D. W. Mayne

UNIVERSITY OF MINNESOTA.

Agricultural Experiment Station.

BULLETIN No. 34.

CHEMICAL DIVISION.

SEPTEMBER, 1894.

I. The Chemical Development and Value of Red Clover.

II. The Russian Thistle. Its Food Value and Draft upon the Soil.

ST. ANTHONY PARK, RAMSEY CO., MINNESOTA.

EAGLE JOB PRINT, DELANO, MINN.

University of Minnesota.

OFFICERS OF THE STATION:

WM. M. LIGGETT,	Chairman.
WILLET M. HAYS, B. S. A.,	Vice Chairman and Agriculturist.
SAMUEL B. GREEN, B. S.,	Horticulturist.
OTTO LUGGER, Ph. D.,	Entomologist and Botanist.
HARRY SNYDER, B. S.,	Chemist.
T. L. HÆCKER,	Dairy Husbandry.
M. H. REYNOLDS, M. D., V. M.,	Veterinarian.
THOS. SHAW,	Animal Husbandry.
J. A. VYE,	Secretary.
ANDREW BOSS,	Farm Foreman.

☞ The Bulletins of this Station are mailed free to all residents of the State who make application for them.

The Chemical Development and Value of Red Clover.

HARRY SNYDER.

Object of Bulletin.—The value of clover as a farm crop is so well known that little need be said by way of introduction as to the importance of the clover crop. Recognizing its importance, many farmers of the state have attempted to raise clover but with indifferent results; hence a complete chemical study of the clover plant was undertaken to obtain a knowledge of some of the more important facts in connection with its growth.

The Failure of Clover not Due to Deficiency of Plant Food in the Soil.—In a few cases where clover has made a poor showing, farmers have sent samples of the soil to the laboratory for chemical analysis, thinking that the cause might possibly be due to the want of some special form of plant food in the soil. The analyses, in all of these cases, have not shown the absence of any of the essential materials for crop growth. From the numerous analyses of soils, partial results of which are published in Bulletin No. 30, it is to be noted that all of the types of soil in the state are well supplied with lime, phosphates, magnesia and potash. This, coupled with the fact that clover does thrive under certain conditions and in certain seasons, indicates that the cause of the failure is due more to the want of the proper mechanical conditions of the soil, as the right time and best crop to seed it with, than to the absence of any special plant food from the soil.

These necessary conditions for clover culture can be learned only after a careful series of experiments in different parts of the state, on different types of soil and under different climatic conditions. This work has already been outlined and undertaken by Professor Hays, agriculturist of the station.

Clover Influenced by Crop with which it is Seeded.—That the yield of clover is influenced by the crop with which it is seeded is shown from the following data: Two adjoining plots of land, an eighth of an acre each, had been in corn for two years (1891-92). The plots were fall plowed and in every way had received the same treatment. In the spring of 1893, one plot was seeded with oats and clover, and the other one to wheat and clover. In the following year 1894, the yields from each of the plots were:

Clover seeded with oats—295 lbs., 1/8 acre plot at the rate of 2,360 lbs. per acre.
Clover seeded with wheat—545 lbs., 1/8 acre plot at the rate of 4,360 lbs. per acre.

A difference of a ton per acre in favor of the clover seeded with wheat.

A review of the growing conditions of the clover in these two plots shows that with the oats, the clover had the disadvantage of being compelled to compete with a more rapid growing, and an earlier maturing crop than when the clover was grown with the slower ripening wheat. The oats were harvested about two weeks earlier than the wheat. This was a period of drought. The oats being harvested left the soil and young clover exposed to the sun, while the young clover which had been sown with wheat was protected until the conditions were more favorable when the wheat was harvested.

On this point Professor Hays says that the poorer chance of the clover seeded with the oats, to get started, was also due to the fact that the oats are apt to grow very rank and dense and that the clover seeded with the oats is far more slender and weak than the plants sown with the wheat, which leaves the clover less able to stand drought and hot weather that may come later in the season, after the oats and wheat are cut.

After a careful series of experiments with raising clover in different parts of the state, many important facts in connection with its growth, will doubtless be observed.

The work recorded in this bulletin has reference mainly to the results of the chemical examinations of clover at different stages of its growth, together with the separate examination of a number of samples of clover grown in different parts of the state.

The Different Periods of Development of Clover.—Sampling.—The clover plant is considered at five different periods in its development. At each of the earlier periods three samples were taken from known areas. One sample was separated into leaves, stems, etc., and each part analyzed separately. In the second sample the entire plant above ground was taken, while with the third sample particular attention was paid to securing the roots. Working in this way the result of each period is duplicated; absolute agreement is not secured among all the duplicates because the clover plants from two different areas are not alike in all respects, yet the results taken as a whole show a satisfactory agreement for each of the periods.

In the first period, the clover was five to six inches in height, the flower head had not yet made its appearance. In the second period, twenty-four days later, the clover was in early bloom and making a very rapid growth. The clover in the third period, fourteen days later, was just a little past full bloom,—in the condition, as will be seen later, for making the best hay. At the end of flowering, and when the clover was ripe, samples were again taken.

The Rate of Formation of Food Constituents.—In order to follow, in a general way, the entire plant above ground through each of the separate periods, the analyses have been calculated to pounds of dry matter, ash, etc., for each period. The largest amount of dry matter, which is found at the flowering is taken as 100, and the largest amount of ash or mineral matter at the end of flowering as 100, and each of the largest amounts of the other compounds that are found in any of the periods as 100. The following table will show the comparative amounts that were present at each of the various periods.

CLOVER AT DIFFERENT STAGES OF GROWTH.

TABLE I—FOOD CONSTITUENTS.

	Dry Matter...	Ash	Nitrogenous Matter	Nitrogenous Matter in the form of proteids..........	Fiber ....
1. Flower Head Invisible	9	14	15	67	5
2. Early Bloom	31	46	37	70	24
3. Full Bloom	97	98	100	88	92
4. End of Flowering	100	100	96	85	96
5. Maturity	97	95	94	83	100

NOTE.—In the table the nitrogenous matter in the form of proteids is represented on the basis of the total nitrogenous material of that period taken as 100. It is the per cent. of total nitrogenous material of each period which is in the form of proteids, as determined by Stutzer's method.

The Earlier Stages of Plant Growth.—This table shows that the most active growing period of the clover is between early and full bloom when sixty per cent. of the dry matter is formed, fifty-eight per cent. of the mineral matter is taken from the soil, and sixty-three per cent. of the nitrogenous matter is produced. The largest yield of clover would be obtained at the end of flowering, but it would not contain as much nitrogenous matter, the important bone and muscle forming material, as when the crop was in full bloom.

Development of the Nitrogenous Compounds.—In the earlier stages of the plant growth there is not so much of the nitrogenous matter in the more valuable form of proteids as when the plant becomes more mature. At the time of full bloom the nitrogenous materials in the clover are in the most valuable food forms. From the time of early bloom until the period of full bloom, a large portion of the nitrogenous materials are assimilated and undergo the transformation from lower (amido) compounds to the more highly organized and valuable food compounds of protein.

The Ripening Period.—The period of full bloom marks the end of the formation of nitrogenous materials. Between full bloom and the end of flowering only two and three per cent. respectively, of mineral matter and dry matter are added to the crop. The period of ripening is simply a period of re-arranging the materials that are already within the plant, and not a period of addition of any new material.

Best Time for Cutting Clover Hay.—The clover hay cut at the time of full bloom contains the largest amount of nitrogenous material in the most valuable food forms, while clover cut at the end of flowering contains the largest amount of dry matter, which is poorer in the valuable nitrogenous compounds.

The largest amount of nitrogen present in the clover plant as found by Dietrich and by Wolff, was at the time of full bloom. Dietrich's results show a decline of 10 per cent. of the nitrogen from full bloom until maturity. (Annales de la Science Agronomique, 1888.)

Assimilation of the Separate Ash Elements.—Of the separate ash elements, potash and lime appear to be assimilated a little in advance of most of the other elements. At the time of full bloom, all of the potash has been taken up by the plant, while the end of flowering marks the highest point reached by the lime and phosphates. The fourth period, end of flowering, marks a period of decline in the potash, which is even greater at the time of maturity.

Retrograde Movement of the Potash.—There is more potash in the clover plant at the time of early bloom than at maturity. This is due to the retrograde movement of the potash at the approach of maturity. The clover crop requires a larger working supply of potash than the amount that is represented in the crop at maturity. In the work of Wolff on the clover, previously referred to, there is a decline of five per cent. in the potash.

The following table gives the rate of assimilation of the principal ash elements of the clover. The highest amount reached in any of the periods is taken as 100.

CLOVER AT DIFFERENT STAGES OF GROWTH.

TABLE II—ASH ELEMENTS.

	Potash	Lime	Magnesia	Phosphates
Flower Head Invisible	15	15	8	14
Early Bloom	50	37	35	34
Fall Bloom	100	97	100	98
End of Flowering	94	100	92	100
Maturity	86	97	91	98

Compared with the growth of the wheat plant, results of which are published in Bulletin 29 of this Station, it will be observed that with the clover there is a more general relationship between the assimilation of the mineral matter and the formation of organic matter. In the first periods of the clover the mineral matter is taken up somewhat in advance of the formation of organic matter, while in the wheat the nitrogen and separate ash elements are assimilated much earlier in the development of the plant.

Mineral Food Required to Grow a Clover Crop.—Taking the entire crop of clover from the plot seeded with wheat, which gave a yield of 4,360 pounds per acre of field cured clover, the pounds of the separate ash materials removed in one acre of the crop are as follows:

Potash	66.	pounds.
Lime	76.4	"
Soda	1.	"
Magnesia	17.4	"
Iron	1.3	"
Phosphates	28.4	"
Sulphates	5.6	"
Carbonates	33.6	"
Chlorine	6.0	"
Silica	15.8	"
Total	251.5	"

Characteristics of the Ash of Clover.—The above table shows the characteristic food of the clover, and the amount of mineral matter that must be furnished by the soil for a good crop. The silica is small compared with wheat, which removes 114 pounds and more per acre. The phosphates are a little lower than the amouut found in a wheat crop. Lime and potash are the two compounds which are required in the largest amounts. The large amount of lime in the clover has caused it to be known as a lime plant.

Best Kinds of Manure for Clover.—Lime in the form of land plaster, and potash in the form of ashes are the most profitable and best materials that can be used on clover. They both have a very beneficial effect in "bringing in clover."

Composition of the Leaves and Stem.—The analyses of the separate parts of the clover plant at the different stages of their development, show that the leaves are very rich in nitrogenous material; from sixty to seventy per cent. of the entire nitrogen in the plant, excepting the roots, is present in the leaves. The first time the leaves were analyzed they contained over thirty per cent. of nitrogenous material—a very high figure and one that is not far from the amount found in the animal body. The leaves also contain a proportionally less amount of fiber. As the plant matures there is a gradual decrease in the proportional amount of nitrogenous compounds in the leaf, and a corresponding increase of fiber and other non-nitrogenous compounds. Over half of the total ash elements of the clover are found in the leaf, with a proportionally higher figure for the lime and potash.

The separate analyses of the clover leaf show its food value to such an extent as to demand that every possible effort be made, in harvesting and handling the crop, to prevent mechanical losses such as breaking the leaves.

Other minor characteristics can be observed from the tables given on the following pages.

Table III gives the composition of the dry matter, and the ash of the entire plant, excepting of the roots, at the five different periods discussed in this bulletin.

The figures under the heading of dry matter represent the nitrogenous material, fiber, ash, etc., that are present in one hundred pounds of the dry clover. The clover hay, field-cured and ready for feeding, contains from ten to fifteen per cent. of water, and when one hundred pounds of clover is fed a correspondingly smaller amount of nitrogenous material, etc., are present than is represented in these tables. Since the amount of water that is present is subject to variations, the results are calculated on the perfectly dry material.

The term dry matter is used to indicate the perfectly dry clover. All of the water is removed by drying the substance for several hours, in a drying oven, at the temperature of boiling water. The drying oven is made of copper and has double walls. The space between the walls is filled with water which is kept boiling. When any material is dried in such an oven it will give up the water which it contains and leave the dry substance.

In order to change the results from dry substance to original substance a simple calculation will illustrate the method. In the first period, when the clover is very young a hundred pounds of it contains 86 pounds of water and 14 pounds of dry matter. The analysis of the dry matter showed 23.61 per cent. of total nitrogenous material; 14 pounds of dry matter would then contain (14 x .2361) 3.36 pounds of nitrogenous matter. The 14 pounds of dry matter is all there is in 100 pounds of the green clover. Hence, if the green clover had been used for fodder, 100 pounds would have contained 3.36 pounds of total nitrogenous material.

The figures for the ash are the amounts of the separate constituents in every hundred pounds of the ash for that period. The amount of each separate ash element in the uncut clover is calculated in the following way: In the first period there is 14 per cent. of dry matter. The analysis of the dry matter shows 10.57 per cent. of ash of which 32.75 per cent. is lime. Hence there is (14 x .1057) 1.48 per cent. of ash in the clover as it stands in the field; 32.75 per cent. of this ash is lime which is equivalent to (32.75 x .0148) .48 of lime in the uncut clover.

In order to avoid too many tables the results in the remaining tables of this Bulletin are all expressed on the dry matter and the ash constituents in per cents. of the total ash.

TABLE III.

COMPOSITION OF CLOVER, ENTIRE PLANT (EXCEPT ROOTS) AT DIFFERENT STAGES.

	I Flower Head Invisible	II Early Bloom	III Full Bloom	IV End of Flowering	V Ripe
Water	86.00	85.59	74.96	71.65	33.47
Dry Matter	14.00	14.41	25.04	28 35	66-53
COMPOSITION OF DRY MATTER.					
Ash	10.57	10.22	6.87	7.02	6.21
Ether Extract	5.35	4.70	5.73	4.26	3.92
Total Nitrogenous	23 61	17 19	14.81	14.40	14.06
Crude Fiber	13.37	20.08	24.62	25.28	26.60
COMPOSITION OF THE ASH.					
Total Insoluble (sand)	6.94	4.44	4.62	6.24	7.16
Potash	28.26	29.48	29.16	26.12	25.12
Soda	1.82	2.42	.72	.41	.60
Lime	32.75	24.32	30.64	30.22	30.66
Magnesia	5.07	7.89	10.54	6.89	7.01
Iron Oxide	.33	2.16	.42	.48	.52
Phosphates	11.33	8.32	11.57	11.22	11.46
Sulphates	3.07	2.88	1.01	2.20	2.12
Chlorides	1.10	2.73	1.93	2.40	1.60
Carbonates	9.06	14.01	9.96	13.23	13.12
Totals	99.73	98.65	100.77	99.41	99.37

In table IV the separate composition of the leaves and stems for the first three periods is given. These figures illustrate the various points that have already been discussed in connection with the development of the clover plant.

TABLE IV.

COMPOSITION OF LEAVES AND STEMS OF CLOVER AT DIFFERENT STAGES OF GROWTH.

COMPOSITION OF THE DRY MATTER.

	First Period		Second Period		Third Period	
	Leaves	Stems	Leaves	Stems	Leaves	Stems
Ash	10.02	11.02	10.07	11.30	9.19	4.87
Ether Extract	....	3.98	....	4.95	....	....
Total Nitrogenous	30.68	13.44	27.38	11.25	19.37	11.26
Crude Fiber	10.48	18.46	10.51	26.32	15.36	35.27

COMPOSITION OF THE ASH.

Total Insoluble (sand)	3.55	9.00	2.83	6.05	1.84	1.23
Potash	26.75	29.66	27.30	37.14	25.88	27.69
Soda	2.02	.94	1.24	2.26	1.06	.65
Lime	37.83	28.79	30.26	19.96	31.74	26.22
Magnesia	4.89	5.05	7.91	7.08	9.70	11.06
Iron Oxide	.61	.26	1.50	1.18	.24	.56
Phosphates	11.41	10.70	10.84	6.78	9.83	12.48
Sulphates	3.00	4.02	2.02	2.08	1.31	1.40
Chlorides	1.19	1.00	1.61	2.84	1.53	1.53
Carbonates	9.32	8.62	15.10	14.20	16.60	16.64
Total	100.57	98.10	100.61	99.57	99.73	99.46

In each of the above periods the per cent. of potash is greater in the stems than in the leaves, while the per cent. of lime is greater in the leaves. When in early bloom, the per cent. of total ash is greater in the leaves than in the stems. In *Wolff's Aschen-Analysen* these same points are to be observed, but the differences of potash and lime content in the stems and leaves are much greater than here recorded. In each period there is a gradual increase in carbonates which is due to a larger amount of the bases lime and potash being combined with organic acids. These organic acids upon combustion leave an increased amount of carbon dioxide.

CLOVER ROOTS.

Importance.—The roots and crop residue left by clover are of the greatest importance for keeping up the fertility of the soil. In Bulletin No. 30 of this Station the continuous cultivation of soils to grain crops was shown to result in reducing the amount of vegetable matter and humus in the soil. The loss of humus was followed by a loss of nitrogen, and a decreased power of the soil for retaining moisture and withstanding drought, as well as rendering some of the mineral matters, especially the phosphates, which are combined and associated with the humus, less valuable as plant food.

When the crop residue and roots of clover decompose they furnish organic matter which increases the humus in the soil, and the minerals which they contain are rendered available for the next crop that is not so able to obtain food from the soil as is the clover.

Fertilizer Constituents in Roots.—At full bloom, the amount of clover roots present from an acre of clover of 4000 pounds yield is approximately 1760 pounds, containing thirty-nine pounds of nitrogen, and 352 pounds of mineral matter composed in part of,

Potash	26.7 pounds
Phosphates	27.8 pounds
Lime	23.6 pounds

Fertilizer Value of Roots.—The nitrogen if purchased in the form of commercial fertilizers would cost $6.63. Since the experiments by Hellriegel and Weilfarth have shown that a large portion of this nitrogen comes from the free nitrogen of the air, a form which most farm crops are unable to make use of, a good share of this nitrogen may be counted upon as a clear gain to the soil.

In addition to the fertilizer ingredients in the roots, the amount present in the stubble and crown must be added, which would make the total even larger. Leaving out this factor, which is a variable one, the figures as given show that the amounts would not be far from what could be expected of even a poorer crop of clover.

Value of Young Clover as Green Manure.—Had the young clover been plowed under for green manure at the first period, May 9, which would have been sufficiently early, in this latitude for planting corn, the amount of fertilizer ingredients furnished to the corn from an acre of the clover, including the roots, would have been:

	Plant.	Roots.	Total.
Dry Matter, pounds	324.	236.	560.
Nitrogen	12.	9.	21.
Phosphoric Acid	4.	2.5	6.5
Potash	10.	6.	16.
Lime	11.	12.	23.

VALUE.

21 pounds Nitrogen @ 15 cents per lb	$3.15
6.5 pounds Phos. Acid @ 6 cents per lb	.39
16 pounds Potash @ 4 cents per lb	.64
Total	$4.18

The clover plant, with its roots, at this period contained as much dry matter, phosphates, and potash per acre as there is present in a ton of good farm manure, and as much nitrogen as is in two tons of the best farm manure.

The important points regarding the value of clover roots, when fully developed, are:

1. An increase of 1500 to 2000 lbs. of organic matter to every acre of soil.

2. An increase of 30 to 50 lbs. of nitrogen per acre.

3. Changing 20 to 30 lbs. each of phosphates, potash and lime into more valuable forms of plant food.

Dry Matter in Roots.—During growth, the roots, at the different periods of their development show a marked change in composition. A gradual increase in dry matter is to be observed. The amount of dry matter, in a square yard of the roots, at the different dates was:

First Period.. 122 grams of roots
Second Period.. 320 grams of roots
Third Period.. 916 grams of roots

Inasmuch as clover roots are of so much importance as a manure, their composition is given in the following table:

TABLE V.

COMPOSITION OF THE ASH OF CLOVER ROOTS.

	First Period	Second Period	Third Period
Potash	12.67	8.41	7.61
Soda	2.12	4.63	2.64
Lime	26.01	5.76	6.73
Magnesia	4.87	5.46	3.84
Iron Oxide	.40	2.95	1.67
Phosphates	5.55	11.28	7.87
Sulphates	2.39	4.86	2.12
Chlorides	1.16	2.12	3.16
Carbonates	4.02	2.12	......
Total Insoluble	40.58	50.86	48.50
Total	99.77	98.45	

COMPOSITION OF DRY MATTER OF THE CLOVER ROOTS.

	First Period	Second Period	Third Period
Ash	20.16	20.16	20.41
Ether Extract	4.11	3.89	2.47
Total Nitrogenous	23.61	16.70	13.81
Fiber	15.85	27.49	33.63

The Nitrogen in the Root Nodules.—The analysis of the dry matter of the clover roots at the third period showed 2.21 per cent. of total nitrogen. There are certain parts of the clover roots that are much richer in nitrogen than other parts. An examination of a healthy and well developed clover root will show little swellings known as root nodules. These root nodules are particularly rich in nitrogen. Analyses made in this laboratory show that they contain from four to six per cent. and more of nitrogen. In one case the light colored and active nodules contained 5.55 per cent. nitrogen, while the dark colored and older ones from the same plants contained 3.21 per cent. These small nodules were separated from the roots by the use of a scalpel. The work was very carefully done by Messrs. Hoverstad and Sandsten, members of the agricultural chemistry class of the

College of Agriculture. The mixed nodules, both active and inactive, from another lot of plants contained 4.60 per cent. nitrogen, while one hundred parts of the entire roots contained 2.21 parts of nitrogen.

These root nodules have been found to be the centres of action of definite and characteristic micro-organisms which transfer the free nitrogen of the air into forms which can be made use of by the plant. When these nodules cease to act the nitrogen and organisms which they contain, according to the investigations of Professor Marshall Ward, are distributed in the soil, which results in increasing the valuable nitrogen in the soil wherever clover has been grown.

In table VI analyses are given of red clover grown in different parts of the state. The first sample was grown in the southwestern part of the state at Camden, on the farm of Supt. Gregg. The clover grown at Rush City is in the northeastern portion of the state; Garfield, Douglas county, in the central western part, and Winnebago City in the southern central part of the state. Each sample of clover was grown on a different type of soil, and under as varied conditions of climate and exposure as one would expect to find in clover culture. The composition of the soil from these sections is given in Bulletin No. 30, and in the annual report of 1893. The greatest variations are shown in the amount of lime and potash that is present in the ash. The amount of nitrogenous material in the different samples is quite constant. The analysis of the ash does not show the want of any of the necessary elements, but rather an abundance, and gives no indication that any of these samples have suffered for the want of mineral food which the soil has failed to supply.

TABLE VI.

COMPOSITION OF CLOVER GROWN IN DIFFERENT PARTS OF THE STATE.

	Marshall	Rush City	Garfield	Winnebago City
Water	17.70	14.16	16.18	12.06
Dry Matter	82.30	85.84	83.82	87.94
COMPOSITION OF DRY MATTER.				
Ash	7.83	7.40	8.53	7.57
Ether Extract	3.85	3.82	3.12	2.95
Total Nitrogenous	12.87	12.96	13.20	12.83
Crude Fiber	27.44	29.34	23.45	27.03
COMPOSITION OF THE ASH.				
Insoluble (sand)	1.73	4.62	2.64	11.84
Potash	27.37	29.53	31.03	29.64
Soda	-75	1.12	.84	1.32
Lime	25.52	32.59	28.54	24.84
Magnesia	7.84	8.95	10.60	11.14
Iron Oxide	.34	.66	.44	1.10
Phosphates	13.07	9.16	10.12	7.10
Sulphates	3.20	1.74	2.13	1.33
Chlorides	1.41	.91	1.12	.86
Carbonates	18.24	10.30	10.86	9.75
Total	99.47	99.58	98.32	98.92

Another beneficial effect from clover has undoubtedly been observed by many farmers, that is, when clover is sown with timothy. A farmer in Southern Minnesota, says that one year he seeded clover and timothy, while his neighbor in an adjoining field planted timothy only. The line between the two fields was not well established, and when the fence was built, twenty feet of the timothy seeding came into the field with the timothy and clover. A marked difference could be observed between the height and yield of grass. For three or four years, even after the clover had all "run out," the timothy seeded with the clover was much superior in quality and gave a larger yield. The seeding of mixed clover and timothy is a favorite method with many farmers of the state.

SUMMARY

OF THE

CHEMICAL DEVELOPMENT AND VALUE OF RED CLOVER.

1. The failure of clover does not appear to be due to a deficiency of plant food in the soil, but is due more to the want of the proper mechanical conditions of the soil. These conditions can be ascertained only after extended experiments with the seeding of clover on different soils, and under different conditions.

2. Clover seeded with late wheat gave a yield of a ton per acre more than clover seeded with early oats. In both cases the clover was sown on fall plowed land which had previously been in corn for two years.

3. The largest yield of dry clover can be obtained at the end of flowering, while the largest yield of nitrogenous matter is from the time of full to late bloom.

4. At the time of full bloom, the nitrogenous materials in red clover have reached their most valuable food forms.

5. The lime and potash are taken up by the plant the most rapidly of any of the mineral matters. Only two per cent. of mineral matter is added to the crop after full bloom. No potash is taken up after full bloom, and when ripe the plant contains less potash than at the time of full bloom, which is due to the retrograde movement of the potash at maturity.

6. From fifty to sixty per cent of the mineral matter taken from the soil by a clover crop is lime and potash; and in the way of fertilizers, clover responds the best to land plaster, which is a lime fertilizer, and wood ashes which is mainly a potassium fertilizer.

7. The leaves of clover are very rich in nitrogenous compounds, from sixty to seventy per cent of the entire amount

found in the plant, excepting roots, is in the leaves. About the same proportion of the lime is stored up in the leaves.

8. When the leaves are young and in the first stages of development they are the richest in nitrogen, on account of the nitrogenous compounds of the plant being developed at an earlier period than the non-nitrogenous compounds. The greatest change from lower (amido) forms of the nitrogen to the higher (proteid) food forms occurs from early to full bloom.

9. Clover roots are of much value for increasing the fertility of the soil by adding organic matter and nitrogen and changing phosphates, potash and lime into more available and valuable forms of plant food for succeeding crops.

10. At the time clover is five to six inches high, the plant, with its roots, if used for green manure, will contain as much dry matter, phosphates and potash per acre as there is in a ton of good farm manure, and as much nitrogen as there is in two tons of the best farm manure.

11. The clovers grown on different soils of the state, show the most variations in lime and potash, varying according to the nature and the amount in the soil. The clover in all cases has a practically equal food value.

12. The root nodules of clover contain from four to six per cent. of nitrogen. A crop of clover will add from thirty to fifty pounds, and more of nitrogen to every acre of land, and in addition to this, enough available mineral food will be left in the crowns and roots for two good crops of wheat.

II.—THE RUSSIAN THISTLE.

CHEMICAL ANALYSIS.

When the Russian thistle is young and tender, a very high food value is claimed for it by many sheep feeders, others claim that the sheep are attracted to the thistle, and relish it on account of the salt which it contains. As no analysis of the plant, grown under the conditions in which it now flourishes in this state, is to be found, a complete analysis of the ash and dry matter at different stages of its growth, was made. It was intended to obtain samples from different parts of the state, and accordingly a number of letters were sent out requesting samples for analysis. Most of the replies were to the effect that there were no thistles in the neighborhood, but "plenty of them in the next township" or "across the river." Fortunately for this work a liberal supply of the thistles are growing in what is known as the Midway Districts, between St. Paul and Minneapolis, where abundant material was obtained, near at home.

Food Value.—The chemical analysis of the plant shows a very large amount of ash materials; in fact, nearly a fifth of the weight of the dry plant is mineral matter. This is an objection, as a fodder; but few agricultural plants contain ten per cent or more of mineral matter, while most of the fodder crops contain a much less amount. A serious objection to its constant use as a fodder, is the large amount of mineral matter, of an alkaline nature, that is present.

One very favorable point, is the large amount of nitrogenous matter which it contains,—from twelve to seventeen per cent., as much as there is in clover or rape. From sixty-five to eighty per cent. of this nitrogen is in the valuable food form of protein, varying with the developement of the plant.

No examination was made to determine whether any of the remaining nitrogen was in the form of alkaloids or other injurious compounds.

Before the developement of the thorns there is not so much fiber, at which time it is more valuable as food, but it is still open to the serious objection of the abnormal amount of alkaline mineral matter. When ripe, the fiber (woody material) and mineral (earthy) matter, make up half of its composition. Although rich in nitrogenous matter it is associated with so much indigestible fiber and ash as to greatly lessen its food value.

COMPOSITION OF THE RUSSIAN THISTLE.

	Small and Tender	No Thorns	Thorns Out	Ripe
Water	82.65	78.59	....	....
Dry Matter	17.35	21.41	....	....
COMPOSITION OF THE DRY MATTER.				
Ash	20.32	21.21	18.25	13.75
Ether Extract	3.91	3.18	2.97	3.77
Total Nitrogenous	17.78	14.71	13.45	12.34
Fiber	16.27	22.45	21.62	37.70
Nitrogen free extract	41.72	38.45	43.71	32.44
Total	100.00	100.00	100.00	100.00

Draft upon the Soil.—The separate composition of the ash shows that the weed has very strong foraging powers, and feeds upon the very best materials that are in the soil. There is a large amount of potash and lime taken up by the plant. From the small amount of silica (sand) present, the plant evidently does not feed upon the silicates, but takes large amounts of the very best materials from the soil.

The amount of sodium, one of the elements of common salt, is large compared with the amount found in agricultural plants, but not any more than is found in the alkali plants to which this is allied. The draft which the plant makes upon the sodium is a benefit to alkali lands, but with the beneficial loss of the sodium from these soils there is a serious loss of nitrogen, lime and potash, and to a less extent of phosphates.

The amount of sodium present in the plant is quite variable, indicating that the plant is capable to a certain extent of adapting itself to conditions where there is a less amount of alkali in the soil. This is generally followed by a diminished vigor of growth.

COMPOSITION OF THE ASH.

	Small and Tender	Thorns well out	Ripe
Total insoluable	1.93	2.43	3.95
Potash	26.82	31.21	27.36
Soda	9.16	4.25	12.46
Lime	26.37	24.55	22.39
Magnesia	9.66	7.66	5.56
Iron Oxide	.86	1.01	.85
Phosphates	3.49	4.00	3.11
Sulphates	1.52	1.26	4.39
Carbonates	19.28	20.25	17.34
Chlorides	....	....	1.56
Total	....	....	98.97

From the time the thorns are out, until ripe, the thistle takes up a large amount of sodium from the soil, and only small amounts of other materials. The thistle makes its heaviest draft upon the soil before the thorns are well out; after that it takes but little of the essential plant food. To prevent the heavy draft of the thistle upon the soil, it should be destroyed while young. In the last stage of growth, the large amount of sodium taken from the soil is a benefit to strong alkali lands, but before this beneficial loss of sodium takes place, there is a serious loss of nitrogen, potash, and lime.

An ordinary thistle of two pounds weight, covering a square yard, will take more potash and lime than two good crops of wheat from the same area.