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A SOIL STUDY:

PART I.

The Crop Grown: SUGAR BEETS.

Approved by the Station Council.

ALSTON ELLIS, President.

FORT COLLINS, COLORADO.

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A SOIL STUDY:

Part I. The Crop Grown: SUGAR BEETS.

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

Among the many questions arising in the practice of irrigation, is the one in regard to the prevention of the alkalizing of low and poorly drained land.

The accumulation of water may not be so rapid that the land becomes waterlogged, though this, in many instances, actually occurs; yet the supply of water, laden with salts, dissolved out of the soil through which it has passed, is sufficient to cause, by its evaporation, a deposition of large quantities of these salts on, and in, the upper portion of the soil. This concentration of the salts is not always indicated by an efflorescence, though this frequently occurs.

The condition upon which the poor drainage depends, is usually the configuration of the surface, but the character of the land and of the strata underlying the soil contribute materially in bringing about this condition.

The difficulty is met with, mostly in limited areas, it is true, but so frequently, and that in otherwise good land, that it becomes a question whether we cannot ameliorate it in some way. Perfect drainage would answer all questions, but this is frequently difficult to obtain, or altogether impracticable. It is, however, not to be inferred that alkalized land is necessarily swampy land, or has such a supply of water that irrigation is unnecessary. Neither of these conditions obtain in general, or when they do, particularly the former, the land must simply be abandoned. The plot chosen for this study is representative of this class of land; it is neither so wet as to be untillable, nor so badly alkalized as to be hopeless.

I recognize that this, like every other agricultural problem, is an involved one, and that it is difficult to determine to which factor the greatest importance should be given. In the present case, there are several patent questions, such as: Does the alkali present produce any effect upon the plant? Is its action directly upon the plant itself or does it act indirectly upon the plant through its effects, mechanical or chemical, upon the soil? Is the starvation of the plants observed in this case, due to an actual deficiency of available plant food, or to the mechanical conditions which obtained? Which is to be taken as the alkali in any given case, the efflorescence, the leachings from the soil, or the salts in the ground water, etc.

I shall devote the subsequent portion of this study to the consideration of the soil and ground water. In this I shall consider the crop grown.

I have chosen to pursue this investigation in a comparative way, believing that this gives the most satisfactory method of checking both observations and results. For this purpose, I selected two plots planted to beets by the Agricultural Department. The beets were of different varieties, and the soils were both good and presumably free from alkali. The investigation was begun and carried on upon the assumption that the character and relative quantities of the soluble salts present have a direct and important bearing upon the amount and character of the mineral matters taken up.

The experiments made in California with sugar beets on alkali soil could not give results necessarily applicable to our case, because our alkali is quite different. The efflorescence, or alkali crusts, are the same, or essentially so, but the leachings of the soil are quite different; ours is much poorer in sodic carbonate and much richer in calcic sulphate. Our alkali crusts are correctly so called, but the salts held in solution in the ground waters, and the leachings of the soil, are both so rich in calcic sulphate that it seems a misnomer to speak of them as alkali, and it should be borne in mind that throughout this bulletin no distinction has been made between the incrustation forming on the soil and the soluble salts in the soil, though there is a great difference between them. The incrustations are sodic and magnesic sulphates, with small quantities of calcic sulphate and sodic chloride, together amounting to about six per cent., while the water residue is largely calcic sulphate, with sodic and magnesic sulphates in smaller quantities.

A brief description of the soil, and a statement of the general condition of alkalization, may be given in this place.

The soil varies from a loam, with some gravel, and having a clayey and somewhat calcareous subsoil, to a fine alluvium, which owes its origin partly to the washings from the immediately surrounding country, and partly to the action of former water courses. It can scarcely be said that there is a true hardpan underlying our experimental plot; but the whole soil, to a depth of five and a half feet, is very retentive of water, and there is a stratum of clay immediately above the gravel, which is quite as efficient in preventing a free passage of the water into the ground flow as a hardpan would be. The gravel below the clay is filled with water, and I believe that the ground water from the higher land to the west finds its way through this to the river.

The water in the alkalized basin and in the gravel stratum are quite independent of one another, so far as I have been able to discover by sinking holes or wells through the soil into the gravel and examining the water. Subsequent study may disprove this, but up to the present I have no reason to doubt it.

Portions of this plot are so rich in soluble salts that incrustations one-half inch in thickness form on the surface of the soil after irrigation, or other favorable conditions. Such are the general conditions of the soil in which I endeavored to grow a crop, in order to study, first, the effects of these conditions upon the crop, and, second, the effects of the cultivation and crop upon the soil.

It is my purpose to record, in this bulletin, the results obtained in regard to the first subject, reserving the further consideration of the second question for a future bulletin.

Several considerations led me to choose the sugar beet as the crop to be studied in this experiment: The whole crop is usable; the weight of the crop is fairly large; its culture has been made familiar to the public by numerous bulletins, and is commanding a large amount of public interest; but the most important one was that the beet is more tolerant of alkali than most of our culture crops. I shall follow the developement of the plant and its sugar content, but this is not the chief object had in view.

Directions for the cultivation of the crop form no part of my plan; besides, they have been given in great fullness by many others. The first question which suggests itself in this study, is: What is the effect of the alkalies on the germination of the seed?

GERMINATION EXPERIMENTS.

I had every reason to expect difficulty in getting a good, or indeed, any stand at all in parts of the plot. The character of the soil and the experience of others justified this expectation. As the general composition of our alkali had already been determined, a series of experiments was instituted to determine, beforehand, whether a failure to get a stand should be attributed to the alkali, to the seed, or to some other cause. I also endeavored to determine the maximum amount of the constituent compounds of the alkali which might be present and still permit the seed to germinate. The amount of sodic chloride present in our alkali is so inconsiderable that it was excluded from our experiments, which were made with the other salts composing the alkali, *i. e.*, sodic carbonate, which is present in small quantities only, sodic sulphate, and magnesic sulphate. There is a very large amount of calcic sulphate in the soil, but no germination experiments were made with it.

My object, as already stated, was to determine the vitality of the seed, the effect of these salts upon the germination of the seed and upon the young plants. The salts were used separately, and also in conjunction, in quantities varying from 0.01 per cent. to 1.0 per cent. of the air-dried soil; for instance, 99 grams of clean, washed, and ignited sand, and 1 gram of dry, neutral sodic carbonate, were taken. The seed used were carefully selected, only fresh, plump burs being taken. The vessels used as germinating cups were ordinary glass tumblers. By using these we avoided the evaporation from the sides of the vessels, which would have taken place had a porous retainer, such as a flower pot, been used, and also any drainage and consequent washing out of the alkali. Evaporation from the surface, and too strong a light, were guarded against by covering each glass with a close-fitting disk of paste board. After the salts had been added to the sand, distilled water was used to wet the mass, and subsequently to replace that lost by evaporation.

The experiment extended over a period of 37 days, from April 11 to May 17, inclusive. The temperature was observed at 7:00 a. m., 12:00 m., and 6:00 p. m. The lowest temperature at 7:00 a. m. was on the day of planting, 46° F.; the highest temperature at this hour was 63° F.; the average of all the readings, 51°. The average temperature at noon for the entire period was 61° F., and at 6:00 p. m., 70° F.

The experiment was divided into four series: The first with sodic carbonate, the second with sodic sulphate, the third with a mixture of these two salts, sodic carbonate and sulphate, and the fourth with magnesic sulphate. The general results of the experiments only are given, because a detail of the daily record would show but little of interest, and occupy a great deal of space. The chief thing which would be gained would be the easily demonstrated fact that the seed germinate more quickly in the solutions of the soda salts, and more slowly in the magnesium salt, than when they are absent, and that the corrosive action of the sodic carbonate made itself manifest when so much as .05 per cent. of it was present in the soil.

SODIC CARBONATE, OR BLACK ALKALI, ALONE.

Variety of Seed Planted.	Per Cent. Sodic Carbonate in the Soil.	Number of Burs Taken.	Number Sprouted.	Per Cent. Sprouted.
Vilmorin	0.00	20	18	90
Vilmorin	0 01	20	17	85
Vilmorin	0.02	20	17	85
Vilmorin	0.03	20	17	85
Vilmorin	0.04	20	18	90
Vilmorin	0.05	20	20	100
Vilmorin	0.06	20	18	90
Vilmorin	0.07	20	19	95
Vilmorin	0.08	20	19	95
Vilmorin	0.09	20	18	90
Vilmorin	0.10	20	15	75
Kleinwanzlebener	0.10	10	4	40
Imperial	0.10	10	9	90
White Imperial	0.20	10	2	20
Lion Brand	0.20	10	5	50
Kleinwanzlebener	0.40	10	0	00
Imperial	0.40	10	1	10
White Imperial	0.50	10	0	00
Lion Brand	0.50	10	0	00
Kleinwanzlebener	0.70	10	0	00
Imperial	0.70	10	0	00
Imperial	0.80	10	0	00
Lion Brand	0.80	10	0	00
Kleinwanzlebener	1.00	10	1	10
Imperial	1.00	10	0	00

SODIC SULPHATE, OR WHITE ALKALI, ALONE.

Variety of Seed Planted.	Per Cent. Sodic Sulphate in the Soil.	Number of Burs Taken.	Number Sprouted.	Per Cent. Sprouted.
Kleinwanzlebener	0.1	10	8	80
Imperial	0.1	10	10	100
White Imperial	0.2	10	10	100
Lion Brand	0.2	10	10	100
Vilmorin	0.4	10	5	50
Imperial	0 4	10	6	60
White Imperial	0.5	10	9	90
Lion Brand	0.5	10	8	80
Vilmorin	0.7	10	7	70
Imperial	0.7	10	7	70
White Imperial	0.8	10	5	50
Lion Brand	0.8	10	7	70
Vilmorin	1.0	10	1	10
Lion Brand	1.0	10	4	40

BLACK AND WHITE ALKALI—EQUAL PARTS.

Variety of Seed Planted.	Per Cent. Sodic Carbonate in the Soil.	Per Cent. Sodic Sulphate in the Soil.	Number of Burs Taken.	Number Sprouted.	Per Cent. Sprouted.
Vilmorin	0.05	0.05	10	1	10
Imperial	0.05	0.05	10	9	90
White Imperial	0.10	0.10	10	6	60
Lion Brand	0.10	0.10	10	7	70
Vilmorin	0.20	0.20	10	1	10
Imperial	0.20	0.20	10	2	20
White Imperial	0.25	0.25	10	2	20
Lion Brand	0.25	0.25	10	2	20
Vilmorin	0.35	0.35	10	0	00
Imperial	0.35	0.35	10	1	10
White Imperial	0.40	0.40	10	0	00
Lion Brand	0.40	0.40	10	1	10
Vilmorin	0.50	0.50	10	0	00
Imperial	0.50	0.50	10	0	00

MAGNESIC SULPHATE (EPSOM SALTS).

Variety of Seed Planted.	Per Cent. of Magnesic Sulphate in the Soil.	Number of Burs Taken.	Number Sprouted.	Per Cent. Sprouted.
Vilmorin	0.10	20	19	95
Vilmorin	0.20	20	17	85
Vilmorin	0.30	20	18	90
Vilmorin	0.40	20	20	100
Vilmorin	0.50	20	18	90
Vilmorin	0.60	20	17	85
Vilmorin	0.70	20	16	80
Vilmorin	0.80	20	18	90
Vilmorin	0.90	20	16	80
Vilmorin	1.00	20	19	90

The preceding experiments were conducted under identical conditions, and demonstrate that good beet seed will germinate freely in soil containing as much as 0.7 per cent. of white alkali, or sodic sulphate, but with as much as 0.1 per cent. of black alkali, or sodic carbonate, free germination of the seed is doubtful, and the action of the black alkali is scarcely, if at all, mitigated by the presence of an equal quantity of white alkali. The result obtained when 0.05 per cent. of black alkali was present is less favorable than was obtained in the first series, when twice this amount, or 0.1 per cent., was present. This difference might have been partly due to the varieties used. It seems that the Vilmorin is more sensitive to the action of the alkali than the other varieties, but the experiments are not numerous enough to really establish this point, and it must also be remembered that another lot of Vilmorin seed might prove much hardier.

The next series of experiments was conducted with the sodic carbonate, or black alkali, alone, at a somewhat higher temperature, the average being 73.76° F., and the young plants were allowed to remain in the soil to enable us to see how long they would endure the alkali. The quantity of alkali added varied from 0.1 to 1.00, the quantity increasing regularly by 0.1 per cent. The variety of seed used was the Vilmorin; a blank was run at the same time. In six days, 90 per cent. of the seeds in No. 1, containing 0.1 per cent. black alkali, had germinated, none of the others containing alkali germinated, though the experiment was continued for twenty days. The seeds in the glass to which no alkali had been added all germinated, and continued to grow in a normal manner so long as we continued to observe them.

The glass containing 0.1 per cent. of sodic carbonate was allowed to remain five days after germinating, when the seedlings were noticed to be drooping. They were carefully removed from the sand by washing, and seven out of the nine had the plumule corroded, and the rootlets of the other two were already blackened. The blank was allowed to remain exposed to the same conditions for nine days longer, and at the end of this period were still healthy and growing. There can be no doubt but that the alkali had caused the death of the plants in the other glass, proving that, while 0.1 per cent. of black alkali in the soil will not prevent the germination of beet seed, the young plants cannot endure this amount. If the plant had already been established, before this percentage of the alkali had been brought into the soil, it might endure it. I am, however, inclined, by what I have seen of the deportment of the beet plant toward alkali, to doubt whether, even under such conditions, it would survive, especially if, as is the case in Colorado, there should be a rapid evaporation from the surface of the soil.

The next and last series of sprouting experiments* was made to study the effects of still smaller quantities of sodic carbonate, as the maximum amount of sodic carbonate which can be present without any serious disadvantage, evidently lies below one tenth of one per cent.

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* The results have been incorporated in the table under the heading of sodic carbonate.

This last statement ought to be modified to some extent, because there is no humus, or other substance, to ameliorate the action of the alkali, in which respect our tests do not resemble the true soil conditions. The humus in our Colorado soils is so small that it would, under all conditions, be a question whether its influence would be great enough to be observable. The result of this experiment was that the beet seed germinate more quickly in soils containing less than 0.10 per cent. of sodic carbonate, than in soils containing no alkali, but that the young plants cannot survive in the presence of 0.05 per cent. of black alkali, or sodic carbonate.

THE CULTIVATION AND COST.

General instructions for the proper cultivation of the sugar beet have been furnished to every section adapted to its culture, so that a repetition of them here would be useless, and I shall confine my statements on the subject of cultivation to a brief account of our operations, which I make that our conditions may be more fully appreciated.

The ground was plowed and subsoiled to a depth of 14 inches; it was then harrowed, planked and replowed, and still its condition was not a desirable one.

The seeds were drilled in, with the rows two feet apart, and the varieties three feet apart. The depth to which the seeds were put in was between two and three inches, but owing to the uneven condition of the ground this varied greatly. The plots were all planted on May 18, 1897. A rain storm set in on this day and the weather continued rainy until June 11. The beets began to come up on June 6, but, notwithstanding the favorable weather, they did not come up well. This was not to be explained by there being too much rain on a poorly drained soil, for on those portions which were under water for from three to five days there were many more plants than on some of the higher portions. The weather being rainy until June 11, the ground did not bake badly before the first hoeing, which was begun on June 14; but from this time on the soil baked badly and was very difficult to keep in any sort of tilth.

THE APPEARANCE OF INSECTS.

On June the 16th, I noticed a striped beetle, *Systena tæniata*, attacking the leaves. These beetles seemed to come from an adjacent fallow plot, which was covered with poverty weed. By June 21, they had become quite abundant and done considerable damage.

While the plants were quite young they were attacked by the leaf hoppers, *Agallia uhleri*, *Agallia sanguineolenta* and *Agallia cinerea*. Prof. Gillette, who determined these insects for me, is of the opinion that these hoppers did no appreciable harm, except while the plants were small.

Insecticides were applied on June 24, with very unsatisfactory results, and during the next few days it looked as though our insect enemies would defeat us.

We had already observed an occasional individual much larger than the striped beetle, *Monoxia puncticollis.* This beetle had become plentiful by July 3, and was doing considerable damage. On this date we sprayed with paris green, suspended in water, one pound to 80 gallons. This gave us the best satisfaction of all the insecticides which we tried.

THE EFFECT OF ALKALI.

The first observed effect of alkali was on June 15 and 16, when we observed some plants, in spots, at the east end of the plot, drooping, just as some had done in our sprouting experiments. Examination showed that the roots of the plants had been attacked, and were already black and dead. This was not due to the evaporation from the surface and concentration of the salts about the stem at the surface; such action was not observed until June 21, and was the worst in those spots where the efflorescences were the most marked. The effect of the alkali upon the roots was observed in spots where no incrustation appeared at any time. The presence of enough alkali to actually destroy the young plants was confined to certain spots, which were small, and gave no other evidence of either greater abundance or variation in character than that of its effect upon the plants. In fact, it appeared to be less abundant in these spots where it was fatal to the plants, than in other spots, near by, where the plants did well in the midst of a thick incrustation. Local variations in the composition, and, consequently, in the character of the alkali, within such narrow limits, may seem improbable to some, but I see no other explanation for these local effects.

I was not able to detect any corrosive effect of the alkali after the plants had become established, and the ground had been tilled and irrigated.

IRRIGATION.

The plot was irrigated twice, June 29–July 1 and August 18–20. The total rainfall for May, June, July, August, and September, was 8.89 inches. The total time spent in raising the crop, exclusive of harvesting, was 330 hours, including man and team for 25 hours.

As the experiment was carried out on a piece of most refractory soil, the cost of raising the crop would be no criterion for the judging of the cost of raising another crop under favorable conditions, therefore the details of cost are not given. The time given suffices to indicate that this particular crop could not yield a profit unless we obtained a yield of upwards of 16 tons to the acre, and could sell it at four dollars a ton.

THE SUGAR IN THE CROP.

We began taking samples for the determination of the sugar content, and also for other purposes, on September 2, and took them weekly from that date until the crop was harvested, October 14.

The plot represents three well-marked soils; the extreme west end representing a fine loam, the middle a clay soil, with some gravel, and the east end a gumbo. The fine earth, or soil material, ranges between 91 and 95 per cent. It bakes badly, and the air-dried lumps require the use of a pestle to break them.

The varieties of beets planted were the Kleinwanzlebener, Vilmorin, Lion Brand, Lane's Imperial, and the Imperial—four rows each. We always took three samples of each variety, corresponding to the different kinds of soil. As a control, and for the sake of comparison, one sample each of the Kleinwanzlebener and Vilmorin was taken from the plots of the Farm Department.

Our object was to observe the time when the sugar is formed in the beet most rapidly; to study, in other words, the effect of the degree of maturity upon the sugar content, and to determine, if possible, what the effect of our bad soil conditions were upon both the formation and the amount of the sugar.

The soil is rich in potash and soda, with an ample supply of lime and a fair amount of phosphoric acid, but it is rather poor in nitrogen.

The sugar in this series of determinations was determined by means of Fehling's solution, and the percentages represent the total sugar. I have made no distinction between sucrose and the other sugars.

The numbers in the table represent the different soil conditions in our plot: Number one, for instance, always being taken along a line near the west end of the plot; number two along one across the middle, and number three near the east end. The stand in this, the east end, was very bad, and we could not adhere so strictly to a given line as at the other two points.

It must be acknowledged that the weekly average for the sugar content has but little value, still I have introduced it that a general view of the rate of increase may be more easily obtained.

TABLE SHOWING PERCENTAGE OF SUGAR.

Date.	Number.	Kleinwanzlebener.		Vilmorin.		Lion Brand.		Imperial.		Lane's Imperial.		Kleinwanzlebener.		Vilmorin.	
		Percentage of Sugar.	Purity.	Percentage of Sugar.	Purity.	Percentage of Sugar.	Purity.	Percentage of Sugar.	Purity.	Percentage of Sugar.	Purity.	Percentage of Sugar.	Purity.	Percentage of Sugar.	Purity.
September 2......	1	7.72	....	7.86	....	8.21	....	8.60	....	....	....	8.36	....	7.24	....
	2	7.60	....	6.75	....	8.14	....	9.21	....	....	....	....	....	....	....
	3	6.94	....	5.57	....	7.18	....	7.47	....	....	....	....	....	....	....
Average	....	**7.75**	....	**7.06**	....	**7.84**	....	**8.43**	....	....	....	**8.36**	....	**7.24**	....
September 8... ...	1	9.06	....	8.42	....	7.61	....	9.69	....	....	....	10.60	....	9.98	....
	2	10.55	....	8.02	....	11.36	....	11.87	....	....	....	....	....	....	....
	3	7.97	....	7.97	....	7.37	....	10.06	....	....	....	....	....	....	....
Average	...	**9.19**	....	**8.14**	....	**8.78**	....	**10.54**	....	....	....	**10.60**	....	**9.98**	....
September 15......	1	10.06	....	7.28	....	9.31	....	9.06	....	....	....	8.55	....	9.73	....
	2	10.88	....	10.46	....	11.20	....	13.19	....	....	....	....	....	....	....
	3	6.88	....	8.33	....	6.21	....	10.06	....	....	....	....	....	....	....
Average	....	**9.61**	....	**8.69**	....	**8.91**	....	**10.77**	....	....	....	**8.55**	....	**9.73**	...
September 22......	1	8.14	74	7.60	76	8.14	74	10.79	77	9.70	81	10.60	75	11.50	77
	2	10.73	76	10.73	83	10.02	77	10.85	72	10.73	77	....	....	....	....
	3	6.24	62	4.80	48	7.06	71	9.03	70	....	....	....	....	....	....
Average	....	**8.37**	**71**	**7.71**	**69**	**8.41**	**73**	**10.22**	**73**	**10.14**	**79**	**10.60**	**75**	**11.50**	**77**
September 29......	1	9.91	76	8.69	72	12.49	89	10.36	74	....	....	10.21	73	9.07	70
	2	10.42	80	9.03	70	10.36	....	11.42	71	....	....	....	....	....	....
	3	8.07	58	6.85	49	7.86	60	7.24	66	....	....	....	....	....	....
Average	....	**9.47**	**71**	**7.86**	**64**	**10.27**	**75**	**9.67**	**70**	....	....	**10.21**	**73**	**9.07**	**70**
October 6..........	1	8.29	....	9.03	70	11.50	77	10.73	72	....	....	12.15	81	10.02	72
	2	9.80	70	10.98	78	11.69	83	12.00	75	....	....	....	....	....	....
	3	8.21	91	7.93	66	6.52	65	9.60	70	....	....	....	....	....	....
Average	....	**8.77**	**80**	**9.31**	**71**	**9.90**	**75**	**10.78**	**72**	....	....	**12.15**	**81**	**10.02**	**72**
October 13...	1	12.15	76	12.49	78	12.84	80	13.61	80	11.25	80	12.32	77	13.02	77
	2	14.70	82	10.13	72	13.61	76	15.20	84	9.91	....	....	....	....	....
	3	8.44	70	10.21	73	11.84	74	12.15	76	9.21	77	....	....	....	....
Average	....	**11.76**	**76**	**10.94**	**74**	**12.76**	**77**	**13.65**	**80**	**10.12**	**78**	**12.32**	**77**	**13.02**	**77**

The increase from September 2 to 15, inclusive, was positive in all cases. But the samples taken on September 22 show a falling off, which is not wholly regained by all the varieties until October 13. The cause of this is, I think, a rainfall amounting to .74 inch, which took place between September 10 and 14—mostly on the 14th. It did not produce a second growth. The beets were still in such condition that they could continue their development without putting out new leaves, but they increased quite markedly in size, and the condition of their roots indicated plainly that they had taken on greater activity and were feeding vigorously. I think that the apparent falling off of the sugar content indicated a relatively greater increase in the other constituents than any decrease in the sugar. The average weight of the beets during this period corroborates this view. In cases where a second growth has taken place the results are unquestionably different, for then new leaves are put forth, and the supply of food stored is begun to be used up.

By the beginning of the second week in October the leaves began to turn yellow, and the plants showed signs of ripening. My opinion is, that it was rather a case of starvation than of natural maturing. The outside rows, in the case of every one of the varieties, and especially the ends of the rows, were much slower in showing these signs than the inside rows; further, the other plots on the Farm did not show the same signs of maturity for more than two weeks after this. The beets were all pulled on October 14.

A comparison of those samples numbered three throughout the table, with the others, gives an exaggerated view of the effect of very unfavorable conditions. I avoid saying alkalized soil, because I am by no means convinced that the effect, so evident in this case, is a direct result of the action of the alkali upon the plant. I am rather of the opinion that the same soil conditions, in the absence of alkali, would be quite as pronounced in their effect as that observed in this case. There is no reason why just as unfavorable conditions should not exist without the alkali; but, the fact remains that we have both in this instance.

The observable effects were, a very poor stand and small beets, having, for the most part, an exceedingly bad shape. The plants did not scald as I expected that they would, and as they did do in some parts of the plot. Whether this was due to a partial adaptation on the part of the plants, or due to other causes, I am unable to state. The appearance of the beets indicated that it was the former. The Kleinwanzlebener and Vilmorin, given as the sixth and seventh varieties in the table, are samples grown on good soil by the Farm Department, the Kleinwanzlebener on alfalfa sod. They were taken in order to have some comparable standard. They seem to have responded more quickly than my less favorably conditioned plot to the rain of September 14, and also to have gained in their sugar content rather sooner than mine.

I have included my sample number three in all of the weekly averages. This is perfectly proper, as the value attached to these averages, and the purpose of their introduction into the table, have been stated; but, in trying to form a judgment of the effect of alkali upon the sugar content of the beets, this sample ought to be excluded, because the quantity of alkali was so excessive, or, as I believe, the other soil conditions were such that really no crop was grown. If it had been due to excessive alkali the samples numbered one ought to approach those numbered three much more nearly than they do, for the soil at this point carries much more soda, sulphuric acid and magnesia, with almost exactly the same amount of potash. In addition to these facts, the soil water in this portion of the field carries, at times, quite as much in solution as that from the east section, or section three, though the amount is usually less by from 10 to 80 grains per gallon. The water from the former carries from 150 to 200 grains per gallon, while that from the latter carries from 200 to 250. This subject of ground water will be treated of at another time.

The amount of alkali in the section represented by samples numbered one, being only slightly, if at all, less than in number three, but, the soil being in much better tilth, affords us better data on which to base our judgment.

The section represented by samples numbered one is in good condition and quite well drained, though it is on the western edge of this alkalized basin. Were it not for its proximity to the lower land it would be considered excellent, but an analysis shows it to contain more soda and sulphuric acid than the rest of the plot.

In order to judge of the effect of the alkali upon the sugar content in the beets, I think that we should take the Farm samples and numbers one and two, taken October 13. The crop had, at this date, reached its maturity—even the beets on the Farm plot, though remaining unharvested for a long time, showed only a moderate gain, not really large enough to positively place it beyond the differences in individual samples, after this date. In this case we observe that the Kleinwanzlebener, Vilmorin, Lion Brand, and Imperial, grown on my plot, and the Kleinwanzlebener and Vilmorin, grown on the Farm plots, are quite close, containing, in the order given, 12.15, 12.49, 12.84, 13.61, 12.32 and 13.02 per cent., while the samples from my plot numbered two, and taken in the same order, show 14.70, 10.13, 13.61, and 15.20 per cent. sugar. There is no room for question as to the character of the soils on which these samples grew. That on which the Farm samples grew, particularly in the case of the Kleinwanzlebener, is as free from alkali as any of our soil and was in good condition. The same is true in regard to the mechanical condition, though to a less extent, perhaps, of that on which my sample numbered one was grown, while that on which my sample number two grew was strongly alkalized, but the beets were richer in sugar than those grown on land practically free from alkali. This is true, also, of the samples taken on other dates, and of all the varieties, with few exceptions.

I conclude that the effect of white alkali, to the extent that it is present in this soil, is, of itself, not detrimental to the sugar beet, so far as its sugar content is concerned. This, though quite contrary to my preconceived notions, based upon previous but limited observations, is in harmony with the conclusions of Hilgard and Loughridge, who conclude, from their investigations made at Chino, California, that beets grown in soil carrying large amounts of alkali may be of good quality, both in regard to their purity and the percentage of sugar contained.

The causes of the low sugar content in the samples numbered three will be studied during the present season. It is evident from the uniformily low percentage of sugar and the low co-efficient of purity that there is some condition obtaining which is very harmful to the plant. Indeed, I am justified in making the statement, that in this section of the plot, the beets did not grow at all.

The table exhibits another interesting point, *i. e.*, the time of the most rapid increase of sugar in the crop, and how it may be influenced by the weather, and the condition of the crop at the time, for instance, of a rainfall. From September 2 to October 13 there is an increase of from three to five per cent., which is unevenly distributed throughout the six weeks, and much less evenly in my samples than in the Farm samples. Up to October 6, no marked increase in the percentage of the sugar had been observable. On the contrary, there had been fluctuations depending, as already pointed out, upon the weather and the condition of the crop. But, from October 6–13, there is a very marked rise in the percentage of sugar in five out of the six series, and a small increase in the sixth, which had shown an increase of about two per cent. during the preceding week. On October 6, the Kleinwanzlebener from the Farm plot, was the only variety yielding marketable beets, unless we include sample number two, of the Imperial. On October 13, however, there is only one sample falling materially below the standard of 12 per cent. This change, which we speak of as the maturing of the beet, makes a difference of from two to three per cent. My plot was harvested on October 14, and no opportunity was had to observe the deposition of the sugar subsequent to that time, but the Farm plots were not harvested until some days later, because they gave none of the accepted signs of ripening. I took another sample of the Kleinwanzlebener variety on October 21, and found 12.30 per cent., with a purity coefficient of 82.

This plot of beets had, according to our samples, been practically stationary in the percentage of sugar from October 6 to October 21, but the crop was increasing, at what rate I did not attempt to determine. Owing to the failure of this crop to ripen, *i. e.*, to show the usually accepted signs of ripening, a portion of it was allowed to remain in the ground, and was subsequently covered with straw to protect the beets against severe freezing. A sample taken December 19 showed 12.7 per cent. of sugar, and co-efficient of purity 81. Another sample taken at the same time, and sent to Grand Island, Nebraska, showed, sugar 13.7 per cent., purity 86. My check on this showed, sugar 13.12 per cent., and purity 81. This is as close as can be expected, when it is considered that the samples were not parts of the same beets, and both had dried out to some, but probably to different, degrees.

On December 30, I took another sample and obtained, sugar 12.54 per cent., purity 85. The last of the beets were dug January 7, 1898, and showed 12.92 per cent. sugar. This is the average of eight beets tested individually. We see that, in this case, in which the variety was Kleinwanzlebener, taken from the same plot, we have a difference of less than 1 per cent. in the increase of the sugar from October 6 to January 8, but there is a positive increase, and it is not to be accounted for by the shrinkage in the crop. It would not be just to take the result obtained at the Grand Island factory as the maximum, because these beets had dried out to some extent. There is no question but that the determination is correct, but the sample was no longer representative.

I believe that this plot of beets represents the average sugar beet grown in this section of the state, and, so far as my observation goes, it represents the beets of the state. The average found by this Station from 1887–1896, inclusive, is 12.8 per cent. sugar, which is essentially the same as shown by the crops grown at the Station this year, and analyzed within a few hours after being pulled.

The time elapsing between the pulling of the beets and the making of the sugar determination, together with the care of the sample, is of the utmost importance. Indeed, there is no difficulty at all in making a most excellent showing for a very poor crop of beets.

THE DISTRIBUTION OF THE SUGAR IN THE BEET.

This question was raised incidentally during our study of the feeding value of the trimmings of the beets—that is, the tops of the beet removed. It has been claimed, and experiments made to show, that the percentage of sugar present in the beet increases from the top downward.

My time did not admit of my extending the series of analyses too greatly, so I have taken the larger sections, thirds, by weight. If there is any difference of sufficient magnitude to be of any practical importance, we should find it between the first and third thirds, numbering from the top downward.

The beets used were of the Kleinwanzlebener variety, freshly dug, and of medium size. The crown was not removed.

The sugar beet, with us, grows almost wholly under ground, and the question of crowns is of much less importance than in some other places.

SUGAR IN THE RESPECTIVE THIRDS.

	Thirds.	Percentage Sugar in Juice.	Percentage Sugar in Beets.	Total Solids in Juice.	Co-eff. of Purity.
Beet No. 1	1	12.70	12 07	14.660	87
	2	12.50	11.88	14.356	87
	3	12.30	11.64	14.312	86
Beet No. 2	1	13 30	12.64	16.646	80
	2	13.70	13.02	17.396	79
	3	13.90	13.21	17.596	79
Beet No 3	1	13.40	12.73	15.437	87
	2	13.80	13.11	16.185	85
	3	14.00	13.30	15.934	88
Beet No. 4	1	14.00	13.30	16.236	86
	2	14.40	13.68	16.352	88
	3	14.10	13.40	16.213	87
Beet No. 5	1	14.60	13.87	16.701	87
	2	14.30	13.78	17.155	85
	3	14.60	13 87	16.608	88
Beet No. 6	1	14.60	13.87	16.701	87
	2	14.60	13.87	16.701	87
	3	14.50	13.78	16.440	88

The sugar was determined by means of the polariscope, but no sample was repeated less than four times; besides, I checked my readings from time to time by means of test plates.

The specific gravity was determined by means of the Westphal balance. This series does not show any pronounced difference between the thirds, taken by weight. There is, in three cases, less sugar by 0.60 per cent. in the first one-third than in the third one-third, but in the other cases there is practically no difference. In taking the thirds by weight, the first one-third includes that portion usually trimmed off as objectionable, but neither the sugar content nor the co-efficient of purity shows any marked inferiority of this portion of the beet. I will anticipate a subsequent paragraph to the extent of stating that neither the amount of dry matter nor the percentage of ash indicates any reason why the crown should be much inferior to the rest of the beet. The averages for all the respective thirds show a difference of less than two-tenths of one per cent. of sugar in favor of the lower two-thirds of the beet. This is of some interest to our farmers, as they can market practically the full weight of their crop.

SUGAR IN THE CROWNS.

I, unfortunately, did not make the determination of the sugar in the crowns from perfectly fresh beets, but used beets which had been stored for a few weeks in the root cellar. I, however, got beets which had been covered with fine soil, and which was still as moist as it was at the time the beets were harvested.

By crown, or neck, I mean that portion of the beet between the base of the leaves and the transverse line, showing in a vertical section of the beet, and transversing it from a point just below the outermost row of leaves.

The beets selected were, perhaps, rather above the average in size, and 14 in number. The average weight of the crowns, as determined from another similar lot of 22 beets, was 136.36 grams, or four and four-fifth ounces. This was about 13 per cent. of the beets. The sugar in the crowns was 15 1 per cent., with a co efficient of purity of 82.35; the sugar in the beets was 16.1, and the co-efficient of purity, 88. Six beets were used in the sample for the sugar determination. The result, however, gives us a full answer to the question as to the sugar value of the crowns, *i. e.*, that it is about one per cent. less than that of the beet. While the statements in this paragraph agree with those made on this subject by others, in making both the percentage and purity somewhat lower than in the beets, my results make the difference much less than that given by others. Ware, in "The Sugar Beet," page 86, quotes Champignon and Pellet as making the difference 2.60 in the percentage of sugar. The Cornell University Agricultural Experiment Station Bulletin 143, makes the difference vary from 1.55 to 2.90 per cent. of sugar, and from 6 to 14 degrees in the purity. The crown, in this case, is really a structural portion of the beet, and not an indefinite part of the root, which has been exposed to the action of the light and air without protection, except that furnished by the foliage. The leaves being very heavy, furnish more protection to the beet grown here than is usual in other sections, but, aside from this, the sugar beet with us grows entirely under ground.

THE EFFECT OF FREEZING UPON THE SUGAR CONTENT.

I regret that my observations on this interesting point are not more extended. The samples in which the sugar was determined were frozen in the ground, but under a covering of straw or earth.

Sample No. 1—Upper third frozen; sugar in juice, 13.5 per cent.; sugar in beet, 12.82 per cent.;* purity, 78. The second third was not frozen; sugar in juice, 12.6 per cent.; sugar in beet, 11.98 per cent.; purity, 91. The bottom third not frozen; juice, 12.6; beet, 11.97 per cent. sugar; purity, 81.

Sample No. 2—Upper third frozen; sugar in the juice, 11.50 per cent.; sugar in the beet, 10.93 per cent.; purity, 73. Middle third frozen; juice, 11.7 per cent.; beet, 11.11 per cent. sugar; purity, 70. Bottom third not frozen; juice 15.1 per cent.; beet, 14.34 per cent. sugar; purity, 88.

Sample No. 3—Frozen solid; juice, 15.00 per cent.; beet, 14.25 per cent. sugar; purity, 84.

* This solution being unsatisfactory, the sugar was redetermined by means of Fehling's solution, and showed 13.11 per cent. sugar in the beet.

Samples No. 1 and No. 2 were individual beets. No. 1 weighed $4\frac{1}{2}$ pounds, No. 2 weighed 2 pounds. The sample of this plot, taken October 13, contained 12.32 per cent. sugar, and samples taken later ran as high as 12.9. The average of these beets is 12.2 per cent., from which, it appears, that the sugar has suffered no diminution, while its redistribution in the beets is very marked.

Sample No. 3 was harvested October 29, and a part of the sample was placed in a shallow silo immediately, in order to avoid any loss of water due to direct exposure to wind and sun; the rest of the sample was taken to the laboratory and the sugar determined. The silo was opened December 19, and the beets found to be frozen hard. The sample analyzed, October 29, showed 14.03 per cent. of sugar, with a co-efficient of purity of 82, while the frozen sample of December 19, showed 14.25 per cent. of sugar, and a co-efficient of purity of 84.

Simple freezing does not cause any change in the sugar. This is an important consideration, or would become so, if our farmers were raising beets for a factory. If thawing could be prevented, the crop is not necessarily lost, if once frozen.

THE DRYING OUT OF BEETS.

I have already made incidental reference to this subject. It is of interest to both the producer and the manufacturer. I stated in a former paragraph that it is an easy matter to make a really poor crop appear to be a good one. It has, for years, been a cause of complaint that parties could always obtain better results from their samples by sending them to the Agricultural Department at Washington, than by sending them to their home Station. The Station undoubtedly gave them too high results in the great majority of cases, and the Department, at Washington, has been giving them still higher, and yet, both of them have been giving them correct results for the samples as analyzed; the samples, however, have not been representative of the crop as it stood in the field.

The Department, at Washington, has repeatedly called attention to this fact. Dr. Walter Maxwell, in his report to Dr. Wiley, records several series of experiments made with the object of determining the amount of this loss, which he gives, as varying from 16 to 26 per cent. for beets tied up in a sack, and kept from the wind and sun for a period of seven days, and from 23 to 35 per cent. for beets under normal exposure to air and sun for the same length of time. Dr. Maxwell makes the average loss, in the case of beets protected from the action of wind and sun, 20 per cent. in seven days.

It may be well to put this statement in a more concrete form, as we receive samples which have been pulled, or harvested, longer than this, and kept without any protection whatever. Assume that our sample, as received, weighs 40 ounces, and the juice shows a reading of 15 per cent., we report the sugar in the beet as 14.25 per cent., showing the presence of 5.7 ounces of sugar. The amount of sugar given is correct, but the percentage of sugar in the beets is entirely too high, for the percentage is calculated on 40 ounces of beets, whereas, it should have been calculated on 50 ounces, and the percentage of sugar in the beets, as harvested, was only 11.4 per cent.

Dr. Wiley, in his report on the experiments with sugar beets in 1892, says:

"Again, the loss of moisture during transportation, or failure of the farmers to send their beets in as soon as harvested, may tend to reduce the amount of water present in the beet, and to raise correspondingly the quantity of sugar therein." In speaking of beets received from California, he says: "In this connection, however, it must be remarked that the beets were long in transit and must have lost a considerable quantity of water. They were somewhat wilted and shriveled in appearance when received. Such beets, of course, would indicate a higher percentage of sugar than they would really contain in a fresh state, and the same remark may be applied to the beets shipped any distance by mail, or to beets which have been exposed any considerable time to the air after harvesting, before the determination of the sugar." In speaking of the Colorado samples, he repeats the same, saying: "In regard to the content of sugar shown by these samples, the remark made with reference to California must be made here, viz., that the amount of sugar indicated on analysis is higher than that actually present at the time of harvesting, on account of the loss of water, during transportation."

These quotations are sufficient to show that the Department of Chemistry, at Washington, is fully aware of the error in the analysis of beets sent from this and other Western states, and no blame can, in any way, attach itself to them, because the figures given for the sugar in our beets is too high, by several per cent.—2.8 per cent. in the assumed case, which is far inside the facts.

This subject has a much wider bearing than the mere fact that determinations made, upon presumably identical samples, here and in Washington, do not agree. The Department of Chemistry has repeatedly warned the readers of its reports, that the figures are too high, and have given data by the aid of which an approximate correction can be made. I was not aware of Dr. Maxwell's experiments when I made mine, but I am gratified to find that the general results agree with his, though they differ in degree, owing, probably, to differences in the condition of the beets at the time of harvesting, the temperature, moisture of the atmosphere, etc.

My first experiments were made by taking two series of samples, wrapping the beets separately in paper, and placing them upon the cellar floor, which is the earth of the cellar, without covering. The light was very moderate. The samples were weighed, from time to time, during 17 days. A third sample was subsequently taken, but the conditions were different; the beets were maturer and had lain several weeks in the root cellar before taken for this experiment, which was made in the laboratory. After the first two days the beets were wrapped up carefully, and covered with four thicknesses of gunny sacking, to protect them more fully from the light. The maximum temperature in the laboratory, during the experiment, was 69° F., and the average about 60° F.

LOSS OF WEIGHT DUE TO DRYING.

Experiment No. 1.

Date of Weighing.	Weight of Sample. Grams.	Total Loss.	Per Cent. Total Loss	Per Cent. Loss from Day to Day.	Remarks.
October 6	2012	....	....	....	
October 7	1902	102	4.8	4.8	
October 8	1834	176	8.0	3.8	
October 9	1775	237	11.3	3.3	
October 11	1668	344	17 1	6.1	Average per day, 3.0
October 13	1584	428	21.2	5.0	Average per day, 2.5
October 16	1455	557	27.7	8.1	Average per day, 2.7
October 18	1392	620	30.8	4.3	Average per day, 2.1
October 21	1302	710	35.2	6.5	Average per day, 2.1
October 23	1240	772	38.3	4.7	Average per day, 2.3

Experiment No. 2.

Date of Weighing.	Weight of Sample. Grams.	Total Loss.	Per Cent. Total Loss	Per Cent. Loss from Day to Day.	Remarks.
October 6	1536	....	....	....	
October 7	1446	90	5.9	5.9	
October 8	1388	148	9.6	4.0	
October 9	1343	193	12.6	3.2	
October 11	1268	268	17.6	5.6	Average per day, 2.8
October 13	1197	339	22.1	5.6	Average per day, 2.8
October 16	1099	437	28.5	8.2	Average per day, 2.7
October 18	1052	484	31.5	4.3	Average per day, 2.1
October 21	987	549	35.7	6.2	Average per day, 2.1
October 23	945	591	38.5	4.3	Average per day, 2.1

Experiment No. 3.

Date of Weighing.	Weight of Sample. Grams.	Total Loss.	Per Cent. Total Loss	Per Cent. Loss from Day to Day.	Remarks.
January 3	5517	....	....	....	
January 4	5226	291	5.2	5.2	
January 5	4933	574	10.4	5.4	
January 6	4672	845	15.3	5.3	
January 7	4532	985	17.9	3.0	
January 8	4379	1138	20.6	3.4	
January 9	4258	1259	22.8	2.8	
January 10	4162	1355	24.5	2.3	
January 11	4055	1462	26.5	2.6	
January 12	3953	1564	28.3	2.5	
January 13	3853	1664	30.2	2.5	
January 14	3744	1773	32.1	2.8	
January 15	3649	1868	33.9	2.5	
January 16	3562	1955	35.2	2.4	
January 17	3487	2030	36.8	2.4	
January 18	3423	2094	37.9	1.8	

The experiments agree in showing a loss of rather more than 38 per cent. in 17 days, and also quite a uniformity in the rate of loss, with the greatest irregularity during the first days of the experiments. The maximum of loss, for any single 24 hours, is 5.4 per cent. of the weight of the beets at the beginning of the 24 hours. It fell from this to about 2 per cent. for each 24 hours, where it remained. Dr. Maxwell made the loss equal to 20 per cent. of the original weight in seven days. I make it rather more, due, probably, to differences of conditions, but there is a substantial agreement between our experiments.

The farmer will appreciate these figures more fully, perhaps, when they are converted into other terms. They mean this to him, *i. e.*, if he has a crop of beets of 20 tons to the acre, and delays marketing them for 24 hours, he has lost one ton, or one twentieth of his crop, and if he delays a week he will lose one fifth of his crop, by weight. The percentage of sugar will be higher, but the tonnage less, by the amount of evaporation, whatever that may be.

It is evident that such large losses totally destroy the value of samples sent to the Station for analysis, unless great care is exercised by the sender, that the beets reach us in as fresh a state as possible, and if they are not quite fresh, the analysis has no value to either the sender or to anyone else. In illustration of this, I give the sugar content of the samples used in the experiments just detailed. A sufficient number of beets were taken from each lot, at the beginning of the experiments, to give us representative samples, and the sugar was determined in them while the samples were perfectly fresh. The sample used in experiment No. 1 contained 9.8 per cent., that used in experiment No. 2 contained 9.3 per cent., and that used in experiment No. 3 contained 14.4 per cent. of sugar. At the end of the experiments, the 9.8 per cent. of No. 1 had become 15.5 per cent., the 9.3 per cent. of No. 2 had become 12. 6 per cent., and the 14.4 per cent. of No. 3 had become 21.6 per cent.

The difference in percentage, shown in samples analyzed immediately after being pulled, and after exposure in the field for 24 hours, was almost exactly 1 per cent. This difference would make the average percentage in the beets from our plots 13.3 per cent. and 13.7 per cent., instead of 12.3 per cent. and 12.7 per cent., respectively.

THE LOSS OF SUGAR ON LONG DRYING.

This question is not of so great and immediate interest to the raiser, unless the factory should refuse to buy and hold the beets, but require the raiser to either hold them until the factory could work them up, or, in some way, make the raiser share the loss during storage.

The loss of sugar in the third experiment was quite significant, amounting to 1 ton in 14 tons of sugar, and this was with mature beets, kept 15 days; but the largest loss was observed in the second experiment, continued for 17 days, in which the loss of sugar amounted to 1 ton in every 6 tons. The loss of sugar in the beets used for the first experiment was quite small, amounting to only 1 ton in 40 tons. This question is, in all cases, of sufficient importance to deserve the attention of the factory people. It is not likely that such high losses, as occurred in experiment No. 2, would often be met with, because these beets were not mature, but those used in experiment No. 3, were such beets as would be readily marketable. This loss of sugar was not due to heating or fermenting, as the term would usually be understood by the farmer; there were no visible marks by which one would judge that any fermentation process had been going on.

I will state in detail the second and third experiments, lest some one should be confused by the two statements that there is a gain in the percentage of sugar caused by the drying out, and that there is also a loss of sugar. The original weight of the sample was 1536 grams, and the percentage of sugar 9.3 per cent., which gives us 143.0 grams of sugar; the weight of the dried-out beets was 945 grams, and the percentage of sugar was 12.6 per cent., which gives us 119.0 grams of sugar. We had, however, 143 grams of sugar to start with, and only 119.0 grams at the end, or a loss of 24 grams, a trifle over one sixth of the sugar present.

In the third experiment, the original weight of the sample was 5517 grams, and the percentage of sugar was 14.44. per cent., showing the presence of 796.59 grams of sugar; at the end of the experiment there remained 3423 grams of beets, having 21.57 per cent. of sugar, *i. e.*, there was only 739.3 grams of sugar, or 57.2 grams less than we had at the beginning; one fourteenth of that present in the fresh beets had disappeared.

These examples will suffice to illustrate the importance of this question, and, also, that there is a loss of sugar, while there is an increase in the percentage of the sugar in the beet.

THE YIELD OBTAINED.

The varieties of beets planted were five in number: Kleinwanzlebener, Vilmorin, Lion Brand, Lane's Imperial, and Imperial. The stand in parts of the plot was thick, and in, probably as much as two thirds of it, the stand was good, but in the other third it was exceedingly poor. The poor stand, in this part of the plot, was not wholly due to failure of the seed to come up, but partly to drowning out of the young plants, and partly to the action of the alkali. The plants were thinned to nine inches apart. It was necessary to let them stand much longer before thinning than I desired, owing to the attack of insects, and to the dry weather. The beets, in the meanwhile, had grown so large that it was found impossible to pull the plants without serious injury to the ones we wished to leave, so we thinned them by cutting them out to the desired distance apart. The beets were harvested on October 14, and gave the following yields:

YIELD PER ACRE.

Variety.	*Tons Beets per Acre.*	*Tons Tops per Acre.*
Kleinwanzlebener	7.9	6.2
Vilmorin	8.6	7.9
Lion Brand	8.1	7.0
Lane's Imperial	15.9	7.1
Imperial	11.8	10.6

I learn from Prof. Cooke, in charge of the Department of Agriculture, that the yield of the College plots varied from eight to twelve tons per acre. It is clear that the yield from my plot does not vary enough from that of the other plots to justify the inference that the alkali had any influence upon the yield. The gross results, however, are not altogether conclusive, for the stand on the Farm plots was seriously affected by a spell of bad weather at planting time. My plot was sown at about the same time, and the stand was, on an average, poor enough, but other factors entered so largely into the question, that it is doubtful whether I would have had any better stand if the weather had been more favorable. The beets from the Farm plots were, as a rule, much finer beets, in shape and general appearance, than mine. I think that the coincidence, in the yields of the different plots, is accidental. The fact that they were grown under the same conditions, as to the weather, does not make them fully comparable.

RATIO OF BEETS TO TOPS.

Ware, in "The Sugar Beet," p. 93, says: "As a general thing, it is ådmitted that the weight of the leaves, in a given crop, is about equal to one half that of the roots, and one fourth to one third for beets containing 8 to 9 per cent. of sugar." Wiley, quoting from McMurtrie's Report, says: "Corenwinder and Contamine find that there is a relation between the size of the leaves and the richness of the roots; that roots which bear leaves of broad surface, are generally more rich in sugar than those having small leaves upon a contracted top, and these facts are confirmed by an analysis of subjects taken from the same field." At the same time, Deherain concludes, from his researches, that the weight of leaves of small beets is relatively greater than is produced by larger ones.

The tables, quoted both by Ware and McMurtrie, are given primarily to show that beets with heavy tops are richer in sugar than beets with lighter tops, and give us the ratio of the tops to the beets. It is for this purpose that I introduce them here:

Variety.	Per Cent. Sugar in Juice.	Weight of Roots. in Grams.	Weight of Tops.	Ratio Tops to Beets.	Per Cent. of the Beet.
Pink Top, 0	9.90	1393.0	281.0	1:4.95	20.0
Pink Top, Enterre	10.18	984.0	375.0	1:2.63	38.0
Improved, 1,093	14.42	863.0	531.0	1:1.62	61.0
Improved, 927	14.78	787.0	531.0	1:1.48	67.5

Other tables given, show that the weight of the leaves varies from 25 to 63 per cent. of the weight of the beets, and stress is laid upon the fact, that the sugar content increases as the ratio of the weight of the leaves to that of the roots increases.

The only other statement that I have been able to find, touching the relative weights of the tops and the roots, is given in Cornell University Station Bulletin 143, where it is shown to be, in one experiment, about 1: 5, or, more exactly, 20.29 per cent., and in another, 1: 3, or 35 per cent. These statements are not at all applicable to the beets grown in Colorado. The figures given on a previous page, under the caption of "The Yield Obtained," show that but one out of the five varieties yield 2 tons of beets to 1 ton of tops; in other words, that only one variety approached the rule, that the weight of the tops equals about one half the weight of the roots.

The figures given on the preceding page is for beets and tops trimmed as they would be for siloing, and not for factory use; if they had been, the Lane's Imperial would have given a much smaller weight of the beets, owing to their green necks, caused by their growing well out of the ground.

It is a patent fact, that the ratio of the weight of the leaves to that of the roots is less, at the time of maturity, than before this period, and that a study of this relation, prior to a reasonable development of the roots, would have no general interest. I began the study of this, and all the subsequent subjects, at the same time that I began to determine the sugar content of the crop, *i. e.*, September 2. The beets had already attained a fair size, the average weight of 93 beets, pulled on this date, being a trifle over 15 ounces, and the largest beets were always avoided. The sugar in the samples taken, on the respective dates, is given in the table under the caption, "The Sugar in the Crop."

RATIO OF LEAVES TO ROOTS.

Date.	Variety.	Number of Beets.	Weight of Tops. Grams.	Weight of Beets. Grams.	Ratio of Weight of Top to Weight of Beets.
September 2	Kleinwanzlebener	18	13111.7	9950.5	1:0.76
	Vilmorin	18	9273.6	6398.0	1:0.69
	Lion Brand	18	12832.7	7461.6	1:0.58
	Lane's Imperial	9	3218.5	5964.7	1:1.85
	Imperial	18	9152.1	5443.0	1:0.59
	Kleinwanzlebener No. 2	6	4485.1	3898.2	1:0.87
	Vilmorin No. 2	6	2789.6	2381.4	1:0.85
September 8	Kleinwanzlebener	12	8708.9	5261.6	1:0.60
	Vilmorin	15	8448.8	6962.7	1:0.82
	Lion Brand	14	9121.6	7805.2	1:0.85
	Lane's Imperial	11	5624.2	7756.4	1:1.27
	Imperial	15	8060.0	6668.6	1:0.82
	Kleinwanzlebener No. 2	6	3487.1	3900.9	1:1.11
	Vilmorin No. 2	2	1905.0	1474.2	1:0.77
September 15	Kleinwanzlebener	14	11475.8	8584.0	1:0.74
	Vilmorin	14	9253.2	8675.8	1:0.93
	Lion Brand	12	7733.7	5057.5	1:0.66
	Imperial	14	11396.4	8447.9	1:0.74
	Kleinwanzlebener No. 2	2	2336.0	2381.3	1:1.05
	Vilmorin No. 2	2	1134.0	1564.9	1:1.38
September 22	Kleinwanzlebener	24	22021.8	15932.3	1:0.72
	Vilmorin	25	17864.0	17417.8	1:0.97
	Lion Brand	26	16635.4	12859.3	1:0.77
	Lane's Imperial	16	7688.4	13743.8	1:1.78
	Imperial	26	19106.3	13131.4	1:0.69
	Kleinwanzlebener No. 2	2	861.8	1224.7	1:1.33
	Vilmorin No. 2	2	1406.1	1247.4	1:0.86
September 29	Kleinwanzlebener	12	6005.9	7481.2	1:1.25
	Vilmorin	12	6395.7	6417.2	1:1.00
	Lion Brand	12	5896.7	5465.8	1:0.93
	Imperial	12	6373.0	6551.4	1:1.03
	Kleinwanzlebener No. 2	2	1179.3	1247.4	1:1.00
	Vilmorin No. 2	2	2404.0	3197.8	1:1.33
October 13	Kleinwanzlebener	30	22180.4	22248.7	1:1.00
	Vilmorin	30	16147.7	19681.1	1:1.23
	Lion Brand	30	17894.1	20991.6	1:1.17
	Lane's Imperial	30	11121.3	29316.7	1:2.55
	Imperial	30	17718.7	18665.2	1:1.06
	Kleinwanzlebener No. 2	8	6576.8	7166.7	1:1.09
	Vilmorin No. 2	8	4266.7	5802.7	1:1.35

The samples taken October 13 represent the mature crop for my plot, and, also, for the Farm plots, given in the table as Kleinwanzlebener No. 2, and Vilmorin No. 2. Omitting the Lane's Imperial, because of its exceptional ratio, and the fact that it grows out of the ground to a very considerable extent, whereas the others do not, we have the following figures, representing our sugar beets for the season of 1897: 136 beets grew 84784.4 grams of tops, equal to 624.2 grams, 22 ounces, of leaves per beet. The roots weighed 94556.0 grams, an average of 695.2 grams, equal to 24.5 ounces. The ratio of the weight of the tops to the weight of the beets is as 1:1.12.

The ratio of the weight of the tops to that of the beets, for the same varieties, deduced from the weights taken in the field, was 1:1.14. The ratios for the five varieties deduced from the yield as given under that head, are as follows:

Kleinwanzlebener	1: 1.274;	weight of tops = 78.5 per cent. of weight of beets
Vilmorin	1: 1.087;	weight of tops = 92.0 per cent. of weight of beets
Lion Brand	1: 1.157;	weight of tops = 86.4 per cent. of weight of beets
Lane's Imperial	1: 2.239;	weight of tops = 44.6 per cent. of weight of beets
Imperial	1: 1.113;	weight of tops = 89.8 per cent. of weight of beets

The tops and beets were both weighed while entirely fresh. The beets were taken and handled in such manner that we lost none of the leaves. In the other samples the leaves were taken at the base of the leaf, but none of the crown was taken. This was weighed with the beet. The change in the ratio of the leaves to the beets, by weight, is due to both the increase in the weight of the beet and to the decrease in the weight of the tops; the average weight of the leaves for one beet, on September 22, was 742; on October 13, 623.4 grams.

Persons familiar with the growth of the sugar beet elsewhere, remark, upon seeing ours, that they grow very vigorous tops. The weights corroborate the judgment. If the relative weights of the tops and beets were an applicable measure of the quality of our beets, they should be very good, indeed, and I believe them to be such; for I think that careful investigation will establish the fact, that it is a very good beet, which, in a perfectly fresh condition, will show a sugar content of 12.5 per cent. We have had individual beets, analyzed immediately upon being removed from the ground, to run as high as 15.5 per cent. sugar, but they do not all run that high, and an individual beet of high excellence does not make the crop excellent.

The ratio between the weight of the leaves and that of the roots of the sugar beet, as grown here, is so entirely different from that given for other localities, that we evidently cannot safely accept their data, as applying to our conditions. The same is true in regard to the size of the beets. I doubt whether a crop of sugar beets can be grown on ground, really suitable for their cultivation, with an average weight, per beet, of less than two pounds. But it does not follow that they will be low in percentage of sugar, or in purity. I have received, from time to time, several samples of large beets carrying a fair percentage of sugar, and of a satisfactory purity, one beet weighing about 5 pounds, which I analyzed simply because it was so large, carried 14.0 per cent. sugar, with a co-efficient of 88, and I received three samples from another party, who excused himself for sending such large beets, but said that they were as near an average as he could get. The largest beet had been cut off at both top and bottom, so that there remained only the middle portion of the beet—this weighed 4.6 pounds. It was in excellent condition, the sugar present was 14.9 per cent., purity 81.2. The smallest beet weighed 3 pounds, and showed 12.1 per cent. sugar, purity 81.8.

These may give an idea of the exceptions to the general rules, as laid down for the sugar beet, with which we frequently meet. I do not know how the weight of the tops of these large beets compares with that of the roots, but evidently it must be less than in smaller beets. I have noticed in all of these cases that the crown is broad and full.

The observations were extended over a sufficient time, and enough of them made to give us conclusive data as to the relative weights of the tops and the roots, and also as to the rate of the increase of both, during the last six weeks of the season. On September 2, we find the average weight of the tops, for the four varieties of beets, *i. e.*, Kleinwanzlebener, Vilmorin, Lion Brand, and Imperial, to be 614.8 grams, or 21.5 ounces. We find the average for the tops of the same varieties, on October 13, 624.8 grams, or 22.0 ounces; in other words, the gain, if any, in the weight of the tops was very small, only one half ounce per beet; on the other hand, the average weight of the beet increased from 421.8 grams, or 14.9 ounces, to 695.2 grams, or 24.5 ounces—an increase of 9.6 ounces per beet, or 0.64 of its weight, on September the 2nd.

There is no material difference in the ratios for beets from the strongly alkalized ground, and from that practically free from it. The slight difference which exists shows the tops to be relatively heavier on the alkalized ground.

The maximum sugar content in the beets was reached as soon in the one case as in the other, and there was but a slight difference between the maxima. The weights of the beets and the percentage of sugar present at the various dates give us the rate of the deposition of the sugar. Both the increase in the crop and in the percentage of sugar, must be taken into consideration. In the case of our beets, it will be seen that, about one third of the sugar, in pounds per acre, was deposited between October the 6th and the 13th.* The same fact is observable in regard to the Farm plots, except that in the case of the Kleinwanzlebener variety, the increase in percentage, corresponding to the maturing of the plant, took place one week

*The average weight of the beets on October 6 was 20.2 ounces, and the percentage of sugar was 10.15 per cent.

earlier. I was unable to discover any assignable reason for this. I thought, perhaps, the absence of alkali might be the cause, but a study of the ash of these beets made me abandon this idea, and I have no explanation beyond the record that it is a fact.

THE DRY MATTER IN THE BEETS.

The dry matter was determined in three sets of samples, taken at intervals of two weeks, beginning on the 2nd of September, and other determinations were made with samples taken as late as December 10. The number of beets has been taken as large as practicable, in order to obtain results from which the variation in the individual beets has been, for the most part, eliminated. This is quite necessary, as this variation amounts to as much as 8 per cent. in beets pulled on the same date and treated similarly. It is, of course, understood that the weight of the air-dry matter, in any organic substance, cannot be made with the same satisfactory sharpness that the moisture in an iron ore can be made. The statement that individual beets, of the same variety, and harvested on the same date, may vary as much as 8 per cent., is based upon carefully made determinations, and probably gives the range of the dry matter in sugar beets, *i. e.*, from 17–25 per cent. The dry matter in the fodder beets is much lower, and the statement just made is not applicable to them.

The table on page 31 exhibits the development of the dry matter in the crops grown on alkalized, and, also, on other ground. I have appended some determinations, made at later dates, and, also, of other varieties of beets, all grown on the College Farm.

The column of percentages shows, very clearly, the difference between the sugar beets and the larger growing stock beets. The latter containing about 14 per cent. dry matter, and the former 18 per cent.

In regard to the Lane's Imperial, it may be proper to state, that I know nothing about the history of the seed. While it may be a true Lane's Imperial, it is certainly not a good strain, and was evidently mixed. I do not mean that it was mixed by seed of other varieties being mingled with it, but had been grown from hybridized beets. This strain attained a maximum percentage of 10.14 per cent. of sugar early in the season, and did not increase materially in the percentage of sugar after September the 22nd.

The amount of dry matter in sugar beets grown on alkali soil is a little lower than in the other samples, the Kleinwanzlebener and Vilmorin marked No. 2. This seems to have been the case throughout the season. The difference, however, is not always in favor of the higher ground, and is not so decided as one could wish it to be in order to base a conclusion upon it. On October 13, for instance, the total dry matter in my samples ranged from 16.69–

18.01 per cent., while the two varieties grown on ground free from alkali, showed 17.5–18.8 per cent., the latter was the Kleinwanzlebener, from the Farm plot. But I am in doubt whether this higher figure is not an accident, as I obtained for beets from the same plot, December 10, only 17:48 per cent.; this, however, is a little higher than the same variety from my plot showed.

AIR-DRY SUBSTANCE IN SUGAR BEETS.

Date.	Variety.	Number of Beets Taken.	Weight of Green Beets. Grams.	Weight of Dried Beets. Grams.	Per Cent. of Air-dried Substance,
September 2..........	Kleinwanzlebener	12	5803.5	730.0	12.58
	Vilmorin..................	15	6092.6	675.5	11.08
	Lion Brand	14	7226.4	892.5	12.35
	Lane's Imperial	12	8777.0	775.5	8.84
	Imperial	15	4995.0	794.5	15.90
	Kleinwanzlebener No. 2..	5	3356.2	447.5	13.33
	Vilmorin No. 2...........	5	1942.4	283.0	14.62
September 22..........	Kleinwanzlebener.........	12	9377.9	1646.0	17.55
	Vilmorin............... ..	13	9956.3	1587.0	15.94
	Lion Brand............ .	14	7745.1	1373.0	17.73
	Lane's Imperial...........	16	10863.5	1458.0	13 42
	Imperial..................	14	7869.7	1400.0	17.79
October 13.............	Kleinwanzlebener.........	18	15603.5	2605.5	16.69
	Vilmorin..................	18	13965.9	2385.0	17.08
	Lion Brand..............	18	15095.0	2718 5	18 01
	Lane's Imperial...........	18	18834.6	2686.0	14 24
	Imperial..................	18	12519.0	2228.5	17.80
	Kleinwanzlebener No. 2...	6	5715.2	1074.5	18.80
	Vilmorin No. 2............	6	4419.7	773.5	17 50
October 21............	Lane's Imperial...........	....	2640.0	373.0	14.13
	Large Pink Beets †........	....	8067.0	982.0	12.25
October 29.............	Lane's Imperial...........	....	5500.0	739.8	13.45
	Long Red Mangoldwurzel	....	4500.0	641.6	14.28
	Yellow Globe.............	....	3850 0	536 3	14.63
December 10...........	Kleinwanzlebener No. 2...	6	7170.0	1241.5	17.48
	Vilmorin No 2*...........	6	8364.0	1709.0	20.43

† The variety unknown. The seed was purchased as Lane's Imperial.
* This sample was taken from the root cellar, where it had lain about five weeks.

I have showed that about 17 per cent. of the crop is formed during the last two weeks of the growing season, also that about 33 per cent. of the total weight of the sugar was deposited during the last week or ten days, but we fail to observe any such increase in the total dry matter of the crop. From September 22 to October 13, there is an average increase in the percentage of sugar present of, say, 3 per cent., and the crop increase was still greater; but the total dry matter is practically the same, only one variety showing an increase of 1 per cent., while another shows a decrease of almost as much, 0.86 per cent. The evident explanation is, that there is a transformation of some of the solids during this period. The following table gives the amount of this transformation between September 22 and October 13, for the four varieties of sugar beets grown on my plot.

THE AMOUNT OF DRY MATTER OTHER THAN SUGAR TRANSFORMED.

Date.	Variety.	Average Weight of Beets. Grams.	Per Cent. of Total Air-Dried Solid.	Per Cent. of Sugar.	Grams of Air-Dried Solids.	Grams of Sugar.	Grams of Solids Other than Sugar.	Per Cent. of Solids Other than Sugar.
September 22........	Kleinwanzlebener	781.50	17.55	8.37	137.15	65.41	71.74	9.18
	Vilmorin..........	765.80	15.94	7.71	134.10	59.04	75.10	9.08
	Lion Brand........	553.20	17.73	8.41	98.00	46.53	51.50	9.11
	Imperial...........	562.10	17.79	10.22	100.00	57.50	42.50	7.56
October 13...........	Kleinwanzlebener	866.80	16.69	11.76	144.80	103.30	41.50	4.79
	Vilmorin..........	775.90	17.08	10.94	142.50	84.90	57.60	7.42
	Lion Brand.......	838.80	18.01	12.76	151.00	107.40	43.60	5.19
	Imperial...........	695.50	17.80	13.65	123.60	94.90	28.50	4.09

The same relations hold good for the percentage of total solids, not sugar, in the Kleinwanzlebener and Vilmorin varieties from the Farm plots on the 13th of October, as is shown in the above table for the other samples. They have been omitted because the data for September 22 were lost. The above series includes representatives of my whole plot, though, as I have pointed out elsewhere, a portion of the beets might, and perhaps ought to be, excluded, because of the excessive wetness and very bad tilth of the ground in which they grew. Still they do not obscure the general rule that there is a very materially less quantity of solids, not sugar, on October 13 than there was on September 22. It would be interesting to establish what this loss may be due to, and what the nature of the total solids, which disappear, may be.

The leaves have been supposed to play an important part in the formation of the sugar in the beet; indirectly they may, but I believe that the disappearance of the solids, not sugar, is the equivalent, in weight, of the compounds already stored in the beet, and whose rapid change into sugar takes place at the maturation of the beet. There is only one other explanation which suggests itself to me; that is, that the ash constituents are either eliminated from the beet, or migrate to the leaves. This, however, is not the case. Fortunately, the answer is of such a character, that it matters not what the movement of the ash constituents in the plant may be, or whether elimination be taking place or not. The answer is simply this: The percentage of ash in the dry matter of the mature beet is not less than in the green beet, and the amount of ash in the beets on October 13, was greater than on September 22, which the following examples will show: On September 22 an average beet of the Kleinwanzlebener variety, contained 71.74 grams dry matter, not sugar, of this 9.92 grams was ash; on October 13 an average beet, weighing more than on the previous date, contained only 41.50 grams of dry matter, other than sugar, and of this 10.97 grams was ash. In the case of the other varieties, the amount of ash present on October 13 was either greater or practically equal to the amount present on September the 22nd; so the suggestion of elimination of àsh has no weight. The weight of the leaves, per beet, is actually less on the ripe beet than on the green one. For instance, I found their weight about 120 grams per beet less, on October 13, than they were on September 22. This corresponds to an actual loss of dry matter, as the percentage of dry matter in the leaves is the same for the two dates, and the same is true for the percentage of ash; so there was an absorption of dry matter and ash constituents by the root during this period. The loss of weight in the leaves, green weight, is very nearly equal to the gain in weight in the beets. This may, in this case, be an accident, but, as it is the average of 105 beets, it is suggestive.

As I have not, up to the present time, examined the leaves for sugar, it is an open question whether this corresponds to the elaboration of sugar by the leaves. But, in consideration of the actual disappearance of dry matter from the beet, accompanied by an increase of the ash and sugar, I believe it points to the elaboration of formative compounds which pass into the beet, and are there transformed into sugar. The observations of Dr. Maxwell, on the deportment of soaked beets, would be easily explicable if this were the manner in which the sugar is formed, but otherwise one must subscribe to the doubt expressed by Dr. Wiley when he says: "The whole science of vegetable physiology and chemistry teaches that sugar is elaborated in the leaves of the beet plant by the condensation of formylaldehyde, which is produced by the action of the chlorophyl cell upon carbon dioxid and water. The beet itself has always been regarded simply as a storehouse, in which the elaborated sugar is conserved for the future use of the plant."

Dr. Maxwell's experiments are given in detail, and show that an actual formation of sugar took place in the beet during the seven days submergence. This seems, to me, to suggest the cause for the diminution of total solids, other than sugar, concurrent with the somewhat sudden increase in the amount of sugar present. It seems much more probable that so large an amount of sugar, as is developed within the brief period of ripening, should be produced from material already stored up in the beet, than by the activity of a dying leaf.

THE DRY MATTER IN THE RESPECTIVE THIRDS.

We have seen that there is only a slight difference in the sugar present in the respective thirds of the beet, taken by weight, and that this difference is so small and irregular that a large number of determinations would be required to establish its value. The same is true of the total dry matter in the beets. There is a small excess in the upper third. This varies in individual beets, but seems to be constant for the different varieties. The following table records the results:

Number of Beet.	Number of Third.	Kleinwanzlebener.		Vilmorin.		Average Per Cent. of Dry Matter.
		Oct 21. Per Cent. Dry Matter.	Dec. 10. Per Cent. Dry Matter.	Oct. 21. Per Cent. Dry Matter.	Dec. 10. Per Cent. Dry Matter.	
1	1	19.93	17.72	25.23	23.22	21.52
1	2	17.52	17.72	24.31	22.58	20.53
1	3	17.85	16.20	25.68	20.64	20.09
2	1	18.32	17.94	25.60	22.70	21.14
2	2	16.60	20.52	24.23	22.86	21.05
2	3	16.79	16.50	24.23	23.21	20.18
3	1	22.17	19.37	22.07	20.45	21.01
3	2	21.91	18.40	21.38	20.30	20.50
3	3	21.15	17.19	21.72	20.60	20.16
4	1	21.50	17.32	20.68	19.56	19.76
4	2	19.20	16.98	20.68	19.78	19.16
4	3	19.54	17.20	20.68	19.78	19.30
5	1	19.68	18.26	21.42	20.22	19.90
5	2	18.63	17.82	20.78	19.77	19.25
5	3	19.68	17.17	22.08	19.85	19.69
6	1	20.58	19.48	22.43	20.00	20.62
6	2	19.42	19.12	19.85	19.02	19.35
6	3	18.55	17.87	20.54	20.24	19.30

The average dry matter contained in these two varieties, on December 10, has already been given, as, 17.48 and 20.43 per cent., respectively, and the table corroborates the existence of a difference between the two varieties in this respect.

The quantity of dry matter is quite uniformily greater in the first third than in either of the others, while there is but little difference between the quantities present in the other two thirds. The dry matter, however, is so uniformly distributed throughout the beet that it requires the taking of the general average to make the law of its distribution evident. In an instance like this, the question, What does air-dry mean, ought to be anticipated. Determinations of moisture, in other samples, made by drying to constant weight, at the temperature of boiling water, showed an average water content of about 2 per cent. This determination is tedious, and somewhat unsatisfactory, but after trying the air bath at various temperatures I adopted the water oven, and heating to constant weight, as the most satisfactory.

Other varieties of beets, particularly stock beets, were experimented with and showed results identical with those recorded in the table, except, of course, that the percentage of dry matter is much lower.

THE MARC.

This is what is left of the beet after the sugar and other substances, soluble in water, have been removed. The extent to which the soluble portion of the beets is removed determines the percentage of marc. This percentage is assumed to be about 5 per cent. My samples were grated, or rasped, and washed with more care than can be given them on a manufacturing scale, and this, probably, is the reason that my figures are slightly below 5 per cent. This was not the case when the beets were simply sliced. The experiments were made to determine the effect of irrigation upon the amount of marc present; also, to study the ash constituents left in this by-product of sugar making.

The average of six determinations, using the Vilmorin variety, was 4.21 per cent.; the average of five determinations, made with the Kleinwanzlebener, was 4.38 per cent. Both of these series were raised with irrigation. Only one lot of beets, grown without irrigation, was tested to determine the marc, and this gave 5.25 per cent. I do not think that this result, though a large sample was taken, is conclusive that beets grown without irrigation really contain more marc than irrigated beets.

THE FODDER ANALYSES OF BEETS.

It is not my purpose to discuss the feeding value of either the roots or leaves of the beets. The value of the roots, for feeding purposes, is fully understood, as also the conditions under which their feeding produces the most favorable results. The primary object of the analyses on page 37 was to discover the effect of the different soils upon the feeding value, and, at the same time, to study the differences due to varieties, if such should be discovered. The samples are parts of the larger samples taken on October 13, and which were used for the other data given throughout this bulletin. All data given for beets, taken October 13, are for the same general sample, and are comparable. The numbers, 1, 2, 3, have the same significance that they have in the table showing the amount of sugar, from week to week. 1, is good soil; 2, is good soil, quite rich in alkali; 3, is soil in bad tilth and rich in alkali, but no more so than 2. The analyses, given in the table, were made in duplicate, but averages are given to save space; the limits of variation allowed were 0.02 per cent. for nitrogen, 0.2 for the other determinations, except for crude fibre, for which 0.4 was admitted.

Analyses Nos. 1, 2, and 3, are of samples grown on excellent ground, and free from alkali. The analyses are intended as standards of comparison by which to measure the effect of our alkali. Analyses Nos. 19 and 20, are of leaves from the same beets, and are taken as standards of comparison for the leaves.

An examination of the table giving the percentage of sugar present in the beets, from the different sections of the plot, will show more clearly than the few percentages given, that the samples from sections Nos. 1 and 2, were quite as rich in sugar as those taken from the Farm plots, which we used as standards. But the samples from section No. 3 almost always showed a lower percentage of sugar. As stated elsewhere, section No. 2, of the plot, shows, upon analysis, more alkali per acre than the other sections, but its sugar content is uniformly high; therefore, I have left it as an open question whether the depression of the sugar percentage in the samples from section No. 3 was due to the alkali, or to general conditions with which the presence of the alkali has but little or nothing to do. This uncertainty is not present in these results. The beets grown on the alkalized soil contain more ash and more crude portein, and less nitrogen free extract. They are better beets for feeding, but not so good for sugar making.

The difference in the leaves is confined to a small excess in the percentage of ash in the samples from the alkali soil.

Analysis No. 10 is of a sample received from New Mexico. The soil on which it was grown is a fine prairie loam, and the sugar content, when received by us, was 17.25 per cent. Owing to the excellent character of the soil, and its richness in sugar, I used it as a futher standard, and it agrees, within quite narrow limits, with the samples from the Farm plots.

FODDER ANALYSES.

Number.	Date.	Variety.	Section of Plot.	Moisture.	Ash.	Ether Extract.	Crude Portein.	Crude Fibre.	Nitrogen Free Extract.	Total Nitrogen.	Per Cent. of Sugar.
					Sugar Beets.						
1	October 13.....	Kleinwanzlebener.....	Farm	1.325	5.510	0.317	6.429	7.212	79.207	1.029	12.32
2	October 13.....	Vilmorin..	Farm	1.662	5.469	0.378	8.578	8.515	75.398	1.372	13.02
3	October 29.....	Kleinwanzlebener.....	Farm	6.620	3.707	0.421	4.944	4.696	79.612	0.791	.....
4	October 13.....	Kleinwanzlebener.....	1	1.709	7.435	0.439	10.975	11.502	67.940	1.756	12.15
5	October 13.....	Kleinwanzlebener.....	2	1.319	6.491	0.674	9.391	7.427	74.698	1.501	14.70
6	October 13.....	Kleinwanzlebener	3	1.565	8.836	0.507	11.756	13.527	63.809	1.881	8.44
7	October 13.....	Vilmorin...	1	1.734	7.723	0.745	10.180	13 111	66.507	1.629	12.49
8	October 13.....	Vilmorin..............	2	1.897	6 561	0.721	9.689	8.054	73.078	1.550	10.13
9	October 13.....	Vilmorin.............	3	2.879	7.109	0.300	8.586	6.164	74.962	1.374	10.21
10	....	Kleinwanzlebener *...	....	2.969	5.344	0.408	7.028	5.655	78.596	1.124	17.25
					Marc.						
11	November 8...	Kleinwanzlebener.....	Farm	4.490	4.542	0.272	5.541	23.122	62.033	0.886	.....
12	January 8......	Kleinwanzlebener.....	Farm	7.490	4.365	0.393	5.673	22.603	59 476	0.907	.....
13	January 8......	Vilmorin.....	Farm	3.282	4.189	0.230	5.719	23.028	63.552	0.915	.....
					Fodder Beets.						
14	October 13.....	Lane's Imperial.......	1	2.035	7.239	0.360	6.789	5.999	77.578	1.086	11.25
15	October 13.....	Lane's Imperial.......	2	1.405	7.756	0.398	8 835	7.528	74 078	1.413	9.91
16	October 13.....	Lane's Imperial.......	3	2.130	9.361	0.480	10.487	11.552	65.990	1.678	9.21
17	October 21.....	Long Red Mangold....	Farm	1.313	7.280	0.422	6.172	6.033	78.780	0.987	.....
18	October 21.....	Large Pink............	Farm	3.417	8.983	0.453	8.322	6.016	72.809	1.335	.....
					Leaves—Sugar Beets.						
19	October 13.....	Kleinwanzlebener	Farm	3.435	20.671	1.790	16.642	12.103	45.449	2.663	....
20	October 13.....	Vilmorin..........	Farm	2.477	26.429	3.066	18.781	12.425	36.822	3.005	.....
21	October 13.....	Kleinwanzlebener.....	1	3.621	24.849	2.567	16.142	10.884	41.937	2.582	.....
22	October 13.....	Kleinwanzlebener.....	2	2.371	27.850	2.666	17.221	10.665	39.227	2.755	.....
23	October 13.....	Kleinwanzlebener.....	3	2.299	27.000	2.521	21.560	11.648	34.972	3.450	.....
24	October 13.....	Vilmorin.............	1	3.298	25.049	2.505	16.509	12 261	40.378	2.641	.....
25	October 13.....	Vilmorin............	2	2.385	29.588	3.550	18.654	11.141	34.682	2.985	.....
26	October 13.....	Vilmorin.............	3	2.442	27.620	2.553	19.593	10.460	37.442	3.137	....
					Leaves—Fodder Beets.						
27	October 13.....	Lane's Imperial......	1	2.544	27.639	2.708	13.715	12.852	40.542	2.194	.....
28	October 13.....	Lane's Imperial.......	2	2.530	31.052	3.652	15.722	11.737	35.307	2.516	.....
29	October 13.....	Lane's Imperial.......	3	2.825	27.932	2.199	18.893	11.706	36.445	3.023	.....
30	October 13.....	Chard's	....	2.382	22.533	1 495	12.546	11.206	49.835	2.007	.....

* Grown in New Mexico.

The difference between the beets from the two soils, will, perhaps, be more easily understood from the statement that the average ash and crude protein percentage in the beets grown on soil free from alkali, is 5.03 and 7.36, respectively, while they are 6.75 and 10.10 for these constituents in the other samples; the proteids are nearly 3 per cent. higher in the beets grown in the presence of the alkali.

The composition of the marc exhibits the fact that five sixths of the crude protein is removed by the diffusion, and about four fifths of the ash. The feeding value of the dry marc is, pound for pound, but a little inferior to the dry sugar beet, others make it slightly better. It may be safe to estimate it as about equal, but it must be kept in mind that it takes 400 pounds of dry beets, or one ton of green beets, to yield 100 pounds of dry pulp or marc.

The dry matter from the leaves is exceedingly rich in crude protein, and were it not for the large percentage of ash present would, doubtlessly, make a good fodder. The green leaves contain about 10 per cent. of dry matter, and 2.7 per cent. ash. I have had no experience in feeding green beet leaves, but it would seem to be a question whether the ingestion of so large an amount of ash constituents, largely potash and soda salts, would be beneficial.

The analyses of the fodder beets are interesting, but in estimating their value it must be remembered, that the fresh beet contains from 86–88 per cent. of water, against 79–82 per cent. in the sugar beet.

The chards were analyzed, purely as a matter of interest. I cultivated them in the hope that I would find them more effective in removing soda salts from the soil than the beets. I was disappointed; they did not endure the soil conditions nearly as well as the beets, and the dry matter in the tops contained less ash than the beet leaves I expected them to produce an immense crop of leaves, but they did not. If success is to be attained by growing a heavy crop of foliage, rich in ash carrying much soda, some other plant than the chard must be chosen.

The percentage of crude fibre in the beets is very irregular, but is uniformly higher in the beets from the alkalized ground than in the others. In the leaves the contrary is noticeable, the percentage of crude fibre being quite constant. The nitrogen free extract is also quite uniform in quantity. The effect of the alkali is greater upon the composition of the beets than upon that of the leaves.

The increase in the proteids is probably due to the presence of nitrates in the ground water. The amount of nitrogen in the soils of my plot is small, varying from 0.04 to 0.065 per cent. The ground water, on the other hand, contains appreciable quantities of nitric acid. The amount of total solids in the ground water varies with the different wells, and at different times. The nitric acid, calculated as potassic nitrate, usually corresponds to about 0.20 per cent. of the total solids, often more, and sometimes much more.

The letters, A, B, C, D, in the following table, represent four wells at points 150 feet apart, on a line running through the centre of my plot; they are sunk to the gravel bed. E is a well to the east of my plot in a piece of ground which has been heavily fertilized with sheep manure, but is about 100 feet west of an underdrain; in other respects the following table explains itself:

POTASSIC NITRATE IN THE GROUND WATER.

	Date.	Total Solids per Million.	Percentage of KNO 3 in Total Solids.
Well A	July 12, 1897	4440.0	0 74
Well A	September 20, 1897	2789.1	0.32
Well B	September 20 1897	3985.7	0.16
Well C	September 20, 1897	2561.4	0.37
Well D	September 20, 1897	3407.1	0.37
Well F *	September 21, 1897	2187.0	0 83
Well E	September 20, 1897	807.1	0.092

* This sample was taken below the gravel in a newly opened well.

I have given the potassic nitrate in one set of samples taken about 23 days before the crop was harvested, which shows that the beets had access to an abundant supply of nitrates, and one greatly in excess of that present in the soil proper.

THE PERCENTAGE OF ASH IN THE BEETS.

The fodder analyses, given on a preceding page, indicate that the general effect of alkali is to increase the percentage of ash in the beets grown on ground affected by it. An attempt to establish this as a general fact, and to follow the accumulation of the ash in the beet plant, is recorded in the following paragraph.

The samples were carefully prepared for this purpose, and any exceptional percentages, appearing in the table, cannot be attributed to the presence of sand. The figures represent pure ash. The number of beets taken as a sample was usually four, in a few cases I took more. The leaves in every case correspond to the beets of that variety taken on the same date and from the same section of the plot.

PERCENTAGE OF ASH.

Sugar Beets.

Date Harvested.	Variety.	Section.	Per Cent. Insoluble Ash.	Per Cent. Soluble Ash.	Per Cent. Ash.	Per Cent. Ash in Green Substance.	Per Cent. Dry Substance in Sample.
September 2...	Kleinwanzlebener............	Farm	1.5166	5.3318	6.8484	0.9129	13.33
September 2...	Vilmorin.................. ..	Farm	1.4190	5.9604	7.3794	1.0346	14.02
September 2...	Kleinwanzlebener............	1	1.5360	4 8770	6.4130	0.7913	12.34
September 2...	Kleinwanzlebener............	2	1.9090	9.1710	10.0800	1.3191	13.10
September 2...	Kleinwanzlebener............	3	1.7610	9.0640	10.8250	1.2806	11.83
September 2...	Vilmorin....................	1	2.0589	8.5761	10.6350	1.2007	11.29
September 2...	Vilmorin....................	2	2.0714	7.4660	9 5390	1.2961	13.59
September 2...	Vilmorin....................	3	1.8998	3.5569	5.4567	0.7187	13.17
September 2...	Lion Brand..................	1	2.3468	9.8608	12.2076	1.3380	10.96
September 2...	Lion Brand..................	2	2.1531	7.4155	9.5686	1.2583	13.15
September 2...	Lion Brand..................	3	2.0873	8.1086	10.1959	1.3479	13.22
September 2...	Imperial....................	1	....	....	9.0543	....	....
September 2...	Imperial....................	2	....	....	7.0858	0.8843	12.48
September 2...	Imperial....................	3	....	....	7.5097	1.2063	15.93
September 22..	Kleinwanzlebener....	1	1.2020	4.0616	5.2604	0.9952	18.92
September 22..	Kleinwanzlebener............	2	1.4228	5.0375	6.4603	1.2604	19.51
September 22..	Kleinwanzlebener.......	3	1.5416	8.4357	9.9773	1.3390	13.42
September 22..	Vilmorin....................	1	1.4072	6.6911	8 0983	1 2086	14.93
September 22..	Vilmorin....................	2	1.3492	5.5881	6.9373	1.2902	18.45
September 22..	Vilmorin....................	3	....	....	9.8277	1.3958	14.20
September 22..	Lion Brand..................	1	1.2450	5.5804	6.8254	1.2038	17.37
September 22..	Lion Brand.............	2	1.3322	4.1254	5.4576	1.1689	21.44
September 22..	Lion Brand..................	3	1.8732	8.1285	10.0017	1.6680	16.68
September 22..	Imperial....................	1	1.3129	6.2825	7.5954	1.2785	16.83
September 22..	Imperial....................	2	1.3198	4.9655	6.2853	1.3111	20.86
September 22..	Imperial	3	1.7768	6.9175	8.6943	1.3850	15.93
October 13.....	Kleinwanzlebener............	Farm	1.5768	3.9330	5.5098	1.0525	18.80
October 13.....	Vilmorin....................	Farm	1.3115	4.1579	5.4694	0.9572	17.50
October 13.....	Kleinwanzlebener............	1	1.5620	5.8727	7.4347	1.2792	17.26
October 13.....	Kleinwanzlebener............	2	1.3885	5.1026	6.4911	1.1742	18.09
October 13.....	Kleinwanzlebener......... ...	3	1.5594	7.2770	8.8364	1.3350	15 11
October 13.....	Vilmorin....................	1	1.4230	6.2996	7.7226	1.2539	16.24
October 13.....	Vilmorin	2	1.4040	5.1560	5.5606	1.1439	18.96

PERCENTAGE OF ASH—(Continued.)

Sugar Beets.

Date Harvested.	Variety.	Section.	Per Cent. Insoluble Ash.	Per Cent. Soluble Ash.	Per Cent. Ash.	Per Cent. Ash in Green Substance.	Per Cent. Dry Substance in Sample.
October 13.....	Vilmorin......................	3	1.3628	5.7462	7.1090	1.2204	17.17
October 13.....	Lion Brand....................	1	1.7794	4.8050	6.6044	1.2548	19.12
October 13.....	Lion Brand....................	2	1.4504	4.2645	5.7149	1.1132	19.49
October 13.....	Lion Brand....................	3	1.9505	7.7976	9.7481	1.3928	14.87
October 13.....	Imperial	1	1.4225	5.6254	7.0479	1.2672	17.98
October 13.....	Imperial.......................	2	1.2384	3.7372	4.9756	1.0866	21.84
October 13.....	Imperial.......................	3	1.9918	8.6668	10.6586	1.4495	13 60
September 2...	Marc, Kleinwanzlebener......	....	3.0214	1.3440	4.3654	....	....
September 2...	Marc, Kleinwanzlebener......	....	1.6100	2.6400	4.2500	....	....
September 2...	Marc, Kleinwanzlebener......	....	....	....	5.0700	....	....
November 11...	Marc. Kleinwanzlebener......	....	....	....	4.4600	0.2283	....
December 31...	Crowns, Vilmorin............	....	1.4188	3.1696	4.5884	1.1201	22.23
December 31...	Crowns, Vilmorin	....	1.1938	3.1358	4.3296	....	....
....	French Seed...................	N. M.	....	....	5.5280	1.1498	20.80
....	Kleinwanzlebener............	N. M.	....	....	4.4950	1.0910	24.27
....	Kleinwanzlebener............	N. M.	....	....	5.0020	1 0700	21.40
....	Kleinwanzlebener............	N. M.	....	....	6.2070	1.2960	20.88
....	Kleinwanzlebener............	Farm	....	....	5.2740	1.0070	19.09
....	Kleinwanzlebener............	....	....	....	5.3780	1.1430	21.25

Fodder Beets.

Date Harvested.	Variety.	Section.	Per Cent. Insoluble Ash.	Per Cent. Soluble Ash.	Per Cent. Ash.	Per Cent. Ash in Green Substance.	Per Cent. Dry Substance in Sample.
September 2...	Lane's Imperial..............	1	1.7773	10.2727	12.0500	0.9627	7.99
September 2...	Lane's Imperial..............	2	1.4668	8.4832	9.9500	0.9044	9.09
September 2...	Lane's Imperial..............	3	1.8504	13.1343	14.9847	1.3456	8.98
September 22..	Lane's Imperial..............	1	1.3232	8 2042	9.5274	1.2509	13.13
September 22..	Lane's Imperial..............	2	1.2995	7.0603	8 3598	1.1586	13.86
September 22..	Lane's Imperial..............	3	1.5112	6.7253	8.2365	1.1939	13.28
October 13.....	Lane's Imperial....	1	1.0732	6.1653	7.2385	1.1371	15.71
October 13.....	Lane's Imperial..............	2	1.2907	6.4652	7.7559	1.1370	14.66
October 13.....	Lane's Imperial..............	3	1.8025	7.5582	9.3607	1.1214	11.98
October 29.....	Lane's Imperial..............	Farm	0.9305	6.5277	7.4582	1.0031	13.45
October 29.....	Yellow Globe.................	Farm	1.0685	7.0353	8.1038	1.1855	14.63
October 29.....	Long Red Mangold..........	Farm	1.1811	6.8990	7.2801	1.0395	14.25
November 11..	Large Pink Beets............	Farm	1.1551	7.8267	8.9826	1.2692	14.13

PERCENTAGE OF ASH—(Continued).

Leaves—Sugar Beets.

Date Harvested.	Variety.	Section.	Per Cent. Insoluble Ash.	Per Cent. Soluble Ash.	Per Cent. of Ash.	Per Cent. of Ash in Green Substance.	Per Cent. of Dry Matter in the Sample.
September 2...	Kleinwanzlebener..........	Farm	6.0100	18.9042	24.9142	3.3206	13.33
September 2...	Vilmorin..........	Farm	5.6108	22.8132	28.4240	2.4121	12.01
September 2...	Kleinwanzlebener..........	1	6.1427	21.6657	27.9084	2.3206	8.35
September 2...	Kleinwanzlebener..........	2	5.7396	24.4700	30.2096	2.4680	8.17
September 2...	Kleinwanzlebener..........	3	4.8003	22.5977	27.3980	2.2581	8.24
September 2...	Vilmorin..........	1	4.8149	22.2602	27.0751	2.2174	8.19
September 2...	Vilmorin..........	2	5.6923	22.5583	28.2506	2.4493	8.67
September 2...	Vilmorin..........	3	5.7813	24.8516	30.6329	2.7630	9.02
September 2...	Lion Brand..........	1	4.8236	23.0358	27.8594	2.0805	7.47
September 2...	Lion Brand..........	2	5.3696	21.8552	27.2248	2.3557	8.65
September 2...	Lion Brand..........	3	5.7520	23.8686	29.6206	2.6373	8.94
September 2...	Imperial..........	1	5.6692	21.8643	28.5335	2.0800	7.29
September 2...	Imperial..........	2	5.9602	21.4842	27.4444	2.5495	9.29
September 2...	Imperial..........	3	5.5796	23.1323	28.8919	2.5713	8.90
September 22..	Kleinwanzlebener..........	1	3.4194	19.2906	22.7100	2.0498	11.00
September 22..	Kleinwanzlebener..........	2	3.3376	23.4965	26.8341	2.8559	10.64
September 22..	Kleinwanzlebener..........	3	3.7002	21.1696	24.8698	2.5049	10.07
September 22..	Vilmorin..........	1	4.7782	21.4531	26.2313	2.5732	9.81
September 22..	Vilmorin..........	2	4.0478	21.8570	25.9048	2.6099	10.07
September 22..	Vilmorin..........	3	4.0378	21.5575	25.5953	2.6448	10.33
September 22..	Lion Brand..........	1	3.2416	19.7522	22.9938	2.5293	11.00
September 22..	Lion Brand..........	2	3.9410	18.2716	22.2126	2.7654	12.45
September 22..	Lion Brand..........	3	4.0769	22.3222	26.3991	2.3830	9.03
September 22..	Imperial..........	1	3.3407	21.5265	24.8672	2.5737	10.35
September 22..	Imperial..........	2	3.8977	21.8771	25.7748	2.9460	11.43
September 22..	Imperial..........	3	5.4272	20.9275	26.3547	2.9754	11.29
October 13.....	Kleinwanzlebener..........	Farm	3.0416	17.6298	20.6714	2.2283	10.18
October 13.....	Vilmorin..........	Farm	5.0199	21.4095	26.4294	2.8675	10.85
October 13.....	Kleinwanzlebener..........	1	3.3282	21.5212	24.8494	2.4395	9.82
October 13.....	Kleinwanzlebener..........	2	3.8774	23.9726	27.8500	3.0944	11.11
October 13.....	Kleinwanzlebener..........	3	3.5996	23.4004	27.0000	2.7081	10.03
October 13.....	Vilmorin..........	1	3.9930	21.0562	25.0492	2.5083	9.97

PERCENTAGE OF ASH—(Concluded).

Leaves—Sugar Beets.

Date Harvested.	Variety.	Section.	Per Cent. Insoluble Ash.	Per Cent. Soluble Ash.	Per Cent. of Ash.	Per Cent. of Ash in Green Substance.	Per Cent. of Dry Matter in the Sample.
October 13.....	Vilmorin......................	2	5.4476	24.1404	29.5880	3.3096	11.19
October 13.....	Vilmorin......................	3	4.2844	23.3354	27.6198	2.7192	10.10
October 13.....	Lion Brand.....................	1	2.9932	20.3170	23.3102	2.6690	11.45
October 13.....	Lion Brand.....................	2	4.1459	20.9634	25.1093	2.9829	11.84
October 13.....	Lion Brand.....................	3	3.3740	21.5660	24.9400	2.3069	9.25
October 13.....	Imperial.......................	1	3.0633	22.6348	25.6981	2.7985	10.89
October 13.....	Imperial.......................	2	3.8809	21.0601	24.9410	2.9729	11.92
October 13.....	Imperial.......................	3	3.6136	22.5378	26 1514	2.1574	8.25

Leaves—Fodder Beets.

Date Harvested.	Variety.	Section.	Per Cent. Insoluble Ash.	Per Cent. Soluble Ash.	Per Cent. of Ash.	Per Cent. of Ash in Green Substance.	Per Cent. of Dry Matter in the Sample.
September 2...	Lane's Imperial..............	1	8.0789	24.9496	33.0285	2.9824	9.03
September 2...	Lane's Imperial..............	2	4.5602	25.7718	30.3320	2.4144	7.96
September 2...	Lane's Imperial..............	3	7.1726	28.8794	36.0328	2.8393	7.88
September 22..	Lane's Imperial..............	1	4.2517	23.7127	27.9644	2.6901	9.62
September 22..	Lane's Imperial..............	2	5.8499	24.8072	30 7591	3.0573	9.94
September 22..	Lane's Imperial..............	3	4.8015	23.3716	28.1731	2.4961	8.86
October 13.....	Lane's Imperial..............	1	4.9276	22.7118	27.6394	2.6094	9.04
October 13.....	Lane's Imperial..............	2	5.5246	25.5276	31 0522	3.2668	10.52
October 13.....	Lane's Imperial..............	3	4.8318	23.0998	27.9316	2.6513	9.42
September 29..	Chards.........................	1	3.1350	17.7539	20.8889	2.1866	10.47
September 29..	Chards.........................	2	4.0638	18.4694	22.5332	2.5937	11.51
September 29..	Chards.........................	3	3.2086	20.6892	23.8978	2.1787	9.12
October 13.....	Chards.........................	....	3.2600	19.2730	22.5330	2.3231	10.31

The table shows that by the 2nd of September, more than one half, and less than two thirds, of the total ash taken up by the roots, has already been accumulated—stated a little more explicitly, about 58 per cent.—while the leaves have stored up about 70 per cent. of the ash contained in them at maturity. The deposition of the greater part of the ash takes place earlier in the leaves than in the roots, but continues in both until the time of ripening, or maturing of the beet. I took no samples of leaves for analysis subsequent to

October 13, but I have elsewhere stated what I mean by the maturing of the beet. The percentage of ash in the fresh roots is seen to slightly decrease with the advancement of the crop; this is due to the rapid increase in the weight of the crop itself, and not to an elimination of the ash constituents. The mature beet, as grown here, contains a trifle over 1.10 per cent. of ash, and the leaves contain a little more than twice as much.

The table also shows clearly the influence of the alkali in the soil upon the percentage of ash, *i. e.*, that it causes an increase of about 2 per cent., reckoning the ash on the dry matter. The results are quite in harmony with those previously given, except that the percentage of ash in the beets grown on alkali soil is still greater than shown by the fodder analyses. The actual percentages for beets grown on good ground and on alkali ground are 5.32 and 7.58, respectively. The varieties of soils within the plot itself, indicated by the figures 1, 2 and 3, show no such evident effect, and there is no regularity in the variations of the percentage of ash in the samples from these sections. The beets from section 3, especially in the latter part of the season, show a higher percentage of ash than the samples from the other two sections. The samples from this section are lower in percentage of dry matter, also in the percentage of sugar, but higher in percentage of proteids, than the others. This is the wettest portion of the plot, and shows, during either cold or dry weather, an abundant efflorescence of alkali, but the analyses of the soils do not show that it contains more, or even as much, as section 1. The corroding effect of the alkali was scarcely noticed at all in this (the 3rd) section, while it was observed in the 2nd. This may be due to the character of the salts in solution, and not to their quantity; still, the total alkalies in section 2 is greater, apparently, than in section 3. The effect of the alkalies upon the tilth of this ground is not clear to me. The soil in this section is so saturated with calcic sulphate that small aggregations of gypsum crystals are plentiful in some portions of it. The tilth is very bad, but whether this is due to the water, and the fineness of the soil, or in any larger measure to the alkali, which is practically sodic sulphate, may be an open question, but I am quite convinced that the alkali has comparatively little effect, directly or indirectly, in determining the character of the beets in this case. The effect of the crop upon the soil was little, or nothing.

It has been shown that the leaves of the sugar beet plant, as it grows with us, are equal to from 70 to 90 per cent. of the weight of the roots. The percentage of ash in the green substance shows that ton for ton, the leaves remove from two to two and one fourth times as much ash material as the roots. I had hoped to find in this ratio, and the tolerance of the beet plant for alkali, a means of keeping down, or removing, considerable quantities of alkali from the soil, especially as I hoped to find that the plant would, in the presence of so large a supply of soda salts, take up a large percentage of them. I expected to find this the case in both the roots and leaves—to a greater extent, of course, in the leaves than in the roots. It was with this idea that I planted chards, but I was disappointed in the results of this experiment, for they made no such crop of leaves as they should have made, and they were not as high in percentage of ash as the leaves of the beets. The experiment with the chards was so evidently a failure, in regard to its primary object, that I practically abandoned it.

The table also contains the results obtained from fodder beets. The crop of roots is usually very much larger, while the percentage of ash in the fresh crop is rather less. In regard to the leaves, their ratio, by weight, to the roots being much lower, amount to about the same on a basis of 2 tons of fodder beets to 1 ton of sugar beets. The percentage of ash is quite the same in the two classes, and the mineral constituents removed by such crops would be about equal. The roots of a crop of fodder beets removes, because of their high tonnage, from two to three times the amount of ash constituents that is removed by a crop of sugar beets.

THE DISTRIBUTION OF THE ASH IN THE BEET.

The sugar and dry matter in the respective thirds of the beet, numbered from the top downward, have been given. Two series of experiments were made with the Kleinwanzlebener and Vilmorin varieties, to see whether we could establish any difference between the ash content of the thirds, and also its value. The series consisted of six beets each; the Kleinwanzlebener samples were freshly dug, but the Vilmorin sample was taken from the cellar. The average percentage of sugar in the Kleinwanzlebener variety was 12.70 per cent.; in the Vilmorin, 14.90. The percentage of dry matter in these series is given in detail under the caption, "Distribution of the Dry Matter in Beets," where it is shown that there is a little more in the first third than in either of the other thirds, but that the difference is very small, varying from three tenths to one per cent.

Variety.	Series.	Thirds.	1		2		3		4		5		6	
			Per Cent. of Ash.	Per Cent. of Ash in Fresh Beet.	Per Cent. of Ash.	Per Cent. of Ash in Fresh Beet.	Per Cent. of Ash.	Per Cent. of Ash in Fresh Beet.	Per Cent. of Ash.	Per Cent. of Ash in Fresh Beet.	Per Cent. of Ash.	Per Cent. of Ash in Fresh Beet.	Per Cent. of Ash.	Per Cent. of Ash in Fresh Beet.
Kleinwanzlebener..	No. 1	1	5.53	1.10	5.83	1.07	5.17	1.15	4.25	0.91	6.48	1.28	4.63	1.05
		2	5.68	1.00	6.36	1.06	5.33	1.17	5.36	1.03	6.27	1.17	5 69	1.10
		3	5.90	1.05	6.63	1.11	5 70	1.21	5.46	1.07	6.05	1.19	6.78	1.26
	No. 2	1	5.91	1.05	5.78	1.04	4.95	0.96	7.67	1.33	5.59	1.02	4.50	0.88
		2	5.90	1.04	5.67	1.16	5.11	0.94	6.84	1.16	5.37	0.96	4.17	0.80
		3	6.44	1.04	4.93	0.81	5.84	1.00	6.50	1.12	5.69	0.98	4.88	0.87
Vilmorin..	No. 1	1	4.95	1.25	4.10	1.05	4.36	0.95	5.46	1.13	6.12	1.31	5.29	1.19
		2	4.32	1.05	4.54	1.10	4.19	0.90	5.12	1.06	6.11	1.27	5.96	1.18
		3	4.57	1.17	4.71	1.14	4.61	1.00	5.71	1.18	5.97	1.32	6.63	1.36
	No. 2	1	5.28	1.23	5.17	1.17	6.21	1.27	7.04	1.38	6.86	1.39	7.10	1 42
		2	4.85	1.10	5.31	1.21	6.48	1.22	6.77	1.34	6.35	1.26	7.10	1.35
		3	5.35	1.10	5.47	1.27	6.69	1.38	6.86	1.36	6.71	1.33	6.95	1.41
Lane's Imperial ...	......	1	7.64	1.09	5.77	1.06	7.56	1.13	......	......	......	......	......	......
		2	7.25	1.01	4.92	0.85	5.53	0.82	......	......	......	......	......	......
		3	7.35	1.04	4.83	0.82	5.77	0.86	......	......	......	......	......	......
Large Pink	......	1	9.53	1.20	9.44	1.25	......	......	......	......	......	......	......	......
		2	8.91	1.07	11.03	1.27	......	......	......	......	......	......	......	......
		3	8.56	1.03	12.46	1.42	......	......	......	......	......	......	......	......

An inspection of the results obtained upon individual beets, leaves the impression that there is a larger percentage of ash in the third, or lower one third, than in the others, which is really the case, but it is much less decided than appears from a simple inspection of the table. The averages, taken by series, is as follows:

Variety.	Thirds.	Series I.		Series II.	
		Per Cent. of Ash in Dry Matter.	Per C·nt. of Ash in Fresh Beets.	Per Cent. of Ash in Dry Matter.	Per Cent. of Ash in Fresh Beets.
Kleinwanzlebener......................	1	5.31	1.09	5.71	1.05
	2	5.78	1.09	5.51	1.01
	3	6.09	1.13	5.70	0.97
Vilmorin..............................	1	5.05	1.15	6.27	1.31
	2	5.04	1.09	6.14	1.25
	3	5.37	1.19	6.24	1.31

Taking the averages of all the respective thirds in their order, we have, for the first third, 5.59 per cent. ash in the dry material, 5.61 per cent. for the second, and 5.85 per cent. for the third, or bottom third. This appears to prove that the percentage of ash increases in the lower portion of the beets. We have already seen that the sugar is a little higher in the lower two thirds than in the upper third, *i. e.*, first third contained 13.08 per cent. sugar, the second 13.22 per cent., and the third 13.19 per cent. sugar. According to this, the percentage of both the ash and sugar increase in the lower part of the beet. If, however, we take the percentage of ash in the fresh beet, which seems to me the proper basis, the matter stands differently in respect to the ash, *i. e.*, it is greater in the first third, and diminishes in the lower portions of the beet, for we have them in the thirds, beginning at the top, 1.15, 1.09, 1.05 per cent. In either case the difference is much less than I had hoped and expected to find. A concrete statement will possibly make the smallness of this difference plainer to some readers. It means, that, if we had a crop of sugar beets, of 15 tons to the acre, and divided every beet into three equal parts, by weight, there would be, in the five tons of upper thirds, ten pounds more of ash than there would be in the five tons of lower thirds.

The percentage of ash given for the dry matter is misleading in this, that it gives no statement of the fact that the percentage of dry matter is greater in the first third of the beet. If we take this into account, we find, on calculating the ash, for the assumed crop of 15 tons to the acre, that there is practically no difference. We get 116.22 pounds in the first third, and 115.77 pounds for the third, or lower third, of our crop. Both methods of calculation lead to the same conclusion, *i. e.*. that the ash in the beet root is quite evenly distributed throughout the beet, with a slight excess in the upper portion of the root, but the percentage of ash is greater in the dry matter of the lower third.

THE COMPOSITION OF THE ASH.

It was my expectation, when this work was planned, to find in the composition of the ashes, particularly of the leaves, a means of removing large enough quantities of soda salts to ameliorate the alkaline condition of the soils, as we find it in Colorado.

The ashes were prepared with care, but it seems to be a difficult task to prepare them so that no organic matter shall be left. The sample was, in every case, first charred, the soluble ash thoroughly washed out, and the carbon then burned out of the residue. The ash of the whole sample was mixed with ammonic carbonate, and heated to 200° C., for two hours.

The portion of ash, insoluble in water, is very variable, especially in the beets. In the leaves it is higher in early September than subsequently, and always lower by 2 or more per cent. of the total ash, than in the roots.

In the following table is given the composition of the ashes of samples taken at three different periods of development, which may be best judged of by the dates on which the samples were taken. With the composition of the ash we complete the data concerning the samples. The same samples were used for the estimation of the sugar, the dry matter, the fodder analysis, and for the work on the ash. For instance, the sample of Kleinwanzlebener, taken on October 13, was taken large enough to furnish material for the different determinations. The data obtained gives a complete history of the plant's development. I may state that 1,200 pounds of beets, and nearly as many tops, were used during the course of this investigation; the object being to obtain results which would be representative.

The plan was to study each of the varieties planted, but I have been compelled to confine the study to the Kleinwanzlebener. I have taken two as comparative standards, the Kleinwanzlebener and Vilmorin. I gave up my original plan the more willingly, as the examination of the one series shows so great a uniformity in composition, that there is no evident object to be gained which is nearly commensurate to the work involved. I give the direct results of the analyses, believing that they convey a sufficiently clear idea of the composition of the ash to the general reader, while the chemist, or other person, who wishes to reduce the terms to another basis, can easily do so.

The following tables have been grouped together so as to present the condition, and the effect of the variety of soil, without further explanation. In the first table I have given the analyses of the ashes which I assumed to be representative of good soils, to which I have added an analysis of the ash of the marc, from Kleinwanzlebener beets, grown on the Farm plot, and corresponding to the analysis given in the first column:

	Kleinwanzlebener.	Kleinwanzlebener.	Vilmorin.	Marc.
Sugar Content in Beets	12.32 per cent.	17.25 per cent	13.02 per cent.	12.90 per cent.
Where Grown	Farm Plot.	New Mexico.	Farm Plot.	Farm Plot.
Carbon	None.	None.	Trace.	None.
Sand	0.699	1.212	0.931	15.671
Silica	1.196	1.506	1.264	4.787
Sulphuric Acid	3.481	2.777	2.878	1.622
Phosphoric Acid	8.607	3.336	6.088	3.283
Carbonic Acid	20.214	18.213	19.177	23.807
Chlorin	5.686	12.500	10.887	0.155
Potassic Oxid	32.334	39.639	40.065	14.802
Sodic Oxid	17.888	9.940	11.161	3.711
Calcic Oxid	3.257	3.458	3.409	15.790
Magnesic Oxid	6.065	7.024	5.264	9.768
Ferric Oxid	0.286	0.468	0.414	1.300
Aluminic Oxid	0.268	0.232	0.774	0.848
Manganic Oxid (brown)	0.298	0.361	0.186	0.364
Loss on Ignition	1.272	2.073	....	(4.126)
Sum	101.544	102.739	102.498	100.034
Oxygen equivalent to Chlorin	1.281	2.817	2.441	0.034
Total	100.263	99.922	100.057	100.000

ASH OF THE SUGAR BEET IN ALKALI SOIL.

Harvested September 2.

	Section 1.		Section 2.		Section 3.	
	Beets.	Leaves.	Beets.	Leaves.	Beets.	Leaves.
Carbon	None.	Trace.	Trace.	Trace.	None.	Trace.
Sand	1.830	4.484	1.892	1.859	1.417	1.549
Silica	1.680	3.154	1.744	2.319	1.957	2.883
Sulphuric Acid	3.212	3.369	3.191	3.612	3.098	2.261
Phosphoric Acid	6.433	2.167	8.758	2.212	7.201	2.823
Carbonic Acid	14.495	12.632	14.817	14.484	16.381	15.991
Chlorin	13.779	20.729	12.315	18.219	11.326	18.000
Potassic Oxid	36.477	21.260	39.832	23.170	32.820	19.657
Sodic Oxid	15.755	23.901	12.130	24.381	19.220	28.577
Calcic Oxid	1.740	2.667	1.190	2.137	1.216	1.661
Magnesic Oxid	4.485	6.577	4.100	7.132	4.474	5.916
Ferric Oxid	0.590	0.652	0.581	0.464	0.682	1 119
Aluminic Oxid	0.276	0.512	0.370	0.330	0.339	0.498
Manganic Oxid (brown)	0.142	0.086	0.133	0.121	0.168	0.128
Loss upon Ignition	2.328	3.095	1.614	5.693	1.994	2.768
Sum	103.222	105.185	102 667	104.123	102.293	103.831
Oxygen equivalent to Chlorin	3.105	4.673	2.775	4.105	2.552	4.056
Total	100.117	100.512	99.892	100.018	99.741	99.775

Harvested September 22.

	Section 1. Beets.	Section 1. Leaves.	Section 2. Beets.	Section 2. Leaves.	Section 3. Beets.	Section 3. Leaves.
Carbon	None.	Trace.	Trace.	Trace.	None.	None.
Sand	0.665	0.538	0.868	0.139	0.610	0.700
Silica	0.858	1.024	0.855	0.651	0.931	1.933
Sulphuric Acid	3.949	3.821	3.612	3.281	2.550	2.976
Phosphoric Acid	7.906	2.286	8 786	1.902	7.688	3.133
Carbonic Acid	16.467	12.528	14.758	10.760	16.471	16.117
Chlorin	11.493	24.923	12.826	27.781	14.408	21.349
Potassic Oxid	36.780	20.738	41.620	28.225	34.895	21.572
Sodic Oxid	13.434	27.608	9.744	22.863	18.637	27.859
Calcic Oxid	2.826	2.699	2.180	2.295	1.254	1.841
Magnesic Oxid	5.783	5.731	5.512	5.110	4.028	5.770
Ferric Oxid	0.309	0.179	0.310	0.058	0.290	0.502
Aluminic Oxid	0.158	0 170	0.156	0.206	0.103	0.395
Manganic Oxid (brown)	0.190	0.139	0 214	0.155	0.114	0.161
Loss upon Ignition	1.690	3.511	1.842	3.261	1.624	....
Sum	102.408	105.895	103.283	106.687	103.603	104.308
Oxygen equivalent to Chlorin	2.590	5.616	2.890	6.265	3.246	4.811
Total	99.818	100.279	100.393	100.422	100.357	99.497

ASH OF THE SUGAR BEET IN ALKALI SOIL—(Concluded).

Harvested October 13.

	Section 1.		Section 2.		Section 3.	
	Beets.	Leaves.	Beets.	Leaves.	Beets.	Leaves.
Carbon	Trace.	None.	Trace.	None.	None.	None.
Sand	0.822	0.408	1.188	0.314	0.497	0.394
Silica	1.144	0.842	1.102	0.758	0.941	0.960
Sulphuric Acid	3.585	3.803	3.476	3.859	3.400	3.580
Phosphoric Acid	8.049	2.051	8.668	1.793	7.504	2.317
Carbonic Acid	14.051	10.628	15.690	10.940	16.734	14.848
Chlorin	14.961	28.511	12.599	27.766	13.561	23.289
Potassic Oxid	38.966	23.780	42.976	25.718	37.491	23.838
Sodic Oxid	12.828	25.375	8.811	22.324	16.123	25.515
Calcic Oxid	2.101	2.437	1.951	2.527	1.331	1.537
Magnesic Oxid	5.339	6.000	5.573	6.169	4.791	5.624
Ferric Oxid	0.815	0.125	0.146	0.128	0.276	0.062
Aluminic Oxid	0.213	0.113	0.538	0.123	0.400	0.173
Manganic Oxid (brown)	0.183	0.068	0.195	0.137	0.197	0.106
Loss upon Ignition	....	2.943	....	4.054	....	3.421
Sum	103.057	107.084	102.912	106.610	103.246	105.664
Oxygen equivalent to Chlorin	3.166	6.425	2.839	6.257	3.057	5.226
Total	99.891	100.659	100.073	100.353	100.189	100.438

ASH OF FODDER BEETS.

	Lane's Imper'l.	Yellow Globe.	Long Red Mangold.	Large Pink.
Where Grown	Farm	Farm	Farm	Farm
Carbon	None.	Trace.	None.	None.
Sand	0.237	0.597	0.216	0.725
Silica	1.044	0.857	0.594	1.052
Sulphuric Acid	3.900	2.189	2.832	2.597
Phosphoric Acid	4.605	6.547	5.232	6.209
Carbonic Acid	23.344	16.949	21.447	21.871
Chlorin	7.813	16.827	9.628	9.252
Potassic Oxid	33.474	38.620	38.787	27.656
Sodic Oxid	21.465	14.559	16.151	24.397
Calcic Oxid	2.015	1.909	2.661	1.992
Magnesic Oxid	3.270	3.189	3.274	3.262
Ferric Oxid	0.191	0.497	0.175	0.254
Aluminic Oxid	0.040	0.777	0.073	0.108
Manganic Oxid	0.210	0.216	0.575	0.194
Loss on Ignition	0.714	0.548	0.923	2.716
Sum	102.322	104.251	102.568	102.285
Oxygen equivalent to Chlorin	1.761	3.778	2.169	2.085
Total	100.561	100.473	100.399	100.200

COMPOSITION OF ASH COMPARED WITH SUGAR CONTENT.

	Vilmorin.	Kleinwanzlebener.	Kleinwanzlebener.	Kleinwanzlebener.	Kleinwanzlebener.	Kleinwanzlebener.
Where grown	Col. Farm	Col. Farm	Col. Farm, alkali soil	Col. Farm, alkali soil	Col. Farm, alkali soil	New Mex.
Sugar content	13.02 per ct.	12.32 per ct.	7.86 per ct	10.73 per ct.	14.70 per ct.	17.25 per ct.
Date harvested	October 13	October 13	Sept. 2	Sept. 22	October 13	?
Silica	1.58	1.54	2.10	1.02	1.33	1.91
Sulphuric Acid	3.59	4.47	3.91	4.37	4.18	3.53
Phosphoric Acid	7.62	11.02	10.73	10.65	10.45	4.25
Chlorin	13.61	7.30	15.08	15.53	15.16	15.90
Potassic Oxid	50.12	41.41	48.74	50.42	51.70	50.59
Sodic Oxid	13.96	22.91	15.05	11.81	10.60	12.65
Calcic Oxid	4.26	4.19	1.46	2.64	2.35	4.42
Magnesic Oxid	6.59	7.76	5.02	6.68	6.70	8.93
Ferric Oxid	0.52	0.37	0.73	0.37	0.18	0.59
Aluminic Oxid	0.99	0.34	0.46	0.19	0.65	0.29
Manganic Oxid	0.23	0.39	0.16	0.26	0.13	0.45
Sum	103.07	101.70	103.44	103.54	103.40	103.54
Oxygen equiv. to Chlorin	3.05	1.65	3.40	3.50	3.42	3.59
Total	100.02	100.05	100.04	100.04	99.98	99.95

Composition of ashes of beets having different percentages of sugar, calculated from data quoted from Champion and Pellet by Dr. McMurtrie:

	Beets Having 10 per Cent. Sugar.	*Beets Having 15 per Cent. Sugar.*
Silica	5.555	5.546
Sulphuric Acid	3.594	3.486
Phosphoric Acid	9.640	9.357
Chlorin	9.310	9.172
Potassic Oxid	47.870	48.807
Sodic Oxid	8.330	8.257
Calcic Oxid	6.860	6.970
Magnesic Oxid	6.210	6.055
Undetermined	2.610	2.385
	99.979	100.035

The leaves, presumably belonging to the two samples whose ash analyses are given above, yielded ashes of the following composition :

	Ash of Leaves from Beets Having 10 per Cent. Sugar.	*Ash of Leaves from Beets Having 15 per Cent. Sugar.*
Silica	1.100	1.110
Sulphuric Acid	5.340	5.400
Phosphoric Acid	7.940	8.000
Chlorin	11.510	11.560
Potassic Oxid	32.880	33.330
Sodic Oxid	11.510	11.560
Calcic Oxid	12.470	12.500
Magnesic Oxid	10.010	10.100
Undetermined	7.230	6.400
	99.990	99.960

The analyses, quoted from Champion and Pellet, evidently include, under the term undetermined, the excess of oxygen corresponding to the chlorin present. The large quantity of silica in the beet ash suggests the fluxing of sand and fine particles of soil during the incineration of the sample.

This source of silicic acid in the ash, has been frequently suggested in my own work, and I am fully convinced, that it is so good as impossible to prepare an ash from a sample containing sand and dust without fluxing some of it, and so bringing silicic acid into a soluble form. And I doubt the correctness of the practice of reckoning even the soluble silicic acid in the ash analysis proper.

Neither the analyses of the ashes from my own series, nor the two quoted, show a sufficiently decided variation in the composition of the ashes of beets, having different percentages of sugar, to admit of any conclusion in regard to any relation existing between the percentage of sugar and the composition of the ash. Further, a comparison of the percentages of sugar and ash present in mature beets, fails to show any relation between the percentage of sugar and the percentage of ash, as a few examples will serve to show:

RELATION BETWEEN PERCENTAGES OF SUGAR AND ASH.

	Per Cent. of Sugar.	*Per Cent. of Ash in Dry Matter.*	*Per Cent. of Ash in Fresh Beet.*
Beets harvested October 13	12.15	7.43	1.27
Beets harvested October 13	14.70	6.49	1.17
Beets harvested October 13	10.13	5.56	1.14
Beets harvested October 13	12.49	7.72	1.25
Beets harvested October 13	12.84	6.60	1.25
Beets harvested October 13	13.61	5.71	1.11
Beets harvested October 13	11.84	9.75	1.39
Beets harvested October 13	15.20	7.05	1.27
Beets harvested October 13	12.15	4.97	1.09
Beets harvested October 13	13.65	10.65	1.45

The only thing shown by these samples is that the ash of the sugar beet, as it grows with us, contains more alkalies than is shown by the two analyses of French beets, by about 7 per cent. The ash from our beets, without any relation to the sugar content, carries about 63 per cent. of potash and soda together. The carbonic acid, sand, and organic matter, is not considered as belonging to the ash. We also find a certain uniformity in the amount of lime and magnesia present. Counting these in terms of lime, we find the range mostly within the limits of 11 and 14 per cent. In the two samples of French beets it is 15.5 per cent. The phosphoric acid in the eight analyses, which we have tabulated, agree closely in six instances, while the other two are much lower. In the case of the sample of Vilmorin, harvested October 13, and carrying 13.02 per cent. of sugar, the low percentage of phosphoric acid cannot, in my opinion, be explained by ascribing it to the lack of this constituent in the soil, it must be ascribed to some other cause. In regard to the sample from New Mexico, I can express no opinion, as I have no intimate knowledge of the conditions under which it was grown. I am frank to say that I doubt whether this New Mexican sample ought to be taken as an example of a beet, rich in sugar. That it showed the presence of 17.25 per cent. of sugar when I received it, is true, but that it did not show that much when it was fresh, is quite as certain. I believe the high percentage to have been due to drying out, rather than to a naturally high degree of richness.

The percentage of ash, in the French samples, is rather lower than we find in our samples, but other data for French beets make it about the same. The percentage of ash in the leaves, assuming the dry matter equal to 10 per cent., is the same as we find for Colorado beets, but the composition of the ashes of the leaves is not at all alike. They are similiar only in containing the same chemical elements. The composition of the ash of the leaves from the French beets is quite comparable to that of the ash of the beets themselves, the differences consisting of an excess in the percentages of soda, lime, magnesia, and chlorin, over that of the beet ash, while the percentage of potash in the ash of the leaves is less than that in the ash of the beets by 15 per cent.

The table on page 54 shows to how great an extent the ash constituents of the leaves differ from those of the beets in their relative quantities, and also, how the ashes, both of the roots and the leaves, of Colorado grown beets differ from those grown in France. I have quoted the analyses of the French beets, and do not know how nearly representative they may be, but as to the Colorado beets, any one of the samples given on previous pages could be used for the same purpose quite as well as the one chosen. This one was taken simply because its percentage of sugar, being so near that of the sample quoted, eliminates any question of doubt which might arise because of differences in the quality of the beets.

I place the analysis of a sample of the ash of Kleinwanzlebener beets, carrying 14.7 per cent. sugar, together with that of the ash of its leaves, side by side with that of a French beet, supposed to carry 15 per cent. sugar, and its leaves:

	Kleinwanzlebener. Grown in Colorado.		Grown in France.	
	Beets. Per Cent.	Leaves. Per Cent.	Beets. Per Cent.	Leaves. Per Cent.
Silica	1.330	0.890	5.546	1.110
Sulphuric Acid	4.180	4.470	3.486	5.400
Phosphoric Acid	10.450	2.120	9.357	8.090
Chlorin	15.160	32.670	9.172	11.560
Potassic Oxid	51.700	30.270	48.807	33.330
Sodic Oxid	10.600	26.270	8.257	11.560
Calcic Oxid	2.350	2.980	6.970	12.500
Magnesic Oxid	6.700	7.260	6.055	10.400
Ferric Oxid	0.180	0.150	2.385*	6.400*
Aluminic Oxid	0.650	0.150	....	....
Manganic Oxid	0.130	0.160	....	....
Sum	103.400	107.390	....	....
Oxygen equivalent to Chlorin	3.420	7.380	....	....
Total	99.980	100.010	100.035	99.960

* Undetermined.

In considering the effect of the soil, particularly of the alkali, upon the percentage of sugar, I adopted, as a standard of comparison, beets grown upon two other plots of ground, free from alkali, and in good tilth. In this case the meteorologic conditions were the same in every respect, and it was simply a question of soil. The same was true in regard to the feeding value, of both the roots and the leaves; with the constituents of the ash, which are obtained wholly from the soil, the question is not so simple, for there is an uncertainty in regard to the measure in which one constituent may replace another in the economy of the plant, and also in regard to the conditions which influence the replacement of one compound by another.

Some points are so evident, regarding the composition of the ashes from my plot, *i. e.*, that the sulphuric acid is very constant at about 3 per cent., and that the magnesia and lime are also nearly constant, that a multiplication of analyses had no object. In the series of samples, taken September 2, we have for the magnesia, in the samples taken from the three sections, 4.48 per cent., 4.10 per cent., and 4.47 per cent., and for the lime we have 1.74 per cent., 1.19 per cent., and 1.22 per cent. The phosphoric acid is almost as constant, its limits being, as a rule, within 1 per cent., as the series taken October 13, in which we have 8.05 per cent., 8.67 per cent., and 7.50 per cent., may illustrate. It was then evident, that, so far as my own series was concerned, the variations in the composition of the ashes were to be looked for in the chlorin and the alkalies. We obtain a clear view, in regard to the amount of alkalies present, by comparing the alkalies in the different samples after we have eliminated the sand, the carbon dioxid, and the organic matter; when we find, for a series of six ashes, the following figures: 64.08 per cent., 64.32 per cent., 63.79 per cent., 62.23 per cent., 62.30 per cent., and 63.24 per cent. There is here a general rule, holding, at least for my samples, *i. e.*, that the total alkalies amount to about 63 per cent of the ash. The percentages of chlorin in the series of six ashes from which the figures for the alkalies have been taken, present one exception; the percentages are as follows: 13.61 per cent., 7.30 per cent., 15.08 per cent., 15.53 per cent., 15.16 per cent., and 15.90 per cent. Owing to the one exception, I will give six others, in two series of three each, one series taken September 22, and the other October 13. Neither has been corrected for carbon dioxid, etc. The September series gave: 11.49 per cent., 12.82 per cent., and 14.41 per cent., the October series gave 14.96 per cent., 12.60 per cent., and 13.56 per cent.

We conclude that the ash of the beet, that is the root, has a pretty uniform composition, represented by the following percentages, the carbon dioxid, organic matter, and sand, included: For sulphuric acid, about 3.5 per cent.; for phosphoric acid, from 7 to 9 per cent., mostly about 8.5 per cent.; for the alkalies, from 48 to 52 per cent.; for lime, from 2 to 3 per cent.; for magnesia, about 6 per cent., and for chlorin, from 11.50 to 14.50 per cent., while the carbon dioxid does not vary by more than 1 per cent. from 15 per cent. of the fine ash.

It is easily recognized that either all of our soils had the same effect upon the ashes of the different samples, or the composition of the ash of the beet root is really constant, and is but little effected by the variety of soil. I believe the latter to be the case, *i. e.*, that the variation in the general composition of the ash of the beet root is constant within narrow limits, and is not materially affected, beyond those limits, by the character of the soil.

I, unfortunately, have almost no analyses of beet ashes at my disposal, and the few I have cannot be reduced to any common basis, and lose much of the value that they might otherwise have. The best I have is an average analysis taken from Wolff's "Aschen Analysen." According to this, the alkalies amount to 66 per cent. of the ash, carbon dioxid, etc., rejected, the lime and magnesia together to 11.5 per cent., phosphoric acid 11 per cent., sulphuric acid 4 per cent., but the chlorin is only 5 per cent.

The two analyses, quoted from Champion and Pellet, by McMurtrie, give 60 per cent. for the alkalies, 10 per cent. for the chlorin, 7.5 per cent. for lime, and 6.5 per cent. for magnesia. The Massachusetts Report, of 1894, gives for the alkalies, uncorrected, 53.3 per cent., for the phosphoric acid 9.7 per cent.

The experiment was undertaken to determine the effect of the excessive quantity of alkali salts upon the beet, and in the hope that we might find the condition of the land ameliorated by the removal of soda salts. The effect upon the percentage of ash in the beet was to raise it from 2 to 3 per cent., and this increase was proportional in the components of the ash, so that the proportion of alkalies remained the same. The ratio of the soda to the potash was not affected, as I had hoped to fine it; in fact, it was lower for the soda to the potash, in the ashes from samples grown on alkali ground, than in that from some samples from the Farm plots which I had taken as my standard. In samples from sections 1 and 2 of my plot the percentage of soda varied from 10 to 15 per cent. The average analysis taken from Wolff's tables is 10.25. The samples taken from section 3, varied from 16 to 19 per cent., with a corresponding depression of the percentage of potash. This increase in the soda ratio is general in the samples from this section, and I, at first, considered it as due to the influence of the alkali, but one of the samples from the Farm plot, where there is no alkali, in the sense in which this term is used, showed 18 per cent. of soda, and the beets were of excellent quality. I think that the causes which brought about the appropriation of the soda in the two cases were different; still so long as the causes are not definitely determined, the presence of 18 per cent. of soda in the latter case fairly raises a doubt whether the excessive soda salts, in the soil, was the real cause of the large percentage of soda in the former case, as I believe they were. The total alkalies taken up from the alkalized ground, was almost exactly the same as that taken up from the good ground.

The chlorin in the ashes, with one exception, is nearly the same, but the average is higher for my plot, owing to the influence of section 3. The conclusion is this, that on soil which is in good, or even fairly good, mechanical condition, the composition of the ash of the beet is not affected by the presence of alkali, but the percentage of ash is raised. On land, however, which is wet and in bad condition, the alkali increases the amount of soda and chlorin in the ash. This increase in the soda amounts to from 4 to 7 per cent., and in the percentage of chlorin to about the same. The conditions which are required to produce these results are so unfavorable, that the production of any other crop is quite out of the question.

The lime and magnesia, as already stated, are constant in their respective percentages, but they are much lower than the percentages for the German and French samples or averages. This cannot be due to any deficiency of these compounds in the soil, for both the soil and the ground water are rich in them. I have neither an explanation nor a theory to offer. The twenty odd analyses agree in showing that, especially, the lime is low. The ground water carries from 125 to 200 grains of calcic sulphate ($CaSO_4$) to the gallon, and the soil is full of this salt. It is evident, from the very low lime percentage in the ash, that the beet does not appropriate it freely—indeed, scarcely at all. The same is suggested by the uniform percentage of sulphuric acid, not only in regard to the calcic sulphate, but also in regard to the sodic sulphate.

In regard to the leaves, I can find no more data than regarding the beets. All that I can find is from the sources already mentioned, Champion and Pellet, quoted as above, and an average analysis taken from Wolff's tables. These agree as well as one could expect, for the German analysis is an average, while the two French ones are of individual samples.

The French analyses make the sulphuric acid 5 per cent., phosphoric acid 8 per cent., chlorin 11.5 per cent., potash 33 per cent., soda 11.5 per cent., lime 12.5 per cent., and magnesia 10 per cent. The German data give the sulphuric acid as 5 per cent., the phosphoric acid as 7 per cent., potash 28.5 per cent., soda 14.5 per cent., lime 14.5 per cent., and magnesia 14.5 per cent. These percentages are only close approximations, but they are sufficient to convey a pretty definite idea of the composition of the ash of the leaves, as given by these authorities.

I have, in the tables, placed the analyses of nine samples of ashes from leaves, side by side, with those of the beets on which they grew, in order that the composition of the leaf-ash and beet-ash might be easily compared, but I have no analysis of a leaf-ash which may be taken as as standard, so there remains nothing else than to take the general averages given by Wolff's average analysis. A comparison of any of my analyses with this shows a wide departure from it. The sulphuric acid is some lower, the phosphoric acid very much lower—5.6 per cent.—the chlorin is over twice as high, the potassic oxid is from 3 to 5 per cent. lower, the sodic oxid 8 to 10 per cent. higher, the lime about 12 per cent. lower, and the magnesia 8 or 9 per cent. lower. In other words, there is no agreement at all, and I take my analyses, of October 13, as representing the composition of the ash of beet leaves, according to which we have, for sulphuric acid, 3.5–3.9 per cent.; for phosphoric acid, 1.8–2.3 per cent.; potash, 23.7–25.7 per cent.; soda, 22.3–25.5 per cent.; lime, 1.5–2.5 per cent.; magnesia, 6.0 per cent.; chlorin, 23.3–28.5 per cent.; carbon dioxid, 10.6–15.0 per cent. The soda may be too high, and the potash too low, by a few per cent., but the percentages serve to indicate the general composition of the ash.

The weight of leaves to the single plant is over 100 per cent. greater than that given for the average good beet in France. The few statements which I have found indicate a higher percentage of dry matter, 11 to 16.5 per cent., than I find for our leaves. It must be remembered that leaves, so succulent as the beet leaf is, lose weight very rapidly, and that the percentage of dry matter in the leaf, at the time of weighing, will depend upon the length of time that they have been pulled, and also, upon other circumstances. The percentage of ash, in the dry matter, is given as 28 to 30 per cent., in ours it ranges from 25 to 31 per cent.

In a preceding paragraph it has been pointed out that, while there is a general composition assignable for the ash of the beets, there is none, in the same sense, for that of the leaves, and I can only compare the samples from different sections of my own plot. In discussing the beet ashes I made no mention of any differences due to the different stages of development at the time the sample was taken. The reason for this apparent omission is, that there is no regular variation large enough, and constant enough, to force one to the conclusion that it is due to this cause. In illustration of this, we will take the beets from section 2 for the three dates, September 2, September 22, and October 13, when we have, for sulphuric acid, 3.19 per cent., 3.61 per cent., and 3.48 per cent.; for phosphoric acid, 8.76 per cent., 8.79 per cent., and 8.68 per cent.; for carbon dioxid, 14.82 per cent., 14.76 per cent., and 15.69 per cent.; for chlorin, 12.31 per cent., 12.83 per cent., and 12.60 per cent.; for potash, 38.83 per cent., 41.62 per cent., and 42.98 per cent.; for soda, 12.13 per cent., 9.74 per cent., and 8.81 per cent., and if the potash and soda be taken together, there is practically no difference in the percentage of alkalies present on the three dates.

The whole analyses might be given, but would show no exception to the statement that the ash in the immature beet had the same percentage composition as that in the mature beet. There seems to be one exception to this rule in the leaf-ashes, and this is in the case of the chlorin, which increases so generally and uniformly that it is suggestive of a relation between the maturity of the plant and the quantity of chlorin present. The percentages are averages for the dates September 2, September 22, and October 13, in the order given—18.98 per cent., 24.68 per cent., and 26.52 per cent. This is the only one of the constituents which shows this variation. The alkalies, on the other hand, are quite constant, with an average of about 48.4 per cent., against 52.0 per cent. in the beets. The alkalies in the leaf-ashes are, in a rough way, divided about equally, with the soda usually, but not always, slightly predominant. We conclude that the ash of the beet leaf has a general composition which is the same throughout the season, except that there is an accumulation of chlorin, as the plant approaches maturity.

The principal differences between the ash of the roots, and of the leaves, are the following: The ash of the roots contains from three to four times as much phosphoric acid; from one half to two thirds as much chlorin; about one thirteenth more alkalies; a little less lime, and two thirds as much magnesia. The most important of these differences is the smaller quantity of phosphoric acid in the ash of the leaves, the larger quantity of chlorin, and, not the difference in the quantity of the total alkalies, but in the ratio of the soda to the potash in them, which has been stated to be 1:1, roughly, with exceptions in favor of a higher soda ratio.

Apropos to the question of this ratio in the beet ashes, I notice a great variation in the analyses taken from Wolff's tables. The ratio for soda to potash is 1:2, and in the analyses of Champion and Pellet, it is 1:6. In my samples the ratio varies from 1:1.8 to 1:5. The largest amount of soda was found in samples from section 3, and the next highest was found in a sample representing the Farm plot, supposed to be entirely free from alkali, and which is in most excellent condition. I have no analysis of the soil from the Farm plot, but as it was a piece of old alfalfa sod, there was probably an abundance of available potash present.

The principal effects of the alkali upon the beet crop were, in cases where the alkali alone was in question, that the percentage of sugar was scarcely affected at all, but rather beneficially than otherwise. That the nitrogen content was increased, and the ash content, also, by about 2 per cent.

THE FOOD REQUIREMENTS OF THE CROP.

I, of course, hoped to find this plant so tolerant of soda salts that it would utilize soda in its economy in place of potash, and thereby to be able to remove them from the soil, or at least to forestall their accumulation to a deleterious extent. As touching this particular object, the study leads to an adverse conclusion, or, at best, leaves it in serious doubt, for, with two exceptions, we do not find the amount of soda removed to be dependent upon the relative quantities of this compound in the soil. In the two cases in which larger amounts of soda than normal, or what appears to be normal, were removed, one could and the other could not be attributed to an alkalized condition of the soil. But we are enabled, by the establishing of a general composition for the ashes of the beets, and of the ratios between the roots and the tops, and the dry matter in each, to give the requirements of this crop in Colorado in quite definite terms. If we assume a crop of fourteen tons to the acre, and this will be a good average crop for our section, we have a total of from 294 to 384 pounds of mineral matter removed by the roots. This is on a basis of 1.05 per cent. ash in the fresh beets, grown on good soil, and 1.3 per cent. for beets grown on alkali soil. The tops will remove about 586 pounds, assuming them to be equal to 80 per cent. of the weight of the roots, and to have an average of 2.62 per cent. of ash, which is their average on our soils. This gives us a total ranging from 880 to 970 pounds of mineral matter per acre—or deducting one seventh for carbon dioxid, we have from 754 to 832 pounds—of which nearly 60 per cent., or from 450 to 500 pounds, is potash and soda together. The ratio of the soda to the potash is so indefinite, as has been shown, that there is no basis for a very close estimate of the amount of soda removed, but, owing to the large large amount of ash in the leaves, and the richness of this ash in soda, about one half of the total alkalies, or from 225 to 250 pounds, must be soda. The total phosphoric acid removed is between 40 and 50 pounds. This is more than the average German crop of equal weight removes. The chlorin removed has possibly more significance for our main question than any other constituent. We may consider the ash of the root, including the carbon dioxid, as containing 12 per cent., and that of the leaves as containing 25 per cent. On this basis the roots remove from 35 to 46 pounds, and the leaves 146.5 pounds of chlorin per acre, which corresponds to about 307 pounds of sodic chlorid, or salt, to the acre. The sodic chlorid seems to be the only constituent of the alkali removed by the beet plant, but as the sulphate of soda constitutes the principal part of the alkali, and this being without influence upon the composition of the ash, it is not clear, even granting that we could raise a crop of 14 tons to the acre, to what extent the removal of this amount of sodic chlorid would better the condition of the soil.

The soil in question contains chlorin to the amount of 0.025 per cent. of the air-dried soil, or, taken to the depth of two feet, about 2,800 pounds of sodic chlorid to the acre. The water, soluble in the soil, varies in different portions of the plot from 0.09 per cent. to 1.4 per cent. of the air-dried soil. The salts, soluble in water, consist of sodic sulphate, 33 per cent.; calcic sulphate ($CaSO_4$) 36 per cent.; magnesic sulphate ($MgSO_4$) 21 per cent.; sodic chlorid 2.5 per cent.; and loss on ignition, rather less than 7 per cent. The quantity removed would soon reduce the supply of the sodic chlorid in the soil if it were not renewed from some source, but the ground water is charged with alkali, of which from 3 to 10 per cent. is sodic chlorid, a quantity quite sufficient to replace that removed by the crop.

A legitimate question here, is whether this amount of sodic chlorid, 2,800 pounds to the acre, taken to a depth of two feet, has any detrimental effect upon the growth or quality of the crop. I think that the answer must be that it does not.

While the experiment was made with sugar beets, I did not exclude stock beets, and an examination of the analyses of these races, given with those of the sugar beets, shows that they remove a much larger quantity of soda salts in the roots than the sugar beet does, but this is confined to the roots, as the ratio of the weight of the leaves to that of the roots is only about one half as high in the stock beets as in the sugar beets; so that the actual weight of the leaves in the two cases is about the same. Still it appears from the analyses that the stock beets would remove more soda salts from the soil than the sugar beets, crop for crop, but not ton for ton. The percentages of dry matter and sugar show what the relative feeding value of the crops would be. It appears, considering all things, that the Lane's Imperial was the best variety for my purpose, and probably would be for feeding purposes, but this discussion lies beyond the scope and purpose of this bulletin.

SUMMARY.

The object of this bulletin is to present the results of my study of the effect of alkali upon the composition of the sugar beet, and to contribute to our knowledge of the chemistry of this plant.

The beet seed will germinate freely in soil containing as much as 0.10 per cent. of sodic carbonate, but the young plants are attacked by as much as 0.05 per cent., and it is doubtful whether any of them can survive when there is as much as 0.10 per cent. of this salt present in the soil.

Sodic sulphate affects the germination to a much less degree, even when it is equal to 0.80 per cent. of the air-dried soil, but it is injurious when present in larger quantities. When both salts, sodic carbonate and sodic sulphate, are present in equal quantities, the action of the carbonate, or black alkali, is only slightly, or not at all, mitigated.

Magnesic sulphate retards, but does not prevent, germination when present in quantities equal to 1 per cent. of the air-dried soil.

Sodic salts hasten germination by from 36 to 48 hours.

The effect of the alkali, present in our soil, upon the sugar content of the beet is, of itself, not detrimental. The maturing, or ripening, of the crop corresponds to an increase of from 2 to 3.5 per cent. of sugar in the beet, and about one third of the total yield of sugar.

Beets may remain unharvested, under favorable conditions, without loss of sugar or weight of crop. In our case, there was a slight gain between October 6, 1897, and January 8, 1898.

The difference in the average percentage of sugar in the thirds of beets, taken by weight and numbering from the top, is less than 0.20 per cent. in favor of the second and third thirds, while average co-efficient of purity is quite the same for the respective thirds.

The percentage of sugar in the crowns is about 1 per cent. less than in the rest of the beet, and the co-efficient of purity is but little lower than that of the beet.

Simple freezing does not affect the quality of the beet. The sugar is not changed thereby, but the distribution of the sugar in the beet may be materially affected in cases where only a portion of the beet has been frozen, especially if subsequent thawing has taken place.

The drying out of beets increases the percentage of sugar, but is accompanied by an actual loss of sugar.

The rate of drying out is about 5 per cent. for the first 24 hours, but by the end of five days it falls to about 2 per cent., and remains practically constant for the next 12 days.

The weight of the leaves of the Colorado grown sugar beet, equals about 87 per cent. of the weight of the roots. The weight of the leaves does not increase materially during the last six weeks of the growing season, but during this time the weight of the root increases by 64 per cent. of its weight at the beginning of the period, or 39 per cent. of the weight of the mature beet.

The presence of alkali increases the weight of the leaves very slightly, and has no marked influence on the date of maturing.

The amount of dry matter is the same in beets grown upon alkali ground as in those grown on ground free from alkali.

As the sugar is formed, there is a disappearance of dry matter, other than sugar, in the beet, suggesting the formation of the sugar in the root by the transformation of substances already deposited therein.

The dry matter in the upper, or first, third of the beet, taken by weight, is a little higher than in the other two thirds.

The effect of the alkali upon the composition of the beet, as shown by the ordinary fodder analyses, is an increase in the percentages of the ash, and the crude protein, and a decrease in the percentage of nitrogen free extract. The effects of the alkali are greater upon the composition of the beet than upon that of the leaves.

The percentage of ash in the fresh roots is about 1.10 per cent., and in the fresh leaves it is rather more than twice as much.

The effect of alkali upon the percentage of ash in the roots is to increase it by about 2 per cent., reckoned on the dry matter.

The amount of mineral matter removed by a crop of stock beets is from two to three times as great as that removed by a crop of sugar beets. The amount of mineral matter removed by the leaves is about the same.

The percentage of ash in the respective thirds of the beet, taken by weight, is, for the fresh beet, a little higher in the upper third than in either of the other two thirds, but the dry matter from the third, or bottom, third is richer in ash than either of the other two thirds.

I have failed to find any relation between the percentage of sugar and the percentage of ash, and also between the percentage of sugar and the composition of the ash.

The composition of the ash of the beets seems not to have been affected by the different character of the soils experimented with, either because there was so great an abundance of available, and to the plant, acceptable mineral matter present that it was not affected by the presence of a large quantity of other salts, or the composition of the ash of the sugar beet is very constant. I think that the latter is the case; the composition of the ash being represented by the following approximate percentages: Sulphuric acid, 3.5; phosphoric acid, 7–9; alkalies, 48–52; lime, 2–3; magnesia, 6; chlorin, 11.50–14.50; carbon dioxid, about 15.

The ash of the beet leaf has a general composition which, like that of the beet, is the same throughout the season, except that there is an increase in the chlorin as the plant approaches maturity.

The ash of the leaves differs from the ash of the roots in the following points: The ash of the leaves contains from one third to one fourth as much phosphoric acid, from two to three times as much chlorin, a little more lime, about one half more magnesia, and about one thirteenth less alkalies. The most important difference is the ratio of the soda to the potash, which is one, or more than one, to one.