, which continued to be the source of our seed supply for several years. It has since been introduced into the contiguous states and territories.

CULTURE.

The Kansas State Board of Agriculture published,in 1894 a report devoted to Alfalfa, or Lucern, being for the most part answers given to a series of questions sent out by the Secretary of the Board, by various alfalfa growers in California, Colorado, Wyoming, Utah, Washington, Oregon, Arizona, New Mexico, Nebraska and Kansas, arranged by states and counties. The results given have, without doubt, been arrived at independently in the various regions and probably without any knowledge of the experience and observations of European growers. The accordance between them and those recorded in this report is remarkable, and goes far to show that the general methods of culture in vogue now have been practiced in all essential features for centuries, and are probably the best admitting of general application.

The variations in culture methods are slight, though the accounts given embrace a large variety of soils and climate, and the plant is claimed to meet the requirements of an excellent forage plant under all of them, indicating its adaptability to very varied conditions. The most trying and most fatal conditions to this plant are cold, wet winters and poorly drained or water-logged soils. It has long been observed that stagnant water has a very injurious effect upon this plant, destroying its roots, an observation that Coloradoans have many opportunities of repeating. The writer has seen plants with roots entirely destroyed to within a few inches of the crown, though still producing some growth, and others killed by soils being filled up with irrigation or perhaps seepage water. In the case here referred to the soil was strongly impregnated with alkali; these salts contributed to the effect produced,but I think that the plants would have simply drowned out had there been no alkali. There are many instances of this to be observed throughout the irrigated portions of the state where depressions in the surface become partially filled with water. The principal points given for its culture are, a well prepared seed bed, "fresh and plump" seed to be covered from "very lightly" to "three inches deep," according to different observers, and varying with the climate and soil. In California and Colorado, and generally in the West, the customary practice is to drill in the seed with a protective crop. I have neither seen nor learned of drill culture being practiced except on a small scale.

In regard to the seed, some assert that two years old seed is scarcely worth the sowing, and others are quite radical in their statements as to the value of shrunken or shrivelled seed. The writer will give his reasons for refusing to accept either of these statements under the subject of "Seed." It may not be a general practice for our farmers to sell their first-class seed and use the screenings for their own sowing, but it is certainly not an uncommon practice among them, and the results are satisfactory. It is even claimed by some that no difference can be seen in the results, the screenings producing just as good a stand of healthy plants as the first-class seed. The meaning of the persons making this claim is so evident, that there is no need of any explanation, still it may be stated that they do not claim that there will be more or less plants to the acre, but plainly that the stand will be sufficient to produce as large a crop in the one case as in the other. Some claim that the vitality of the alfalfa seed is at best small and that the shrivelled seed produce puny plants which are even less likely to survive the first summer than plants from plump seed of which, in ordinary field culture, very many perish.

Much stress is laid by some writers upon the necessity of growing the plants in a deeply prepared bed and rather abundant water supply during the first year, in order that they may establish themselves thoroughly, i. e., send their tap roots down deep into the soil. This suggestion has much force as applied to the conditions obtaining here, more, perhaps, than it would have in the East, and is by no means equally applicable to all of our lands. The root system of the alfalfa plant is greatly modified by the soil in which it grows. The so-called first bottom lands of our valleys do not favor the development of as long a root system as the higher grounds do. I have recently had occasion to study some plants which, though they were producing vigorous tops, could scarcely be said to have a tap root; for in no case, did it exceed eighteen inches in length. Had I never seen other alfalfa roots I would have considered them typical, for they were bright, without apparent deformity, and healthy. There was nothing about the plants or roots to indicate anything abnormal. The long tap roots are not always present and the old method of transplanting, as well as the continuance of gopher-eaten plants in some soils, fairly raise the question as to their necessity under all conditions. As stated above, the conditions of soil and climate prevailing here give strong justification for the practice and much force to the recommendation, but too much stress ought not to be placed upon it.

The history of fields of transplanted lucern is interesting in this connection. The practice of transplanting was at one time commended by some European agriculturists. The procedure and culture were briefly as follows: The plants were grown in seed beds in drills, were taken up in August or September, when the plants had attained a length of eighteen inches, the tap root was cut off eight, nine, or ten inches below the crown, the stalks about five inches above it, and they were then set six inches apart in rows, with two feet between the rows. This was subsequently found to be too thick. The plantation was cultivated by horse power; its duration and yield were claimed to be greater than an equal area sown broadcast. The character of the hay produced by the two methods, especially as to its coarseness and the readiness with which it was eaten by sheep, horned cattle, and horses, did not escape observation and comment. Such a method is clearly not to be considered, but they cut the tap root off eight, nine, or ten inches below the crown of the plant, and some asserted that six or seven inches below the crown would be even better. They cut three crops of hay in England and obtained large yields. When they harvested a crop of seed they obtained only one crop of hay and considered the seed crop as injurious to the roots as four cuttings. In Italy from four to six cuttings were made; in Catalonia as many as seven, frequent irrigation being necessary to obtain so many cuttings. The hay from broadcast alfalfa is finer and softer than from drilled. The yield of hay is put at more than four tons. Such are some of the statements made of the practice and results obtained. The life of the plant grown without transplanting is variously estimated at from two to fifty years. The former is evidently too low and the latter is exceptional. Columella gives it at from ten to twelve years, which is more consonant with general observation. Miller observes that, when alfalfa is cultivated and assisted by manure, he has not observed it to decline at any age, but sown broadcast, it declines and even wears out very fast after seven or eight years. From the various statements it is evident that, under some conditions, the tap root is not necessary to the continued healthy growing of alfalfa. The susceptibility of the plant to culture and its requirement for water applied to the surface, its prompt response to the application of fertilizers, and its deportment when transplanted, suggests that we attribute more importance to the tap root than it deserves. Mr. Mills, of the Utah Experiment Station, speaking of the amount of water required by alfalfa and the part the tap root performs in supplying it, says: "Though the roots go deep and probably lift water from below, this water is not furnished rapidly enough to supply the rank growing alfalfa. The only real advantage derived from the long roots seems to be that enough water is thereby supplied to keep the plants from perishing during seasons of dry weather." The complaint that alfalfa plants are difficult to exterminate by plowing them up, is very common, and Tull is quoted as having seen alfalfa plants mangled by the plow for twenty-two successive years and still flourishing. There will be some further similarly suggestive facts found under the discussion of the roots.

It is generally recognized that alfalfa flourishes best in an open loamy soil, but its power to adapt itself to other soils is very evident. Its doing well in heavy clay and light sandy soils, but being less productive in the latter unless well provided with plant food, attest that the plant is a heavy feeder. The range of altitude through which it will flourish is also great; while its range is less than that of timothy, it still reaches quite 8,637 feet on this side of the Rocky Mountains. I have seen a field of alfalfa in the San Luis valley, said to be fourteen years old, with an elevation of 7,900 feet, in which the stand was quite good and the plants healthy. It has also been successfully grown above Telluride, in this State.

VARIETAL DIFFERENCES.

The characteristics of alfalfa, which commend it for general culture by the farmers of the west, do not exhaust its points of interest to them. It is not constant in its specific characteristics, as almost every one has observed, some of the plants differing in color, shape, and size of both stem and leaves, and often very greatly in hue and color of flowers. The variation in color and size of the leaves is often very noticeable, and the suggestion that proper selection and careful propagation might result in establishing varieties with special merits for our climate and soils is no doubt true. The deep-green, narrow-leaved, red-stemmed plants, mostly with deep violet purple flowers, present a very different growth and mature earlier than the lighter green, larger leaved, green-stemmed and, as a rule, lighter-flowered plants. It has not been the writer's good fortune to have the opportunity of seeing many recognized varieties of alfalfa, but the few which I have seen differ less from one another, or certainly in no case more than many individual plants do growing side by side in our alfalfa fields. We have not, as we desired to do, analyzed separate plants to learn whether they have a varying composition. We have found it feasible only to take samples representing the plant as grown for hay. Among the analyses will be found, however, four samples of as many different varieties; three from French seed and one from seed from Turkestan. The results of these samples do not bear out the suggestion made above in the measure that we might expect, but the differences between the three French varieties practically disappeared in our soils and climatic conditions. The same could not be said of the variety from Turkestan. This was distinct in habit and very uniform, and, while the composition of the hay differs but slightly from the others, the agreement between them being as close as we would expect two different samples taken from different parts of the same field to be, there is an advantage in favor of this variety because of habit, growing erect with leafy and numerous stems. As to earliness of maturity, there was but slight difference. I made no endeavor to study the relative draft made upon the soil by these varieties; in other words, the ashes were not analyzed, and only one series of samples was taken and each sample analyzed in duplicate. This is clearly too limited an investigation on which to base other than tentative conclusions, since the composition is so near to the average for alfalfa hay made from plants in the same degree of maturity. It is very probably true, that, so far as these varieties are concerned, the only advantage of any one of them over the others is an advantage due to earliness of maturity, productiveness, or the ratio of stems to leaves, and not in its chemical composition. There are, doubtlessly, other qualities entering into the alfalfa plant affecting its desirability for hay making, but which lie beyond our power to recognize, just as there is a very readily recognized difference between the different cuttings of alfalfa or between old and new hay.

The samples used in the following analyses were taken at different stages of growth for the first and second cuttings and partly so for the third cutting. We cannot give the treatment of every sample in detail without repeating to a wearisome extent. The general method was to select and cut by hand the samples to be prepared. A quantity was weighed off, cut up without loss, placed in a sack, and exposed to the wind and sun until it came to a constant weight. This process was very tedious for samples weighing from five to ten pounds. The samples were then ground, bottled, and sealed. Duplicates were made of some samples, one being dried as above, the other in the hot air bath at a temperature not exceeding 100 degrees. The analyses showed no difference due to the manner of preparation. A higher temperature, however, is not safe; this was especially true with the roots, which showed by both their color and odor that at 110 degrees decomposition of some of their constituents had set in. A temperature ranging below 70 degrees was found to answer well.

The samples were taken to represent the plant without any bloom, beginning bloom, half bloom, full bloom, with seed formed and with mature seed. The plant has been further separated into roots, the outside or bark and interior portion, stems, leaves, flowers, and seed. Two samples were taken early in May before any blossom buds appeared, for the determination of crude fiber, to ascertain how great the relative increase of this substance is as the plant matures. Former analyses made at this Station have made it enormous.

The ashes of the principal samples have been analyzed to aid in forming some clear notion of the amount of plant food, other than nitrogen, required to produce a crop of alfalfa hay. We have no theory concerning the benefit of alfalfa growing to wheat exhausted soils, but simply seek the facts and their explanation to which, as before stated, this bulletin is simply a contribution.

PROTEIDS.

The fodder analyses of the first cutting give the following results for the amount of proteids, dates of collection being omitted except in the first instance. This sample was secured May 5th; plant 21 inches high; no blossoms; buds not visible; stem red; leaves small, dark green; air dried matter (hay) 27.53 per cent.; moisture, 72.74 per cent. Another plant with green stem, broader leaves of light green color, and equally immature as the preceding gave 28.21 per cent. hay and 74.79 per cent. water. The proteids in the above samples were respectively 19.95 per cent. and 21.79 per cent.

Proteids in first cutting alfalfa hay:—

	Per cent.
1. Plants green, (average of preceding)	20.87
2. " green, but nearing bloom	15.60
3. " beginning to bloom	14.30
4. " in half bloom	14.41
5. " in full bloom	14.08
6. " in full bloom	13.95
7. " just past full bloom	13.38
8. " in full seed	12.16
Average	14.85

Proteids in second cutting alfalfa hay:—

	Per cent.
1. Plants not yet in bloom	16.40
2. " just coming in bloom	18.47
3. " in half bloom	16.11
4. " in ½ to ¾ bloom	13.03
5. " in full bloom	12.88
6. " half ripe	12.50
7. " half ripe	11.65
Average	14.43

Proteids in third cutting alfalfa hay:—

	Per cent.
1. Hay, College Farm	12.53
2. " Rocky Ford Station	13.57
Average	13.05

The sample from the Rocky Ford Station was unusually leafy, while that from the College Farm was taken from the cock and was average hay.

The following are samples from the Farm Department, all of which were prepared by Prof. W. W. Cooke:

Proteids in first cutting alfalfa hay:—

	Per cent.
1. Hay	17.72
2. "	17.08
3. "	12.15

Numbers 1 and 2 represented individual plants cut May 28th, just before the field was mown. Number 3 is hay from the same field, cut on the 28th, but was damaged by rain.

Proteids in second cutting alfalfa hay:—

	Per cent.
1. Hay	12.15
2. "	12.29
3. Plants just showing bloom	15.26
4. " " " "	16.26

The samples of hay, Nos. 1 and 2, were cut from the same roots as Nos. 1 and 2 of the first cutting.

Proteids in third cutting alfalfa hay:—

	Per cent.
1. Hay	15.83
2. "	12.61
3. "	12.57

Condition of plants at time of cutting not given.

The average percentage of protein found in our samples for the first cutting, including all the different stages of development, is 14.85, but excluding samples cut May 5th, it is 13.98 ; for the second cutting, 14.43 ; and for the third, (this is based on too small a number of samples) 13.05. The farm samples show the same relative values for the respective cuttings, though the samples are fewer in number. For the first cutting, 14.92 per cent., for the second, 13.99 per cent., and for the third, 13.47 per cent. Perhaps analysis No. 3—first cutting—of the farm samples, ought not be included in the averages, because it was not gathered into the mow for fifteen days after it was cut, during which time it had been exposed to several rains.

As this is the only sample of alfalfa hay damaged by rains that we have analyzed, we will make mention of it in this place. The average of the analyses made of samples taken from the same field and cut the same day, but dried in an air bath, shows the composition of the prime water-free hay to be:—

	Per Cent.
Ash	12.18
Crude Fiber	26.46
Crude Fat	3.94
Crude Protein	18.71
Nitrogen free extract	38.71
	100.00

The sample of damaged hay gives :—

	Per Cent.
Ash	12.71
Crude Fiber	38.83
Crude Fat	3.81
Crude Protein	11.01
Nitrogen free extract	33.64
	100.00

The total rainfall between May 28th and June 12th, the respective dates of cutting and of putting into the mow, was 1.76 inches. The weather during this time was cloudy and the temperature ranged from 72 to 81 degrees. Any calculations based upon the above, without further data, would evidently be liable to lead to erroneous conclusions, but it suffices to show that the popular estimate of the value of such hay is not far from correct, i. e., about one-half that of good hay. The damage is not simply the amounts of proteids and nitrogen free extract (carbohydrates) lost, but also the loss of those general qualities recognized as essential to good hay. The mechanical loss in such cases is very large. We undertook to determine by direct experiment the total loss by the solvent action of water, fermentation, and handling, but it became evident that the results would indicate nothing of general value because there was no limit at which we would have to stop and no criterion by which we could judge when our experiment had become comparable with the average article (if there be such) of damaged hay. This sample gives us a somewhat definite measure of the sensitiveness of this hay to rain and exposure. The rain fell in three portions: the first fall amounted to .31 inch; the second 1.49 inches; and the third .27 inch, with intervals of two days or more. The weather was cloudy and warm. The mechanical loss of leaves and stems would tend to change the composition of the hay in the direction indicated by the analyses, but for good reasons, we do not consider this to enter largely into this particular case; but attribute the changes in the composition of the hay to the action of the moisture and heat.

Judging by the amounts of proteids in the three different cuttings, the first and second cuttings stand very close to each other in value with the difference in favor of the first cutting. In the farm samples, leaving out the damaged sample, the first cutting is materially the best of the three. I would here remind the feeder, who prefers the second or even the third crop for certain feeding, that the amount of proteids present is not the only measure of good hay. Not only is the quantity of proteids greater in the first cutting, but the yield is also greater and the hay cut just at the beginning of bloom is richer in this constituent than when cut later. From beginning bloom to half bloom the amount of proteids seems to be nearly stationary and the crop is also probably at its maximum. There are no figures accessible to me on this point, but it is in keeping with my observations. If the plant continues to store up organic matter after this period is past, I am inclined to think that the loss by the dropping of leaves, due to the maturing of the plant and the action of the fungus common on our alfalfa, more than compensates for the gain. While I am inclined to think that the farm samples are exceptional in their quality, they confirm the results obtained on the laboratory samples and make the first cutting very decidedly richer than the second. The development of the plants is not given, but as the date of cutting was May 28th and it was intended to cut the field four times, it was probably just before bloom, in which case the apparent excessive richness in proteids is largely and probably wholly accounted for. If the very early cutting be rejected from my series, and I think this should be done for no one would cut the crop so immature, it changes the results in favor of the second cutting.

CRUDE FIBER.

It has been stated by others that this portion of the plant increases materially with age. Our results indicate the same, but not to the extent claimed in a former bulletin issued by my predecessor, wherein he showed it to increase from 12.88 per cent. in hay, cut when the plant was beginning to bud, to 20.23 per cent. in hay made from alfalfa with fully ripened seed. (Bulletin No. 8, of this Station, page 11, analyses Nos. 1 and 4.) The method of determination is given as that adopted by the Association of Official Agricultural Chemists, convention of 1888. Whatever influence of the greater or less succulency of the plant may have upon the amount of crude fiber in the dry matter, it cannot in this case be appealed to to account for the low percentage of fiber, for the percentage of dry matter in the plant is given in some cases even higher than any which we have found. In Bulletin No 8, it is given as ranging from 22 to 50 per cent. of the green weight. In two samples cut on May 5th, we found the dry matter to be 25.2 per cent. and 27.53 per cent., and the crude fiber to be 22.56 per cent. and 29.79 per cent. respectively. These samples were taken from two separate and very unlike plants, grown without cultivation or irrigation. The average of these two, 26.18 per cent., is near the truth for alfalfa hay cut before flowering. Differences in cultivation, and varieties may make a difference of a few per cent.

Laboratory Samples.

Crude fiber in first cutting alfalfa hay:—

	Per cent.
1. Plants quite young (average)	26.18
2. " in bud	35.17
3. " in bud	37.39
4. " in half bloom	36.54
5. " in full bloom	40.18
6. " in full bloom	32.48
7. " just past full bloom	36.19
8. " in full seed	46.12
Average	36.28

Samples numbered 5 and 6 were collected in different localities. No. 5 from heavy first bottom land; the growth was very rank, many of the stems were upwards of five feet in height; and the average diameter of one hundred stems, taken large and small as they grew, was nearly one-fifth of an inch—.19. The lower portion of such stems was woody and devoid of leaves. The stems in numbers 3 and 4 (100 from each sample), were also measured and were only a trifle smaller, having an average diameter of .17 of an inch. The sample on which analysis numbered 6 was made grew on a sandy loam, without irrigation. The plants had an average height of three and a quarter feet; and were very leafy, probably more so than the average.

The following are also laboratory samples of first cutting hay, but made from supposedly distinct varieties, grown on a rich loam, in drills, with irrigation:

Crude fiber in first cutting alfalfa hay:—

	Per cent.
9. Plants in full bloom	36.39
10. " in full bloom	32.74
11. " in full bloom	35.51
12. " in full bloom	31.96
Average	34.15

The average of which is 34.15 per cent., while that of Nos. 5 and 6 is 36.33 per cent., which is probably the range of the average percentage of crude fiber of first cutting alfalfa hay cut when the plant is in full bloom; while the average percentage of the samples taken before blooming, including those taken as early as May 5th, is 32.91 per cent., the lowest being 22.56 per cent. and the highest 37.39 per cent., the difference being due to development of the plant and to the differences of conditions under which they were grown, particularly of soil and irrigation.

Crude fiber in second cutting alfalfa hay:—

	Per cent.
1. Plants not in bloom	28.66
2. " coming in bloom	32.46
3. " in half bloom	37.39
4. " in half bloom	37.24
5. " in full bloom	38.06
*6. " past full bloom	31.10
Average	34.15

Crude fiber in third cutting alfalfa hay:—

	Per cent.
1. Hay, College farm	39.35
2. " Rocky Ford station	34.67
Average	37.01

Farm Samples.

Crude fiber in first cutting alfalfa hay :—

	Per Cent.
1. Hay, cut May 28	24.54
2. " " "	24.68
**3. " " "	35.09
Average	28.10

Crude fiber in second cutting alfalfa hay:—

	Per cent.
1. Taken 35 days after first cutting	26.16
2. Taken 35 days after first cutting	29.07
3. Taken about 48 days after 1st cutting	34.59
4. Taken about 48 (?) days " "	38.08
Average	34.37

*This sample was obtained from the farm of Charles Evans, northeast of Fort Collins. The land is high and under irrigation. The alfalfa was average in growth. Its age is not known to us.

**This sample was damaged by rain.

Crude fiber in third cutting alfalfa hay:—

		Per cent.
1.	Hay	28.89
2.	"	37.39
3.	"	34.91
	Average	33.70

As already remarked, the results, especially of the laboratory samples for the first and second cuttings, show an increase in the crude fiber as the plant matures, but there is a considerable variation in the samples, with a few apparent contradictions, which is to be explained by differences under which the samples were grown and taken. The determinations were made in duplicate, and sometimes in triplicate, or until we were satisfied that the difference in the results was in the sample and not in the analyst's work. From the beginning of bloom to half bloom, the increase is not very rapid and the averages obtained for the hays of different cuttings are nearly equal, at least not so far apart as public judgment assumes; for the first, 35.21 per cent.; for the second, 34.15 per cent. (laboratory sample), 34.47 per cent. (farm sample); and for the third cutting, 37.01 per cent.; 33.70 per cent., three samples of hay from the farm department.

FAT OR ETHER EXTRACT.

We find in our laboratory samples a considerable variation in the amount of fat. If the differences be expressed in terms of the total fat found, they are large; but if in per cent. of the sample, they are constant. In twenty samples of alfalfa hay, but one yielded as much as 2 per cent. or more of fat soluble in ether, and only one below 1.1 per cent., with the average equal to 1.539 per cent. In the case of the farm samples, though our results on the duplicates were satisfactory, there is no concordance when the series of samples is taken as a whole, one sample falling as low as .86 per cent., and another in the same sub-series giving 2.76 per cent.; and still another 4.20 per cent. We have been unable to discover any reason for such variations in the farm series itself and quite as unable to find out why the two series should be so different. If we neglect the samples of first cutting hay in the farm series and take the samples representing the second and third cuttings, the average for the fat is, 1.641 per cent.; while the average fat content of the twenty laboratory samples is, 1.539 per cent., with most of them quite close to the average.

The fat as determined in the sample in full seed is, doubtlessly, too low (1.03 per cent.) for the reason that any seed which was in the hay was not crushed in the grinding of the sample and would yield so good as none of its fat in the sixteen hours' treatment with ether. We subsequently established this fact by direct experiment with whole unhulled seed. With this one exception, if it is an exception, there is no clearly indicated difference in the amount of crude fat present at the different stages of development examined in this study.

NITROGEN FREE EXTRACT.

The substances embraced under this name, having heretofore been determined by the difference between the sum of the proteids, crude fiber, fat, ash and moisture, and one hundred, will vary inversely as and quite nearly with the substance present in the largest quantity, which is the crude fiber. By this we mean that, if the crude fiber is high, the nitrogen free extract, which includes sugar starch, etc., called carbohydrates, will, as a rule, be lower than in another sample having less crude fiber. If the direct determinations have been made with care, the nitrogen free extract determination will be quite accurate enough for all purposes.

Laboratory Samples.

Nitrogen free extract in first cutting alfalfa hay:—

	Per cent.
1. Plants not in bloom	29.79
2. " not quite in bloom	32.91
3. " half bloom	32.50
4. " full bloom	27.85
5. " full bloom	37.64
6. " full bloom	30.59
7. " full bloom	33.24
8. " full bloom	33.11
9. " full bloom	31.41
10. " just past full bloom	30.41
11. " full seed	29.22
Average	31.69

Nitrogen free extract in second cutting alfalfa hay:—

	Per cent.
1. Plants not in bloom	36.49
2. " coming in bloom	31.58
3. " half bloom	33.29
4. " half bloom	28.90
5. " full bloom	32.02
6. " past full bloom	39.45
7. " past full bloom	38.13
Average	34.27

Nitrogen free extract in third cutting alfalfa hay :—

		Per cent.
1.	Hay, College Farm	31.35
2.	" Rocky Ford Station	34.09
	Average	32.72

It ought to be mentioned, perhaps, that these samples are from different places, some grown with and others without irrigation on different soils. With the exception of analysis No. 4, first cutting, the results indicate that the nitrogen free extract is greatest at or about full bloom.

Farm Samples.

Nitrogen free extract in first cutting alfalfa hay :—

		Per cent.
1.	Hay, cut May 28	35.67
2.	" " " "	36.42
3.	" damaged by rain	30.97
	Average	34.35

Nitrogen free extract in second cutting alfalfa hay :—

		Per cent.
1.	Cut 35 days after 1st cutting	32.77
2.	" " " " "	31.11
3.	" about 48 (?) days after 1st cutting	37.84
4.	" " " " " " "	34.43
	Average	34.04

Nitrogen free extract in third cutting alfalfa hay :—

		Per cent.
1.	Hay	36.78
2.	"	34.81
3.	"	35.84
	Average	34.74

The moisture in our samples of air dried hay ranges from 4 per cent. to nearly 9 per cent., with an average of 6.21 per cent., for the first; 5.94 per cent., for the second and 5.93 per cent. for the third cutting; while the average for all three is 6.03 per cent. Such hay takes on moisture readily. While preparing our first cutting samples, we had a spell of damp weather lasting from July 3d to 6th, during which some samples gained as much as 5.70 per cent. The smaller samples gained more proportionately than the larger ones because there was relatively more surface exposed.

The moisture in the farm samples is higher than in the laboratory samples. This is noticeably the case with the second cutting ; the results are, for the first cutting, 7.59 per cent.; for the second, 8.05 per cent.; and for the third, 5.63 per cent. The average of the three is 7.09 per cent., from which we may judge that the moisture in alfalfa hay, under average Colorado conditions, is not far from 6.52 per cent. and not above 7.09 per cent.

ASH OR MINERAL CONSTITUENTS.

This component in alfalfa hay has some importance in general feeding, but very much more for the purpose of this bulletin as a measure of the draft made upon the plant food in the soil, both as to kind and quantity. I have not considered the physiological function of the constituents of the ash to be of such importance as to require any attempt to determine for instance the amount of phosphoric acid existing as such in the hay as fed, but have simply determined the amount of this acid in the ash, as prepared ; though it is almost certain that some of the phosphorus determined in the ash as phosphoric acid does not exist as such in the plant. The same can be said of sulphur. The total amount of this in the plant has been determined in several instances ; not, however, with the purpose of determining the portion present as sulphuric acid and that present in other forms, but simply to get the total sulphur in the form of sulphuric acid.

The amount of ash in alfalfa hay varies with different plants, different soils, etc. We do not speak here of the variation in the amounts of the different constituents, but simply of the total ash present.

ASH IN ALFALFA HAY.

Laboratory Samples.

First cutting :—

		Per cent.
1.	Plants quite young, (cut May 5)	10.64
2.	" quite young, (cut May 5)	12.16
3.	" not in bloom	10.21
4.	" not in bloom	9.14
5.	" in half bloom	9.30
6.	" in full bloom	10.46
7.	" in full bloom	9.24
8.	" in full bloom	9.94
9.	" in full bloom	10.19
10.	" in full bloom	10.99
11.	" in full bloom	11.34
12.	" just past full bloom	9.93
13.	" in full seed	6.77
	Average	10.03

Second cutting :—

		Per cent.
1.	Plants not in bloom	10.51
2.	" coming into bloom	11.95
3.	" in half bloom	9.48
4.	" in half bloom	9.91
5.	" in full bloom	10.97
6.	" half ripe	8.87
7.	" half ripe	9.98
	Average	10.24

Third cutting :—

		Per cent.
1.	Hay, College Farm	9.38
2.	" Rocky Ford Station	10.28
	Average	9.83

The percentages given above are practically for fine or pure ash, numbers 1 and 2, for the first cutting, being the only ones which ought to be designated as crude ash. The average percentage of ash for the first cutting, after rejecting the first and last two analyses, for no one would cut either of these samples for hay unless compelled to, is 9.08 per cent.; for the second cutting, 10.24 per cent.; and for the third cutting, 9.83 per cent.

Farm Samples.

First cutting :—

		Per cent.
1.	Hay	10.97
2.	"	11.68
3.	" damaged by rain	10.94
	Average	11.19

Second cutting :—

		Per cent.
1.	Hay, cut 35 days after first cutting	9.72
2.	" cut 35 days after first cutting	10.31
3.	" cut about 48 days after first cutting	11.26
4.	" cut about 48 days after first cutting	10.63
	Average	10.48

Third cutting :—

		Per cent.
1.	Hay	10.29
2.	"	9.94
3.	"	9.99
	Average	10.07

These percentages represent the pure ash, excepting the small amount of sand contained in them. The averages for the respective cuttings are as follows: first cutting, 11.19 per cent.; second cutting, 10.48 per cent.; third cutting, 10.07 per cent. The average for the two series is, for the first cutting, 10.35 per cent.; for the second cutting, 10.28 per cent.; and for the third cutting, 9.95 per cent. From which it appears that there is but little difference in the amount of mineral constituents removed by a ton of first, second and third cutting hay; the lowest figures requiring 199 pounds and the highest 205.6 pounds. While the percentage of ash found is not correct, due to loss of some of the constituents of the ash, chlorine and sulphur, these numbers serve to show very clearly that a five ton crop, which is some times obtained, forms a heavy drain upon the mineral elements of plant food, amounting to not less than 871 pounds per acre, after deducting the carbonic acid in the ash, or 1,025 pounds if we do not make this deduction.

WATER IN ALFALFA.

The moisture given up by green alfalfa in becoming well cured air dry hay, is as follows:

		Per cent.
1.	Plants cut very young	74.79
2.	" " " "	72.74
3.	" in bloom	70.90
4.	" in bloom	72.65
5.	" half bloom	73.06
6.	" full bloom	73.61
7.	" full bloom	74.06
8.	" full bloom	73.22
9.	" full bloom	73.67
10.	" full bloom	71.45
11.	" full bloom	74.39
	Average	73.14

Second cutting:—

		Per cent.
1.	Plants not in bloom	71.52
2.	" coming in bloom	74.35
3.	" in half bloom	68.65
4.	" in half bloom	70.40
5.	" in full bloom	74.50
*6.	" half ripe	62.91
	Average	71.08

* Not included in average.

As our analyses of the third cutting were made on hays, as prepared to put in the mow, we have no figures showing the amount of moisture lost in curing.

The average of the eleven samples of first cutting is 73.14 per cent., which means that every 100 lbs. of alfalfa as it stands in the field will give 26.86 pounds of well cured hay for the first cutting. An examination of the preceding table shows that there is not so great a difference in the amount of moisture in the alfalfa at the different stages of its growth at which it is cut for hay, or even for soiling, as might be supposed.

The average for the second cutting is some lower than for the first, but no very immature samples are included. The number of samples is also smaller, i. e., five samples with an average of 71.08 per cent. according to which each 100 pounds green crop gives 28.92 pounds of hay at second cutting. These results are much more uniform, and indicate less loss on account of moisture than those given by others. The average moisture in alfalfa hay, first cutting, is 6.03 per cent., the average of 13 samples, lowest, 3.77; highest, 8.87; for the second cutting, 5.94 per cent., the average of nine samples, lowest, 4.31; highest, 7.25. The average water content of green alfalfa, at time of first cutting, is 74.76 per cent., and at time of second cutting, 72.80 per cent.

Dr. Allen kindly furnished me with the results recorded by Dietrich and Koenig as 76 per cent. at beginning bloom; also 76 per cent. at full bloom. These are averages, the former of results ranging from 72.2 to 82 per cent.; the latter of results ranging from 70.0 to 83.1 per cent. The New Jersey Report for 1888, gives water for first cutting as 79.46 per cent.; for second, 64.37 per cent., alfalfa in drills; 80.61 per cent. for first cutting, 61.69 per cent. for second cutting, when sowed broadcast. The uniformity in our results is probably attributable to our climatic conditions and mode of culture, rather than to differences in the soils of New Jersey and Colorado. The New Jersey averages show the first cutting to contain more water, or to be more succulent than the second; while the results recorded in the Texas Bulletin No. 20, 1892, show the reverse, i. e., for the first cutting, 69.40, per cent., average of four analyses with 62.44 per cent., as the lowest, and 75.65 per cent., as the highest, and for the second cutting, 76.54 per cent. with 71.77 per cent. for the lowest and 81.59 per cent. for the highest.

AMIDE NITROGEN.

The proteids as given represent the whole of the nitrogen. There should, however, be a slight reduction made because of the fact that some of the nitrogen is present in a form of much less value than the proteids. The second column in the accompaning table gives the percentage of the total albuminoids corresponding to the amide nitrogen found. The following is the amount of amide nitrogen found in the respective samples :

First cutting :—

	Per cent. Amide Nitrogen.	Per cent.
1. Plants not in bloom	0.284	11.30
2. " not in bloom	0.187	7.48
3. " in half bloom	0.372	16.16
4. " in full bloom	0.176	7.80
5. " in full bloom	0.230	10.22
6. " in full bloom	0.239	12.26
Average		10.85

Second cutting :—

	Per cent. Amide Nitrogen.	Per cent.
1. Plants coming in bloom	0.517	17.82
2. " in half bloom	0.350	13.59
3. " in half bloom	0.614	29.47
4. " in full bloom	0.393	18.84
Average		19.93

Third cutting :—

Hay, College Farm	0.100	5.03

The proportion of proteids in the nitrogenous substances of alfalfa is represented, according to these results, by 89.13 per cent., for the first cutting ; 79.93 per cent. for the second cutting ; and 94.97 per cent. for the third. The percentage here given for the third cutting being based upon a single sample of hay, and at variance with the other results, is at best doubtful ; it is, however, the result obtained. I have found but one other series of analyses of alfalfa, in which the amide nitrogen is given, i. e., by Mr. H. H. Harrington, in Texas Bulletin No. 20, 1892. The dates on which the samples were taken are given instead of the development of the plant ; but, as the period of collecting covers forty days, I infer that the samples represent successive stages of development corresponding approximately to those given in this bulletin. The third column gives the percentage of total proteids corresponding to amide nitrogen found :

	Per cent Total Nitrogen.	Per cent. Amide Nitrogen.	Per cent.
Apr. 20	2.90	1.08	37.19
" 29	3.19	1.22	38.24
May 11	3.07	1.32	43.01
" 30	2.45	.46	18.77
" 30 (2d cut)	3.77	1.10	29.29
Average			34.31
Alfalfa not irrigated :—			
Apr. 3	4.12	0.13	3.14
" 21	4.11	1.15	28.00
May 11	2.78	0.80	28.85
Average			19.99

According to this series of analyses the proteids make up for the average, 65.69 per cent. of all the nitrogenous compounds in the first cutting alfalfa hay grown under irrigation ; and 70.71 per cent. of those of the second cutting grown under like conditions. But of these compounds, in the first cutting grown without irrigation, the proteids form 86.69 per cent., if we take the average of the three determinations given, or 71.58 per cent. if we leave out the sample taken April 3, which brings it in better accord with the other results.

These two series of determinations show clearly that the total amount of nitrogen in two different samples of hay, grown under different climatic conditions and expressed as proteids, cannot safely be taken as a measure of their relative value for feeding. As an example in point we will compare the Texas sample, collected May 11, with our sample of first cutting hay, made when the plant was in half bloom. According to Mr. Harrington's analysis, the Texas sample shows, nitrogen equal to 19.18 per cent. proteids or albuminoids, and our own air dried sample 14.41 per cent. We should, accordingly, give preference to the Texas hay, but, when we deduct the amides, we find the Texas sample has 10.97 per cent.; while the Colorado sample has 12.08 per cent. of the more valuable albuminoids left. So far as these are a measure of the feeding value of hay, the Colorado sample is really the better. If the plant were to be turned under as a manure, the more nitrogen the better, other things being equal. The difference in the amount of amides present in the two series is very great, but the methods used by the analysts were the same, the figures corresponding closely to the difference in the samples.

Our series of samples shows that the second cutting is richer in amides than the first cutting, which is still the case if we reject analysis No. 3, which seems abnormally high and for which we have no explanation to offer; also, that the amides attain their maximum in the whole plant at about the time of half bloom. It may here be remarked that the flowers, an analysis of which will be given later, are also quite rich in these amide compounds, and their abundance at the time of half bloom may determine the time of the maximum amount of amides. There is not the same fluctuation in our results as is shown in those of Mr. Harrington; they agree in showing a disappearance of these compounds as the plant begins to go out of bloom.

NITROGEN AS NITRIC ACID.

The well-known effect of alfalfa hay, particularly new hay, upon horses and the detection of large quantities of potassic nitrate in cornstalks grown under peculiarly favorable conditions, suggested the possibility of the occurrence of nitric nitrogen in this rapidly growing plant. The albuminoidal nitrogen was determined according to Stutzer's method, the filtrate rendered alkaline and subjected to distillation until ammonia ceased to be given off. The residue was acidified with sulphuric acid, run in from a graduate, and the nitric acid reduced by nascent hydrogen with the usual precautions, and after complete reduction, rendered alkaline again and distilled. The average of the results thus obtained gave us exactly the average of the blanks made with our reagents by Kjeldahl's method. The number of tests made was eighteen, and the nitric nitrogen was absent or present in exceedingly minute quantities. The roots were not tested for nitric nitrogen, but as the amids are present in them in rather large quantities, it is doubtful whether they contain more nitric nitrogen than the rest of the plant.

THE PLANT.

The preceding paragraphs have dealt with the whole plant as represented in hay, including leaves, flowers, and stems. The laboratory samples were prepared in such a manner as to preserve all the plant, and they consequently preserve the natural ratio of the different parts of the plant, which is not true of field-cured hay. In the succeeding paragraphs is given the composition of the separate parts of the plant, i. e., stems, leaves, flowers, seeds, and roots.

STEMS AND LEAVES.

Reference has already been made to the size which these attain, the diameter of 300 stems giving an average of nearly .17 of an inch, and they attain a hight of five and one-half feet under favorable conditions. It is a somewhat hackneyed observation that horses eat them (stems) more readily than they do the leaves, if not all too coarse; while cattle prefer the leaves. The percentage of stems and leaves, including flowers, varies with different plants from 40 to 60 per cent. A very leafy, small-stemmed plant may have more than 60 per cent. leaves and, consequently, less than 40 per cent. stems, but the stems of an average plant will amount to between 40 and 60 per cent. These numbers are of importance when it concerns hay making, as common experience teaches that the leaves are readily lost if the hay is not handled carefully and advantageously. In as much as many of the smaller stems may go with the leaves, the loss in making hay can, and in some cases, does amount to from 50 to 60 and even more per cent. We undertook to determine, by weight, this loss in making hay, but desisted after a very brief trial for reasons similar to those given under the subject of damage done to hay by rain. We have been led by our experience and observation, to the conclusion that the minimum loss from the falling off of leaves and stems in successful hay making amounts to from 15 to 20 per cent., and in cases where the conditions have been unfavorable, as much as 60 or even 66 per cent. of the dry crop, or, for each 1,700 pounds of hay taken off the field, at least 300 pounds of leaves and small stems are left, and, in very bad cases, as much as 1,200 pounds may be left for each 800 pounds taken. Of course, the latter is extreme, but it does occasionally happen even in this land of perpetual sunshine. The chemical loss has been referred to under proteids, farm sample, first cutting, analysis No. 3.

The stems loose 59.79 per cent. of their weight in curing, and yield 40.21 per cent. of air dry substance with the following composition:

	Water.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen Free Extract.	Total Nitrogen.	Amide Nitrogen.
Air dried	5.41	4.91	.94	6.34	54.40	28.00	1.015	0.07
Air dried	5.71	4.99	.85	6.35	54.32	27.79	1.015	[0.07]
Water free	....	5.19	.953	6.479	57.51	29.87	1.035	....
Water free	....	5.30	.900	6.469	57.61	29.72	1.035	....
Digestible	....	....	.456	4.63	25.00	20.21	.....	....

Ratio, 1 : 10.

This shows the stems to be very high in crude fiber and low in nitrogen free extract, while the proteids are almost equal to the average amount in timothy hay and the fat is less than one-half as much. Assuming the coefficient of digestibility for the stems to be equal to the average coefficient of digestibility for alfalfa as given by the New York and Colorado Stations, we have in the stem the following proportions: Digestible fat, .456 per cent; proteids, 4.63 per cent; crude fiber, 25.00; nitrogen free extract, 20.21 per cent., with a nutritive ratio of 1.10, requiring the addition of about 1.31 per cent. of digestible proteids to make the nutritive ratio 1 : 7.8, Wolff's standard ratio for horses at moderate work. The stems used in the above analyses were very coarse for alfalfa stems, and the proportion of fine stems was small. I interpret the high percentage of crude fiber as indicating this, which I otherwise know to be a fact. The stems as selected by horses from the hay probably approach considerably neared to the ratio of an agreeable, sufficient, and advantageous ration than that deduced from the above analyses. The amide nitrogen is very low.

LEAVES.

The samples of leaves were carefully picked free from all stems. They were not free from the fungus, which causes the dark brown spots and which is described in the Third Annual Report of the Delaware Station, 1890, page 79, under the name of *Pseudopeziza Medicaginis;* also in New Jersey Report for 1889, pages 152-160, as *Phacidium Medicaginis.* This fungus was so prevalent at the time of gathering the leaves, that the avoidance of every affected leaf was practically impossible. The affected leaves were not sufficient in number to have any perceptible effect upon the results. Analyses of affected leaves may be found in the New Jersey Report referred to above. Fresh leaves yield 68.72 per cent. water and 31.28 per cent. air dried matter. The water is low, for one cannot pick them without their wilting somewhat.

COMPOSITION OF LEAVES.

Condition.	Moisture.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen Free Extract.	Total Nitrogen.	Amide Nitrogen.
1. Early bloom	4.63	14.29	2.94	24.33	13.12	40.70	3.892	....
2. Early bloom	4.93	14.48	2.96	23.33	13.15	41.16	3.732	....
Water free	....	15.03	3.08	25.50	13.76	42.63	4.088	....
Water free	....	15.54	3.11	24.50	13.83	43.42	3.920	....
3. Early bloom without irrigat'n	8.40	13.60	4.10	22.18	10.67	41.05	3.549	....
4. Early bloom, without irrigat'n	8.53	13.35	3.43	22.60	10.66	41.45	3.639	....
Water free	....	14.84	4.77	24.24	11.37	44.78	3.878	....
Water free	....	14.61	4.75	24.69	11.65	45.30	3.950	....
5. Half bloom	8.62	11.39	4.28	22.30	12.48	40.90	3.568	....
6. Half bloom	8.38	11.39	4.28	23.31	12.48	40.60	3.733	....
Water free	....	12.48	4.69	24.30	13.65	44.88	3.892	....
Water free	....	12.48	4.69	25.29	13.65	44.09	4.046	....
7. Past full bloom	4.49	14.50	2.88	20.20	16.16	41.77	3.232	.506
8. Past full bloom	4.52	14.51	3.05	20.20	16.00	41.72	3.232	....
Water free	....	15.19	3.02	20.73	16.92	44.14	3.319	....
Water free	....	15.19	3.19	20.73	16.72	44.17	3.319	....
Digestible	....	....	1.47	14.75	7.43	28.40	....	....
Nutritive Ratio—1 : 2.7.								

The high percentages of ash and proteids are the salient features of the composition of the leaves. Using the same coefficients of digestion as before, we obtain a nutritive ratio of 1:2.7, a very close ratio and one on which probably no animal will do so well as on a wider one. The large percentage of ash may have some effect upon the taste of the leaves; such is readily conceivable. The ash constituents will be discussed later in connection with the fertilizing value of the leaves. As the mechanical loss suffered in hay making consists very largely of leaves, they play an important part in the improvement of the soil observed in such as has been to alfalfa for a few years and in the quality of the hay.

FLOWERS.

The flowers do not constitute at any period in the growth of the plant a large percentage of the whole, but as their appearance is the sign of the approaching retrogression of some of the food constituents, or indicates the turning point in the life of the plant, we have submitted them to analysis to aid in tracing the course of development and also of the mineral constituents. The water in them is quite as much as in the average plant, i. e., 72.69 per cent.; and the air dried matter 27.31 per cent. This sample was gathered with great care and then sorted, so that there should be nothing but the racemes of flowers, without seed pods, except very young ones. The racemes taken presented the largest number of full blown flowers and probably contained the maximum of food stored up preparatory to the formation of seed.

COMPOSITION OF THE FLOWERS.

	Moisture.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen Free Extract.	Total Nitrogen	Amide Nitrogen.
Air Dried	4.46	9.41	2.11	21.33	19.92	42.77	3.413	.692
Air Dried	4.78	9.68	....	21.48	20.08	......	3.437	.....
Water Free	....	9.85	2.21	22.35	20.85	44.74	......	......

The ash scarcely differs from the amount present in the whole plant, but the proteids and nitrogen free extract are very much higher; the former seemed probable without the analytical results and it is almost evident that they should be rich in carbohydrates. The function to be fulfilled by the accumulation of these two important components does not come within the scope of this bulletin, even if we were competent to discuss it, but it is suggestive that these two components are also present, the proteids in even larger proportion, in the seed. The ether extract, however, does not foreshadow the large amount of oil in the seed. The proteids are most abundant in the hay, when cut at about half bloom, as the flowers themselves do not form a sufficient percentage of the hay to account for the total increase; it is probable that there is really more proteids elaborated just before or at this period of growth than at any other. In making this statement we bear in mind the total weight of the plant as well as the percentage composition. Some of our analyses indicate that the dry matter contains a higher percentage of proteids if the hay be made from very immature plants, (samples cut on May 5,) but others cut at a later date, the (plants not yet in bud) do not show the same richness in albuminoids; and Mr. Harrington's series, Texas Bulletin No. 20, leaves it doubtful whether it be true, that the dry matter from very immature plants contains a higher percentage of proteids than that cut at a later stage of growth, but previous to the formation and ripening of the seed. The analyses of the leaves shows the proteids to be practically stationary from early bloom on, but to decrease after the plant has past full bloom.

We have treated so far principally of the compounds entering into the question of hay making and have selected our samples with the view of gaining information as to the best time for cutting, the influence of high or low land, and of irrigation. The results are tabulated below, being given on a hay or air dry basis. I have chosen to do this because such results correspond more nearly to the article with which our average reader is familiar than if they were reduced to the basis of dry substance. The results reduced to this basis may be found in the appendix. The statements made under the subject crude fiber seem pertinent to the other food constituents and the plant in general. The water in the hay does, as is clearly understood, make some difference; but it varies so little that its effect upon the relative results is negligible. The fats are present in comparatively small quantities, being equivalent to from 3 to 5.5 per cent. digestible carbohydrates and do not vary enough in the different samples to show clearly that the variations are due in any way to the stages of plant development; while the fat—ether extract—in Mr. Harrington's analyses (Texas Bulletin No. 20) is very much higher throughout than mine, and, in the irrigated alfalfa, shows a diminishing percentage as the season advances. The sample, which had no irrigation, shows the reverse. The fat content as shown by Mr. Voorhees's analyses (New Jersey

Rep. 1888), is also somewhat higher than mine, showing an average for hay, supposing it to contain 8 per cent. moisture, of 3.31 per cent., for drilled alfalfa and 3.02 per cent., for broadcast. The minimum is found in the third cutting, broadcast, with .53 per cent. As four cuttings were made they were probably cut quite immature. The percentage of fat, however, in Mr. Voorhee's samples agrees quite well with our farm samples, first cutting. None of the analyses show that there is as a rule more fat in the dry material of the very early cutting than in that of maturer plants.

Using the coefficients of digestion, 46 for crude fiber and 68 for nitrogen free extract, these being the average of the coefficients found by the New York and Colorado stations for the respective substances, we find the total digestive carbohydrates, neglecting the fats, to range between 36.41, as a minimum, and 40.51, as a maximum, or a variation of 4.1 per cent., including samples cut green, beginning bloom, half bloom, and full bloom, as well as the first, second and third cuttings. The proteids, as stated under this topic, appear to attain their maximum at the beginning of bloom and remain practically stationary until half bloom, or a little later, when they diminish rather rapidly. This period, during which the loss and the gain in the proteids is nearly equal, is the most advantageous time to cut for hay, both for quantity and quality, so far as the composition is a criterion. Hay possesses certain general qualities which make it acceptable to the animal and which are not dependent upon the composition. Many persons, I am informed, give preference to the second or third cutting for certain feeding. The composition of the respective cuttings shows but very little difference, the following figures giving the averages for each:—

	Ether Extract.	Crude Proteids.	Digestible Carbohydrates.
First cutting	1.54	14.85	38.03
" "	——	13.98*	
Second cutting	1.40	14.43	38.06
Third cutting	1.46	13.03	39.15

The average precentage of proteids for the third cutting is based upon the two samples of hay, which alone, would not be sufficient, but the average for the samples from the farm department makes it only 13.47 per cent., and the results of Mr. Voorhee's analyses give, for the third cutting of hay, allowing 8 per cent. moisture, 13.67 per cent. These figures for the first and second cuttings are nearly

* Not including samples cut May 5th.

the same, with a slight difference in favor of the second cutting if we reject the very early cuttings (May 5th). This, however, is compensated for in part by the larger quantity of amids present. The third cutting is inferior in composition to either of the others. The following table presents, in tabulated form, the analyses of the different samples; first, those prepared by ourselves in the laboratory; second, those received from the farm department.

Laboratory Samples.

Number.	Number of Cutting.	CONDITION AT TIME OF CUTTING.	Moisture.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen Free Extract.	Amide Nitrogen.
1	1	Very immature	4.85	12.16	....	21.79	*22.56	.. ...	....
2	1	" "	5.15	10.64	....	19.95	*29.79	......	....
3	1	Not in bloom	4.17	10.21	1.94	15.60	35.17	32.91	.284
4	1	" " different locality from preceding	7.86	9.14	1.52	14.30	37.39	29.79	.187
5	1	Half bloom	6.04	9.30	1.19	14.41	36.54	32.50	.372
6	1	Full bloom, without irrigation	4 49	9.24	2.20	13.95	32.48	37.64	.176
7	1	Full bloom, low land	6.30	10.46	1.13	14.08	40.18	27.85	.230
8†	1	Full bloom, high land	7.14	9.94	1.40	14.54	36.39	30.59	....
9†	1	" " " "	7.46	10.19	1.54	14.83	32.27	33.24	....
10†	1	" " " "	3.77	10.99	1.40	15.22	35.51	33.11	....
11†	1	" " " "	7.60	11.34	1.67	15.92	31.96	31.41	....
12	1	Just past full bloom	8.87	9.94	1.40	14.54	36.39	30.59	....
13	1	In full seed	4.70	6.77	1.03	12.16	46.12	29.22	....
1	2	Not in bloom, without irrigation	6.48	10.51	1.46	16.40	28.66	36.49	....
2	2	Coming into bloom, upland	4.40	11.95	1.14	18.47	32.46	31.58	.517
3	2	Half bloom	6.61	9.91	1.18	16.11	37.24	28.90	.350
4	2	Half bloom	5.29	9.48	1.52	13.03	37.39	33.29	.614
5	2	Full bloom	4.31	10.97	1.76	12.88	38.06	32.02	.202
6	2	Half ripe, upland, with irrigation	7.24	8.92	1.99	12.08	30.99	38.79	....
1	3	Hay, College Farm	5.78	9.38	1.61	12.53	39.35	31.35	.100
2	3	Hay, Rocky Ford Station	6.08	10.28	1.31	13.57	34.67	34.09	....

LEAVES, ETC.

..	....	Leaves, with irrigation	4.93	11.48	2.96	23.33	13.15	41.16	....
..	....	" " "	4.63	14.29	2.94	24.33	13.12	40.70	....
..	....	" " "	8.40	13.60	4.10	22.18	10.67	41.05	....
..	....	" without irrigation	8.53	13.35	3.43	22.60	10.66	41.45	....
..	....	" " "	8.62	11.39	4.28	22.30	12.48	40.90	....
..	..	" half bloom without irrigation	8.38	11.39	4.28	23.31	12.48	40.60	...
..	....	" " " "	4.49	14.50	2 88	20.20	16.16	41.77	....
..	....	Plants past full bloom	4.52	14.51	3.05	20.20	16.16	41.72	....
..	....	Stems	5.41	4.91	.94	6.31	54 40	28.03	.070
..	....	Flowers	4.46	9.41	2.11	21.33	19.92	42.77	.692
..	....	Seed	6.35	3.19	14.41	29.26	9.35	37.04	....

* Not included in average.
† Samples 8, 9, 10 and 11 grown in drills.

Farm Samples.

Number.	Number of Cutting.	Condition at Time of Cutting.	Moisture.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen Free Extract.	Amide Nitrogen.
1	1	Individual plant	7.27	10 97	3.89	17.72	24.54	35.67	....
2	1	Individual plant	6.71	11.68	3.43	17.08	24.64	36.42	....
3	1	Hay, damaged	9.61	10.94	3.44	9.95	35.09	30.97	...
1	2	Individual plant	4.88	9.72	.82	12.15	34.59	37.84	....
2	2	Individual plant	3.71	10.31	1.17	12.29	38.08	34.43	....
3	2	Individual plant	11.61	11.26	1.69	15.26	29.07	31.11	....
4	2	Individual plant	11.75	10.63	2.43	16.26	26.16	32.77	....
1	3	‡ Sample, Field D	6.28	10.29	1.93	15.83	28.89	36.78	....
2	3	Prime hay	4.71	9.94	1.24	12.01	37.29	34 81	....
3	3	Prime hay	5.58	9.94	1.11	12.57	34.91	35.84	....

‡ Sample somewhat charred in drying.

ALFALFA AND CLOVER HAY COMPARED.

The plants from which these hays were cut, were growing side by side under identical conditions, were cured in the same manner, and are comparable in every respect. The clover was very vigorous; the flowers were very nearly half turned; the stems were stout, but leafy; and the whole plant was in prime condition. The hay was cured in a sack as before described in the account of the preparation of our alfalfa samples. A sample of alfalfa also in prime condition and in half bloom is chosen for the comparison. The green clover yielded 24.25 per cent. of hay, and 75.75 per cent. of water, and the alfalfa 26.94 per cent. of hay and 73.06 per cent. of water.

	Moisture.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen Free Extract.	Amide Nitrogen.
Clover, heads half turned	5.36	10.17	1.88	13.43	28.97	40.20	.155
Clover heads, half turned	5.22	9.97	2.03	13.43	28.83	40.53	....
Water free substance	....	10.75	1.99	14.18	30.61	42.46	....
Water free substance	....	10.52	2.15	14.18	30.42	43.74	....
Average, water free	....	10.63	2.07	14.18	30.52	43.10	....
Alfalfa, half bloom	6.04	9.30	1.19	14.43	36.54	32.50	.372
Alfalfa, half bloom	6.29	9.33	1.51	14.43	36 38	32.06	....
Water free substance	....	9.89	1.26	15.37	38.88	34.60	....
Water free sub-tance	....	10.06	1.61	15.37	38.53	34.43	....
Average, water free	....	9.98	1.43	15.37	38.71	34.51	....

The coefficients of digestion for good quality clover hay is given, in Massachusetts State Experiment Station Report for 1893, as 48 for crude fiber, 49 for proteids, 43 for ether extract, and 58 for nitrogen free extract; and for alfalfa, 46 for crude fiber, 73 for proteids, 51 for ether extract, and 68 for nitrogen free extract.

One hundred pounds of this clover hay contain, when perfectly dry, 47.49 pounds digestible food, of which 6.95

pounds is proteids, while the alfalfa furnishes 54.43 pounds digestible food with 11.22 pounds proteids. The green alfalfa crop yielded in this case almost 2.5 per cent. more dry matter, which contains about 7 per cent. more digestible food than the clover.

ALFALFA, RED CLOVER AND PEA-VINE ENSILAGE COMPARED.

The loss in making alfalfa hay, together with other considerations, has led to some experiments in making alfalfa silage. The following samples were received, one in late summer and the other in late winter. The condition of each was considered good, and cattle were reported to eat them freely, even in early fall when they had access to green pasture. The average dry matter, as determined in three samples, is 30.19 per cent.

Sample No. 1—Farm Department—Silage made from first cutting :—

	Moisture.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen Free Extract.
1. Alfalfa Ensilage	8.98	13.19	2.93	14.18	30.77	29.95
Water Free	....	14.46	3.22	15.57	33.49	33.25
2. Alfalfa Ensilage	2.21	11.91	1.19	17.63	36.06	31.00
Water Free	....	12.19	1.22	18.02	36.89	31.70
3. Pea-vine Ensilage	4.71	14.91	3.24	10.95	30.06	36.13
Water Free	....	15.63	3.40	11.03	31.39	38.54
4. *Red Clover Ensilage	....	9.30	4.10	15.00	29.90	41.70

*Expt. Sta. Bul. No. 11, p. 52.

These samples of ensilage were in good condition when received at the laboratory. The alfalfa silages, particularly No. 2, had a marked disagreeable odor and taste ; the pea-vine ensilage was bright, with an agreeable odor and a pleasant acid taste. Mr. Empson, of Longmont, through whose kindness this sample was furnished, informs me that the vines used in making silage are of varieties grown by their company for canning. The peas are threshed out and the vines are put in silos and subsequently fed to sheep or lambs. The vines are cut when the crop is in best condition for canning. It is evident that this pea-vine silage is poorer than pea-vine silage would be by whatever of nitrogen, etc., is removed in the peas. The ash in the pea-vine silage is really not so high as appears in the analysis. It amounts to 8.96 per cent., after the deduction of sand. It will seldom be advantageous for the farmers of this country to make their alfalfa crop into ensilage, but if they should choose to, the ensilage produced, as shown above, will compare favorably with a very good quality of alfalfa hay, and is quite as well adapted to this use as red clover or pea-vines. Alfalfa, when stacked with a great deal of moisture in it, sometimes passes through a fermentation, producing a hay which may be considered as intermediate between alfalfa hay and ensilage. In the cases which have been called to my attention this result has been obtained by accident, and, of course, without special care or extra labor. This is very near to the so-called brown hay ; its color is reddish and it is a very agreeable fodder to cattle.

As to the digestibility of either the ensilage or of this red or brown hay, I find no data; but cattle fed on either are said to thrive admirably, and it seems probable that the digestibility in these cases does not differ materially from that of the field-cured hay. In making alfalfa ensilage, the silage must be carefully protected from the influence of conditions producing further changes than those producing the ensilage fermentation. The following analysis of damaged ensilage will enforce this statement:

	Moisture.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen Free Extract.
Damaged Alfalfa Ensilage	5.90	17.89	2.34	15.47	46.18	12.22
Water Free	....	19.01	2.49	16.41	48.90	13.19

The decrease in the percentage of nitrogen free extract and the increase in that of the ash and crude fiber are equally noticeable.

What the loss of dry matter was in either of these cases I do not know. Storer, in his Agricultural Chemistry, quotes the loss of dry matter in making alfalfa ensilage at 27 per cent. The amide nitrogen was not determined in these ensilages, and, while it is known that there is a retrogressive change in the nitrogenous compounds in making ensilage, I have no data on which to base an approximate estimate of the loss of these in either of the preceding instances. The damaged ensilage is richer in total nitrogen than the prime ensilage, No. 1, and the nitrogenous compounds seem to have changed slowly ; this, however, is subject to modification, due to the formation of amides; also a small amount of ammonia from the albuminoids.

ELEMENTS OF PLANT FOOD TAKEN FROM THE SOIL.

The leguminous plants, to which order alfalfa belongs, store up in their stems a large amount of nitrogen which they are believed to obtain largely from the atmosphere, and for this reason they are considered as nitrogen gatherers, adding to the soil more nitrogen than they draw from it, provided the plants are not removed, but fall where they grow or are plowed under. But, when the hay is taken off the field, the problem is a different one, and whether it adds to the nitrogen in the soil or takes from it, depends upon the ratio of the nitrogen in the leaves and stems which fall and decay upon the soil to that taken from the soil proper in the form of nitric nitrogen. As I know nothing of the value of this ratio, I am compelled to content myself with the general results which are well known; still, under the discussion of the roots, we shall see that there are reasons why we are justified in doubting whether the store of nitrogen in the soil is added to by growing alfalfa; on the contrary, while this plant is provided with tubercles—micro-organisms which enable it to appropriate atmospheric nitrogen—it is also a greedy feeder upon the soil nitrogen.

The benefits which accrue to soils cropped to alfalfa are unquestionably great, but whether they are lasting, or call for a quick rotation in order to be maintained, is still to be established. The case of the other elements of plant food is not involved by any compensation as in the case of nitrogen; but every pound taken away is at the expense of the supply in the soil. As our soils have not been under crops of any kind very long, and to alfalfa only a short time, it is a reasonable assumption that the average mineral constituents of the ash correspond very nearly to the requirements of the plant. The quantities given by our analyses, representing plants supplied with an abundance of available food, are probably high enough.

The accompanying table gives the ash constituents taken from the soil with every 1,000 pounds of hay. The sand, carbon, and carbonic acid are rejected in this table. There may appear to some to be a discrepancy between the table as given on page 31, and the following; the two are, however, the same as concerns the following subtances contained in the ash:

POUNDS PLANT FOOD PER 1,000 POUNDS ALFALFA HAY.

Cutting.	CONDITION OF PLANT.	Silica.	Phosphoric Acid.	Sulphuric Acid.	Chlorine.	Lime.	Magnesia.	Iron Oxide	Alumina.	Manganese Oxide.	Potash.	Soda.	Total.	Nitrogen.
1	Green..........	1.158	4.923	4.349	9 655	22.352	3.159	.371	.159	.163	29.720	1.174	77.183	24.96
1	Green..........	1.006	4.031	4.323	5.169	21.528	3.314	.386	.147	.109	25.848	1.237	67.098	22.89
1	Half bloom.....	.924	4.105	4.418	3.865	21.690	3.343	.295	.165	.109	26.078	1.434	66.426	23.08
1	Half bloom.....	1.404	4.138	5.230	6.288	22.182	5.523	.369	.235	.174	22.209	1.708	69.461	21.40
1	Full bloom.....	.813	4.839	5.182	10.052	25.522	3.509	.248	.083	.156	22.398	.869	73.671	23.16
1	Full bloom.....	1.808	4.015	3.412	6.829	25.647	3.776	.074		.064	28.137	.857	74.619	22.53
1	Full seed.......	.706	3.474	2.705	4.851	12.934	2.864	.261	.157	.155	17.985	2.586	48.678	19.46
2	Begin'g bloom..	.917	4.709	7.306	10.359	31.038	4.031	.360	.066	.230	30.324	2.223	91.563	28.91
2	Half bloom.....	.631	4.812	7.356	10.174	26.626	3.824	.259	.109	.156	27.930	1.838	83.715	25.89
2	Full bloom.....	.919	4.882	7.194	10.541	28.390	4.358	.363	.186	.205	26.076	1.073	84.187	20.61
2	Past full bloom.	1.353	4.238	4.257	8.428	27.426	4.124	.115		.084	10.643	.948	70.616	20.85
3	Hay.............	.402	3.397	3.087	40.839	18.694	3.605	.175	.081	.107	24.693	4.255	63.335	18.95
..	Red clover......	1.831	3.661	1.260	2.573	23.778	5.227	.102	......	.203	25.160	.223	64.018	21.49
..	Flowers	2.971	7.248	5.887	4.593	15.948	3.720	.957	1.110	.191	24.076	3.787	70.487	34.12
..	Leaves..........	2.673	4.367	16.704	7.009	45.425	7.626	.821	.814	.317	13.196	5.396	104.348	31.77
..	Leaves..........	1.009	5.114	13.062	8.665	33.042	5.395	.344	.273	....	21.277	4.411	92.592	35 68
..	Leaves..........	1.048	4.661	9.381	10.906	52.569	5.839	.602	.141	.266	15.846	1.062	102.221	35.49
..	Leaves..........	1.159	4.900	15.356	8.490	50.488	6.425	.610	.139	.447	15.447	5.157	108.618	38.92
..	Stems...........	.790	2.198	1.711	2.934	7.002	2.563	.225	.233	.082	13.184	4.110	35.032	10.09
..	Stems...........	1.099	3.039	2.392	4.102	9.768	3.604	.328	.334	.112	18.394	5.710	48.882	.....
..	Stems..........	.731	3.769	1.297	6.381	9.117	2.915	.340	.183	.098	20.817	2.813	48.461	......
..	Stems...........	1.015	3.272	1.254	6.525	11.671	2.871	.239	.244	.097	24.159	.721	52.068	......

These results show that, with each ton of first cutting hay, there is removed an average amount of 143 pounds of ash constituents; with each ton of second cutting hay, 165 pounds; and with the third cutting, 127 pounds per ton. Our sample of red clover gives 128 pounds against 143 pounds for the alfalfa. The following are the amounts of the most important plant foods taken from the soil and air by the successive cuttings of alfalfa and red clover hay per ton of 2,000 pounds:

	Nitrogen.	Phosphoric Acid.	Potash.	Sulphuric Acid.	Chlorine.	Lime.	Magnesia.
First cutting..........................	46.00	8.69	51.46	8.97	13.95	46.40	7.54
Second cutting.........................	48 13	9.32	51.99	13.06	19.75	56.74	8.17
Third cutting	37.90	6.79	49.39	6 17	8.16	37.39	7.21
Average for alfalfa hay	44.01	8.27	50.95	9.40	13.95	43.51	7.64
Alfalfa in full seed	38.92	6.95	35.97	5.41	9.70	25.87	5.73
Red clover, heads half turned..........	42.98	7.32	50.32	2.52	5.15	47.56	10.45

This table gives the amount of plant food removed by a ton of average hay; but if the amount removed by an average crop is desired, we have taken 1.65 tons for first cutting, 1.2 tons for the second cutting, and 1 ton for the third cutting. This is estimated on a yield of 3.8 tons for the three cuttings, which is not far from the average crop. This correction changes the total amount of mineral matter removed from 167.23 to 169.26 pounds. Actually weighed crops seem not to be of record in such numbers as to give them value as a basis. That four, five and more tons have been cut per acre, is not doubted, but such yields are not the rule. The land of the Rocky Ford Station has yielded a trifle over five tons and so has land near Loveland, in this county, and doubtless at many other places, but these are large and not average yields. Estimated yields are seldom too low and measured tons are only approximately correct, but they serve a good purpose when nothing better is available. Adopting the judgment of sixteen farmers of Colorado, some of whom are known to the writer as practical and conservative men, we make the average yield 3.7 tons per acre. Mr. A. A. Mills, of the Utah Station, makes the yield from measured areas 4.24 tons per acre. These figures seem exceedingly conservative when compared with many current estimates, but they are fully high enough for the average crop and close approximations to its upper limit.

ALFALFA SEEDS.

The ordinary analysis of the seed is given in the table on page 31, and the ash analysis in the appendix. The fat or oil—ether extract—was determined by both my assistant, Mr. Ryan, and myself. Mr. Ryan obtained 14.41 per cent. and I 14.04 per cent. Mr. Ryan extracted his portions for many days; I extracted mine for eight hours. There seems to be a volatile portion, which gave Mr. Ryan trouble in determining the moisture.

AMOUNTS OF SEED COMMENDED FOR SOWING PER ACRE.

The practice followed by many intelligent farmers of selling the good seed and sowing the screenings, led us to make the following experiments, even though they digress from the main purpose of this bulletin.

The fresh seed has a light greenish yellow color which is sensitive to the light, eventually becoming reddish brown. The size of the seed varies; it is described as larger than clover seed. A sample gathered by hand from plants growing singly on a poorly irrigated piece of ground, had the following properties: bright greenish yellow color; more than twice as long as broad; and as a rule not as thick as broad; thicker at one end than at the other, giving the seed a slightly twisted appearance; length a little more than 3-32 of an inch. The pods were full, the seeds pressing one upon the other. The analysis of these seeds is given in the table. When well dried the seeds absorb moisture readily. Fifteen portions of one gram each were weighed off, after thoroughly shaking the sample, and counted. The average was found to be, 456 seeds to the gram ; lowest number per gram, 450 ; highest number 463 ; number of seeds per pound, 206,837.

Sample No. 2, purchased in the market, gave 458.6 seeds per gram ; 208,021 seeds to the pound. These seeds were not so even in size as the first sample. There were a few shrunken seeds. The sample was clean, containing less than one per cent. by number of foreign feed. Sample No. 3, also purchased in the market, was of a brownish yellow color; sample contained 8 per cent., by number, of foreign seed, mostly of an amaranthus. The average number of seeds to the gram of this sample was 504.46. The seeds were very even in size ; minimum number to the gram, 503 ; maximum, 505. The number of seeds to the pound was 228,818.

Sample No. 4, consisted of first quality screenings, furnished by J. E. Gauger, Rocky Ford, Colo., about 65 per cent. of which was immature when cut. The seed was shriveled and dark brown in color. The sample was quite free from grass seeds, weed seeds, and stems, and contained 259,340 seeds to the pound.

Sample No. 5, first quality screenings from the same source as No. 4, was dark and contained many shriveled seeds, in which by weight there was 23 per cent. of impurities—grass and weed seeds. This sample contained 344,123 seeds to the pound.

Sample No. 6, first quality screenings (J. E. Gauger) seed evidently well cured, many seeds green and immature, contained 266,233 to the pound.

Sample No. 7, second quality screenings (J. E. Gauger), containing more stems and weed seeds, especially of an amaranthus, than any other sample, contained 331,383 seeds per pound.

Sample No. 8, third quality screenings (J. E. Gauger), was quite clean. The seeds were large, but shriveled, numbering 312,385 to the pound.

We may assume that a pound of first-class seed contains 210,000 seeds; first quality screenings, 260,000 and occasionally many more on account of shriveled seeds ; and for second and third quality screenings, about 320,000 seeds to the pound.

THE QUESTION OF WHAT IS A GOOD STAND.

The amount of seed sown to the acre in this state varies exceedingly, the smallest that I know of as having been sown for a hay crop, being seven pounds per acre; and having examined the stand personally, I have no doubt but that it will produce as large a crop as a heavier seeding would, but whether there is the same certainty of getting an even stand is a question. In this case it was very even. The highest amount that I have seen given as sown to the acre is thirty pounds. Twenty and twenty-two pounds to the acre is common. This gives us, supposing prime seed to be used, from 1,470,000, with seven pounds, to 4,620,000 seeds when twenty-two pounds of seed are sowed to the acre. There is certainly a wide difference in practice, and it is claimed, with no difference in the result, either in quantity or quality of hay. The majority is unquestionably in favor of heavy seeding, but the minority seem to me to have more reason on their side.

The quantity of seed to be sown to the acre was touched upon by Miller (1807). "In sowing broadcast Rocque directs fourteen pounds to the acre; in Kent they sow twenty pounds, which is generally allowed to be the proper quantity; in France they allow near thirty pounds to an English acre. Some sow only ten pounds with six pounds of broad clover, to have a crop the first season, both with a thin crop of barley or oats." Again, he says: "The field was sown broadcast with Lucern seed. * * Twelve pounds to the acre sown at twice." And of another field of broadcast Lucern sown twenty years before with barley. "The plants were in patches or single, often two or three feet apart; yet it produced four tons of hay on an acre, at three cuttings. * * * It also shows what a large space plants of Lucern will fill."

Two reasons can be urged in favor of heavy seeding, and if they are founded on facts, they are sufficient to justify the practice. One is that a thick stand produces a more desirable hay than a thinner one; the second is that a large amount of seed is necessary to obtain such a stand. In the first proposition there is clearly a lack of definiteness in the term "a thick stand." Very few persons who use the term have any idea whether they mean by this one or twenty plants to a square foot, and I doubt whether there is any increase of crop or quality of hay gained in one field with 260,000 plants to the acre over another with one-half that number, assuming that the stand is equally even in the two fields and that other conditions are similar. This is six and three plants to the square foot respectively.

We have given ourselves some trouble to establish something definite regarding the terms stand, good stand, etc., in connection with the weight of stubble plowed under.

A piece of alfalfa, six months old, contained fifteen plants to the square foot, or 653,400 per acre (Prof. W. W. Cooke), which is one plant for every seven seed on the basis of twenty pounds of seed to the acre. A measured piece, twenty-five feet square, was plowed up and the plants picked out of each furrow in turn, the whole of the soil being turned over by hand, and the number of plants to the acre was found to be 526,793. Prof. A. E. Blount writes me that this field was seeded to alfalfa May 10, 1886, and was consequently ten years old. The roots were very small, not over one quarter of an inch thick at the crown, and were in a remarkably healthy condition. This portion of ground is as high as any other cultivated portion of the college farm and is a fine, loamy soil. The yield last year was rather over four tons (weighed) per acre.

Mr. Philo K. Blinn, Superintendent of the Rocky Ford Experiment Station, in Otero county, at my request, measured off a square twenty-five feet on the side and counted the plants. He found 139,392 to the acre. This is a most excellent piece of land, alluvial soil. The yield of alfalfa hay last year was 4.4 tons per acre. Mr. Blinn measured two small squares, 5x5 feet, obtaining 291,000 and 305,000 plants in these.

I selected an average plat 25x25 feet in a field one year old seeded with twenty-two pounds of seed to the acre, cross drilled 11 pounds each way. The soil is a fine loam, subsoil sandy clay succeeded by fine sand. This plat has been in cultivation a number of years. The stand would be designated as "very good." The cross drilling showed plainly at this date, April 29. Number of plants per acre, 331,122.

A piece 25x25 feet of another field, sowed to alfalfa May 17, 1884, twenty pounds of seed to the acre, (Prof. A. E. Blount), was plowed up. This field of alfalfa is in bad condition. The stand is very irregular, large patches of ground being entirely bare. The soil is a sandy loam, with clay subsoil; water plane four to eight feet from the surface. Number of plants per acre, 70,283. Nearly every plant has a hollow crown and root; yield per acre last year something over three tons. At three tons this is approximately 1 1-4 ounces of hay or less than 4 1-6 ounces green weight to the plant for the season. In the case of the 562,-793 plants and four tons yield, it is only 1-4 ounce of hay to the plant, or one ounce of green weight for the three cuttings. I sought out twenty plants growing singly, which had received no care whatever. They were in patches of volunteer plants. The weights were taken immediately upon cutting and averaged 14.4 ounces or 3.8 ounces of hay to the plant. The average number of stems was 39 to the plant; the highest number was 58. The lowest weight was about 1-3 of a pound, the highest 2 1-3 pounds. Any one familiar with alfalfa will recognize that these plants can be duplicated easily and are by no means unusually large. I found a plant standing quite by itself in the field of James Whedbee, the space in which the plant grew being about three and possibly as much as four square feet. There arose from the crown of this plant 161 stems. I dug up one other plant, which had 360 stems on it; the space covered by this crown was about three square feet. The weight of these I regret was not determined. Others have observed even larger plants. Miller says that he had a plant whose crown was eighteen inches in diameter, and from which he cut nearly four hundred stems at one time. M. Duhamel states that a flourishing plant will produce a pound of well dried hay. These facts seem to me very suggestive. I have noticed with some degree of attention the size of the stems on these large plants and I do not find them of noticeable coarseness. I believe that every advantage supposed to be obtained by crowding the plants, whether the claim be well founded or not, will be produced with an even stand of not more than four plants to the square foot, and of two or even one under favorable conditions. The importance of favorable conditions is admirably shown by the yields of the plat giving 526,793 plants per acre. In 1893 it yielded 2 2-5 tons at the first cutting; this year about one ton. Moisture is necessary to the production of a crop of alfalfa. I regret that we have no analyses of hays cut from crowded and from singly growing plants. Granting, however, that a stand of a half million plants to the acre is desirable, is so large a quantity of seed as twenty pounds, about 4,200,000 seeds, necessary to produce it? This will depend first of all upon the germinating power of the seed, and also upon the vitality of the plants produced.

VITALITY OF ALFALFA SEED.

It is claimed that alfalfa seed soon looses its germinating power, and that the young plants are very tender, though hardy enough when established and older. Concerning the former, Loudon says: "Great care should be had to procure it (Lucern seed) plump and perfectly new, as two years old seed does not come up freely." In North Carolina Bulletin No. 60, these seed are described as twice as large as red clover seed with a brownish yellow hue. "The vitality of Lucern seed is so low that seed over one year old is scarcely worth sowing." The author of that bulletin records two sprouting experiments made with presumbly two years old seed, showing only 6 and 12 per cent. of the seed capable of germinating. This is quite in accord with the statement of Loudon. Not finding myself able to unhesitatingly subscribe to these results, I collected the following samples of seed. I experienced difficulty in obtaining in our local markets seed two years old, even after explaining my desire and object.

1. Prime seed, two years old, gathered by myself.

2. Prime seed, two years old, obtained in market fresh and kept in laboratory.

3. Prime seed, obtained of P. Anderson & Co., probably two years old.

4. Prime seed, two years old, grown in Otero county, (J. E. Gauger).

5. Prime seed, three years old (J. E. Gauger).

6. Prime seed, six years old, obtained from Professor Crandall, whose record shows that this seed was obtained from P. Henderson & Co., of New York, through the Department of Agriculture at Washington, D. C., in the spring of 1891. This sample had been kept for most of this time in a 2-oz. bottle, exposed to the light in a show case. The seeds were discolored, reddish brown, and emitted a rancid odor when poured out for the purpose of mixing. I, of course, have no record of the variations in temperature to which these seeds had been subjected, but they were certainly great. Their state of moisture varied, also, but probably less than any other external condition.

7. Screenings, first quality, one year old, (J. E. Gauger).

8. Screenings, first quality, two years old, (J. E. Gauger).

9. Screenings, first quality, three years old, (J. E. Gauger).

10. Screenings, second quality, two years old, (J. E. Gauger).

11. Screenings, third quality, one year old, (J. E. Gauger).

The following tests of these seeds were made with such facilities as are at the command of every farmer. A common tumbler was filled with crumpled paper to about half its hight and pressed down until it was quite even. On this were placed three disks of ordinary blotting paper ; the seed were strewn upon the upper one of these disks and covered with two similar disks of blotting paper and one of cardboard. The crumpled paper was thoroughly wetted, the disks and seed put in place, and enough water added to fill the bottom of the tumbler to the depth of about half an inch, and placed on a box behind the sitting room stove. The water that evaporated had to be replaced, and required the addition of a tablespoonful night and morning. The tests were continued for fourteen days; the record is as follows:—

RESULTS OF SPROUTING EXPERIMENTS.

No. of Sample.	Quality.	Years Old.	Number of Seeds to the Pound.	Seeds Taken.	Seeds Rotted.	Seeds Left.	Seeds Sprouted.	Average per cent. Sprouted.
1	Prime seed	2	206,837	100	0	0	100	96.0
				100	0	8	92	
2	Prime seed	2	228,818	100	1	9	90	92.0
				100	0	6	94	
3	Prime seed	2	208,021	100	1	7	92	95.5
				100	1	0	99	
4	Prime seed	2	....	100	1	13	86	88.0
				100	5	5	90	
5	Prime seed	3	....	100	0	2	98	98.5
				100	0	1	99	
6	Prime seed	6	....	100	5	1	94	93.0
				100	5	3	92	
7	Screenings, first quality	1	259,340	100	23	11	66	66.5
				100	20	13	67	
8	Screenings, first quality	2	344,123	100	42	7	51	55.5
				100	29	11	60	
9	Screenings, first quality	3	266,233	100	24	1	75	79.0
				100	16	1	83	
10	Screenings, second quality	2	331,383	100	59	7	34	38.0
				100	53	5	42	
11	Screenings, third quality	1	312,385	100	66	1	33	38.5
				100	48	5	47	

The seed designated as "left" or hard seed, make from 1.5 to 9 per cent. of the samples of prime seed and from 1 to 12 per cent. of the screenings. These seem not to imbibe water for a long time, but eventually they do when they swell and sprout in large numbers. The hard seed remaining at the end of the sprouting tests were put together and the test continued for an addional twenty days, when 78 per cent. of them had sprouted, 13 per cent. rotted, and 9 per cent. were still left. This explains, in part at least, the observations that some alfalfa seed seems to lie dormant for a time.

The sprouting tests were continued for from 13 to 16 days, but a sufficiently accurate estimate of the germinating power of the seed could have been formed by the end of the third day, as the following shows :—

THE NUMBER OF SEEDS WHICH HAD EITHER ROTTED OR SPROUTED AT THE END OF THE THIRD DAY.

				Per cent.
Prime seed, two years old				87.00
Prime seed, six years old				80.50
First quality screenings, one year old				84.00
" "	"	two	" "	85.00
" "	"	three	" "	85.00
Second "	"	two	" "	85.00
Third "	"	one	" "	93.00

There is a considerable difference in the readiness with which the different samples of the same age germinate, more even than between samples of different ages. The quickest of the eleven samples to germinate was the one six years old. The results are positive in showing that the age of the seed up to six years old does not effect their germinating power. In regard to the vitality of the plants produced, I have made no observations, but so far as I could judge from the vigor with which the seeds sprouted, I would say that it depended upon the seeds themselves rather than upon their age; the seeds of some samples being obviously stronger than those of others, and each sample showed this difference between the individual seeds.

These tests and observations also strengthen the claim made that in practice screenings produce as satisfactory results as prime seed. Taking it on the basis of the germinating power in the most unfavorable sample, second quality screenings two years old, with only 38 per cent. germinating, we have, where twenty pounds of seed are sown to the acre, 1,325,532 plants, and assuming that one-seventh of them live, there would be 189,361 plants to the acre, or over four to the square foot, a sufficient number surely to produce a maximum crop. It sometimes happens that it is necessary to re-sow a field the second year, even with twenty-two pounds of seed per acre. Such failures are not due to the quantity of seed nor to the germinating power. I do not believe that it would happen oftener with eleven pounds to the acre than it does with twenty. It is not my province to seek the causes of such failures, but I think I have adduced sufficient proof that it does not lie in the germinating power of the seed.

ROOTS OF ALFALFA.

That this plant is an exceptionally deep rooting one, has been recognized by every writer on the subject, as is evidenced by the statements to be found scattered through the literature on this subject ascribing a length of ten, fifteen, thirty-five, and even more feet to its roots. The popular estimation of their length has been and is equally appreciative of their power to penetrate to considerable depths. The size attained by the roots has also been stated to be large, but the writer does not recall having seen any figures given to convey a definite ideâ of the size actually attained under stated conditions of soil, age of plant, cultivation, etc., but rather that the root is a tap root, large and fleshy, "resembling a carrot" more or less,or is represented as forming a symmetrically formed but inverted cone, in which system the tap root is, as a matter of course, the longest and central portion or axis.

The size of alfalfa roots is not so great as the usual adjectives used in describing them would lead one to infer. It is a strong root, but is under one-half inch in diameter, rather than above it. This statement is true of the plants when grown in a deep, sandy loam, under favorable conditions as to irrigation and climate, including mild winters. Larger roots have been observed by the writer, but there have been special conditions obtaining wherever this has been the case and these roots represented the size which the alfalfa root may attain, and not the average size which they actually do attain when growing in ordinary soil, and standing thick enough to produce, say 3 1-2 tons of hay per acre, with three cuttings annually. The largest root measured by me, was 2.82 inches in diameter, being nearly circular in section, though not quite ; its largest diameter was rather more than three inches. An examination proved that this was an anomalous root. For some reason, not discovered, the tap or central root was short, not exceeding 1 1-2 feet, at which point it divided, giving rise to several rather small branches which were not followed as they spread out, running several feet almost horizontally. This dividing could not be attributed to the roots having encountered a hardpan or other obstacle, for the soil at this depth was uniform in hardness above and below the point of spreading. I have seen several very large roots, but have found upon digging them out, that they were in every case short and at variance with what seems to be the normal type.

The root system of this plant, growing in our soils, is exceedingly simple and is shown in the plates. The roots represented, are from three different counties, the soils varying from sandy loam to heavy clay. They show a marked permanency in type of development in a simple tap root, running down to from three to five feet and then sending off a few side roots, or rather dividing into a few branch roots about equal in size and length. These branches do not, as a rule, deviate more than a few inches from the course pursued by the tap root before division. I have in no case found a system of small roots starting out below and near the crown, extending laterally for several feet and then turning downward, forming a symmetrical conical system, whose broadest part was near the surface. The absence of such roots was a matter of note to me, but after having observed it in upwards of three hundred and fifty instances, I was satisfied that it was a habit of the plant. In cases where I found any root or roots setting out from the tap root immediately under or near the crown, they were large, usually as large as any of the roots formed by the branching of the tap root, and in every instance in which I was able to follow them to the end, they extended to almost or altogether as great a depth as the tap root itself or any of its divisions. When such side roots occured, we found but few of them, as a rule only one or two. This is well shown in one of the plates. The tap root, as well as all its divisions, are remarkably smooth and free from fibrous roots. The tap root is often perfectly smooth, save for the wart-like excressences on it, caused by its symbiotic micro-organisms; so much so that it can be removed after having been properly exposed, leaving a perfect cast of the root in the undisturbed soil. Close investigation of the adjacent soil has failed to show small roots even a few inches in length, such as may be found practically possessing the ground for many inches—twenty or more—about the vetch, tomato, or almost any of our garden plants. It may be stated here that the plants studied had not been cultivated, that is, the soil about them had not been disturbed from the time the seed was planted until the plants were dug up, except in cases where the fact will be explicitly mentioned.

The absence of these small fibrous roots has been and still is perplexing, as it was anticipated that such a vigorously growing plant would be well supplied with such, each provided with its spongiole to provide the plant its necessary sustenance. While the number of spongioles found was in the aggregate large, it was much smaller than expected and the spongioles were at the extremities of the roots themselves and almost exclusively at a depth corresponding to that attained by the root. This observation is in perfect accord with the usual statement that alfalfa is a deep feeder and furnished a very convenient explanation for the observed effect of an alfalfa rotation upon an exhausted soil; but it is contrary to another fact which has also been observed, i. e., that alfalfa responds quickly to top dressings of fertilizers, barnyard compost and ashes being the fertilizers here referred to. Other fertilizers may produce equally quick and marked effects, but reliable observations have been made with these two. The spongioles were found mostly at or near the depth reached by the tap root. The form and size of it varied greatly. It was as a rule cylindrical, from one to one and a half inches long and terminated by a rather stiff hair-like projection. The root leaving it was much smaller than the spongiole for several inches behind it, and, consequently, was growing in a free space made by the extending spongiole. The amount of work done by the plant in this manner is very great. While the cylindrical form prevails, others also occur, a double cone shape being quite common. As already intimated, these were not found in large numbers near the upper part of the roots; and at no other point except where the softness of the ground and a greater abundance of food encouraged their development. Such conditions were found, for instance, in refilled prairie-dog holes which were always crowded with them and in places very thickly so.

THE DEPTH ATTAINED BY THE ROOTS.

The depth to which the roots penetrate and at which they feed varies, as a matter of course, with the soil; and in cases where the permanent water table lies within twelve feet of the surface, with this also, as the roots do not according to my observations enter the water for a greater distance than from four to eight inches. The popular notion that the roots cannot endure the water, but cease to grow and decay as soon as they reach it, is not substantiated by observation. They do cease to extend further downward, but all that I have had opportunity to observe were healthy and vigorous. I entered the permanent water plane at two localities where I dug out the roots. In one instance the water was alkaline (Jas. Whedbee's place, 1½ miles from Fort Collins); in the other (Rocky Ford, Otero County) the water, an analysis of which will be given later, was as bitter as a solution of Epsom salts. The roots, however, penetrating it were not dead. In the former case the water was only six feet seven inches and in the latter twelve feet from the surface. The roots do cease to descend, as would be expected, when they reach permanent water; but they do not on the other hand continue their downward growth under all circumstances until they reach permanent water. In choosing a place at which to dig up alfalfa roots, several things had to be considered, especially as my original plan was, after having found plants of some age, to make an excavation of sufficient size and depth and then to remove the plants by washing away the soil. I succeeded in finding the plants and water favorably located, but a little examination of the manner in which the soil had withstood the action of the waste water from an irrigating ditch suggested that it would be utterly impractical to wash out the roots; and this was the case. The site chosen was about twelve miles from Fort Collins, on the place of Mr. J. H. Walter, in Weld county, at a point where a ditch had been cut through a hill, making a cut at the deepest point of rather more than twelve feet with a flume crossing it at this point. The lake, or reservoir which the ditch had been cut to empty had not been filled, so I was informed, for several years and the soil at the bottom of this cut had had no other than rain and snow water to wet it in that time. I do not know at what depth the water plane lay at this point; but unless the water plane was somewhat above the level of the water in the lake near by, which, after making allowance for the damming back of the water in the soil, seemed to me very improbable, it must have been a good way below the bottom of the cut, so that the roots had most favorable conditions to seek it if they did not get enough moisture otherwise. These plants were either five or six years from the seed, were growing a few feet from the edge of the cut, were exceptionally vigorous, and were at that time in full seed, not having been cut that season. I do not know how much water they had received, but judging from the condition of the corn and alfalfa growing within a few feet of them, the supply had not been very liberal, and I inferred that they owed their luxuriant growth to the fact that it had probably been made during the time of early rains and to their advantage of position, in that they were growing in a little sag in the surface of the ground. A section of this soil was as follows: about three inches of blown dirt, leaves, dead stems, etc., from previous years; in other words, soil made about the plant subsequent to their establishment there; then followed twenty-one and a half inches of a black, compact soil which had not been disturbed by the plow except very superficially. This was so firm and tough that it had to be removed with a pick. Succeeding this was six inches of a white marl; next a calcareous clay, three feet; then a hard, tough clay of three inches, followed by a rather sandy clay of three feet thickness; and then a second band of tough, hard clay, three inches; and lastly a fine sand. This soil from top to bottom was only slightly damp, and the sand and sandy clay in the bottom of our excavation was as dry as any portion of it except the very top. These roots were the largest that I have ever seen anywhere and supported the most luxuriant growth of tops. The crowns were large and the stems were very tall, measuring five feet three inches. The streaks of hard clay had not caused the roots to spread out and seek the contact between it and the softer soil, but it had caused them to double upon themselves, to twist and knot, and then run horizontally for some inches when they changed their course and descended again. It was almost as difficult to get them out of this without cutting or breaking as it had evidently been for them to make their way through it. I did not observe a single instance in which the root had divided in penetrating these hard layers. These plants sent their roots down eleven feet nine inches, with their ends, for the most part, in a fine sand; but the deepest ones were in a sandy clay where they would have had comparatively little work in penetrating to a greater depth, and it was not the abundance of moisture which caused them to cease growing.

The next place where I undertook to dig up roots was between an irrigating ditch and a railroad cut. Quite a large quantity of clay had, at a previous time, been taken from this point for the manufacture of brick. The character of the soil was almost the same from the top to the bottom; here the roots, were not gnarled as in the preceding instance, and they attained a length of twelve feet three inches, with their ends in soil just as dry as that through which they had passed. Though these roots were longer by about six inches than those from Mr. Walter's place, they were much smaller, their diameter being not more than two-thirds of that of the former; but they were still above the average. The age of these plants was either six or seven years. These are all the observations that we have had opportunity of making upon the effect of the depth of the water plane upon the length of the alfalfa roots. We are convinced that, when it is encountered by the roots, it practically determines their length; but when it is not actually encountered, its effect is problematical. If for any reason the depth of the water plane should be permanently lessened, as is the case when the higher land about a basin-shaped area is brought under irrigation, or irrigation water is increased, it would undoubtedly have a very serious effect upon the alfalfa, even to the killing of it if it should rise nearly or quite to the surface, especially if stagnant.

The water under the Whedbee field had a very strong flow; that under the field at Rocky Ford did not appear to have any; it was so far from the surface, however, that its effect would not be that of water filling up a basin-shaped area, and immersing the roots, in which case they would die out and rot.

EFFECT OF AGE UPON THE SIZE OF ROOTS.

There is no other point on which our observations are so at variance with one another as they are on this point. While we have not seen any young plant having a root so large as those mentioned from Weld county, we have seen many roots of six-year-old plants smaller than roots of other plants which we knew to be only nine months old. It can be stated in a very general way only, that one may expect larger roots among older plants than in a young stand. One of the chief causes of this is the fact that there is a natural process of thinning out, and the remaining plants have more room to grow and perhaps can avail themselves of the remains of the dead plants as a fertilizer.

DEATH RATE.

How fast this thinning out process takes place is difficult to answer. If there is any rule I have failed to observe it. In one instance I compared the casts of dead roots with the living ones in a piece of alfalfa five years from seeding, and the ratio of two to one seemed to hold good for the dead to the living plants. This is evidently open to question as to whether I could recognize the remains of plants that had been dead for several years, three or more; second, as to whether this ratio would hold for other soils as the death rate will vary under different conditions. The productiveness of this piece of alfalfa had not deteriorated very much and the variation in its tonnage may have been due to other causes than the dying out of a portion of the plants. This loss in number of plants is compensated for in part or wholly by the increased size attained by the remaining crowns. In the case of young plants or those crowded on account of the thickness of the stand twelve or fifteen stems may arise from a single crown, while crowns standing alone, i. e., occupying from six to eight or more square feet of surface, will throw out almost any number of shoots. I have counted as many as one hundred and sixty-one, and seen others two years old which had thrown out many more. For this reason I do not consider it of much importance whether the rate of dying is slow or rapid within reasonable limits and provided the dying out is not confined to certain spots. There are two ways in which these plants perish: one is, that for some reason or other, the root just below the crown rots off, leaving the lower portion of the root perfect in every respect, so far as is evident to the naked eye. This is not apparently due to age or exhaustion of the vitality of the plant. The second manner in which they perish is due to age and other causes. If the stubble of the second year be examined by splitting it open down to the crown, there will be observed at the node above the crown a blackening of the tissue and also that it gradually extends downward into the root itself. It begins in this manner and continues until the whole center of the crown has been destroyed. The new shoots come out from the outside of the crown under the old growth and are in communication with the outer portion of the root and not with the interior vascular bundle. The central portion of the crown and interior of the root may be entirely destroyed to a depth of eighteen inches or more. This cavity serves as a nesting place for a variety of larvæ, but they have no direct part in causing it. The decay finally extends to such an extent that it involves the whole neck of the root and the plant perishes. This condition can be found in alfalfa of different ages. I have in mind one field,about seven years old, where the roots are large and nearly all of them are more or less affected in this way. I know of another six years old where the stand is extraordinarily thick and the roots small, and so few of them show this that one may say the roots are perfectly healthy. The former piece is on land which is rather low, with the water table about seven feet from the surface; the latter is on high land. The distance of the water table from the surface does not seem to be the sole cause of this dying, for I have observed it in plants growing in ground where the water table was probably not less than twelve feet from the surface, as this was its depth on a neighboring farm. This condition of the roots is illustrated in plates XV, XVI and XVII. The crown does not generally perish all at once, but is broken up into parts which die successively. The field from which the plants represented were taken yielded about three tons to the acre last year,and is, according to the best information I could obtain, over ten years old. The stand in this field is not much over one crown to the square foot, and the remains of many plants which have died within the past few years are still easily recognized.

The alfalfa root when destroyed below the crown does not throw out new buds and re-establish the plant, as many other plants do, and its ability to repair an injury to its roots by throwing out adventitious roots seems to be very moderate. I have seen but few roots that have been eaten off by the pocket gopher or cut by the plow where it has calloused and thrown out roots which would be efficient in sustaining the plant if it had to depend upon them. I did not observe many with any roots produced in this way, but I have seen a few.

ALFALFA ROOTS CUT BY GOPHERS.

In a piece of bottom land near the Cache-a-la-Poudre river, I found a piece of alfalfa which was infested by these animals, and an examination of these roots showed that eighty per cent. of the plants had their roots eaten off, and this was doubtlessly the cause of the death of some of the plants, but they endured this severe root pruning to a surprising degree.

NODULES ON THE ROOTS.

Nodules appear on the roots in three forms: as warthy excressences mostly near the neck; as single nodules on small roots, and united into large colonies. The first form appears at shallow depths and whether these are identical with the others or not, they cease to appear on the roots at greater depths; while the third was found most abundant from three to five feet from the surface, and the second at all depths up to eleven and a half feet. There was a very great difference in the number of these on the roots at different localities though the plants seemed to be equally vigorous, and the proteids in the hay did not vary materially. They were found much more abundant on the plants grown in a garden soil, and also much nearer the surface than in the fields. The development of the colonies illustrated most vividly the influence of the alfalfa roots as mechanical agents for opening up the soil and admitting the air. I frequently found the passage left by the decayed root entirely filled by a colony or group of these nodules, whose axis agreed with the axis of the hole left by the root. Groups were almost invariably found occupying such passages or other cavities or clefts in the soil; while the single nodule was found scattered anywhere along the course of the root from the surface of the soil to the end of the root. Plate No. XI. shows some of the nodules as they occur near the extremity of the roots; these roots were about seven feet long. Plate No. XIV. shows large groups of them as found at a depth of from two and a half to five feet from the surface, and it also gives an idea of the size and character of the smaller roots of this plant. The largest nodules were nearly spherical and were from an inch to an inch and a half in diameter. Some were irregularly hemispherical and nearly two inches long. Others resembled the antlers of a stag, some of the individual portions having a length of more than half an inch. Compared with the nodules on the vetch and red clovers, as they grow in our soils, the alfalfa is but poorly supplied with them; this is particularly true with some of the vetches, but the groups of these nodules are incomparably larger on the alfalfa. The branched groups occur on the vetches as well as on the alfalfa.

Some of these groups were submitted to a partial analysis. The samples were obtained from plants growing in a rich, dark loamy soil. The groups were found about three and one-half feet from the surface and rather more than this from the permanent water below. They were washed to remove the sand and dried between filter paper. The nodules contained 61.67 per cent. of moisture and the dried material 5.725 per cent. of nitrogen; while the bark of the roots contained 2.25 per cent. nitrogen. This included any nodules which chanced to be on the bark. No attempt was made to avoid them. The washing of both the roots and the nodules was quite unavoidable. There is no doubt that the composition of each was altered by the process; not enough, however,to materially detract from the significance of the results. The effect of washing the roots is described elsewhere.

RATIO OF THE ROOTS TO THE TOP.

The largest root which I dug up, was twelve feet six and one-half inches long, and the average diameter of all the roots measured (150) is one-half inch at the crown, and one-third of an inch, six and a half to seven inches below the crown, or at the average depth of plowing. The tops on the other hand at a period of their growth vary even more than the roots do, varying exceedingly as to the number of individual stems, and these vary even more in their thickness, leafiness and hight. In a plant of one season's growth, having but few stems and these slender, the root may be several times heavier than the top; and on the other hand the top of a favorably located plant may attain a weight of from four to seven and even more pounds, green weight, while the root will seldom exceed a pound. Our heaviest root weighed 418 grams, equal to about thirteen ounces, and was nine feet nine inches long Taking the average of all the plants which we have weighed, we find the ratio of roots to tops to be 1 : 1.3.

This at best can only be considered an approximation; first, for the reason stated above; second, because it is almost impossible to remove plants of the size of the ones with which we had to deal without loosing some leaves and stems, and still more difficult to get their original weight; for, do the best we could, evaporation from both roots and tops took place, though they did not show wilting to any extent. We weighed thirty-two plants, and the difficulty of the task may be appreciated in some measure when it is considered that the shortest plant handled, counting root and top, measured nine feet nine inches. The weight obtained for the roots is very nearly correct; while the weight of the tops is far too low, for the plants were already in seed when they were dug, and the loss by breakage and falling off of leaves was large, and to this is to be added the loss due to evaporation, which was unavoidable, as many of the plants which we weighed were secured twelve miles from the laboratory. There was no way of determining this loss, and we have no basis on which to estimate it. The closest approximation that we can make is on the following basis: first, assuming that the roots which we weighed were representative, we find their average weight to be 106.5 grams, green weight; second, we are justified by actual count in assuming that a good stand of five-year old alfalfa has about 140,000 plants to the acre; third, experiment indicates that the stubble is equal to about one-sixth of the green crop; fourth, five-year-old alfalfa referred to cut two and one-quarter tons of hay to the first cutting last year (1895), or 5,000 pounds, adding a loss of about twenty per cent. Seventy per cent. of the green crop is water, and thirty per cent. hay. All these data are based upon determinations made with as much accuracy as the subject will permit. Before proceeding with this calculation, it should be observed that the weight of the roots of the smaller plants exceeds the weight of the tops, sometimes being over three and one-fourth times as heavy. If the smaller ones are nearer the average, as is probably the case, the weight of the roots will exceed that of the tops of any single cutting.

Basing our calculations on these results, we have the two and one-half tons of hay, corresponding to 16,666 pounds of green crop; now adding one-sixth for stubble, gives us 19,443 pounds, or 9.72 tons. With 140,000 roots, each weighing 106.5 grams, we have, taking one pound as equal to 453.4 grams, which is near enough for our purpose, a total of 16.44 tons of roots, or a ratio of 1.69:1 for the roots to the total tops produced at this cutting, which means that it is more than the average alfalfa plant on which the top equals or exceeds the root in weight.

STUBBLE.

Two efforts were made to determine the ratio of the stubble to the crop removed where the stubble includes the roots to the depth that they would be cut by the plow and the stems to the hight left by the mowing machine. In the first attempt the ratio of the stubble to the tops was determined by cutting off the plants at the depth of six or seven inches below the crown, weighing the whole plant, and then removing the top about as a mowing machine would cut it and weighing each. In this manner we would detect any loss if it occurred. The result of this method was that we found the ratio of 1:1.4 for the stubble to the green crop as cut for hay making. The second method was by plowing up a small piece of alfalfa five days after it had been cut, picking out the roots, and weighing them. The result of this was, allowing two and one-half tons for the total dry matter cut off of one acre at first cutting, that we obtained the ratio of 1:1.69. The agreement here is better than we expected, as the plants in the first case were all large, and, growing singly, and had larger than average crowns; while the second observation was made upon a field with a good stand in which the plants were crowded compared with the others. We are not far from the truth when we assume that the stubble turned under after the first cutting bears the ratio of 1:1.5 to the green crop removed, or is equal to two-thirds of the green alfalfa which has been cut, assuming that there has been no loss by falling off of leaves, breaking off of stems, etc., to which subject reference has already been made.

Three plats of 675 square feet each were plowed up at the end of April (April 28-29-30), and the stubble carefully picked out and weighed. On May 26, after having been kept for upwards of three weeks in the laboratory, the results obtained were, for Plat No. 1, 526,793 plants to the acre, ten years old, and 3.34 tons stubble. Plat No. 2, 333,514 plants to the acre, one year old, .81 tons. Plat No. 3, 70,238 plants to the acre, ten years old, 2.55 tons of stubble per acre. Omitting the one-year-old plat—no one would plow up a good stand of one-year-old alfalfa under ordinary circumstances—we have an average of 2.94 tons of air-dried substance per acre. On a subsequent page, under the manurial value of the stubble, it will be seen that we assume the amount to be 2.86 tons for plants five years old. This quantity was arrived at by accurately weighing a small number of plants and estimating the total quantity. The agreement of the results by the two methods leaves nothing to be desired. The increase in the amount of stubble after the first year seems to be large, but it is not always so pronouced as appears from the above figures. I have seen one and five-year-old roots nearly equal in size, but the crowns of the plants five years old were much the larger.

COMPOSITION OF THE STUBBLE.

The stubble, of which an anslysis is herewith given, was obtained in the first effort to determine the ratio of stubble to the tops, already referred to. The plants were in seed at the time of cutting.

	Moisture.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen Free Extract.	Total Nitrogen.
Air dried	5.16	4.24	.516	11.56	36.48	42.04	1.869
Water free	....	4.47	.518	12.16	38.19	45.00	1.945
Air dried	5.39	4.27	.577	11.15	35.50	43.05	1.788
Water free	....	4.51	.610	11.75	37.40	45.73	1.880

ASH CONSTITUENTS IN 1,000 POUNDS AIR-DRIED STUBBLE.

The following table gives the pounds of the various components of the ash in each one thousand pounds of air-dried stubble on the basis of 4.24 per cent. of ash :

Silica.	Phosphoric Acid.	Sulphuric Acid.	Chlorine.	Potash.	Soda.	Lime.	Magnesia.	Oxide of Iron.	Alumina.	Oxide of Manganese	Total.
1.104	4.155	1.261	1.156	7.762	2.307	8.831	2.681	.434	.289	.110	30.09

COMPOSITION OF THE ROOTS.

It was hoped that we would find time to submit the roots to a chemical investigation, but no other than the fodder analyses and analyses of the ashes of the bark, the inner portion of the root, and the whole root have been made. Trouble was met in preparing a sample of the roots. At first we endeavored to clean them by washing and wiping. This method proved inapplicable, for, as was noticed, the roots when moistened became sticky, absorbed water greedily, and yielded a large portion to the wash water. Wiping with a wet cloth was also tried and finally rubbing with a brush was resorted to. This was the only practicable method, though it left much to be desired.

The green roots dried to a constant weight in the air gave 60.41 per cent. moisture and 39.59 per cent. of dry matter. The roots in sample No. 17 were from Weld county; No. 17-a Larimer county.

	Water.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen Free Extract.
No. 17, air dried	4.55	3.79	.71	10.81	25.13	54.98
Water free	....	3.97	.72	11.35	26.33	57.63
No. 17—a, air dried	5.04	3.69	1.07	10.07	24.18	55.95
Water free	....	3.88	1.15	10.66	25.46	58.85

The difficulty in preparing our samples suggested the following experiment: The roots were exhausted with hot water, the solution filtered, and evaporated to dryness. The residue, dried at 100 degrees C., amounted to 36.2 per cent. of the weight of sample No. 17 and to 45.3 per cent. in sample No. 17-a. A similar experiment with another sample showed that 44.23 per cent. of the total ash constituents were taken into solution. These facts show why washing the roots is inadmissable; also the extent to which the dead roots will give up their mineral as well as a portion of their organic matter to the soil waters, whose action is probably still greater than that of distilled water. Nothing was done towards determining the nature of the dissolved subtances except that their reducing power was determined by Fehling's solution. It corresponded to 12 per cent of sugar in the dried extract. This amount was not increased by boiling with sulphuric acid, with the usual precautions taken in the conversion of starch into sugar. The filtered extract seems not to have contained starch. The aqueous extract of the roots is acid toward litmus. It is possible that the sugar was produced by the action of the acid solution on the starch. I have expressed this reducing power in terms of sugar because it is convenient, not because it is known to be due to sugar. The taste of the roots in early spring is first sweet and afterwards bitter; the bitter taste is much more marked when the plant is more active. Cattle and hogs are fond of the roots, and I am informed, that horses also, readily acquire a liking for them.

ASH CONSTITUENTS IN 1,000 POUNDS OF AIR DRIED ROOTS.

	Silica.	Phosphoric Acid.	Sulphuric Acid.	Chlorine.	Potash.	Soda.	Lime.	Magnesia.	Oxide of Iron.	Alumina.	Oxide of Manganese	Total
No. 17, washed	1.443	3.512	1.268	.295	8.879	.976	7.207	3.308	.453	533	.141	28.015
No. 17—2, not washed	1.267	4.554	2.266	.741	10.925	.944	8.540	4.245	.378	.325	.067	34.252
No. 17—a, washed..........	1.405	2.229	.706	.219	7.126	.396	7.430	1.921	.592	.418	.203	22.645
No. 17—a—2, not washed...	1.323	4.048	1.829	.471	10.201	1.831	4.777	2.300	.437	.406	.224	27.874

It is unfortunate that samples No. 17 and 17-2 are not portions of the same larger sample. They are roots obtained at the same place, but not at the same time. The same is true of No. 17-a, and 17-a-2. A comparison of the results indicates that the acids and the alkalies are removed from the roots in large quantities by washing them. This operation did not last more than ten or fifteen minutes at the longest and consisted in immersing them in water with gentle rubbing, until the dirt was loosened and then wiping them with a towel. The result in regard to lime is doubtful, as sample No. 17-a-2 contains less of this substance than the washed roots from the same place. Because of this doubt, a portion of sample No. 17-2, although it had lain in the laboratory about five months and the solubility of its ash constituents had possibly changed, was treated with tepid water, the extract evaporated to dryness and incinerated with the same precautions which had been taken in the preparation of ash from other samples. A partial analysis of this ash was made with the object of corroborating the results of the preceding analyses. The results are calculated on 1,000 pounds air-dried matter as before; on the basis of 1.6 per cent. ash dissolved out, 1,000 pounds yield to water sixteen pounds ash, containing 11.99 pounds fixed ash ingredients.

ASH OF AQUEOUS EXTRACT.

	Silica.	Phosphoric Acid.	Sulphuric Acid.	Chlorine.	Potash.	Soda.	Lime.	Magnesia.	Oxide of Iron.	Alumina.	Manganese	Total.
No. 17—2, air dried..	.850	2.050	1.252	—*	5.166	.554	.660	1.270	.118	......	.070	12.0

* Not determined.

Showing that even a larger proportion of the phosphoric acid, sulphuric acid, and particularly of the potash, went into solution under these conditions than the preceding analyses indicate as probable.

MANURIAL VALUE OF THE STUBBLE.

Others have shown the fertilizing value of alfalfa hay, as grown in the east without fertilizers,to be $9 per ton, and when grown with fertilizers, $10.84 per ton.—Mass. State Rep. 1888, p. 165. Our farmers can not afford to turn under a crop of alfalfa preparatory to seeding to wheat or planting to potatoes, even if they get only from two to six dollars per ton for the hay as fodder, but they can afford, (and it would be good practice) to break up their alfalfa, say every six years, for at this age the average field has passed its maximum yield, and put in some other crop. To break up a field of alfalfa is a different task from breaking up one of clover or a timothy sod. In the case of clover it may be allowed to make a considerable growth in the spring before being turned under. This is not the case with alfalfa, for if the plant is allowed to stand late enough to make a growth sufficient to be of value as a green manure, or in fact any considerable growth, the toughness of the roots makes it difficult to break up; therefore, any attempt to estimate the manurial value of alfalfa in a field from a practical standpoint ought to be made on the basis of the stubble and roots taken while the plant is dormant. Our stubble was taken when the plant was active, and perhaps at the height of its activity, and our results are correct only for this period. We find the amount of stubble taken to a depth of about six and one-half inches to be 11,812 pounds per acre, and the moisture which this gives up in drying in the air to be 51.57 per cent. This moisture is undoubtedly rather low, and consequently, the air-dried material too high, due to the fact that our sample had lost water before it was possible for us to begin the determination. According to the preceding we obtain 5,720.8 pounds, or 2.86 tons air-dried matter per acre. Each ton of 2,000 pounds contains 8.31 pounds of phosphoric acid, 15.52 pounds of potash, and 36.37 pounds of nitrogen which, at fifteen cents per pound for the nitrogen, five and one-fourth cents per pound for the potash, and five cents per pound for the phosphoric acid, give the total value of the stubble at $19.28 per acre, $6.75 per ton for the stubble. The three substances mentioned are the ones to which it is customary to assign a money value. These are not the only elements which are returned or added to the soil by this manner of green manuring, nor have we in the preceding estimate the whole of these. We have stated that we included only the first six and one-half inches of the roots, the rest of th roots corresponding to 5.14 tons of air-dried matter per acre, is left below the assumed depth of six and one-half inches.

MANURIAL VALUE OF THE ROOTS.

The manurial value of this portion is not equal pound for pound to the stubble, still it is by no means a negligible quantity. The nitrogen is equal to 14.98, practically 15 pounds per ton of 2,000 pounds; the phosphoric acid 4.45 pounds, and the potash 14.25 pounds; or stated differently, there is less than one-half as much nitrogen, one-half as much phosphoric acid, and about the same amount of potash in the roots as in the stubble, the first six inches of the roots being taken with it. On the other hand, while there is 2.86 tons of air-dried matter in the stubble, there is 5.14 tons in the rest of the roots, making them about equal to the stubble in the total nitrogen and phosphoric acid contained, and twice as rich in potash; or expressed in dollars and cents, the value of the roots below six and one-half inches, and to an average depth of ten feet, is phosphoric acid, $1.14; potash, $3.84, and nitrogen $11.60, a total of $16.58 against $19.32 for the stubble, making a total value per acre for the portion left after removing all the crop above ground of $35.90. In estimating this value all the other constituents of the ash and the organic matter have no value signed to them; whereas we know that the organic matter, particularly for our soils, has a comparatively high value, and the other ash constituents presumably in a more favorable condition for absorption by other plants than they are in the soil, can not be indifferent, though it is not usual to place any value upon them.

It may be questioned whether a large portion of the plant food stored in these roots does not lie so deep that it is beyond the reach of ordinary crops, such as potatoes and wheat. Whatever the answer of this question may be, it is a well attested fact, that the yield of wheat on alfalfa ground is often doubled and always greatly increased; and while the alfalfa is an exceptionally deep-rooting plant, no violence is done to observe facts in assuming that the roots of the wheat stimulated by the presence of plant food in certain channels left open by the decaying of the alfalfa roots, may penetrate to greater depths than they do when the food is disseminated evenly through the soil. The roots, of the wheat plant, however, have been observed to penetrate to the depth of seven feet—Schubart cited by Johnson, "How Crops Grow," page 264—which is as deep as a large percentage of the alfalfa roots penetrate into our soils.

It is necessary in this connection to distinguish between the roots and the soil in which they have grown, for while the roots contain, as we have seen, a large amount of plant food, particularly nitrogen, it does not follow that the soil itself contains as much of this element as it did before the alfalfa was grown in it ; in other words, if the alfalfa roots were removed, the soil might be poorer in nitrogen as it certainly would be in other elements of plant food. If the amount of nitrates in cropped soils be taken as the measure of available nitrogen in a soil, alfalfa exhausts a soil faster than many other crops. Aikman,in " Manures and Manuring," page 157, quotes the amount of nitrates found in cropped soils per acre (Rothamsted soils), from which it appears that there is the following amount of nitrogen as nitrates in each acre of soil taken to the depth of nine feet: In soil cropped to white clover, 102.8 pounds; to vetches, 54.6 pounds; to wheat, after fallow, 18.4 pounds, and to alfalfa, 17.0 pounds. It is further shown for the soil cropped to alfalfa, that while the first nine inches of soil contains 8.9 pounds per acre, the last nine inches taken, that is, from eight feet three inches to nine feet, contain only 0.4 pounds; while in the soil cropped to white clover there is at the same depth (eight feet three inches to nine feet), 10.0 pounds, showing how great a draft the alfalfa had made upon this form of nitrogen in the soil.

There is a suggestive fact shown by the figures of the table as quoted, i. e., the first nine inches of soil contain after vetches a trifle less than one-fifth of the total taken to the depth of nine feet, and more than one-half of the total after alfalfa. The dimunition of the nitrogen after the alfalfa is almost continuous to the depth of eight feet three inches; where, as given above, the amount of nitric nitrogen is only 0.4 pounds per acre; while in the other cases, the dimunition reaches its maximum at a depth of between two and three feet, from which point on the nitric nitrogen increases somewhat, being present in the largest quantity after white clover at a depth of four and one-half to six feet.

The figures given in this connection show more clearly than any others with what avidity and also the depth to which alfalfa feeds. I do not think that the movement of the nitric nitrogen (nitrates) in the soil can operate to produce this marked result in the case of the alfalfa, but that the nitrogen is appropriated by the plant.

LEAVES AND STEMS AS A TOP DRESSING.

It has been repeatedly stated that the mechanical loss in making alfalfa hay is very considerable, and while I have no figures established by experiment—the reason has been given elsewhere—I estimate the minimum to be between fifteen and twenty per cent. of the total dry matter, including all the leaves that fall during the growth of the plant and the making of the hay. I believe twenty per cent. of the dry matter to be a reasonable estimate. The amount of matter added to the soil in the form of a top dressing on this basis of loss is more considerable than at first appears. The actual amount ranges from .95 ton for a 3-ton yield of hay to one ton for a 5-ton yield. It is not only twenty per cent. of the total dry matter, it is about one ton of the richest portion of the crop, equivalent to the addition of 70.4 pounds of nitrogen and 168.8 pounds of ashes. Some of the nitrogen may be lost, but the whole of the ashes is available. The table quoted by Prof. Aikman shows that the first nine inches of the cropped soils are rich in nitric nitrogen, and in the case of the alfalfa they contained more than one-half of the total found to the depth of nine feet, 8.9 pounds out of a total of 17.0 pounds.

These facts may be more directly related than at first appears. The ashes contain seven pounds of phosphoric acid and 28.6 pounds of potash, which have been brought up from below. A portion of this is, doubtlessly, taken up by the plant and utilized in making the next year's crop; but there is a remainder each year which accumulates to the enrichment of the surface portion of the soil. The accumulation of nitrogen is probably less in Colorado than it would be were our conditions more favorable to the formation of humus in the soil. There is no series of analyses showing how great the changes in the surface soil are in respect to humus, nitrogen, or ash constituents; we have only the general results as measured by the increase in wheat produced, and this only in general terms. I have presented the composition of the plant and its parts; the amount of plant debris added year by year; the stubble added to the soil at the end of one, five, and ten years; also the amount of roots not included with the stubble; and I have also intimated another source of addition to the soil during a part of the life of an alfalfa field, i. e., by the perishing of the inner portion of the roots. The composition of the plant debris has been given and the following tables contain the analyses of stubble and roots and the fixed ash constituents for each thousand pounds of air-dried material:—

	Moisture.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen Free Extract.	Total Nitrogen.	Amide Nitrogen.
Stubble	5.16	4.24	.546	11.56	36.48	42.01	1.849	.202
Stubble	5.39	4.27	.577	11.15	35.50	43.04	1.788	....
Roots, Weld County	4.64	3.72	.72	10.99	25.30	54.63	1.840	.281
" Weld County	4.46	3.86	.66	10.73	24.96	55.33	1.794	....
" Larimer County	5.03	3.69	1.04	9.96	24 15	56.13	1.590	.257
" Larimer County	5.04	3.69	1.13	10.17	24.21	55.76	1.630	.....
" outside portion	4.38	5.21	2.06	14.08	21.75	52.52	2.253	.....
" inside portion	3.77	3.50	2.81	7.70	29.19	53.03	1.231	.....

ASH CONSTITUENTS IN 1,000 POUNDS AIR DRIED SUBSTANCE.

	Silica.	Phosphoric Acid.	Sulphuric Acid	Chlorine.	Lime.	Magnesia.	Iron Oxide	Alumina.	Manganese Oxide.	Potash.	Soda.	Total.	Nitrogen.
Stubble	1.104	4.155	1.261	1.156	3.831	2.681	.434	.289	.110	7.762	2.307	30.090	18.186
Roots, Weld Co	1.267	4.554	2.266	.741	8.540	4.245	.378	.325	.067	10.925	.944	34.252	18.400
" " washed.	1.443	3.512	1.268	.295	7.207	3.308	.453	.533	.141	8.879	.976	28.015	17.94
" Larimer Co	1.323	4.048	1.829	.471	4.777	2.300	.437	.406	.224	10.201	1.831	27.847	16.30
" " washed.	1.405	2.229	.706	.219	7.430	1.921	.592	.418	.203	7.126	.396	22.645	.....
" bark	3.075	4.768	3.206	1.086	7.298	3.337	.728	.824	136	13.277	2.998	40.733	22.53
" bark	2 386	4.285	3.190	1.218	8.225	5.558	.507	.738	.205	11.469	1 118	38.899	.....
" inside	.403	3.937	1.776	.434	5.060	4.197	.242	.053	.078	8.204	2.574	27.008	12.31
" inside	.361	5.389	1.642	.477	7.070	4.085	.174	.079	.098	6.282	.815	26.472	.....

The work on the soils from our standpoint is quite unsatisfactory, but either someone else or ourselves may be able to make a systematic study of this subject which is of some importance as well as of interest to the West.

The soil in which the Weld county samples were growing was sampled to the depth of eleven and one-half feet in three parts, corresponding to the large variations in the character of the soil; at the same time a sample of soil was taken a few feet distant from a field planted to corn, but owing to lack of water it was practically fallow at the time. The corn plants had made no growth during the season; subsequently a fifth sample was taken of the blown soil which gathers about the large crowns of alfalfa containing a great many leaves and plant refuse. This enables us to present the composition of the plant, the root, the soil accumulation about its crown, the soil proper, the subsoil in two sections, and that of a sample of the soil not in alfalfa. The alfalfa was six years old. The plants were very large, some of the stems being over five and one-quarter feet high, and the largest of the roots one and one-half inches in diameter, with abnormal roots, i. e., such as had short tap roots two to three feet long attaining a diameter of two and seven-eighth inches. The soil is a very fine clayey loam, almost black in color and 21½ inches deep. It had never been broken by the plow to any depth and was so compact that we were compelled to use a pick in working a part of it. This is succeeded by six feet of marly clay and fine sand, the upper four to six inches of which was a white marl and the next three and a half feet fine clayey sand. The sample from the cornfield corresponds to the 21½ inches of black soil. For fodder analysis of plant see page 31, first cutting, analysis No. 12.

The total fixed ash constituents removed by 1,000 pounds of hay, on a basis of 8.87 per cent. moisture and 9.94 per cent. crude ash, is 75.32 pounds, distributed as follows:—

Silicia	1.49
Phosphoric acid	4.43
Sulphuric "	5.59
Chlorine	7.92
Lime	23.65
Magnesia	5.89
Oxide of iron	.40
Alumina	.25
Oxide of manganese	.19
Potash	23.69
Soda	1.82
	75.32
Nitrogen	22.31

ANALYSES OF THE ASHES.

Plants.	Per cent.
Sand	1.765
Silicic acid	1.513
Phosphoric acid	4.459
Sulphuric "	5.636
Chlorine	6.776
Calcic oxide	23.905
Magnesic oxide	5.951
Ferric "	.397
Aluminic "	.253
Manganic " (brown)	.188
Potash	23.934
Soda	1.840
Carbonic acid	25.151
	101.768
Less O equivalent to Cl	1.523
	100.245

Roots.

	Per cent.
Sand	2.380
Silicic acid	2.875
Phosphoric acid	10.270
Sulphuric "	5.093
Chlorine	1.322
Calcic oxide	19.008
Magnesic oxide	9.492
Ferric "	.844
Aluminic "	.729
Manganic " (brown)	.149
Potash	24.443
Soda	2.110
Carbonic acid	21.742
	100.457
Less O equivalent to Cl	.299
	100.158

ANALYSES OF THE SOIL.*

	Soil Blown about Roots.	Black Soil to Depth of 21½ Inches.	Marly Soil fr'm 1 Ft. 9 In. to 7 Ft. 9½ In.	Fine Clay and Sand from 7 Ft. 9½ In. to 11 Ft. 3½ In.	Soil from Corn Field, Corresponding to Black Soil.
Insoluble Matter	78.472	66.700	55.032	68.145	63.258
Soluble Silicic Acid	9.174	15.110	12.921	10.082	16.086
Potassic Oxide	.327	.610	.531	.416	.409
Sodic Oxide	.093	.235	.368	.250	.152
Calcic Oxide	.562	.570	9.182	4.775	.755
Magnesic Oxide	.551	.852	2.016	1.185	1.251
Manganic Oxide (brown)	......	......	......	......	......
Ferric and Aluminic Oxides	5.835	8.931	7.937	7.005	9.780
Phosphoric Acid	.143	.186	.195	.132	.148
Sulphuric Acid	.065	.070	.102	.057	Trace.
Chlorine	.004	.005	.007	.003	.003
Carbonic Acid	Trace.	.017	7.842	3.606	.293
Moisture	1.400	1.797	1.629	1.431	2.052
Volatile and Organic Matter	not det.	3.338	2.050	3.291	5.534
Total	......	98.421	99.812	100.378	99.721
Nitrogen	.085	.076	.035	.025	.062
Humus	......	.400	......	.200	......

* Analyses by Mr. Chas. Ryan.

In the mechanical analyses of the soils we followed as closely as we could the method of Osborne, but we had no sieve corresponding to .1 mm., and but one portion is made between .25 mm. and silt. There is a large quantity of calcic carbonate and silicate, particularly in sample B., which is distributed between the three last portions. Imperfect as the analyses are, they serve the purpose for which they are used.

	.5 mm.	.25 mm.	.10 mm. and Sand.	Silt.	Clay.	Dust.
Soil A	6.888	8.820	72.450	3.433	.410	7.999
Soil B	4.416	11.130	73.745	3.213	2.247	5.249
Soil C	6.011	15.200	68.650	5.090	.120	.493

Analyses by Mr. Chas. Ryan.

The physical condition of this soil is excellent when it has been mellowed by tillage, but is compact when it retains the natural firmness acquired by its long-settling and the firming of its particles. The degree of flocculation is small. The particles are fine and puddle easily. The amount of alumina and iron—we may say alumina, for their is very little ferric oxide in the soils—together with the soluble silica convey a fair idea of the exceedingly fine state of division prevailing in them. The amounts of potash, phosphoric acid, and nitrogen are abundant. We used hydrochloric acid sp. gr. 1.115 in extracting the soil, and with the large amount of calcic carbonate present in some of the samples, the action of the solvent was propably not excessive; so that, after entertaining every misgiving as to the value of the results obtained by a chemical analysis, we may accept the amount of plant food taken into solution as representing approximately the amount available in this soil. Here it should be noted that no attempt was made to determine the extent of this soil, but as it is common to find it, we assume that it is not an exceptional soil, though it is by no means so common that it can fairly be claimed to represent the general soil of the county.

In estimating the amount of ash ingredients removed by the crop of alfalfa from this soil, the basis of 9,000 pounds of hay per acre may be assumed as a convenient estimate. The amount of ash ingredients removed for each 1,000 pounds of hay has been given for this particular case as 75.32 pounds, or for the 9,000 pounds—four and one-half tons—677.88 pounds distributed as follows :

	Pounds.
Silicic acid	13.41
Phosphoric acid	39.87
Sulphuric acid	50.31
Chlorine	71.28
Lime	212.85
Magnesia	53.01
Oxide of iron	3.60
Alumina	2.25
Brown oxide of manganese	1.71
Potash	213.21
Soda	16.38
	677.88

The nitrogen in the hay amounts to 200.79 pounds. The amount of plant food in the soil, however, is so large that it is scarcely possible but that a very large excess over that required by the crop was obtainable at all times throughout the season. The total plant food present in the soil penetrated by the roots in this case is so large that it seems to have no object in trying to express the quantity in figures. The quantity of phosphoric acid present in one acre of this soil and its subsoils taken to the depth of eleven and one-quarter feet is approximately thirty-four and one-quarter tons, and about three times as much potash, or one hundred and two tons. It would seem probable that,under these conditions, the plant would contain as large a quantity of ash ingredients as it could take up,but the average ash content of alfalfa hay,including all cuttings and varieties of alfalfa grown in Europe and different parts of this country, is 7.44 per cent., or nearly as great as the average of the samples collected by ourselves, including this particular one, 9.08 per cent., for the first cutting and rather higher for the second and third cuttings. Our averages are something higher than that given by Mayer and others. This difference is reduced a little when the lower water content of our hay is taken into consideration; but there still remains an excess over the average ash content. This may correspond to the amount which is taken from our soils in excess of the normal amount due to an excessive supply. It is to be remembered that the alfalfa in our case is practically growing in a virgin soil, even if the upper soil has previously been sown to wheat, for the wheat roots, whatever depth they may attain in loose open soils, can not attain great depths in our prairie soils unless they have been opened by some preparatory crop or process. It is probable that the amount of ash constituents taken up by our alfalfa does not exceed ten, or at most, fifteen pounds per hundred, indicating an amount necessary for the perfect maturing of this plant, which only a rich soil can furnish or a most vigorous root system collect.

We have no other series of soil samples so complete with the hay produced upon the same, but we have one sample from Rocky Ford, Otero county. The hay is a sample of the third cutting; the yield for the year, three cuttings, was five tons. An analysis of the hay gave the following: water, 6.06 per cent.; ash, 9.87 per cent.; fat, 1.29 per cent.; crude fiber, 32.69 per cent.; protein, 13.69 per cent., and nitrogen free extract, 36.40 per cent. The fixed ash constituents amounted to 73.788 pounds for each 1,000 pounds of hay, as follows: silicic acid, .828 pound; phosphoric acid, 3.258 pounds; sulphuric acid, 5.280 pounds; chlorine, 7.444 pounds; lime, 23.684 pounds; magnesia, 3.033 pounds; oxide of iron and alumina, .662 pound; brown oxide of manganese, .153 pound; potash, 27.197 pounds; soda, 1.976 pounds; or the total removed from the soil by the five-ton crop, supposing it all to have been as rich in ash as the third cutting was 737.88 pounds.

The Weld county sample, already given, shows 677.88 pounds ash constituents, based upon the first cutting and a yield of four and one-half tons. If we assume a five-ton yield, to make them more easily comparable, we have 737.88 pounds of ash in Otero county, third cutting, as against 753.2 pounds in Weld county, first cutting; a difference of about 15 pounds, only three pounds for each ton, or only about two per cent. of the total ash constituents considered. This difference is less than that usually found between two samples cut at different times from the same plat.

We fortunately have an analysis of the Otero county soil, also made by Mr. Ryan. The point at which this sample of soil was taken is not, as in the case of the Weld county sample, the one at which the hay sample was gathered; but, after examining the soil, I am satisfied that, owing to its uniformity, no error is introduced by the fact that the sample is not the identical soil in which the plants had grown and there can be no doubt but that its value is as great as that of any chemical analysis which might be made of this soil.

ANALYSIS OF SOIL FROM OTERO COUNTY.

	Per cent.
Insoluble	77.72
Potash	.25
Soda	.11
Lime	1.55
Magnesia	.11
Ferric oxide	2.93
Alumina	4.70
Phosphoric acid	.90
Sulphuric acid	.45
Chlorine	.04
Carbonic acid	1.01
Moisture, at 110 degrees	1.66
Loss by ignition	3.70
	100.45

This sample does not represent the soil to a greater depth than four and a half feet; while the preceding ones, together, represent the Weld county soil to a depth of eleven and a quarter feet. The twenty-one inches of Weld county soil contain 11,208 pounds of phosphoric acid to the acre; while the Otero county soil, calculated to the same depth, contains 55,125 pounds of this acid, or nearly five times as much. The ratio of the potash in the two soils is markedly in favor of the Weld county soil, it containing in the first twenty-one inches 37,362.5 pounds; while the Otero county sample contains 15,312.5 pounds. The amounts of these substances removed by the respective crops bear no such relation to each other as the total amounts of them bear to one another. The amount of phosphoric acid removed by one thousand pounds of hay from the Weld county soil is 4.43 pounds; while the amount removed from the Otero county soil, by an equal weight of hay, was 3.58 pounds. With a total quantity of phosphoric acid, five times greater than that present in the Weld county soil, the plants have taken up a little more than three-quarters as much of it. The potash removed by a thousand pounds of hay from the Weld county soil was found to be 23.69 pounds; while from the Otero county soil, with less than one-half as much total potash, this weight of hay removed 27.197 pounds. The magnesia, it was hoped, might give a clue as to the amount of food brought up from the lower portion of the soil, as we have the ground water quite heavily laden with salts of this base; but an examination of the results obtained failed to show any such relation as might even be suggestive that these solutions had anything whatever to do with the nourishment of the plants. The Weld county sample contains for each 1,000 pounds of hay, 5.89 pounds magnesia; the Otero county sample only 3.033 pounds. The Weld county soil contains about one per cent. of magnesia and the Otero county soil only a little over 0.1 per cent., but in the latter case the roots penetrate the ground waters, which are rich in magnesia salts, as the following table illustrates:

COMPOSITION OF GROUND WATER.

Calcic sulphate	155.650
Sodic "	341.771
Magnesic "	51.880
" chloride	29.027
" carbonate	16.026
Insoluble	2.412
	596.766

The total solids per gallon was 596.766 grains.

Examination failed to reveal the presence of phosphoric acid or potash, despite the large amount of the former in the upper portion of the soil and a fair abundance of the latter. The condition of the roots was good, although they were very different from those in Weld county, and also from others in Larimer county, which had penetrated into flowing water near the level of the Cache-a-la-Poudre river. These roots were neither "rotten" nor dead, but living, and were doubtlessly discharging their functions. I, of course, cannot tell to what extent their action had been modified; but it is evident that, so far as the magnesia is concerned, they had not taken enough of it into the plant system to make its amount equal to that taken from the Weld county soil. We are in this case debarred from trying to explain the difference in the amount of magnesia appropriated by the plant by the less amount of lime in the Weld county soil, for the fact is, that the Weld county soil is very much the richer of the two in lime; and moreover, the amount of lime in 1,000 pounds of the samples is almost identical, i. e., 23.65 pounds in the Weld county sample and 23.69 pounds in the Otero county sample; nor yet is it probable that the potash taken up influenced the amount of magnesia so far as the analyses indicate; the Weld county sample has 23.69 pounds and the Otero county sample 27.20 pounds of potash for each 1,000 pounds of hay. There is here an excess of potash in favor of the Otero county sample, about equal to the deficit of magnesia, which fact alone would have but little significance; but it acquires some weight when it is observed that the sum of the lime and potash, including magnesia with the former and soda with the latter, is constant within comparatively narrow limits, i. e., they are equal to from 55.5 to 59 or 60 per cent. of the total ash constituents of the plant above ground; but this is not true of the roots to the same extent, nor of the leaves and stems taken separately. The magnesia in the roots is as a rule higher than in other parts of the plant; while the nearly constant sum of these four constituents—the two, potash and soda, rising as the lime and magnesia fall, or contrariwise—might be interpreted as indicating an intimate relation between their relative quantities and a partial interchange of functions. The varying relation of their quantities in the ash of the leaves, stems, and roots, obscures this to such an extent that we can say nothing definite about it; and for this reason we believe it improbable that the four per cent. more of potash in the Otero county sample has any direct bearing upon the lower percentage of magnesia in it than in the Weld county sample. There was an abundance of magnesic salts presented to the absorptive action of the roots of the Otero county plants, but the fact is the salts were not taken up, nor is the amount of soda present in this sample apparently influenced by the soda salts present in the soil waters, for in the Weld county hay we find 1.82 pounds of soda for each 1,000 pounds of hay, and in the Otero county 1.98 pounds. In other samples, grown in alkali soils, we have from two to three times as much soda present as we find in either of these samples. We have omitted some essential condition or we are justified in concluding that the supply of plant foods is so excessive in both of these soils that the plants in each case have taken up as much of the various ash constituents as they could appropriate, or that the available supply in the two soils was about the same and that the ground waters exercised no decided influence upon the character or amounts of these constituents taken up. Such a conclusion, if established, would be in harmony with the suggestion already made, that the alfalfa plant may feed at greater depths, but it does not necessarily do so, and that it can dispense with its long tap root and still flourish.

The ground water met with in the above instance is rather a "bitter water" than an alkaline water, even though there is a large portion of sodic sulphate present. Combining the bases with the acids in the following order: sodium, calcium, magnesium, we have the following percentage composition of the thoroughly dry residue:—

	Per cent.
Silicic acid	0.5
Sodic sulphate	57.3
Calcic sulphate	26.0
Magnesic sulphate	8.7
Magnesic chloride	4.8
Magnesic carbonate	2.7
	100.0

The composition of the water accounts for its nauseating, bitter taste. It was clear and almost sparkling. We give the following analysis of a seepage water collected late in the season from a newly opened drain running through an alkalized and somewhat marshy swale. The larger quantity of salts held in solution and their difference in character, distinguish the ground water from the seepage water. The magnesic salts in the seepage water have evidently been taken up from the soil. The water used for irrigating was practically snow water. I have no analyses of the Arkansas river water at my command. I have no doubt but that it is quite as different from the ground water as the seepage water is, and resembles the latter much more than it does the former.

Ground Water.

Total grs. per gal.	596.766
Sodic sulphate	341.771
Calcic "	155.650
Magnesic sulphate	51.880
" chloride	29.027
" carbonate	16.026
Insoluble	2.412
	596.766
Total magnesic salts	96.933

Seepage Water.

Total grs. per gal.,	97.85
Sodic sulphate	54.38
Calcic "	29.47
Magnesic chloride	7.50
" carbonate	5.27
Insoluble	1.23
	97.85
Total magnesic salts	12.77

This seepage water is from Larimer county, and the different conditions of soil and the different waters used for irrigation influence the character of the salts taken into solution or left by evaporation and consequent concentration. The writer does not know the history of the land from which this drain water was taken; but there is no doubt that it is a seepage water which had collected in the lower portions of the farms and was drawn off by the laying of this drain. The water used for irrigating was taken from the Cache-a-la-Poudre river. The water supply for the city of Fort Collins is taken from the same source, and as delivered for domestic use contains in the month of February, when the water is low, rather less than ten grains of solid matter to the gallon. This gives us a general, though somewhat indefinite, idea of the amount of salts due to concentration and solution from the soil.

The Arkansas river water may contain more solids when taken out for irrigating purposes, but there is little doubt that the magnesic salts, in both cases, are taken into solution as the result of chemical changes between the salts of the soil and those taken into solution by the water. The ground water is not so different from the seepage water, but that it may be considered as a product of the concentration of seepage waters. This is not the place to discuss the manner in which this concentration has been effected. We have intimated an answer to the most patent inquiry, i. e., whence the magnesic salts contained in both the samples, the ground as well as the seepage waters, especially as the irrigating water used is river water, supplied by melting snows and flowing for the greater part of its course over gneissic or granitic rocks. This is more literally true of irrigation water used in parts of this county (Larimer) than it is of that used in Otero county, which is farther removed from the mountains. The analyses of drain waters taken in European soils are not closely comparable with our seepage waters, for these soils have been washed out and ours, in this semi-arid climate, have not been; still even the European drain waters show a relatively large amount of magnesic carbonate present in them ranging from one-third to one-twelfth of the total lime salts.

This subject may form the basis of some future work by the department, though the subject has already been approached in Bulletin No. 9, of this Station.

The relation of soil water to the salts taken up by plants is apparently not the same as that sustained by solutions in water culture. Our alfalfa roots have not taken it up from this depth. We have given analyses of the soils and of the ground water and we place the analyses of the ashes of the hays side by side for easier comparison.

	Weld Co. Per cent.	Otero Co. Per cent.
Carbon	.000	.020
Sand	1.765	1.261
Silica	1.513	.858
Phosphoric acid	4.459	3.714
Sulphuric acid	5.636	5.477
Chlorine	6.776	7.721
Lime	23.905	24.524
Magnesia	5.951	3.141
Ferric oxide	.397	.683
Aluminic oxide	.253	
Brown oxide of manganese	.188	.156
Potash	23.934	28.209
Soda	1.840	2.055
Carbonic acid	25.151	24.053
	101.768	101.777
Less O equivalent to Cl	1.523	1.739
	100.245	100.038

The results of our study and observations as to the effect of alfalfa growing upon our soils are briefly stated as follows :

The biological relations of the soil are probably materially improved by the maintenance of a more uniform tempature during the heat of the summer days, by the maintenance of greater uniformity of moisture, and by a supply of organic matter. The shade and moisture furnished or conserved by a growth of alfalfa must evidently exert a pronounced influence upon the soil conditions, and not only improve the biological conditions, but also favor chemical changes, particularly humification processes.

There is added yearly to the surface portions of the soil a large amount of mineral matter by the falling portions of the plant, leaves, stems, etc., which, with the shade and moisture furnished to facilitate their decay, amounts to an excellent top dressing. The slowness with which straw, leaves, etc., decay in our soils with the ordinary supply of moisture, almost prevents such material from serving any good purpose as manure or as a means of forming humus in the soil, and anything which facilitates this process is of a decided advantage ; for the physical condition of our soils, while good, can be improved in this direction.

There is no doubt but that the return of the plant food appropriated and deposited in the leaves and stems which fall upon the surface may be slower than it would be under humid atmospheric conditions; still it goes forward somewhat faster under the influence of the shade and conserved moisture of a thick growth of alfalfa than it would otherwise do, and the surface soil must have a very considerable amount of mineral ash constituents added to it in the course of six or more years. Some may be flooded off by irrigating, some may be blown away, and a large amount may be taken up in the production of subsequent alfalfa crops; still there can scarcely fail to be a large residual amount of available plant food collected in the first few inches of the soil. I am satisfied that this factor in the improvement of the soil has not received the consideration it deserves. It is one of those factors, however, that is just as potent without as with recognition, for the leaves fall and can not be prevented. I have elsewhere, in speaking of the loss in hay making, stated that from fifteen to twenty per cent. is about the minimum, and taking it at twenty per cent., and this is scarcely too high, we have a top dressing of leaves weighing one ton for every five tons of hay taken off, and as this amount of hay may be cut from an acre in one season, though it is too high for the average, we may calculate the annual dressing of leaves, etc., at one ton per acre. The total ash in this is 269 pounds, taking the ash of the leaves at 13.45 per cent., which is the average of four determinations. The 269 pounds of ash contain 11.83 pounds of phosphoric acid and 49.22 pounds of potash, equal to 25.79 pounds bone phosphate and 77.73 pounds chemically pure muriate of potash. To these are, of course, to be added the ash ingredients, for instance, the lime equal to 76 pounds caustic lime and upwards of 30 pounds sulphuric acid (SO_3); also nitrogen, equal to 74 pounds. It would require 449 pounds of sodic nitrate to furnish this amount of nitrogen. The yearly top dressing from this source alone is equal to 25.79 pounds pure calcic phosphate (bone phosphate), 77.73 pounds pure muriate of potash, and nitrogen equal to 449 pounds pure sodic nitrate. We take into consideration the facts that the organic nitrogen is not worth as much as the nitric nitrogen; that some of these constituents may be lost; also that much of it will be used by the growing plants, and still, as I have before said, the residual manurial elements must be large.

The value of the stubble and roots in the soil has been shown to be about $35 per acre, for the nitrogen, phosphoric acid, and potash, attributing neither influence nor value to the other fertilizing elements, which is justifiable only on the ground that we have neither a commercial nor a conventional measure of value for them, particularly the easily decomposable organic matter which has more value in our soils than it would have in many others. The humus in our soils is not high—in the samples given 0.4 and 0.2 per cent. respectively—and they produce good crops, but the addition of this form of organic matter would better their mechanical condition and very probably their productiveness. As the increase of humus in these prairie soils is not easy, I believe that we ought to value highly the easily decaying alfalfa roots.

There is still another manner in which the growing of this plant benefits our lands for cultivation: it opens up channels through compact substrata to a considerable depth, allowing the entrance of water and air. The writer unfortunately does not know whether hardpan streaks are frequently met with or not, but, so far as his observation goes, they are not; compact layers are met with, but the alfalfa roots have penetrated all of these which he has examined with this point in view. The size and length of the average roots in this country are not at all consonant with popular estimate, nor yet with the descriptions given of them as found elsewhere; but their power to penetrate tough clays and hard streaks is great enough to make them most excellent subsoilers. The soil of a field which has been to alfalfa has practically been deepened for a subsequent sowing to wheat. I have not seen, nor do I know of any observations having been made upon the root development of wheat in our prairie soils or as to the depth to which they penetrate in virgin soil, where there is a very fine, compact, and tough substratum, the result of the settling and compacting of ages To plant such a soil to alfalfa is to perforate this compact subsoil with numerous channels for the passage of water and air and for the entrance of other roots when those of the alfalfa have rotted. The work done by the alfalfa roots in accomplishing this is very great, but this work is to the benefit of the soil, the advantage of the succeeding crops, and to the profit of the owner, being the cheapest labor as well as the best directed and most efficient of any which he can employ.

A very common practice among our ranchmen ought to be particularly mentioned here, though it is only incidental to the object of this bulletin and is self-evident, needing only that attention should be directed to it. The great benefit accruing to worn out wheat soils by being sown to alfalfa is so marked that it is a matter assumed to be a fundamental fact of our Colorado farming. Alfalfa hay does not, at present prices, bear transportation, except it can be converted into some more markatable form; and this has been the case for years. Until recently the fattening of steers was profitable, and, consequently, a favorite manner of marketing alfalfa hay. The crop was fed in the field, the animals pasturing and feeding on the ground upon which the crop grew; this was practically equal to returning the crop to the soil from which it was taken. Of course, the practice is not without some drawbacks; still the crowns were not tramped to death and the voidings of the animals were equivalent to manuring the surface soil with the crop grown upon it. There is no question but that this is not an economical way of treating the manure; but, in spite of the losses, a large amount of the manurial elements of the crop were returned to the soil. This does not hold for sheep feeding, and unless our farmers pay more attention to the manure of the sheep-fold, some of the beneficent effects of alfalfa growing observed in the past will be wanting in the future. The care of this manure is an important question to the people of this community. The alfalfa is a heavy feeder and lays a tax upon the soil for every benefit it bestows. The apparently wasteful methods of the past have tended to gain all the advantages from growing this plant and to obviate any disadvantages. If the same good results are to be maintained under a changing system of feeding, care must be exercised, and the manurial equivalent of the crop must be returned to the soil.

APPENDIX.

In the preceding pages I have given the general results of our study of the development of the alfalfa plant, mostly in numbers based upon hay, because this is the condition with which the average reader is most familiar, and the details of the preparation of samples, so far as there is any need of their being given at all, have been given; but there are some details deserving of mention and yet of less interest to the public than the general discussion. Some of these may find place here, together with the tabulated results based upon thoroughly dry material.

PREPARATION OF THE SAMPLES.

The samples of hay were prepared with the utmost care in order that the samples should represent the best grade of hay possible to be prepared from plants in that stage of development. They were protected from undue exposure to sun, wind and rain; in fact, they were cured in muslin sacks and brought into the laboratory whenever there was any rain and during the night; so that they were not exposed to the effects of dew or moisture other than the hygroscopic changes in the atmosphere itself. We found that the protection from blowing sand and from loss of leaves due to the wind and drying of the plants was absolutely necessary in order to have our samples represent the plant as it actually was at the time of cutting. The sand found in the analyses of plant ashes is partly accounted for, in our cases, by its being blown upon the plant during the preparation of the sample; some of it, however, is lodged in the axils of the leaves and stems, or even driven into their tissues by the winds. This method was very tedious, requiring as many as ten days, even in this climate, to get some samples to a constant weight. A few experiments were made to determine the effect, if there was any, of drying the sample at 100 degrees C. and then exposing the dried hay to the air until it had saturated itself with moisture under the usual atmospheric conditions. We found this much more convenient and without effect upon the analytical results. The samples, however they might have been prepared, had to be sealed, and every precaution taken to prevent their absorbing more moisture, which in the closed bottle, they did not so readily give up.

PREPARATION OF THE ASH.

The method pursued in preparing the ash was, to heat a large platinum dish over the flame of a small Argand burner so strongly that the bottom, the room being partially darkened, began to show a dull redness over an area from one to one and a half inches in diameter; the weighed sample was introduced in separate portions until the charred mass filled the dish to rather more than two-thirds full, when it was allowed to continue heating until the volatile matter was nearly or quite expelled; the bulky mass was then transferred to a porcelain casserole and allowed to burn of its own accord so long as it would. The mass was stirred frequently and new portions of the sample were treated in like manner until the whole of it was brought into the casserole. When it had burned out and cooled sufficiently the still highly carbonaceous ash was extracted with water and washed so long as the wash water showed the presence of chlorine. The insoluble portion free from chlorine was then burned to whiteness at as low a heat as was feasible. This often proved to be a tedious operation. The solution containing the alkalies was evaporated to dryness in a platinum dish after the addition of the insoluble portion and enough ammonic carbonate to convert the calcic oxide formed into calcic carbonate. The ash was eventually dried at 200 degrees C., at last with addition of solid ammonic carbonate and bottled while still hot and carefully corked. If the ash thus prepared has to be kept for any length of time, it is necessary that it should be sealed. This degree of care was taken to avoid loss of chlorine and also possibly of sulphur. During the course of the preparation, however, we became convinced that the precautions taken were inadequate, because the loss of chlorine was not due to the volatilization of the sodic or potassic chlorides, but due to the formation of ammonic chloride. The odor of ammonia was very marked at certain stages of the process and was present in sufficient quantities to react upon red litmus paper, and a glass cylinder, placed over the already charred mass became coated with a white film whose solution in distilled water reacted strongly for chlorine. The temperature of the mass was at this time very low, and the escape of the potassic and sodic chlorides from the mass, whose surface was covered with a layer of already cooled ash, even if the temperature at the glowing points was high enough to volatilize them, is difficult to believe. But one proof has already been adduced, that with this highly nitrogenous plant, chlorine did escape, whatever may be the facts relative to the sodium and potassium. The loss of chlorine was also noted by direct observations in the incineration of a sample of seed, but the conditions were not similar and the film of chloride, collected on the cool platinum foil used in this instance, may have been the chloride of one of the fixed alkalies, or perhaps of both. No less care had to be exercise to avoid the formation of the alkaline sulphides either directly or by reduction of the sulphates, principally, if not exclusively, by the latter process. Close observation shows that, if the combustion is slow enough to avoid a high temperature in any part of the mass, there will be no sulphides formed, but otherwise yellow points may be detected in the mass by careful examination before it has been stirred too much. In burning large quantities it is almost impossible to avoid its formation because of our inability to control the rate of combustion in all parts of the mass.

The time consumed in preparing the samples of ash was very great, and, as we shall subsequently see, did not produce results commensurate with the care bestowed upon it. The only point in which satisfactory results were obtained was in producing an ash practically free from carbon and one in which we had no free bases, either lime or alkalies. The evaporation of the ammonic carbonate solution to dryness and heating to 200 degrees C., with the addition of the insoluble, was probably without any other effect than to assure the conversion of any caustic lime into the carbonate. That it may have been the cause of the loss of any chlorine ors ulphuric acid, particularly the latter, is very doubtful. This question suggested itself, and calcic sulplate was repeatedly heated in this manner without change in weight.

THE METHODS OF ANALYSES.

As the methods adopted in this work are not identical with those commended by the Association of Official Agricultural Chemists, we deem it just to give the methods used, which, in our hands, are convenient and very satisfactory. The general method was to dissolve 4-5 grams of the ash in hydrochloric acid and to separate the silicic acid by evaporating to dryness and heating in an air bath at 115 to 120 degrees for two hours, after which the mass was wet with strong hydrochloric acid and evaporated to dryness again on the water-bath, taken up with water and as little hydrocholoric acid as possible, and the solution made up to 250 c. c. The soluble silicic acid was separated from the sand and carbon by means of caustic potash solution. The sand, etc., was washed from the filter into a platinum dish, a solution of caustic potash, corresponding to three grams of the solid salt, was added, and the whole evaporated to dryness on the water-bath. This gives us fixed conditions for all the analyses. Fresenius and Will have shown that sand is not attacked under these conditions. There was not carbon enough in any sample of ash analyzed to give any trouble and the solutions were clear and colorless. The residue, insoluble in caustic potash, was washed with hydrochloric acid and subsequently with water until free from chlorine and weighed on a tared filter. The carbon was burned off and the sand weighed. The silicic acid was separated from the potash solution as usual and weighed as silica. One portion of the solution, corresponding to about one gram of ash, was taken from the determination of the sulphuric acid, oxide of iron, and alumina. A second portion, equal to the first, was taken for the phosphoric acid, manganic oxide, lime and magnesia, and a third one for the determination of the alkalies. The sulphuric acid was thrown down as baric sulphate from the boiling solution by hot dilute baric chloride solution; this precipitate was filtered off, washed until no chlorine could be detected in the wash water, ignited, and as a precaution, weighed. It was then fused with sodic carbonate or sodic-potassic carbonate—the solution of the sulphate must be complete—whereby the excess of barium and any iron and alumina is separated, the solution was acidulated with hydrochloric acid and after standing until the excess of carbonic oxide had escaped, was heated to boiling, and the sulphuric acid again precipitated by a hot dilute solution of baric chloride; this precipitate was washed and weighed, then dissolved in concentrated sulphuric acid, and the baric sulphate cystallized by evaporation to dryness and washed with boiling water. The fusion, with the alkaline carbonates, is advisable to remove excessive baric salts, iron and alumina, the solution in sulphuric acid to remove alkaline salts from the baric sulphate. These operations lengthen the analyses, but the results are very different from the first weights obtained in the determinations.

The ferric and aluminic phosphates were thrown down from the filtrate by means of ammonia, and acetic acid added to dissolve the other phosphates. This precipitation had to be repeated at least three times to get rid of baric and calcic phosphates. There was not maganese enough in any sample analyzed to come down with ferric and aluminic phosphates in sufficient quantity to be detected. The ferric oxide was separated by means of citric acid, ammonia and ammonic sulphide. If the precipitate of phosphates is not heated too strongly, even partial fusion must be avoided, their solution in hydrochloric acid is easily effected, and the separation is easily performed.

PHOSPHORIC ACID, MANGANESE, LIME AND MAGNESIA.

A quantity of pure ferric chloride, sufficient to combine with all the phosphoric acid, was added and then, if the solution was not too acid, solid sodic acetate sufficient to convert all the bases into acetates, and the whole evaporated to dryness on the water-bath. If the solution was too acid, it was partly neutralized with sodic carbonate before the addition of the acetate. The dry mass was moistened with acetic acid and boiled out with water. As a rule, I do not wash this precipitate thoroughly, but dissolve it in hydrochloric acid and evaporate the second time with the addition of sodic acetate. The precipitate contains neither manganese, lime nor magnesia and the solution is free from iron and alumina, from which no trouble is experienced in precipitating even traces of maganese by bromine water, and has the further advantage of being small in volume. The lime was precipitated as oxalate, with the ordinary precautions, to obtain its complete precipitation. I allowed it to stand as long as at all convenient, washed and dried it partially and ignited it in a platinum crucible or dish until all the oxalate was destroyed; it was then brought into solution and reprecipitated as oxalate. This precipitate was free from magnesia. The filtrates containing the magnesia were evaporated to a convenient volume and the magnesia thrown down by ammonic phosphate ; this precipitate was purified by solution and reprecipitation. A nitric acid solution of the precipitate of ferric oxide, containing the phosphoric acid, was obtained either by dissolving it in nitric acid directly, or by first dissolving it in hydrochloric acid, precipitating by ammonia, washing and then dissolving it in nitric acid. The latter method will be found the shorter, as a rule, and more satisfactory. The phosphoric acid was thrown down from this solution by ammonic molybdate, the precipitate washed with dilute nitric acid, dissolved in ammonia, and precipitated with magnesia mixture. The precipitate was allowed to stand, though precipitated hot with the aid of violent stirring, for twelve hours, and then, after washing, dissolved and precipitated, often with the addition of a little citric acid if there was any suggestion of the presence of ferric phosphate in the phospho-molybdic acid. The third portion of the solution was used for the determination of the alkalies. I added to the boiling solution baric chloride, enough to precipitate the sulphuric acid, and ferric chloride to combine all of the phosphoric acid and then washed milk of lime to alkaline reaction, washing the precipitate free from chlorine. If too much milk of lime is added this is rendered much more difficult. I prefer to add no more milk of lime than is necessary to precipitate the ferric salts and render the solution alkaline, filter and wash out the precipitate, add lime water to filtrate and evaporate down to a small volume, filtering off the magnesic and calcic salts which separate before precipitating with ammonic carbonate; by which, together with a little oxlate of ammonia, the lime was removed. The last portions of the lime are removed as usual. The addition of baric salts makes this portion of the operation more difficult, but if more than traces or only small quantities of sulphuric acid are present, the addition of baric chloride is advisable. The potassic-platinic chloride was uniformly dissolved in boiling dilute hydrochloric acid and crystallized by evaporation on the water-bath. If enough hydrochloric acid is added, there will be no trouble experienced by the formation of a crystalline film to prevent evaporation; on the contrary, the salt will crystalize in large, well defined crystals, as good as free from water, if not entirely so. The potassic-platinic salt was weighed on a tared filter after drying in the water-oven for not less than two and one-half hours.

CHLORINE AND SULPHUR.

The chlorine was determined in two ways; first, from the ash and second from the plant. I was induced to do this by two observations, the first of which has already been given, i. e., an observed loss of chlorine; and the second was the fact that I obtained such unusually high percentages of chlorine in the different ashes that I at first felt that probably I had made some mistake, particularly so as there was not even an approximate agreement between the results obtained from what would be considered comparable samples. The first method was, to dissolve a weighed portion of ash in cold dilute nitric acid with immediate addition of argentic nitrate, and sometimes I used a mixture of argentic nitrate and nitric acid as the solvent. The argentic chloride was dissolved in ammonic hydrate, filtered and thrown down by nitric acid and eventually weighed on a tared filter. The very highest result that I could find given for chlorine in the ash of this plant was a little over eight per cent., and the usual quantity given was about two per cent. or less ; and still finding from five to six and even eight per cent., although I knew that chlorine had been lost in preparing the ash; I concluded that I was in error and resolved to determine the chlorine in the plant or dried sample. To this end from ten to thirty grams was taken, from two and one-half to eight grams of pure sodic carbonate was dissolved in water and made up to a volume sufficient to wet the sample thoroughly. The sample was then placed over a free flame and thoroughly charred, the mass being extracted with hot water; the filtrate was usually slightly colored, especially in cases where a larger portion had been taken, but when the charring had been successfully done, the solution was colorless. The carbon was washed free from chlorine and then burned until the ash was white. As the organic matter is an unpleasant material to have in the solution, I evaporated the same to dryness and ignited it to complete the carbonization. This was easily effected at a temperature which would produce no volatization of the sodic chloride from the mixed salts. The solution was filtered off and added to the nitric acid solution of that portion of the ash insoluble in water. As a matter of course, care was taken to avoid loss from effervescence, escape of hydrochloric acid, etc. From this point on the two processes were the same, but the results were much higher than before. This induced me to treat the whole series in this manner. It has been stated that a loss of chlorine can scarcely be avoided in incinerating the plants ; but either the loss has been considered insignificant or the determination of chlorine has been deemed of so little importance to our study of the plant's requirements that the determination of chlorine in the ash has been accepted, perhaps with good reason, as quite sufficient for our purposes. Be this as it may, we have made the series of determinations in which our results approximate closely to the chlorine in the plants at the time they were cut ; and, while the loss is very varying, it is observable in every case and shows that the amount of care bestowed upon the preparation of the ash was not sufficient to give us more than a relative idea of the amount of this element in the plant. The results are expressed in the percentage of ash found in the air-dried samples, and contain a small error which may, in this case, be neglected. The results are grouped so as to show the chlorine in different parts of the plant, as well as the differences in the results of the two methods of analysis. The samples from the same locality are brought together as far as convenient.

The first column gives the percentage of chlorine found in the ash, and the second the amount corresponding to that obtained from the plant, calculated on the basis of the per cent. of ash found in the air-dried samples.

Hay Samples.

Coming in bloom, 2nd cut	7.758	8.670
Full bloom	8.500	10.880
Half bloom, 2nd cut	7.919	9.637
More than half bloom, 1st cut	7.010	8.888
With seed formed, 1st cut	8.150	9.609
With seed formed, 1st cut	5.760	7.166
Stubble	1.598	2.762
Not in full bloom, 1st cut	4.036	5.665
Half bloom, 1st cut	3.358	4.201
Full bloom, 1st cut	6.020	6.531
Red clover	2.500	2.527
Not in bloom	8.311	9.457
Third cutting	4.753	5.161
Third cutting	7.727	8.180
Some seed formed, 1st cut	6.776	7.966

Parts of Plant.

Whole roots, washed	.523	.746
Whole roots, washed	.318	.609
Whole roots, not washed	.985	1.357
Whole roots, not washed	1.322	1.615
Outside portion of roots	1.226	2.000
Outside portion of roots	1.771	2.333
Inside portion of roots	.756	1.151
Inside portion of roots	.603	1.375
Stems		5.988
Stems	8.510	9.923
Stems	8.180	9.667
Leaves	4.835	.....
Leaves	6.463	7.388
Leaves	6.246	6.773
Leaves	4.822	5.941
Flowers	4.881	.....
Seed	.767	1.453

The ash of the stems appears to contain the highest percentage of chlorine, but that of the leaves by far the largest quantity, as they have an average ash content of about 13.5 per cent., against 5 per cent. in the stems; the roots and seed have but little, both the percentage of ash and its content of chlorine being small.

I have one sample of red clover grown under conditions identical with those under which one of the alfalfa samples was grown, and is therefore comparable with it. The clover contains 10.07 per cent. ash, with only 2.5 per cent. chlorine; while the alfalfa hay grown under the same conditions has 10.42 per cent. of ash with 6.53 per cent. of chlorine.

According to E. Wolff as quoted by Mayer in his Agrikulturchemie, red clover ash contains 3.95 per cent., and alfalfa ash 3.48 per cent. of chlorine; while E. Wolff, in his ash analyses, gives 2.57 for the percentage of chlorine in alfalfa ash from plants in bloom. The difference between these determinations may be accidental and I regret that I have not enough of the sample to either establish the fact, for instance, that alfalfa does require more chlorine for its proper maturing than clover does, or that this result is an accident. As it is the result is suggestive only. It ought to be remarked here that alfalfa does better throughout this country than clover does, although good crops of clover can be grown here. I never saw a finer specimen of red clover than the one used in this determination. The chlorine may have a very important function in the development of alfalfa, and hence its large amount, this may or may not be the proper explanation, but it is evident that the ordinary method of preparing the ash gives too low results and, after allowing for differences due to differences of soils, we have differences due to the degree of maturity; but in all the samples the percentage is high. I have found but few analyses that are nearly as high. Wolff gives three with 6.97, 7.00 and 8.05 per cent. chlorine. Harrington, in Texas bulletin No. 20, also gives three, with 5.07, 6.90 and 8.57; while the average percentage in the ash of alfalfa hay, as we have found it, is 7.85 per cent., with 10.88 per cent. as a maximum and 4.20 per cent. as a minimum.

The sulphur was determined and estimated as sulphuric acid. That some of the sulphur may escape as sulphuretted hydrogen on dissolving the ash in hydrochloric acid, is a well-known and an almost hackneyed observation. As the albuminoids which may contain sulphur are abundant, and also as the alfalfa is a lime loving plant (its leaves containing an abundance of calcic sulphate), the sulphur seems to promise as great a loss as the chlorine. As my time did not permit of an extended series of experiments in this line; and further because of the tedious character of the operations, only a few samples were chosen in which to attempt the more accurate determination of these components, sulphuric and phosphoric acids. Two samples of roots and one of leaves were chosen for this work; the leaves because of the large amount of sulphuric acid, and the roots because of their relative richness in phosphoric acid as well as low percentage of ash.

In the following table, the first column gives the percentage of sulphuric and phosphoric acids found in the ash, and the second column gives the percentage which the ash should contain to correspond to the percentage found in the plant.

Leaves:—		
Sulphuric acid	10.841	12.843
Phosphoric acid	3.459	3.600
Inside portion of roots:—		
Sulphuric acid	4.881	8.091
Phosphoric acid	16.032	15.982
Whole roots:—		
Sulphuric acid	5.093	7.653
Phosphoric acid	10.270	10.048

Here we observe a loss of 2.001, 3.210, and 2.561 per cent. of sulphuric acid; while the phosphoric acid determinations agree as well as could be expected. The preparation of the ash samples has been given. The determination directly from the air-dried samples was made as follows: from ten to thirty grams of the sample, according to the amount of ash it had yielded, was placed in a silver dish and thoroughly saturated with a solution of a mixture of ten grams potassic hydrate to two and one-half grams of nitre and ignited with subsequent addition of weighed portions of nitre until the mass had become white. The sulphuric acid in the potassic hydrate and nitrate was determined and deducted from the total found. Every precaution heretofore given was exercised in these determinations of sulphuric acid, and equally so in the case of the phosphoric acid, which was thrown down from the filtrate from the baric sulphate as ferric phosphate and then by ammonic molybdate as usual.

These results make evident the error in the sulphuric acid determinations by the method of direct incineration as given for these samples; but show no loss for the phosphoric acid. These were the primary objects of the determination, but the samples were chosen with the purpose of giving duplicate determinations of these constituents, particularly of the sulphuric acid in the ash of the leaves and of the phosphoric acid in that of the roots, which seemed anomalously high, but the correctness of the other determinations was more than fully established in this far, that the ash of the leaves contains large quantities of sulphuric acid, and that that of the roots is next to that of the seed in richness in phosphoric acid. The leaves are rich in albuminoids, chlorine, and sulphuric acid. We have no where made any distinction between sulphur and sulphuric acid, and, though it is probable that a large proportion of the sulphur is present in the leaves as sulphate of lime, it is certainly not all present as such. There are two ways of explaining this that suggest themselves to the ordinary mind: either they are simply accumulated there, being brought here more rapidly than they can be disposed of by the plant, or they are gathered there for some functional purpose. The decision of this matter we leave to the physiological botanist; but until we learn better we shall continue to think it more probable that it is for the functional purpose rather than the result of simple accumulation.

Reference has been made in the bulletin proper to the attempt to determine the nitric nitrogen in alfalfa hay. The reducing agent used was neither of those recommended for this purpose; but was metallic iron in conjunction with precipitated copper. I have found this a most convenient and efficient reducing agent for converting nitric acid into ammonia and have given it preference in this work. I am not aware that this has been recommended by any one previous to this time. I added two grams of crystallized cupric sulphate and one and one-half to two grams of reduced iron. As this will give from 13.78 per cent. to 13.83 per cent. of nitrogen in potassic nitrate, I deemed it of sufficient delicacy to give reliable indications in this investigation and have already given the results obtained.

All methods not given in this appendix were the conventional methods.

The fodder analyses were made by Mr. Ryan; also the soil analyses. All others were made by myself.

We have brought together in the following tables our own analyses of alfalfa hay and separate parts of the plant, calculated on the basis of dry matter; also all the analyses of other stations so far as we have been able to find them. Many of these are given in the original publications as analyses of hay; others as analyses of the green plant; and still others in the form here adopted. Of course, all of the first two classes appear here in different percentages from those in the originals.

The writer is not familiar with the conditions in California, Texas, etc., but the results of the analyses show in some cases most remarkable differences. With us in Colorado, the youngest plants analyzed (cut while very immature—May 5th—from three to four weeks before blooming), show 25.72 and 31.52 per cent. of crude fiber for two different types of plants. These are the lowest percentages obtained by us for crude fiber from any Colorado sample; but none of the New Jersey samples reach 25 per cent. The Texas samples vary greatly, and the Kentucky samples are all below 25.2 per cent. The fat in these samples is from two to four fold that found in our samples, and the nitrogen free extract is as a rule higher, though in some cases it is lower. Those of all the samples which approach nearest to Colorado alfalfa are given by the Massachusetts Experiment Station. There are two points in which all the analyses agree, i. e., in showing high percentages of ash and proteids, the latter reaching its maximum in the Texas samples, followed closely by the Kentucky and Georgia samples; while the Colorado samples are very low in the series, the single samples from California and Vermont being the only ones below them in this respect.

It is futile for a person unacquainted with the soil conditions, the climate, the cultivation, and every detail of the conditions under which the plants were grown, the stage of development of the plants at the time of cutting, treatment of samples, etc., and even to these are to be added other very imperfectly understood factors, to attempt to explain the causes of the differences in the samples. The distance between Cape Ann and New Brunswick, N. J., is nearly the same as that between Fort Collins and Rocky Ford, and from New Brunswick to Raleigh, N. C., is about twice as far, while the latitude of New Brunswick and Fort Collins differs by only about one degree. Yet, the samples from Massachusetts and North Carolina are nearly identical with the Colorado samples; while the New Jersey samples differ very materially from them. We have four samples grown in different climates and soils; three of them agree in composition and the fourth one differs. The differences are not so marked in the other samples. I have found no complete analyses of alfalfa ash in any of the Station bulletins; the only ones that I have noted being four partial analyses given in Texas Bulletin No. 20, and two in Massachusetts State Experiment Station Report for 1888. These analyses were made with reference to the fertilizing value of the mineral constituents contained in them and not to determine all of the ash components.

FODDER ANALYSES.

	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen Free Extract.	Total Nitrogen.
FIRST CUTTING.						
Cut very young	......	......	22.890	25.720	......	3.318
Cut very young	.....	......	21.030	31.520	......	3.365
Not in bloom	10.66	2.020	16.270	36.700	34.345	2.604
Not in bloom	10.54	2.011	16.275	37.180	33.895	2.604
Not in bloom	9.92	1.650	17.120	40.580	30.730	2.740
Not in bloom	9.82	1.740	17.120	40.920	30.400	2.740
In half bloom	9.89	1.260	15.370	38.880	34.600	2.549
In half bloom	10.06	1.610	15.370	38.530	34.430	2.549
In full bloom	9.68	2.300	15.304	......	......	2.420
In full bloom	9.88	2.240	15.304	38.500	34.760	2.420
In full bloom	10.53	1.250	15.027	42.880	30.313	2.404
In full bloom	10.43	1.360	15.027	42.670	30.513	2.404
In full bloom	10.71	1.530	15.660	36.110	35.990	2.506
In full bloom	10.81	1.730	15.840	36.390	35.230	2.534
In full bloom	11.01	1.664	16.020	35.380	35.930	2.566
In full bloom	11.19	1.622	15.490	34.590	37.110	2.478
In full bloom	11.41	1.450	15.840	36.900	34.400	2.534
In full bloom	11.55	1.510	16.190	36.520	34.230	2.590
In full bloom	12.27	1.810	17.240	34.590	34.070	2.758
In full bloom	12.20	1.640	16.360	33.900	34.900	2.618
In full seed	7.11	1.080	12.812	48.390	30.610	2.050
In full seed	7.41	.960	12.656	48.380	30.590	2.025
In full seed	10.24	2.060	14.690	40.800	32.210	2.350
In full seed	10.44	2.210	15.310	39.450	32.590	2.450
SECOND CUTTING.						
Not in bloom	11.23	1.340	17.560	30.860	38.810	2.810
Not in bloom	10.91	1.610	16.670	30.920	39.890	2.670
Coming in bloom	12.50	1.190	18.820	33.950	33.540	3.011
Coming in bloom	12.44	1.190	18.850	34.320	33.200	3.018
Half bloom	11.31	1.260	16.080	39.880	31.470	2.572
Full bloom	10.01	1.600	13.781	39.480	35.129	2.205
Full bloom	9.90	1.430	13.781	38.910	35.979	2.205
Full bloom	11.47	1.840	13.240	39.770	33.680	2.119
Full bloom	11.50	1.860	13.630	39.570	33.490	2.180
Early seed	9.56	1.220	12.580	33.200	43.440	2.013
Early seed	9.68	1.220	12.580	33.520	43.000	2.013
THIRD CUTTING.						
Hay from College farm	9.09	1.710	13.000	39.550	36.650	2.080
Hay from College farm	8.66	1.710	13.060	39.160	37.410	1.930
Hay from Rocky Ford	10.47	1.380	12.910	34.670	40.570	2.064
Hay from Rocky Ford	10.08	1.410	12.680	33.880	41.950	2.029
PARTS OF PLANT.						
Seed	3.15	15.230	31.340	22.540	27.640	5.014
Seed	3.19	15.400	31.700	22.570	27.170	5.072
Flowers	9.85	2.210	22.350	20.850	44.740	3.576
Flowers	10.20	......	22.350	21.090	......	3.576
Leaves	15.19	3.020	20.730	16.920	44.140	3.319
Leaves	15.19	3.190	20.730	16.720	44.170	3.319
Leaves	12.48	4.690	24.300	13.650	44.880	3.892
Leaves	12.48	4.690	25.290	13.650	44.090	4.046
Leaves	14.84	4.770	24.240	11.370	44.780	3.878

FODDER ANALYSES—CONCLUDED.

	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen Free Extract.	Total Nitrogen.
Leaves	14.61	3.750	24.690	11.650	44.300	3.950
Leaves	15.03	3.078	25.500	13.760	42.630	4.088
Leaves	15.54	3.109	24.500	13.830	43.420	3.920
Stems	5.19	.953	6.480	57.510	29.870	1.035
Stems	5.30	.900	6.470	57.610	29.720	1.035
Stubble, includes 6½ in. of the roots	4.47	.518	12.160	38.190	45.000	1.945
Stubble, includes 6½ in. of the roots	4.51	.610	11.750	37.400	45.730	1.880
Roots	3.90	.760	11.500	26.530	57.310	1.758
Roots	4.04	.680	11.210	26.120	57.950	1.717
Roots	3.88	1.090	10.690	25.430	58.910	1.710
Roots	3.89	1.190	10.640	25.490	58.790	1.703
Barks of roots	5.40	2.160	14.750	22.790	54.850	2.360
Inside portion of roots	3.64	2.920	8.000	30.330	55.140	1.280

COMPILED ANALYSES.

	Ash.	Ether Extract	Crude Protein	Crude Fiber.	Nitrogen Free Extract	Total Nitrogen.	
Fertilized	7.97	1.12	16.27	34.39	40.25	2.603	Mass. State Expt. Sta.
Not fertilized	7.10	1.04	14.41	32.41	45.04	2.306	Mass. Rep. 1888, p. 165.
No description given	8.25	4.47	12.60	32.94	41.74	2.020	Vt. Rep., 1891, p. 49.
Drilled, 1st cut	9.88	4.34	20.30	24.34	41.14	3.240	New Jersey Rep., 1888
" 2nd cut	7.89	3.73	15.24	18.36	54.78	2.438	" " " "
" 3rd cut	9.19	4.22	17.72	18.24	50.63	2.835	" " " "
" 4th cut	10.55	5.14	21.72	21.06	41.53	3.475	" " " "
Broadcast, 1st cut	10.52	4.07	20.73	23.11	41.57	3.316	" " " "
" 2nd cut	8.22	3.24	16.76	23.70	48.08	2.681	" " " "
" 3rd cut	9.80	0.69	17.64	21.60	50.27	2.822	" " " "
" 4th cut	10.42	5.81	19.64	21.58	42.55	3.142	" " " "
Cut April 20, irrigated	12.91	6.14	18.13	27.56	35.27	2.900	Texas Bul. No. 20, 1892
" " 29, irrigated	12.30	5.18	19.93	29.87	32.72	3.190	" " " "
" May 11, irrigated	10.34	4.87	19.18	33.61	31.98	3.070	" " " "
" " 30, irrigated	8.00	3.61	15.31	34.23	38.85	2.450	" " " "
" " 30, 2nd cut	15.26	3.10	23.56	25.20	32.88	3.770	" " " "
" April 3, not irrigated	10.94	6.30	25.75	16.64	40.37	4.120	" " " "
" " 21, not irrigated	10.59	7.25	25.68	22.98	33.50	4.110	" " " "
" May 11, not irrigated.	8.04	6.60	17.37	30.25	37.70	2.780	" " " "
Flowers begin to appear	11.85	4.48	23.38	19.76	40.53	3.140	Ky. Rep., 1889-90, p. 19
In bloom	7.72	3.00	16.86	25.15	47.27	2.698	" " " "
Pods formed	9.67	2.07	14.83	25.19	48.22	2.405	" " " "
* No description given	7.93	2.49	17.42	33.54	38.62	2.787	N. C. Rep., 1889, p. 82
† Sample inferior hay	5.79	1.66	9.06	39.97	43.52	1.450	Cala. Rep., '91-2, p. 125
No description given	4.28	2.22	21.86	29.55	42.09	3.498	Ga. Bul. No. 7., 1890.
No description given	7.87	2.66	16.24	31.08	42.15	2.569	N. Y. State Rep. 1889
Beginning to bloom	10.5	2.5	16.3	25.4	45.3		Mass. State Expt. Rep. '85, p 70
First cut (b)	9.3	2.6	20.1	28.3	39.7		N. J. Exp. Sta. Rep. 1886, p. 160
Second cut (b)	6.9	1.9	18.6	35.0	37.6		" " " " " "
Third cut (b)	6.6	2.1	16.0	33.5	41.8		" " " " " "
In bloom, 1st cut fertiliz'd	7.2	1.5	11.1	28.5	51.7		Mass. St. Exp. Rep. '87, p. 131
" " " not fert'z'd	7.8	2.0	13.0	27.9	49.3		" " " " " "
Coming into bloom	8.8	2.2	18.8	30.1	40.1		Vt. Expt. Sta. Rep. 1887, p. 130
Seed in dough	8.6	2 4	16.1	32.8	40.1		" " " " " "
Time of cutting unknown	8.1	3.2	16.6	24.2	27.9		Colorado Expt. Sta. Bul. 8, 1889
‡Third cut, not irrigated	11.5	3.0	21.9	18.6	45.0		" " " " "
Cut for seed, Sept. 25	7.9	4.2	12.3	24.5	51.1		" " " " "
Third cut, very coarse.	9 1	2.4	12.2	26.3	50.0		" " " " "
Cut July 15, in bloom	11.2	2.5	11.6	15.4	59.3		" " " " "
" June 6, not irrigated	9.8	2.8	13.5	21.0	52.9		" " " " "
" July 25, irrigat'd twice	7.9	2.0	12.4	25.0	52.7		" " " " "
" July 25, irrigated once	8.5	2.9	11.3	24.1	53.2		" " " " "
Second cut	8.8	2.7	12.9	22.2	53.4		" " " " "

*The analysis of the North Carolina samples, as it appears in their report, contains a typographical error, as the analysis shows an excess of 5 per cent. I have assumed that the error was in the nitrogen free extract, and have re-calculated the analysis giving the percentages on the basis of dry matter.

†The writer of the article in the California report states that the sample was mostly stems and that it was not a fair sample of California alfalfa hay. ‡26 days from time of previous cutting.

ANALYSES OF ALFALFA ASH.*

	Carbon.	Sand.	SiO_2.	P_2O_5.	SO_3.	Cl.	CaO.	MgO.	Fe_2O_3.	Al_2O_3.	Mn_3O_4.	K_2O.	Na_2O.	CO_2.	Sum.	Less O = Cl.	Total.
FIRST CUTTING.																	
Not in bloom	.031	1.087	1.181	5.028	4.440	8.311	22.833	3.223	.378	.162	.166	30.346	1.199	23.559	101.944	1.872	100.072
Not in bloom	trace	.781	1.150	4.630	4.965	4.063	24.750	3.806	.440	.166	.123	29.712	1.423	24.513	100.529	.915	99.614
Half bloom	"	.656	1.065	4.713	5.068	3.358	24.880	3.833	.337	.187	.123	29.892	1.652	25.361	101.125	.766	100.359
Full bloom	.112	.829	.881	5.234	5.608	8.500	27.620	3.798	.269	.089	.168	24.240	.943	23.730	102.220	1.920	100.300
Full bloom	.110	1.370	1.810	4.050	3.440	6.020	25.870	3.810	.090	....	.060	28.380	.860	25.200	101.070	1.350	99.720
In full seed	trace	2.142	1.083	5.404	4.216	5.760	20.146	4.462	.407	.241	.239	28.017	4.039	25.134	101.290	1.289	99.992
In full seed	"	1.765	1.503	4.459	5.635	6.776	23.905	5.951	.397	.253	.188	23.934	1.840	25.151	101.768	1.523	100.245
SECOND CUTTING.																	
Coming in bloom	"	.982	.776	3.941	6.114	7.758	25.973	3.373	.301	.055	.193	25.376	1.860	24.766	101.468	1.749	99.719
Half bloom	"	.907	.584	4.633	7.073	7.919	25.610	3.678	.249	.104	.149	26.865	1.756	22.606	102.133	2.003	100.130
Full bloom	.070	1.590	1.600	4.600	4.530	7.010	29.810	4.500	.140	.300	.080	21.340	1.020	24.440	101.030	1.580	99.450
Full bloom	.090	1.580	1.300	4.590	4.710	7.010	29.670	4.440	.100	.300	.110	21.250	1.050	24.440	100.640	1.580	99.060
Full bloom	.080	1.590	1.450	4.600	4.620	7.010	29.740	4.440	.021	.300	.090	21.300	1.040	24.440	100.850	1.580	99.270
Full bloom	.286	1.761	.850	4.519	6.640	8.150	26.273	4.033	.335	.171	.188	24.112	.991	23.625	101.934	1.836	100.098
THIRD CUTTING.																	
Hay	.011	.608	.431	3.903	3.551	4.753	21.497	4.142	.195	.092	.122	28.395	4.890	28.413	101.003	1.070	99.923
Hay	.020	1.216	.858	3.714	5.477	7.721	24.524	3.141	.397	.189	.156	28.209	2.055	24.003	101.680	1.739	99.941
PARTS OF PLANT.																	
Seed	trace	1.470	.640	38.863	1.370	.767	5.379	9.542	.485	.095	.209	35.213	1.547	4.536	100.116	.172	99.944
Flowers	"	9.187	3.157	7.702	6.256	4.881	16.949	3.953	1.013	1.179	.203	25.586	4.024	.....	....	.	......
Leaves	.023	4.104	1.844	3.013	11.520	4.835	31.327	5.259	.562	.591	.218	9.101	3.722	.....	....	....	......
Leaves	trace	.498	.866	4.399	11.241	6.463	28.435	4.642	.294	.208	trace	18.310	3.797	22.327	101.480	1.456	100.024
Leaves	"	.728	.767	3.407	6.246	6.697	38.370	4.266	.440	.103	.194	11.585	.777	28.113	101.693	1.509	100.184
Leaves	"	.524	.818	3.459	10.841	4.822	35.643	4.536	.430	.098	.315	10.905	3.641	24.031	100.064	1.086	98.978
Stems	"	1.727	1.604	4.437	3.492	5.988	14.260	5.261	.479	.488	.163	26.851	8.335	......	......	....	......
Stems	"	1.227	1.171	6.060	2.085	8.511	14.660	4.688	.545	.290	.157	33.487	4.522	24.368	101.771	1.915	99.856
Stems	"	.754	1.541	4.961	1.904	8.180	17.713	4.360	.362	.369	.145	36.688	1.093	23.858	101.928	1.802	100.124
Stubble	"	4.540	2.673	10.010	3.040	1.598	21.280	6.471	1.044	.697	.262	18.705	5.550	23.895	99.765	.360	99.405
Roots	"	5.907	3.561	8.888	3.208	.523	18.241	8.374	1.147	1.348	.357	22.474	2.469	23.567	100.154	.119	100.037
Roots	"	9.277	4.011	6.359	2.014	.318	21.208	5.481	1.689	1.188	.573	20.331	1.127	26.567	100.143	.038	100.105
Roots	"	2.058	3.865	11.821	5.337	.985	13.949	6.716	1.275	1.182	.681	29.784	5.355	17.630	100.638	.221	100.417
Roots	"	2.380	2.875	10.270	5.093	1.322	19.008	9.492	.844	.729	.149	24.443	2.110	21.742	100.457	.299	100.158
Bark of roots	"	5.119	6.045	9.375	6.318	1.226	14.357	6.563	1.430	1.619	.267	26.122	5.896	16.001	100.338	.276	100.062
Bark of roots	"	5.527	4.670	8.389	6.244	1.771	16.012	10.885	.993	1.444	.400	22.447	2.187	18.268	99.327	.398	98.929
Inside of roots	"	.860	1.125	11.144	4.973	.751	14.159	11.757	.675	1.148	.218	23.037	7.214	23.065	99.126	.169	98.957
Inside of roots	"	1.163	1.072	16.032	4.881	.603	21.021	12.148	.525	.235	.290	18.675	2.424	21.177	100.246	.135	100.111
Red clover	.120	1.730	1.950	2.890	1.330	2.500	25.330	5.550	.100	.....	.210	26.800	.230	30.640	100.380	.360	100.020

* Lithia was not detected in any sample, but strontia was present in all of them.

PLATE I.

The plant represented in this plate grew in a rich, loose soil, with a heavy clay subsoil and an abundant supply of water, the water level ranging from 4 to 8 feet from the surface at different seasons of the year. The diameter of the top was 18 inches, and the number of stems 360. The plate shows how these crowns gather soil around them, for the length of the underground stems is seen to be several inches, and this represents the accumulation of nearly this much material about it.

This is one of the largest plants that I have yet found. The specimen, as photographed, was dug April 30th, 1896.

PLATE II.

This photograph represents the face of an opening made to the depth of rather more than 13 feet in an alfalfa field on the Experiment Station Farm, at Rocky Ford, Otero County, Colorado. The soil is a fine alluvium. The roots penetrated to a depth of 12 feet 6 inches, and the simplicity of the root system is well shown, the roots being shown in their natural position. The upper margin of the photograph represents the surface of the ground, which lacks sufficient sharpness to show the crowns and stubble in the picture.

This alfalfa was four years old and cut from four to five tons of hay a year. The diameter of these roots, just below the crown, averaged a little less than ½ inch.

PLATES III. AND IV.

The two succeeding plates represent the largest alfalfa roots that I have seen. The root system and the tap roots are exceedingly large; they were of very nearly the same length—11 feet 9 inches—measuring from the crown of the root to the deepest point to which the roots had penetrated. They were not dug at the same time and are different types of roots. The tops of these plants measured over 5 feet 3 inches. They were obtained on the place of Mr. J. H. Walter, in Weld County, Colorado.

PLATES V. AND VI.

The two succeeding plates represent typical roots, grown on the place of Mr. J. H. Walter, in Weld County, Colorado. The smaller roots have been placed as nearly in the relative position which they had when taken from the soil as possible. These roots were very large, having a diameter below the crown of 1 inch. Unfortunately it was impossible to have the plants photographed immediately after digging them, and the leaves have fallen from the stems.

PLATE VII.

This cut represents an unusual form for an alfalfa root. It has not arisen from the tap root having received an injury at some time, for it is present, as may be seen upon close inspection, in perfect condition. It is difficult to distinguish between the branches of this root; they have about the same size and length, and one of them would serve as well for the tap root as any other. The root seems to have divided into five roots a little below the crown, each division going down separately, as an independent root, instead of going down as a single tap root. The length of this root was nearly 11 feet.

PLATE VIII.

This plate shows a root with more than the usual amount of branching, also the crown as dead on one side and developing on the other. The particular and anomalous feature about it is the throwing out of the two small roots at the crown. This is one of the very few instances of this which I have seen. In this case, as in all others which I have seen, these roots, although small in diameter, are as long as the larger roots.

PLATE IX.

Yearling plants grown on a highly cultivated soil; the maximum depth to which any of them had penetrated was 3 feet 9 inches. The soil was a fine prairie loam, with a clayey subsoil, succeeded by a fine yellow sand. This soil offered no resistance to the growth of the roots. The black spot on one of the roots is the remnant of a dead root, which, having died and decayed, left an open channel which the alfalfa root had followed. I have traced alfalfa roots for four and five feet where they have followed the course of decayed willow roots.

PLATE X.

These roots had a length of 9 feet 4¾ inches and were nine months old. The field had been sown to alfalfa with oats in the spring, and one cutting of alfalfa hay was made in the fall. The yield was about three-fourths of a ton.

The difference in the development of these young roots is no greater than is often found, and I see no satisfactory explanation for the facts. The yield from fields in which the roots are small is just as good as from those in which the roots are larger, without any perceptible difference in the quality of the hay. Some of these seedling roots were almost as large as any of the roots of the plants four years old, growing in an adjacent land. I do not know how soon an alfalfa root may acquire its full growth.

PLATE XI.

It was not possible to get the details of the small roots in photographs of plants whose roots were from 7 to 11½ feet long. We present in this plate the terminal portions of two roots, 7½ feet from the surface, each showing nodules, which appear as round or irregular black spots on the roots.

The extremities of the tap roots, I regret, were broken off.

PLATE XII.

This plate represents the terminal portion of a tap root, 11 feet 9 inches long. There was a fair degree of moisture, but no water at this point. There are a few nodules observable in the plate, but they are few in number and small. This root was in a perfectly healthy condition and was apparently growing vigorously. The spongioles were long, bright, and had every appearance of health and vigor.

PLATE XIII.

This is a mat of roots as it was exposed near the bottom of an excavation by the removal of a part of a layer of coarse gravel, leaving the roots in a cavity. It was due to the looseness and size of the gravel that we were able to obtain the fibrous roots intact. This gravel bed was filled to its upper margin with water, into which these roots penetrated for about 6 inches.

PLATE XIV.

Root nodules are often small and present in large numbers, being strung along the root as small, more or less round or cylindrical bodies, as may be seen to great advantage by digging up a plant of some of the small growing vetches or red clover, although on the latter the nodules are less abundant and larger. They usually occur on the roots of the alfalfa, isolated or grouped together, often forming colonies of considerable size, as shown in the accompanying plate, the largest of which were over 2½ inches across. These groups were of all shapes; some were globular, others flat and irregular in outline. The figures show this plainly. Some of them were broken and shrivelled; others were white and solid. The nodules represented were found at the depths of from 2½ to 5 feet.

PLATES XV., XVI., AND XVII.

The following series of three plates, with six plants, is intended to show the progress of the decaying of the roots at the crown, mentioned elsewhere in this bulletin.

In the first plate one part of the plant has been pulled to the side to show the cavity, which would otherwise have scarcely been seen. In the second one the root has been split down to show a more advanced stage of decay, and also the manner and depth to which it penetrates into the interior of the roots. The rest show different stages in its advance and the manner in which it affects the crown, finally killing it.

PLATE XVIII.

It is stated in the text, under the head of Roots, that it is difficult to explain the fact that alfalfa plants whose roots have been cut by gophers or mice continue to grow. As we believe the long roots to be necessary to the feeding of the plant, the statement is made in this connection that the alfalfa root does not, when eaten off, throw out adventitious roots, which are sufficient to supply so heavy a feeder as this plant is. The following plate is intended to show this and is of plants said to be ten years old. The plants were very much crowded and were all small. They were plowed up on April 29th, and the one with the smallest roots had as large a growth of top as any of the other plants. I cannot judge how long it was since the injury to the roots occurred

Plate I.

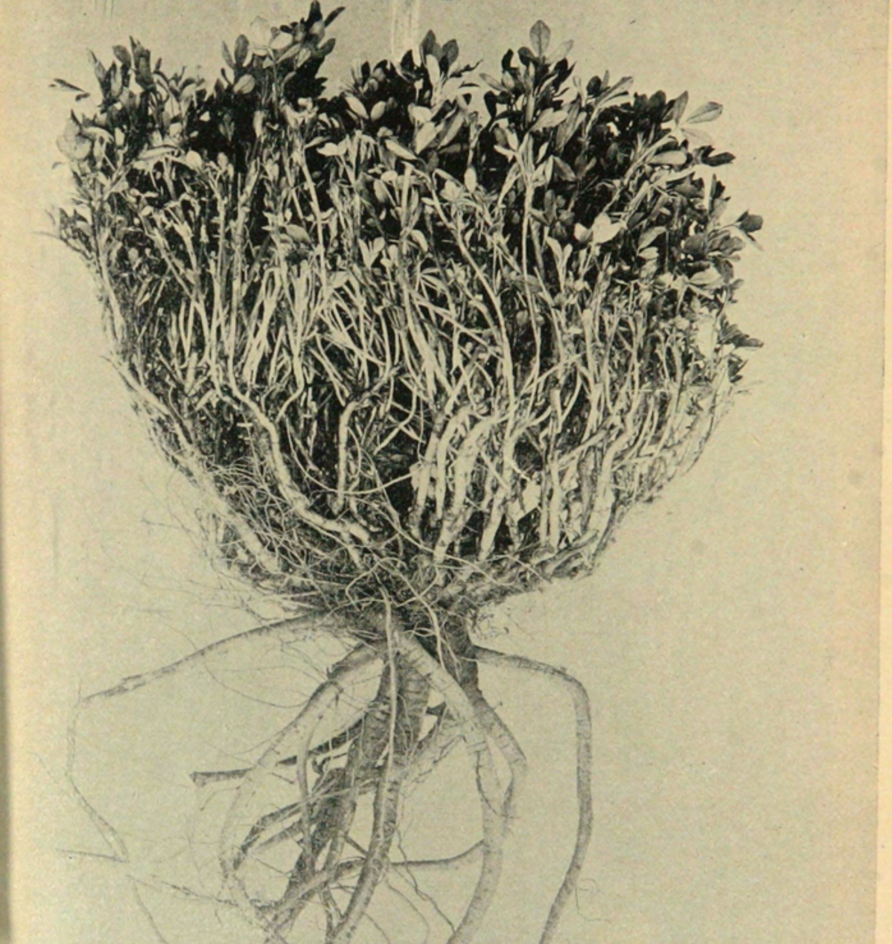



Plate II.

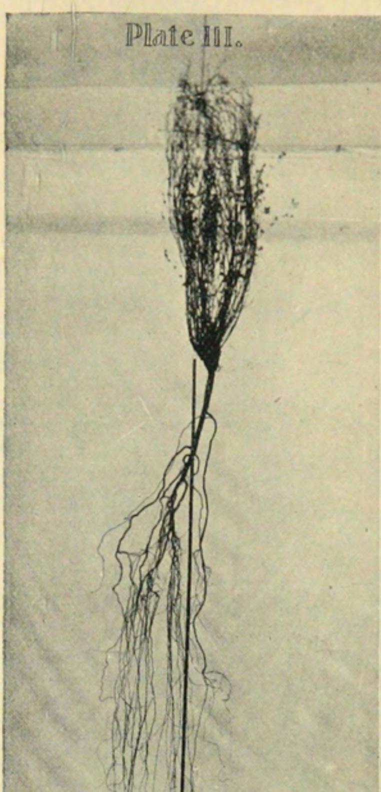


Plate III.

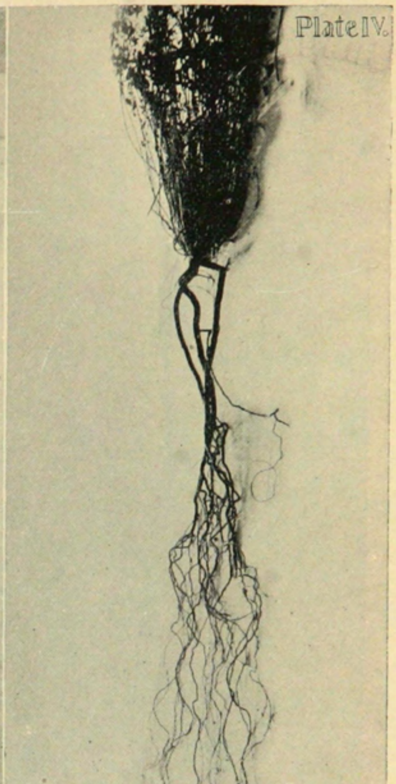


Plate IV.

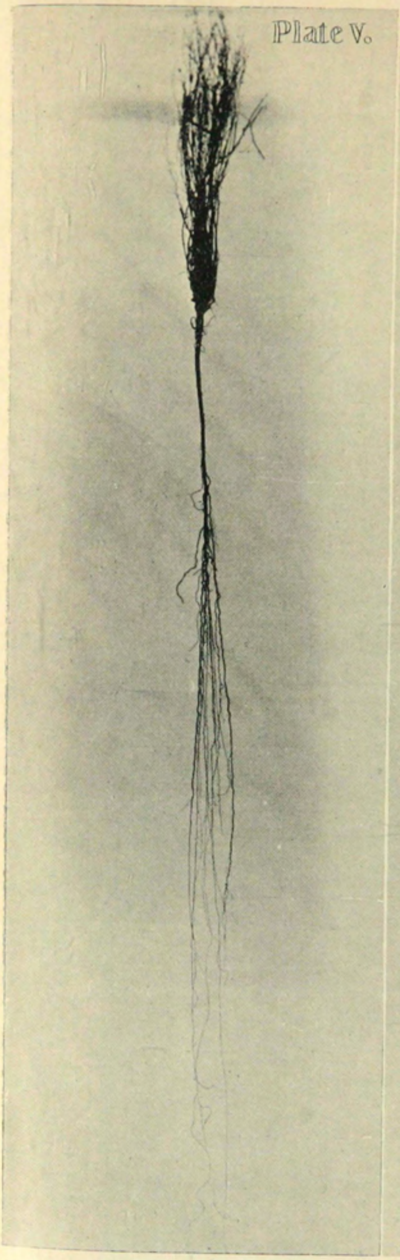


Plate V.

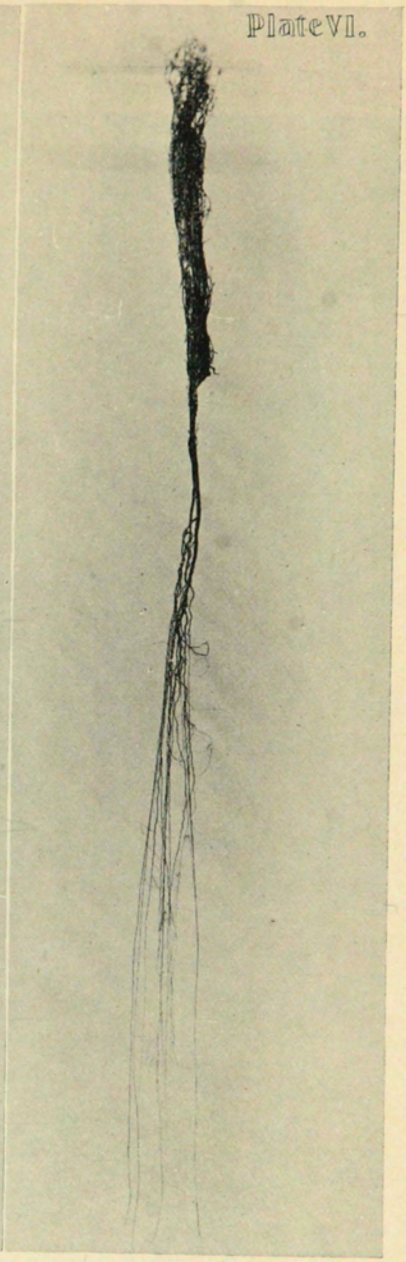


Plate VI.

Plate VII.

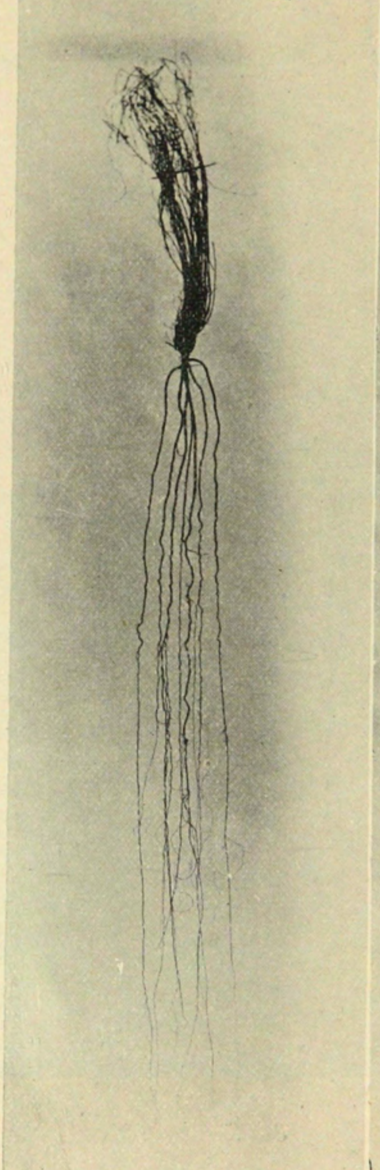


Plate VIII.

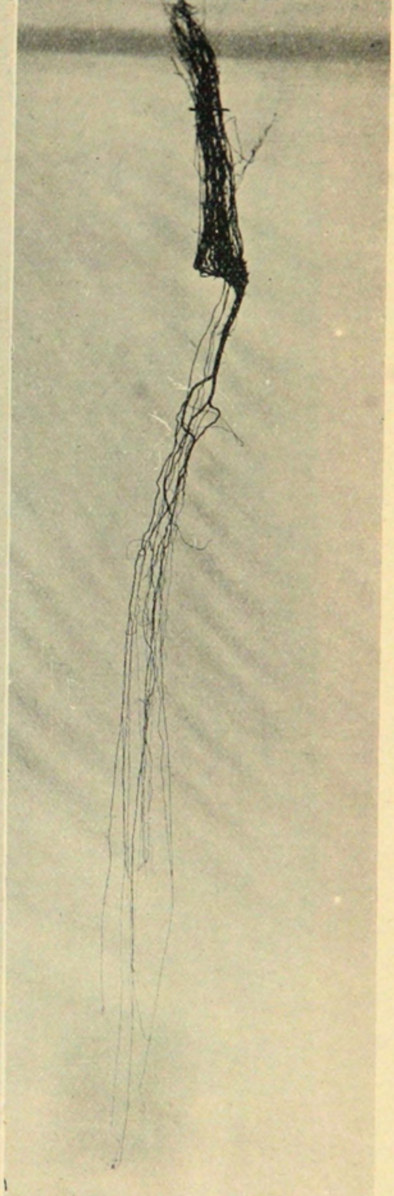


Plate IX.

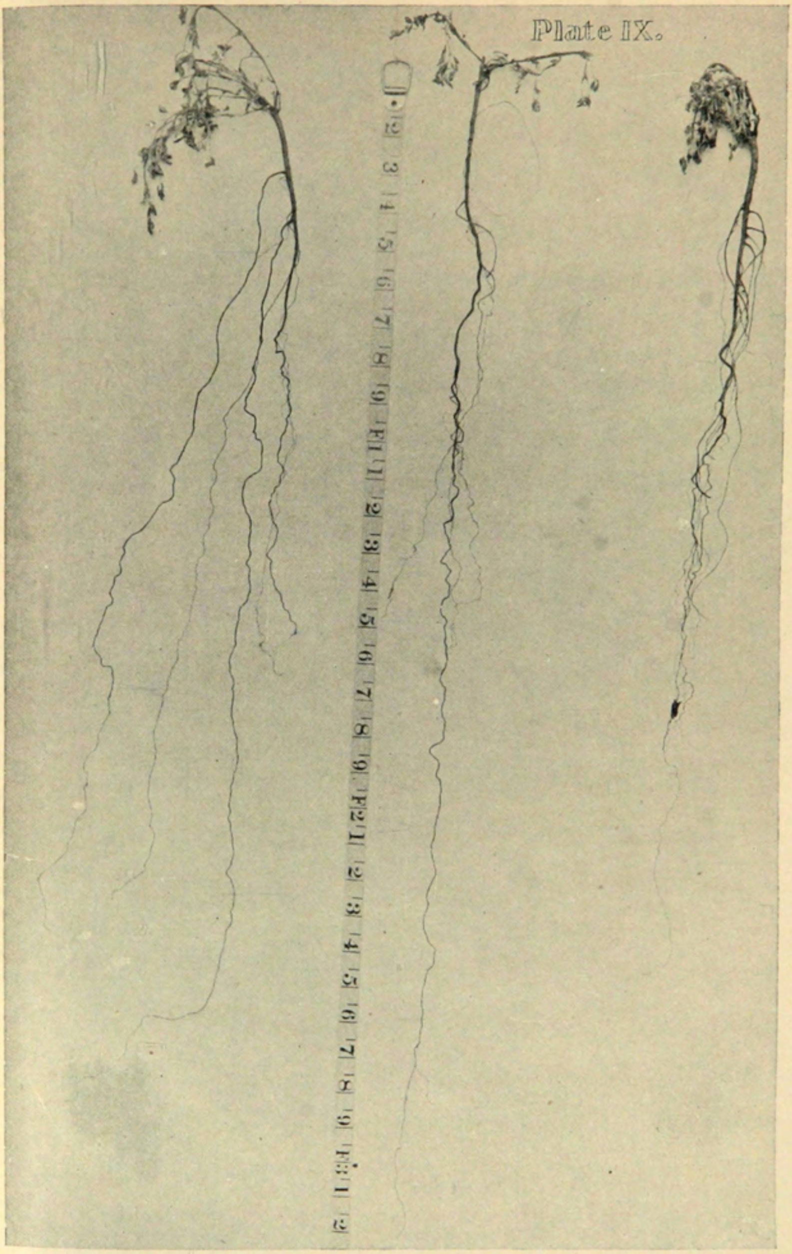


Plate X.

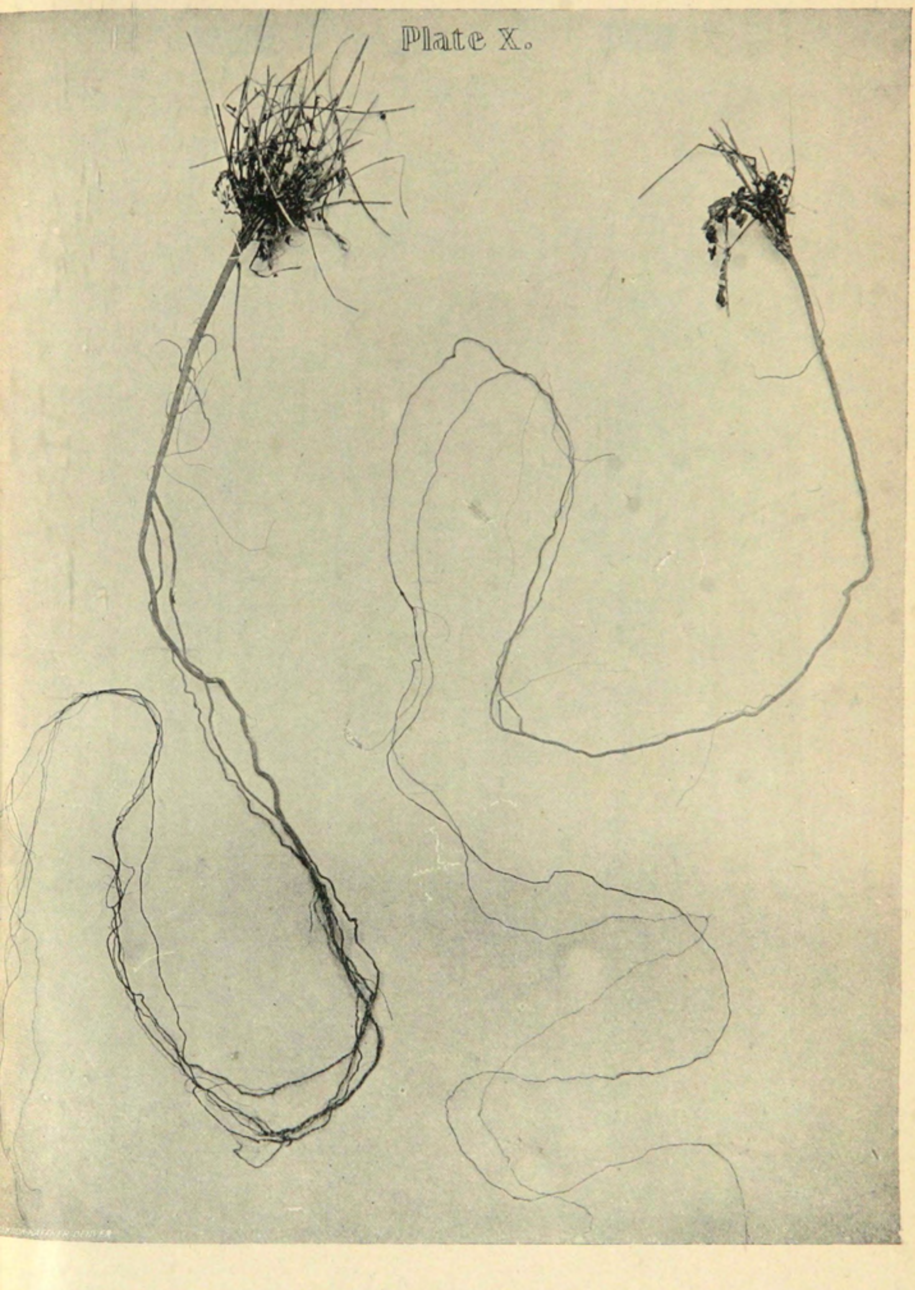
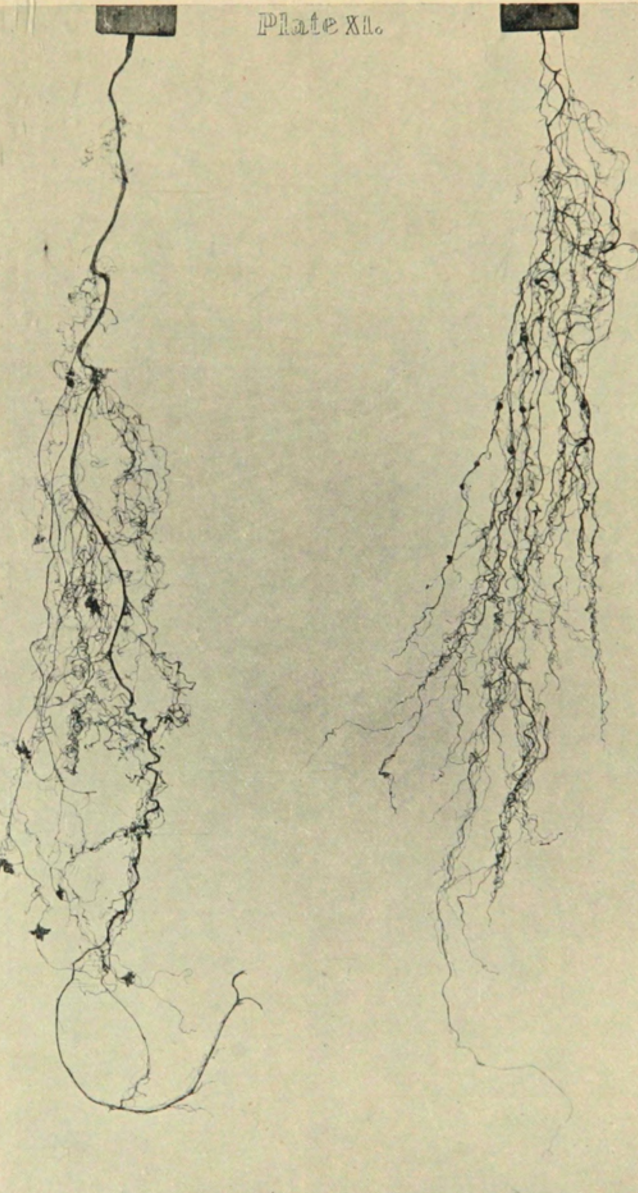


Plate XI.



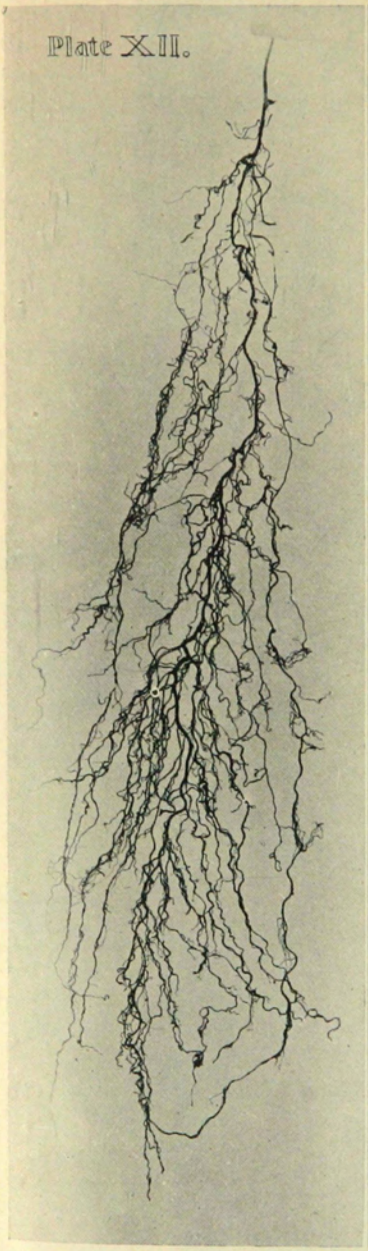


Plate XII.

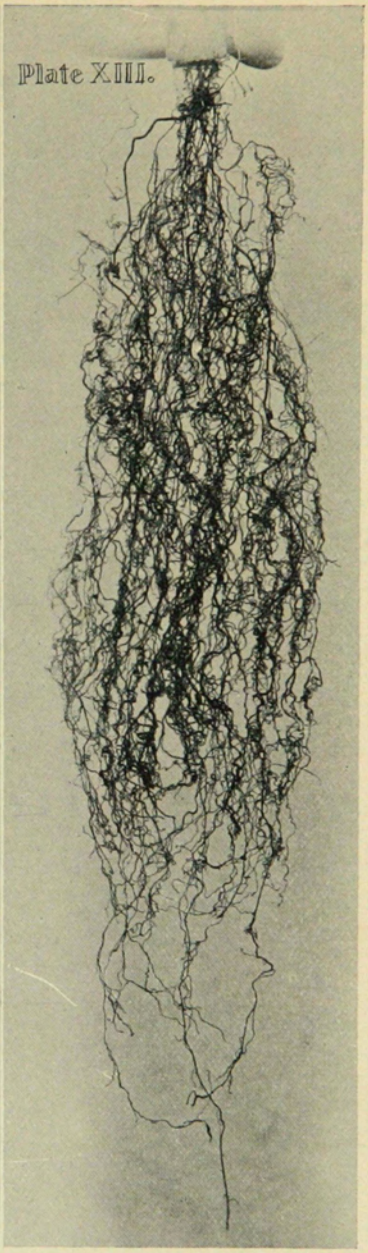


Plate XIII.

Plate XIV

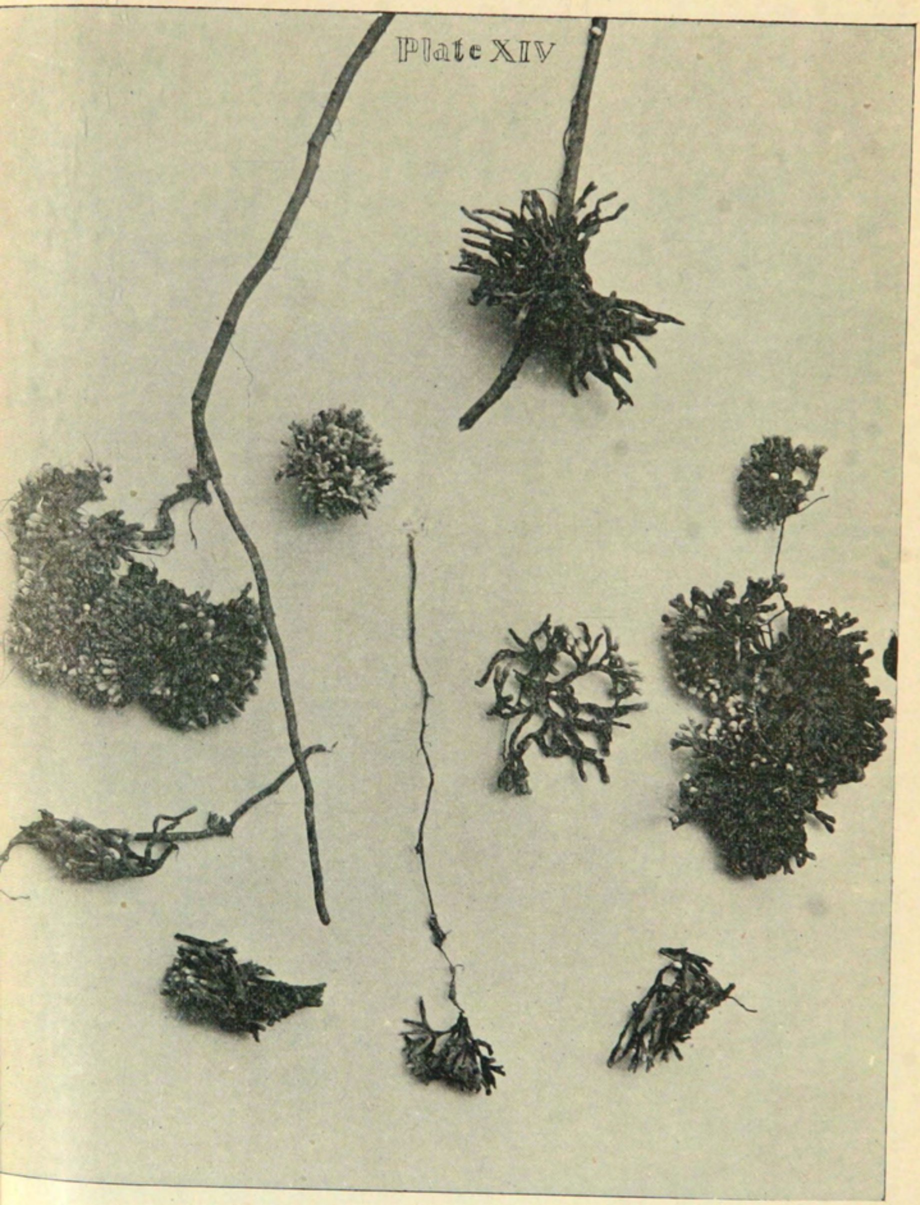


Plate XV.

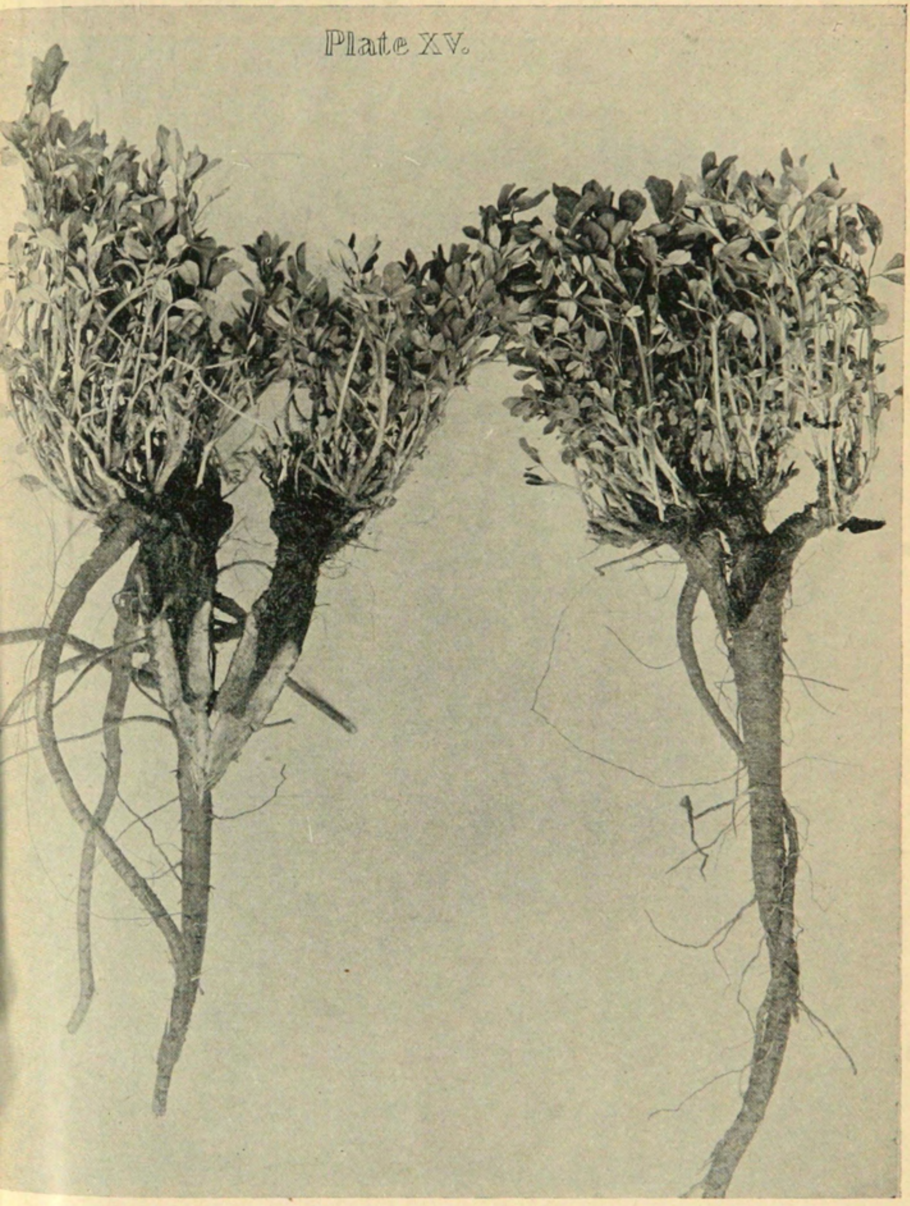


Plate XVI.

Plate XVII.

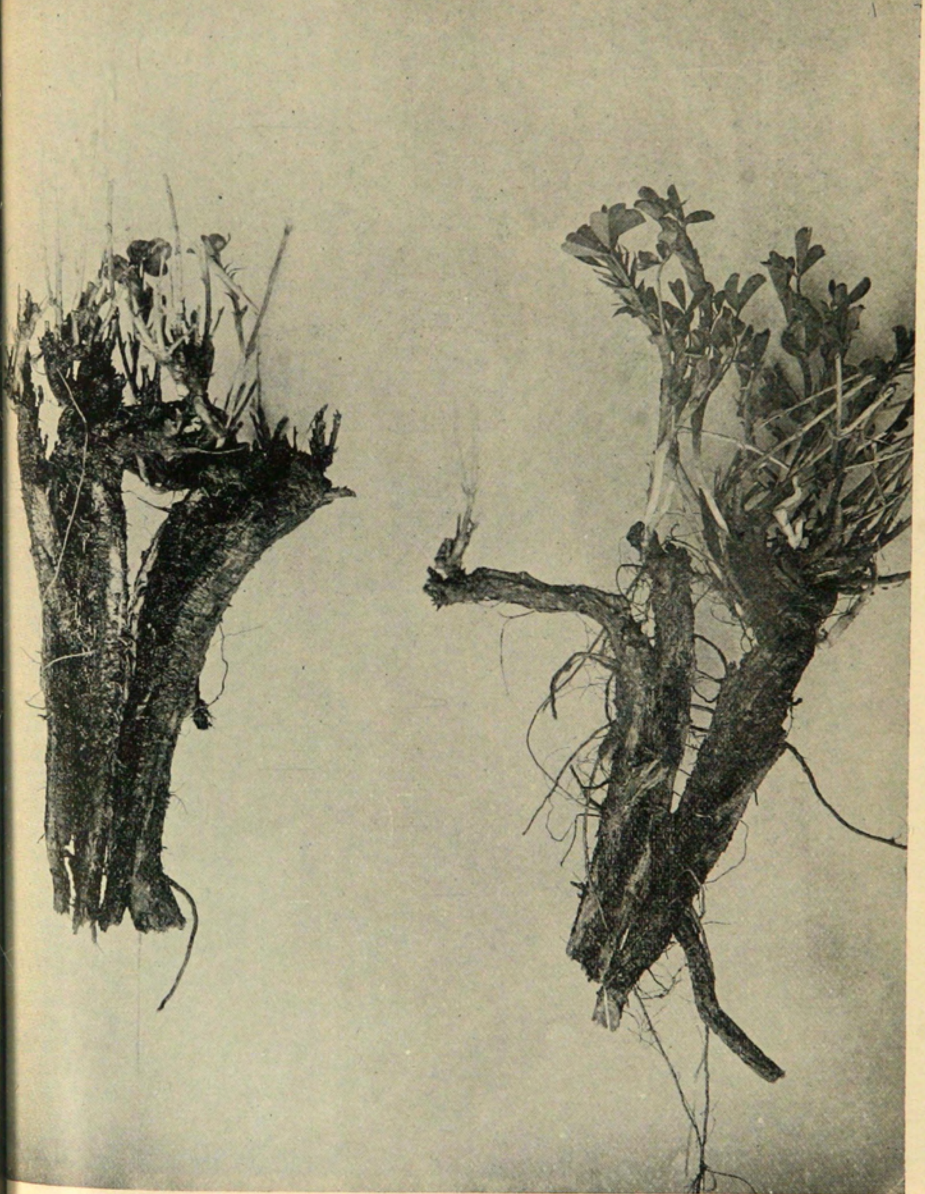


Plate XVIII