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A SOIL STUDY.

PART II.

The Crop Grown: SUGAR BEETS

—BY—

WILLIAM P. HEADDEN.



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The Agricultural Experiment Station

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Address, L. G. CARPENTER, Director,
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A SOIL STUDY :

Part II.* The Crop Grown: SUGAR BEETS.

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

INTRODUCTORY.

PREVIOUS WORK OF THE STATION ON SUGAR BEETS.

§ 1. This Station has already published nine bulletins on the subject of sugar beets, seven of which have been devoted to the demonstration of the fact that remunerative crops of sugar beets can be grown in the irrigated sections of this State up to altitudes of 7,800 feet. The earliest experiments recorded, 1888, show a trifle over 12 per cent. of sugar as the maximum per cent. present in any of the varieties experimented with. The only object aimed at in the experiments of that year seems to have been to determine whether the beet could be successfully cultivated under our conditions. The results were most encouraging, both in regard to the percentage of sugar present in the beets and also the tonnage, which ranged from 24 to 30 tons per acre. This yield was estimated from the product of an average row 450 feet long.

§ 2. The experiment of 1888 was not continued in 1889, but another line of work was undertaken, namely, to study the effect of various soils upon the composition of the ash, the percentage of the sugar, and on the feeding value of the beets. The results of this investigation were published in 1890 as Bulletin 11.

* Part I., forming Bulletin 46 and issued in 1898, is out of print. Most of the reports of the Station have something about sugar beets. Of the bulletins treating of sugar beets, none but 36, 51 and 57 can be supplied, except to libraries. Those printed are as follows:

7. Potatoes and Sugar Beets. April, 1889. Profs. Cassidy and O'Brine.
11. Sugar Beets. April, 1890. Director Ingersoll and Dr. O'Brine.
14. Progress Bulletin on Sugar Beets. January, 1891. Dr. O'Brine.
21. Sugar Beets; Potatoes; Fruit Raising. October, 1892. F. L. Watrous.
36. Sugar Beets. March, 1897. Prof. Cooke and Dr. Headden.
42. Sugar Beets in Colorado in 1897. February, 1898. Prof. Cooke and Dr. Headden.
46. A Soil Study. Part I. The Crop Grown: Sugar Beets. June, 1898. Dr. Headden.
51. Sugar Beets in Colorado in 1898. March, 1899. Prof. Cooke.
57. Farm Notes. Alfalfa; Corn; Potatoes; Sugar Beets. July, 1900. Prof. Cooke.
58. A Soil Study. Part II. The Crop Grown: Sugar Beets. August, 1900. Dr. Headden.

§ 3. During the season of 1890, Pres. Ingersoll, who was the Director of the Station, and Dr. O'Brine, Professor of Chemistry, joined in a study of the general condition and outlook for the beet sugar industry; while the Horticultural and Chemical Departments cooperated in further study of the sugar beet. The specific subjects with which they experimented during this season being a study of the effect of the distance between the beets in the row upon the amount of sugar contained in the beets, and of the relation between the size of the beet and its sugar content.

§ 4. A number of persons had, by this time, become sufficiently interested in the subject to grow sugar beets and send them to the Station for analysis. The descriptions of the samples, as received at the laboratory, were very imperfect, as was to be expected, but the results obtained fully justified the conclusion of Bulletin 14, which I can do no better than to quote:

We believe that it has been established that the soil and climate of Colorado are favorable to the production of sugar beets, and that they can be successfully and profitably raised to the advantage, both of the farmer and manufacturer.

§ 5. Experiments were continued during the years 1891 and 1892, not only by the Station at Fort Collins, but also at the Substations in the San Luis Valley, Arkansas Valley and the Divide, also by individuals in the Arkansas Valley and in the neighborhood of Fort Collins. The chief importance seems to have been attached to the endeavor to determine how much irrigation is required to produce the best results, and to notice the effects of both too little and too much irrigation upon the crop, and the percentage of sugar in the beet. The effect of the distance between the beets in the row was also studied, but was subordinated to the questions of irrigation and cultivation. The results obtained at the Arkansas Valley Substation at Rocky Ford during these years, 1890 to 1892, were published in Bulletin 21, October, 1892. The rest of the results were not published until March, 1897, in Bulletin 36, which contains a succinct statement of the results recorded up to that date; some of which, about one third, had not been published in any previous bulletin.

§ 6. In the spring of 1897 the public seemed sufficiently interested to justify the Station in again taking up the subject, and having received quantities of seed from the Department of Agriculture at Washington, and also from other sources, it was distributed to persons in different sections of the State, together with explicit instructions how to plant, to cultivate, and especially how to harvest the samples for analysis. The results obtained were, more satisfactory data concerning the time of planting, cultivation and harvesting of the crop. In addition to this, experiments were made at a greatly increased number of localities throughout the State. In

other words, the experiments were greatly multiplied and made simultaneously. So far as quantity and quality of crop was concerned, we only corroborated the results of previous years, *i. e.*, that the soils of Colorado produce beet crops which compare favorably with those produced elsewhere, where the beet sugar industry has proved a profitable venture. There was added to this the results of a study of the conditions at and around the beet sugar factories of Nebraska, Utah and New Mexico, making the statement of facts concerning this industry as complete as possible, and giving the public the fullest possible data wherefrom to draw their own conclusions as to the advisability of engaging in this industry.

§ 7. At this time, the season of 1897, the Department of Chemistry began an independent investigation, whose principal object was a study of the chemistry of the crop as affected by an alkalinized condition of the soil. This work traversed a number of questions pertaining to the crop in a fuller and more systematic manner than had previously been done. The sugar in the beets was determined weekly, beginning September 2, and continued until October 13, when the crop was harvested; and from time to time till January 8, 1898, in beets left in the ground and covered with straw to protect them against severe freezing. This gave us data respecting the effect of alkali upon the amount of sugar present and its effect upon the time of maturing; the composition of the ash at various periods of growth, the distribution of both sugar and ash constituents in the beet, the composition of the beets and leaves in regard to their feeding value, the total dry matter in the leaves and roots, its quantity in the respective thirds of the latter, etc. The results of this year's work are contained in Bulletin 46. In 1897 the Station carried on two lines of experimentation with sugar beets, one economic and the other almost purely chemical, resolving itself into a soil study, which it was intended to be.

The work was continued in 1898 and 1899. Some of the results of 1898 have already appeared as Bulletin 51. This consists of more extended experiments upon the effects of the date of planting, methods of planting, time of thinning, distance between plants in the row, experiments with varieties, and a comparison of home grown and imported seed in regard to the quality of the beets produced.

§ 8. The following pages record the further observations made during the years 1898 and 1899, being, in fact, a continuation of Bulletin 46, and for that reason a few of the conclusions of that bulletin are reproduced here:

The effect of the alkali, present in our soil, upon the sugar content of the beet is not, of itself, 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.

The rate of drying out of beets 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 twelve days.

The weight of the leaves of Colorado grown beets 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, but has no marked influence on the date of maturing.

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 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 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 is 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.

§ 9. The trials in different parts of the State in 1897 aroused sufficient interest in the possibilities of the sugar industry in Colorado, for the resources of the Station to be supplemented by aid from the United States Department of Agriculture, from the Chamber of Commerce of Denver, and from various counties in the State. This aid was largely given through the solicitation of the Chamber of Commerce, and was principally in form of prizes to induce growers to compete for good results. The field trials were directed by Prof. W. W. Cooke. Over 800 analyses were made by the Station. The results of these tests, together with the study of the best methods of growing sugar beets, is given in Bulletin 51.

§ 10. Some additional tests on methods of cultivation, dates of planting, distance between rows, and irrigating the seed are given in Farm Notes, Bulletin 57, by Prof. W. W. Cooke. These are the results of cooperative trials with growers in different parts of the State. The same bulletin reported the results of the tests made throughout the State in cooperation with the Department of Agriculture and the Chamber of Commerce.

THE CHEMICAL WORK OF 1898 AND 1899.

DESCRIPTION OF THE CONDITIONS.

§ 11. The plot on which the beets were grown in 1898 was the same as that used in 1897. The character of this plot having been fully described in Bulletin 46, p. 5, it will not be repeated in this place. The cultivation of the preceding season and the effects of the soil remaining thrown up in ridges over winter, exposing it to the weathering action of the season, tended to better its mechanical condition. This was, as I stated in Bulletin 46, the result most desired in order to reduce our study to the question of the effect of the alkali upon the crop. In addition to the weathering, effected as above stated, I endeavored to further modify the mechanical condition by the application of manure and straw. The plot was divided into sections one hundred feet long and twenty-five feet wide; alternate sections received an application of manure at the rate of sixty-four tons to the acre, and one section of the plot, the most difficult one to handle, received a dressing of cut straw at the rate of fourteen tons to the acre.

My object was twofold: First, to study the effect of the manure upon the soil; second, to observe its effect upon the crop.

The straw was used that we might be able to judge, in a measure at least, of the relative effect of the manure as a mechanical agent and as a fertilizer. The crop raised was, as in 1897, sugar beets, and we were successful in getting the same varieties, but the seeds were from different lots, for the crop of 1898.

The cultivation was similar to that received by the preceding crop, but having gotten rid of a patch of poverty weed on the south side of the plot, we were not troubled by insects to nearly the same extent as during 1897, still both of the beetles, *Systema taeniata* and *Monoxia puncticollis*, observed then, appeared again and did some damage. We, however, did not have recourse to the use of insecticides as in the preceding year. In our case we found that removing the poverty weed and keeping our crop well tilled sufficed to keep the beetles down to such an extent that the damage done by them was not serious.

The alkali appeared nearly as bad as heretofore, and we had trouble with the same sections that had previously given us trouble.

The corroding effects of the alkali was observed, but not to the same extent, and the spots of ground showing it were not so large as in 1897. There was a small spot in which but few seeds germinated; there seemed to be an abundance of moisture, the seed were found at a depth of an inch and a half, and the mechanical condition of the soil was good. This failure of the seed to germinate, for they did not come up at any time during the season, remains unexplained. It was observed that some beets in this part of the patch continued to come up for weeks after the first had made their appearance, especially after irrigation. It is very improbable that this was due to lack of moisture, for this was observed in a very wet portion of the patch, but not the wettest, nor indeed is it more strongly alkalinized than some other parts of the plot. The analyses of the soils taken from these spots, and those of the ground waters also, show a larger amount of magnesia present than in other places within the plot; this is more markedly the case with the ground waters than with the soils. Experiments show that magnesian sulfate retards the germination of seeds, but neither the soil nor the ground water, nor yet the water-soluble portion of the soil, shows a sufficient quantity of magnesian sulfate to account for this. The inorganic substances present do not suggest any solution for the failure of the seed to come up.

THE WATER CONDITIONS.

§ 12. The ground was very wet in the spring, so much so that it caused a delay of two weeks or more in planting. The crop was not planted till June 4; some of it not till June 13. This, however, was not due to the condition of the soil. The only irrigation that we were able to give this crop was given from July 8 to 10, and this was with seepage water, of which we had only a scant supply, so scant that we could not obtain any sample of off-flowing water. But a few days later, a heavy rain having fallen in the mountains to the west of us, more than doubling the flow of the river, a large quantity of water was turned into the Larimer County Ditch No. 2 and its laterals. One of our dams was washed out and the lower portion of our beet plot flooded. This happened between the afternoon of the 13th and the morning of the 14th of July. The drains for receiving the off-flow water were immediately opened and the water turned out of the ditch. Samples of both on and off-flow water were taken. The patch drained rapidly, the surplus water being removed in about three hours. This was the only irrigation that the crop received. The total rainfall for the months of July, August, September and October was 2.8 inches. The total amount of water received by the crop, from the time of planting till harvested, was about eight inches. The ground was wet at the time of planting and the water plane was within less than two feet of the surface.

The level of the ground water fell about a foot in the next 30 days. The irrigation given from the 8th to the 11th was not sufficient to raise the level of the ground water quite as high as it was at the time of planting and it then fell rapidly, making a fall of almost exactly two feet in eleven days. This fall represents the rate of drainage and evaporation. The weather was hot and evaporation was rapid, but that drainage was active can scarcely be questioned. Especially so because the water level in the adjoining, and lower lying, land had not been raised and there was only our small and local supply of water to be removed.

The water level, at a point about two hundred feet to the east of my plot, was not at any time sensibly effected by the irrigation of my plot. The well, the measurements of which form the basis of this assertion, is not very far from an underdrain, perhaps 75 feet from it, but I do not think this fact has very much, if anything, to do with our failure to perceive any change in the level of the water in this well. I think it more likely that the amount of water used was simply insufficient to force its way so far through the soil.

§ 13. This is not the place I intended to discuss the question of water, further than to state the supply furnished to the crop, but it was observed that the different wells fell at very different rates. I have given the maximum fall for the eleven days immediately succeeding the 14th inst. From this date on the water plane fell slowly until it reached its greatest depth for the season during the first week of October. But during the next fourteen days it rose a foot, in some of the wells rather more.

§ 14. The water level at the lower end of the plot ranged, from the end of July to October 10, from 3 to 4.5 feet below the surface, and there were but few beets in this section, as was repeatedly noted in Bulletin 46, but at the western, or higher end, the water level was from 5.2 feet to 6 feet below the surface, and the crop was excellent. At an intermediate point we have the water level ranging, during this same period, from 3.5 to 4.5 feet, with an abundance of alkali and yielding a good crop. With a part of the facts before us it would be easy to justify the inference that beets will not grow where the water plane is from 3 to 4.5 below the surface, but in view of other facts, observed at the same time, we hesitate to offer any statement relative to the cause of the failure of the crop to grow in the section in question, either in regard to the alkali or the water.

§ 15. Notwithstanding the nearness of the water to the surface of the ground, the crop showed the need of water throughout the latter part of the season; our field notes showing that on July 22 the beets were wilted and the water plane low. The weather

was hot and the wilting may have been dependent upon this as much as upon a lack of water in the soil, but on August 13, it is remarked that the crop needs water and on the 17th the condition of the ground is designated as dry, though we had had in the meantime, August 4 and 5, a rain fall of 0.78 inch. The ground had been kept as mellow as possible and free from weeds, having received, in all, five cultivatings and five hoeings.

§ 16. There was no need of irrigating the plot during the season of 1899, though we gave it a thorough soaking from August 31 to September 2, not because the crop needed it, but for the purpose of puddling the ground and of studying the changes which took place in the water by its contact with the soil.

§ 17. The chief cause of our abundance of water was the fact that we received a sub-irrigation July 1 to 7, coming from the western part of the farm. There is a drain immediately west of my plot which should have taken off the greater part of this underflow, but it did not prevent my plot being filled nearly to the surface with water. The water plane being raised to within 18 inches of the surface, as was proven, not only by the water in the wells, but also by several holes dug in order to verify this observation. This development was something entirely new. I knew that the stratum of gravel underlying the plot was filled with water and that there was probably a flow to the eastward through it. I thought that it came from a more distant source, believing that we were fully protected against sub-irrigation of this sort by a ditch constructed to utilize the seepage water gathered for a mile or more to the westward of us, and further, by the drain alluded to. I believe that these two really gather all the water that, under ordinary conditions, drains from the higher land to the westward of us, but in this instance an unusual supply of water enabled the Farm Department to run water night and day for a week, with the result that the water found its way down into and filled up my lower lying land. The wetness of the land interfered with the cultivation of the crop, but the mechanical condition of the soil was greatly improved over that of the preceding seasons, so that the cultivation was much easier than in 1897 and '98.

§ 18. The ground was not disturbed after the irrigation of September 2, but it was allowed to bake and harden as much as it would. This crop was cultivated twice, hoed twice and irrigated once.

In 1898 the crop was irrigated but once, because we could not get water to irrigate with. This single irrigation was only a light one, applied July 8 to 10, and a part by accident on July 14. Subsequently the ground became very hard, in spite of our efforts to keep it mellow. In 1899 we sought to pack and allow it to be-

come hard and dry after the irrigation of September 2. The crop, taking the whole patch, was in 1898, 13 tons to the acre, and in 1899, 14.5 tons. I attribute the increased crops to the improvement in the condition of the soil and to a rather better stand, without considering whether this latter was due to the improved condition of soil or not.

THE EFFECT OF THE MANURE UPON THE STAND AND THE BEETS.

§ 19. The effect of the manure was very marked, improving the stand by at least 10 per cent. I believe that under ordinary conditions the effect of so heavy a dressing of manure would not be followed by an improvement in the stand, but in our case it was; the weather conditions turning favorable just after the planting.

The planting took place on May 11, followed by a rainfall of over 1.5 inches during the rest of the month, which was well distributed, rain falling on twelve of the remaining twenty days of the month. Had this not been the case, it is a question whether the manure might not have facilitated the drying out of the soil sufficiently to more than offset its stimulating effect upon the germination of the seed. As it was, the seed germinated better, the plants were more vigorous throughout the season, and the weight of the crop was greater; but the shape of the beets was inferior, very many of them being rooty, forming a chunky beet with a number of roots spreading out from it, literally covered with masses of fibrous roots. The ratio of tops to roots was not determined, but it was evidently higher than where no manure was used. The six plots used for manuring agreed fully in justifying the above statements. There is no reason to suppose that other conditions would have modified any of these results, except the one already mentioned as possibly exceptional, *i. e.*, that manuring improved the germination and stand. Our observations on the effect of coarse manure, under our conditions, leads to this doubt, which we would not otherwise entertain.

EFFECT OF THE MANURE AND ALKALI ON THE SUGAR IN THE CROP.

§ 20. In 1897 we found that the ripening of our crop, or better, that the formation of the sugar, was much more rapid between October 6 and 13, than at any other period during the season, either before or subsequent to this date. Our results showed that about one third of the sugar contained in the crop made its appearance during these seven days. As the crop of 1898 was later than that of 1897, both in planting and maturing, we did not attempt to follow the development of the sugar throughout the season, but contented ourselves with endeavoring to determine the effects of our alkali and manure upon the date and amount of sugar produced during the period of this maturing process. Our first samples were

accordingly taken on October 3. These were trial samples taken to help us in judging of the condition of the crop. We had already received a number of samples from the Farm Department, but these varied greatly, and we did not know from which of the different plots the sample had been taken. It was, furthermore, out of the question for us to take the plot most nearly representing the plot taken for comparison in 1897, for this plot had been hastened into ripening by lack of moisture. This was so pronounced, at this date, that the tops wilted to the extent of lying flat on the ground. The soil was dry to a greater depth than that reached in digging the beets. If there had been no other differences, these facts make it evident that we cannot compare these plots, so I shall use another whose history is as follows: In 1891 it received a dressing of manure, was planted to potatoes; 1892, trucked, not manured; 1893, fallow; 1894, rye, crop cut green and removed from plot; 1895-'96-'97, fallow; 1898, planted to beets but not manured. The varieties grown on this plot were Vilmorin Improved, White Imperial, White French and Dippe's Improved Kleinwanzlebener.

§ 21. In the following table we do not see the pronounced increase in the amount of sugar as the season advanced or the crop matured, as shown in the crop of 1897, but the season was very different. In 1897 we had, in the early part of September, enough rain, 0.74 of an inch, to stimulate the beets into an increased growth, after a period of comparative inactivity. This produced a material increase in the weight of the crop, but the relative quantity of sugar was less than before this period. The effect was noticeable for two and a half weeks or more, at the end of which period the sugar had increased again and reached its maximum for the season. In 1898 we had no such an abundance of water as in 1897. We were unable to irrigate more than once, and then far less copiously than in 1897, and the rainfall from August 6 to October 15, a period of 70 days, amounted to only 0.74 of an inch, which is the same amount that fell in four days, September 10 to 14, in 1897. The crop of 1898 received its moisture from the soil, developed continuously under very uniform conditions, and matured without showing a so uniformly large gain at the maturing period. In 1897 this amounted to from 2 to 3.5 per cent.; in 1898 the greatest gain for this period was 1.44 per cent. in two weeks. This observation is true in regard to the Farm plot as well as for our own. Furthermore, it is observable in the records of the Department that there is no such great increase in the percentage of sugar just at the time of ripening, unless the beets were already mature at the time of taking the first samples, which was not indicated by the department of the beets when grated, as the earlier samples became very black on being exposed to the air. The Department received a sample harvested September 27, 1898, original Kleinwanzlebener, which

contained 15.23 per cent. of sugar; a sample of the same variety, harvested November 2, contained 15.12 per cent. of sugar. These samples, harvested thirty-five days apart, show almost exactly the same percentage of sugar, and the coefficient of purity is also quite the same, *i. e.*, 83 and 81.

§ 22. The varieties grown by the Farm Department remained almost constant from October 3 to October 22, only one of the three varieties showing any material gain, and in this case a gain of only one per cent. I infer that this difference in the department of the crops of the two years was due entirely to the season, and not to either the cultivation or to the soils. There are three different soils and nine varieties of beets included in this comparison; five of the varieties of beets were grown on our alkali soil and the four others on two different soils. Our soil caused no deviation in this respect, and the conclusion of the preceding years, *i. e.*, that the alkalinized condition of our soil produces no effect upon the development of the beet, is corroborated. The statement, however, that the maturing of the beet represents an increase, that is, a sudden increase, amounting to from 2 to 3.5 per cent., now seems to be an extreme variation. The following table showing the results obtained during the season of 1899 strengthen this view; the greatest increase being 1.1 per cent. from October 10 to 24, and we find no further change, though the experiments were continued until November 10:

TABLE II.—SUGAR IN THE MANURED AND NOT MANURED CROPS OF 1899.

DATE.	Number of Section.		Kleinwanzlebener.				Zehringen.			
	(M) Manured.	(N) Not Manured.	Percentage of Sugar in Beets.		Number of Beets in Sample.	Average Weight of Beets. Grams.	Percentage of Sugar in Beets.		Number of Beets in Sample.	Average Weight of Beets. Grams.
			Percentage	Purity.			Percentage	Purity.		
October 10	1	M	15.10	79.4	12	627.2	14.25	79.8	13	760.0
	1	N	16.34	82.4	12	661.5	14.06	79.6	11	688.1
	2	M	15.01	82.9	14	517.0	12.83	72.1	12	680.4
	2	N	16.34	81.5	12	491.4	16.06	81.3	12	456.2
	3	M	11.88	74.5	14	488.0	11.97	73.4	12	712.3
	3	N	13.97	82.0	12	846.0	14.92	83.8	12	610.0
Average.....		M	13.99	78.9	.....	540.0	13.01	75.1	.....	714.0
		N	15.55	81.9	.....	666.3	15.01	81.6	.....	585.0
October 18	1 } 2 } 3 }	M	13.20	77.7	29	666.6	12.83	71.1	18	710.5
	1 } 2 } 3 }	N	14.54	78.8	18	645.5	15.10	80.1	12	583.5
October 24	1	M	15.44	84.6	12	532.6	15.72	81.7	12	572.3
	1	N	15.58	82.3	12	615.8	17.57	89.1	12	496.7
	2	M	15.96	83.7	12	473.1	13.92	78.0	12	646.4
	2	N	15.58	81.9	12	587.2	16.34	84.2	12	527.4
	3	M	13.77	76.8	12	588.2	12.82	73.3	12	834.6
	3	N	14.87	78.3	12	728.3	15.82	80.2	12	538.6
Average.....		M	15.06	81.7	.....	531.3	14.15	77.7	.....	683.3
		N	15.34	80.8	.....	643.8	16.24	84.5	.....	517.6
October 27	1 } 2 } 3 }	N	14.06	77.2	30	676.1	14.81	78.7	30	509.8
November 10	1 } 2 } 3 }	N	15.77	82.0	15	629.2	15.86	84.2	15	543.5

§ 23. The results of 1897, given on p. 13, Bulletin 46, and those of 1898 and 1899, given in the two preceding tables, but more especially the results of 1897 and 1898, because these are compared with beets grown on ground free from alkali and in good tilth, leave no doubt about the effect of alkali upon the quantity of sugar developed in beets grown on soils abounding in these salts; *i. e.*, they are not detrimental so far as the sugar and the coefficient of purity are concerned, nor does it effect the time of maturing.

THE EFFECT OF THE MANURE.

§ 24. It is usually stated and generally accepted that land on which a crop of beets is to be grown should not receive a dressing of manure immediately before being planted, but that it should receive the manure and be planted to some other crop between the manuring and the planting to beets. As already stated, I manured my plot heavily, 64 tons to the acre, in February, plowed it under in May and planted it to beets. The primary object was to observe its effects on the soil, but it presents an excellent example of the effects of manure upon the crop. I have already mentioned the fact that its effect upon the stand and growth of the crop was evident, and the tables show its effect upon the percentage of sugar and the coefficient of purity. The average for the fifteen samples taken from manured plots on October 3, 1898, is 12.79 per cent. sugar in the beets, with a coefficient of 78.1; the average for the corresponding set from the unmanured plots is 13.30 per cent. sugar in beets, with a coefficient of 78.4; for the samples taken October 15 the averages are: 13.00 per cent. sugar, 79.3 purity, and 13.40 per cent. sugar, 79.6 purity; for October 22 we found 12.92 per cent. sugar, 80.8 purity, and 14.18 per cent. sugar and 83.9 purity. The averages are in harmony with our statement that manuring land immediately before raising a crop of sugar beets on it tends to lower both the sugar content and the coefficient of purity; but its range is only from 0.5 to 1.2 per cent. sugar and from 0.1 to 3.1 in purity, provided we attribute the whole of these differences to the effect of the manure.

§ 25. The effect upon the form of the beets was in our case a much more serious consideration than the diminution of the sugar content and the coefficient of purity. The form of the beets was decidedly objectionable. The bad tilth of the ground of itself tended to the production of ill shaped beets, but the manure made them very rooty, giving rise to a short, chunky beet with several spreading roots and a large mass of fibrous roots. This was very noticeable and common to all of the varieties, but shown in different degrees.

§ 26. The crop of 1899 shows the same results, but the manure, having become more fully incorporated with the soil, effected the form of the beets less than in the preceding year. The percentage of sugar and the coefficient of purity were effected quite as pronouncedly as in 1898. This is evident from the tabular statement of the results for 1899, from which it appears that the manure caused a depression of as much as 2.3 per cent. (See Zehringen, samples taken October 18.) The effects of the manure upon the stand, color of the tops and development of the crop, were almost as

evident in '99 as they were in '98. The residual value of the manure, judging by its effects upon the second crop, is greater than one would be justified in anticipating. This is largely due, without doubt, to the peculiar resistance to complete decay and humification shown by manures in our soils. It is an often observed fact that manure when applied to a tilled crop remains a long time in the soil without undergoing that disintegration which we are accustomed to see in Eastern soils, where there is an abundance of rain and cloudiness prevails for a much larger percentage of the time than with us. This fact was not new to me, but I was of the opinion that the soil, with the water level within from 4.5 to 3 feet of the surface, would remain moist enough, especially when shaded by the tops of the beets, to cause the complete rotting of the manure early in the season, but it was not so. The manure, some of it scarcely decomposed at all, was abundant when the beets were plowed out and can at the present time, two years subsequent to its application, be easily recognized as distinct from the soil. The practical recognition of this is the wasteful custom, still too general, of making no effort to convert the straw and other litter of the farm into manure, or of using the manure to fill mud holes in the roads or dumping it on the commons when it has become necessary to remove it from the neighborhood of the houses. It is a question with the ranchman how to treat the manure so as to get good results without materially adding to the labor of irrigation. This is especially true of cultivated crops. The beets did not produce shade enough to effect, even with the aid of the moisture in the soil, the rotting of the manure.

§ 27. The straw with which we dressed one section did not withstand decay so persistently as the manure. This may be explained by the fact that there was less of it, by its being loose, without any matting together, and by its having been more uniformly mixed with the soil.

§ 28. The effect of the straw upon the sugar content and coefficient of purity is not pronounced, but it is certainly less prejudicial than that of the manure. I cannot say that I observed any effect upon the form of the beets which I could attribute to the direct action of the straw. But its ameliorating effect upon the soil was quite as pronounced as that of the manure.

This is in harmony with the view expressed in Bulletin 46, *i. e.*, that the soil experimented with is so rich in plant food that the effect, if any, of the alkali upon the growth and composition of the crop is obscured, and that it is not the chemical composition but the mechanical condition of the soil which is the factor of greater importance in any endeavor to improve its condition. This statement would be of little importance did it not apply to all of

the alkali soils that I have seen in this State, which I firmly believe that it does.

§ 29. The numbers of the sections 1, 2 and 3 in the tables have the same signification as in Bulletin 46. Section 3 is described as in very bad condition and low, very wet and alkaliized to such an extent that the surface becomes coated to the thickness of from one quarter to upwards of half an inch with alkali. Its condition is, in fact, so unfavorable that I have at all times questioned whether it is not rather to this, than to the alkali *per se*, that the difficulty of growing any thing in this section ought to be attributed. The alkali may be responsible in part for this condition, but there is no question in my mind but that the water is the direct cause of this to a greater extent than the alkali. The very great improvement caused by addition of the manure and straw to this soil is corroborative of this view. I see nothing in the addition of straw to modify in the least the effects of the alkali nor to diminish its quantity, but it does change the texture of the soil, permitting aeration and disintegration to a beneficent extent.

§ 30. The third crop grown on this section still leaves it somewhat doubtful whether we should charge any of the evil to the direct influence of the alkali. A few of the young plants were undoubtedly killed by it, but after they had become established it seemed to do them no injury. I believe it to be of far less injury than it is usually thought to be. Both the sugar content and coefficient of purity of samples taken from this section during the three seasons are slightly lower than in samples taken from the other two sections. There are exceptions to this statement, but they are not of sufficient importance, in number or degree, to cast any doubt on the fact that beets grown in this section are inferior to those grown on the other sections. They have, however, improved in quality during the three years. The average of all varieties grown in 1897 was 10.66 per cent. sugar in beet, with a coefficient of 73.3; in 1898, including both manured and not manured, the average was 12.68 per cent. sugar, 76.2 purity; and in 1899 the average was 14.13 per cent. sugar, 77.1 purity. This is a marked improvement in the quality of the beet. The figures represent the total improvement, including that due to the soil, to culture, and the differences in the season. The two latter are more important than we are at first inclined to think. A good year is a familiar expression, but its equivalent in tons of beets, or pounds of sugar, is a very indefinite notion, especially to those who use it most frequently. Though three years of observation is too brief a time to form an estimate of the seasonal influences on this crop. I am inclined to credit a large share of the improvement in the quality of the crops to this cause, and also something to the

differences in culture; but after making due allowance for these factors, there remains a decided improvement, due to the improved soil conditions, and, so far as I can now see, this improvement is wholly in its mechanical condition, brought about by the subsoiling, cultivation, manuring and by being left in ridges during the winter, exposing it to weathering. That it is not due to improved drainage is evident from facts which will be dwelt upon at a subsequent time.

§ 31. The important fact in this connection is simply this: That the water table has not been lowered, except temporarily by prolonged dryness or a lack of irrigating water.

In connection with this question, the influence of the height of the water table, an attempt was made to determine the capillary power of the soil. It was necessary to break up the natural compactness of the soil, so we passed it through a 40-mesh sieve and packed it as firmly as we could, by gentle tapping, into a glass tube, $1\frac{1}{8}$ inches in diameter. Experimenting in this manner we found that the water had passed upward $31\frac{1}{2}$ inches in seven weeks, and in one year and five months the soil was perceptibly moist at a distance of 45 inches from the water surface, and quite wet at 39 inches from the same. If these figures represent the value of capillarity in the soil in its natural, undisturbed condition, it would seem that our crops ought to have been pretty well supplied with water at all times, there being but a short time when the water level was more than 45 inches below the surface of the ground. The evaporation from the surface in the open field, exposed to a hot sun and the winds, is quite different from the evaporation from a small, shaded and protected surface, such as that exposed in my tubes. I have made no attempt to determine how much of a part this may play in my experiment; I simply acknowledge that it has something to do with it, and that is all.

§ 32. I was at one time quite doubtful whether there was any drainage at all out of the area which I was cultivating, and thought to test the question by introducing some lithia chlorid into one of the wells and observe how long it would require for it to make its appearance in the adjacent wells. Lithia had been looked for in the analysis of the residues obtained from the ground water, and reported as absent, so I thought that my plan was feasible; but on examining the water more carefully, using larger quantities, I found it present in easily detected quantities. I had samples of the residues from the ground water, obtained during the preceding eighteen months, and an examination of these showed this element to be present at all times. I do not know whether this is true of other soil waters in this region or not. It, however, rendered this means of detecting a flow of water through our plot inapplicable,

but a subsequent experiment showed that the water level is lowered, by drainage or otherwise, from 0.7 to 1.0 foot in about 36 days. Observations, in 1898, on the rate of the fall of the water level after having raised it by irrigating, showed about 40 days as necessary for a like fall, *i. e.*, from 0.7 to 1.0 foot, in the different wells. The lowest point the water plane has reached below the surface of the ground, at the east end of the patch, corresponding to section 3, at any time during the three years, was 3.29 feet, which is less than the value of capillarity in this soil. Under such conditions of moisture it would seem that, in some respects, it would be an advantage, rather than otherwise, to have a long dry season. Such seems to have been the case, but not more so with this plot than with others more favorably conditioned.

THE DRY MATTER IN THE CROPS.

§ 33. The average percentage of sugar present in the crop of 1898 was materially higher than in the crop of 1897, and the crop grown by the Chemical Department in 1899 was very rich in sugar. I have already stated that in the latter years there was a scarcity of water, and that the rainfall during the latter part of the seasons was small, so that the soil became dry to a depth exceeding the length of the beets. I believed that this had the effect of increasing the dry matter in the beet, just as drying out under any other conditions would have done, and would account, in part at least, for the higher percentage of sugar. Accordingly, samples were taken, thirteen in number, ranging in weight from 800 to 10,500 grams, and the dry matter determined. The results ranged, in 1898, from 18.63 per cent. to 25.62 per cent., with an average of 22.00 per cent., as against 17.39 per cent. in 1897, when the range was from 16.69 to 18.01 per cent. These figures represent four varieties and seventy-two beets. The highest average obtained in 1897 was for the Kleinwanzlebener and Vilmorin, six beets each, which gave 18.95 per cent. as the highest percentage of dry matter, showing that there was an average of 3 per cent. more dry matter present in 1898 than in 1897, or at least one sixth more. In 1899 we find an average of 22.76 per cent., or three quarters of one per cent. more than in 1898; but this is with two varieties only, the Vilmorin and Zehringen. We did not find any difference between the beets which had grown on manured or unmanured sections in this respect. There were variations, but they were not constant in either direction. I think that this difference of from 3 to 3.75 per cent. in the total dry matter is mainly due to the difference in the seasons.

THE DRYING OUT OF BEETS.

§ 34. During the season of 1898 we received a considerable number of samples from different parts of the State and the results

were uniformly high. An attempt was made to obtain the weight of the fresh samples, but it was very unsatisfactory. I was informed that it was impossible for many of the parties to obtain the weight of the samples sent with any degree of accuracy, and this must have been the case, for quite a number of the samples received weighed more by 250 grams than when they were mailed to us, from three to five days previously. Why the senders should give us such under weights is not easy to understand. In spite of these accidents, we obtained 336 samples which we considered usable, in estimating the deduction to be made from the average percentage of sugar found in order to approximate the actual percentage in the beets in a fresh condition. The amount of drying out was very varying, often evidently too low, and sometimes so high that the result obtained had to be rejected as improbable; but none of the low ones were rejected and are included in the 336 samples used. The correction to be applied as based on these is 1.49 per cent. These samples were all wrapped separately in paper and inclosed in a cotton sack or cloth. As the weights given by the senders were unsatisfactory, I repeated the experiments of 1897 with even more care, having regard to the temperature at which the room was kept during the time of the experiment. The mean temperature for September, during that portion of it in which we received samples, was 61.3°, and for October it was 46.3°, but the mean maximum was 61.0°. I endeavored to keep the room about 60°. I took 4,660 grams of beets and obtained the following results, the loss being expressed in percentage of weight at beginning of the twenty-four hours.

TABLE III.—SHOWING THE RATE OF DRYING OUT OF BEETS.

<i>Days.</i>	<i>Weight. Grams.</i>	<i>Temperature of Room. Degrees.</i>	<i>Percentage of Loss.</i>
—.....	4660.0	.....	....
1.....	4460.0	57-66	4.39
2.....	4322.0	56-62	3.08
3.....	4182.0	56-57	3.24
4.....	4066.0	57-62	2.77
5.....	3915.0	57-62	3.71
6.....	3801.0	57-62	2.91
7.....	3695.0	57-65	2.79
8.....	3617.0	60-60	2.11
9.....	3547.0	.....	1.93
10.....	3468.0	.....	2.23
11.....	3391.0	57-60	2.17
12.....	3305.0	60-67	2.42

§ 35. The conclusion arrived at in 1897, was that the maximum loss was 5.4 per cent. for the first 24 hours, and that after a few days it fell to about 2 per cent. and remained quite constant up to 17 days. The experiment just recorded was made under similar conditions as those in 1897. The beets were covered with gunny sacking to protect them from light and to protect them from drafts

of air as much as possible. In 1897 the loss in the first 12 days varied from 30 to 33 per cent. of the original weight of the beets; in 1898 we obtain 29.00 per cent. loss, and after the first seven days the daily loss is roughly 2 per cent.

As but few samples received from different parts of the State were analyzed sooner than five days after being harvested, the deduction of one and one half per cent. on account of drying out is quite within reasonable limits, as according to the most favorable results obtained by experiment, a deduction of upwards of 2 per cent. would be allowable. Our own samples were analyzed within 24 hours after being taken and lost less, and tend to correct the error and justify us in taking the lower figure, 1.5 per cent.

§ 36. The importance of this is apparent if we consider the effect of it in stating the average percentage of sugar in the crop of 1898. We have 813 samples of this crop and the average of the analyses as made is 15.12 per cent., but allowing for the drying out by deducting 1.5 per cent., we have 13.62 per cent. as the average, which I believe is the nearest approach to the truth that we can make.

§ 37. The records of this department show that the average of all samples recorded from 1888 to 1896 inclusive, is 12.8 per cent., according to which the crop of 1898 was above the average.

§ 38. It should be remembered that the question of drying out is of much greater importance in considering small samples sent to the Station than it would be in samples taken from car-load lots sent to a factory. The factory sample would be likely to be nearer correct than the sample sent to some chemical laboratory to be tested.

COEFFICIENT OF PURITY.

§ 39. In connection with the last question, that of the coefficient of purity is of some importance, not as to what extent it is effected by the drying out, but as to how near the truth the ordinary determination comes. Two series of experiments were made, five with Vilmorin and six with Kleinwanzlebener. These beets ranged in sugar from 9 to 14 per cent., and the coefficient obtained by evaporating to dryness to determine the total solids was sometimes higher and again lower than that found by the ordinary method, but the average of the five determinations made with the Vilmorin was the same and that with the six Kleinwanzlebener samples differed by 0.2 per cent. The average obtained as ordinarily determined being higher by this small amount.

THE EFFECT OF SIZE OF BEETS ON PERCENTAGE OF SUGAR.

§ 40. The impression is that large beets will be low in sugar and that small beets will be rich in sugar. I do not recall having seen it so stated by any one writing on the subject. It is, however, claimed, and that justly, that medium sized beets are apt to be richer in sugar than larger ones, and under ordinary conditions they will be richer than very small ones. It should be remembered that such statements are only true in a general sense and do not exclude exceptions either way. Having seen so many exceptions to the statement that large beets were apt to be poor in sugar, I endeavored to determine the influence of size upon the percentage of sugar.

We sometimes find large beets in a row where the stand is regular, and the large and small beets have, to all appearances, had equal chances, with the general conditions favorable to the formation of beets rich in sugar. Again we find beets grown under conditions which we know from observation to be unfavorable to the growth of beets rich in sugar, whether they are large or small. Again, we know that beets grown from different seed, and on different plots of ground, differ in quality. I shall give examples showing this to be the case with different parts of rows, one end yielding markedly better beets than the other, without regard to size.

§ 41. In order, then, to study whether a large size has any prejudicial relation to the sugar content, I took beets of different sizes grown under the same conditions, *i. e.*, I took all of the beets growing in a certain length of row and analyzed each one separately where they were large enough to make a sample; if not, two were taken together.

This was done with a number of rows, and the results are given in the following table:

TABLE IV.—RELATION OF SIZE OF BEETS TO SUGAR CONTENT.

Number.	Weight of Beet in Pounds.	Percentage of Sugar in Beet.	Coefficient of Purity.
1.....	4.40	13.35	79.6
2.....	4.00	14.16	73.0
3.....	3.25	14.96	81.9
4.....	2.90	16.06	85.1
5.....	2.60	14.77	80.8
6.....	2.40	14.44	76.8
7.....	1.75	16.96	82.5
8.....	1.60	15.39	79.7
9.....	1.50	15.06	81.0
10.....	1.50	15.68	83.1
11.....	1.45	16.44	79.9
12.....	1.20	15.77	85.8
13.....	.75	14.73	77.5
14.....	.62	15.44	81.0
15.....	.62	15.58	83.4
16.....	.62	12.97	70.3
17.....	.50	14.30	74.5
18.....	.40	14.58	78.0

§ 42. This set of samples shows that beets ranging from 1.20 to 1.75 pounds, Nos. 12 to 7 inclusive, are preferable to either larger or smaller beets. It happens that we have six beets ranging from 2.4 to 4.4 pounds, showing an average of 14.62 per cent. of sugar, and six beets weighing less than a pound each, whose average sugar content is 14.60 per cent. I consider this a reasonably fair test of this point, as the samples are of the same variety and taken consecutively, and from a portion of the rows where the stand was perfect. The beets were mature and in fine condition.

§ 43. Another set of samples was taken of another variety which had grown near an irrigating ditch, and near the edge of the patch. I knew that these conditions tended to the growth of large beets of low quality. But I desired to see what the relation of size to quality was in these. This variety was not known. The seed was purchased for Lane's Imperial, but they were not Lane's Imperial, being a sugar beet of the type of the Kleinwanzlebener, and but little inferior to this variety when grown under like conditions. This variety, under fairly favorable conditions, showed an average of 13.25 per cent. sugar, against 13.97 per cent. for the Kleinwanzlebener. A sample of this variety, grown on my own plot and taken a few days before these, showed 12.59 per cent. sugar, with a coefficient of purity of 77.6.

TABLE V.—RELATION OF SIZE OF BEETS TO SUGAR CONTENT—
(Continued).

<i>Number.</i>	<i>Weight of Beets in Pounds.</i>	<i>Percentage of Sugar in Beets.</i>	<i>Coefficient of Purity.</i>
1.....	8.62	10.59	67.5
2.....	8.12	10.45	68.3
3.....	6.90	9.64	62.5
4.....	5.70	9.50	65.2
5.....	5.16	10.45	65.9
6.....	3.15	12.11	72.3
7.....	2.88	10.45	67.0
8.....	2.82	9.26	62.1
9.....	2.71	10.21	64.7
10.....	2.27	8.46	66.6
11.....	2.01	9.98	66.0
12.....	1.78	10.45	66.5
13.....	1.55	12.35	70.1
14.....	1.08	10.45	65.9
15.....	0.25	11.88	69.7

§ 44. This set of samples is no more decisive than the preceding. If it shows anything, it is that beets from one quarter to one and three quarter pounds will be better than larger beets; but taking the individual beets, we observe that the eight-pound beets are as good or better than the one pound sample, and that the three-pound sample is better than the one quarter pound one. The size seems less determinative under conditions of abundant moisture and favorable soil conditions than under others.

§ 46. The beets from the west half are by far better than those from the east half, and this, too, without regard to size, so that the beets from the two halves cannot be compared with one another. The number of beets exceeding 1.5 pounds from the east half stand to those from the west half as more than 2 to 1. The length of row dug was carefully measured, and the distance apart in the row determined; for the Vilmorins it was 7.3 inches in the east, and 8.25 inches in the west half; for the White Imperial it was 6.99 in the east and 6.66 in the west half; for the White French, 8.13 inches in the east and 9.3 in the west half, and for the Dippe's Kleinwanzlebener it was 6.3 in the east and 6.48 inches in the west half. The distance between the beets is well within the generally assumed proper limit. The shortest section of row dug was 20 feet, and the length of the rows was 400 feet.

§ 47. A casual inspection of the table leaves the impression that the beets from the west end of the patch are smaller than those from the east half, and are richer in sugar than these. This is true, but I do not believe that the rest of the inference likely to be drawn, *i. e.*, that it is because of their smaller size that they are richer, is justified. I believe that this depended upon some other factor.

§ 48. It is difficult to satisfy oneself by a study of the results given in this table that there is anything shown by it more definitely than by the preceding ones. Taking each of the samples by itself, that is, comparing beets grown side by side, we find only two sets in the six where there is any decided difference in favor of the smaller beets, and these two are of the same variety, the White French, and the larger beets weigh from 3 to 7 times as much as the smaller beets. We cannot even allow this uncertain advantage to the smaller beets, in regard to coefficient of purity, for, according to the table, the difference is in favor of the larger beets. If from this table we select beets of the same size for comparison, we will find that those from the west end are the richer and better beets. The few exceptions which we find to this statement are confined to the White French variety. If we had dug the whole of the rows, and selected all of the beets weighing upwards of two pounds, we would have gotten at least two thirds of the sample from the east half of the patch, and if we had, in the same manner, collected a sample of beets weighing less than one pound, we would have gotten more than half of it from the west end, and these samples would not give us the data to judge of the relation of size to percentage of sugar. It would be, in a considerable degree at least, equivalent to comparing the large beets grown in the one half with the small beets grown in the other half, which conceals the relation between the size of the beet and its percentage of sugar.

If from the preceding table we take the average of all the samples in which the individual beets exceed two pounds, and compare it with the average of all those in which the beets weighed less than one pound, we find a difference of 1.5 per cent. sugar in favor of the small beets, which is actually a greater difference than is shown between the largest and smallest beets in any single experiment in the series. In order to make this comparison, we must take beets grown side by side, which we have endeavored to do, finding as the result of the eight experiments recorded in the last table, that beets weighing about one half pound contained, as compared with beets weighing upwards of two pounds, in one case more than 1 per cent. more sugar, in two cases more sugar by 0.67 per cent., in one case more by 0.19 per cent., and in one case less by 0.19 per cent. Of four varieties experimented with, the maximum difference shown by three of them in favor of the small beets is 0.67 per cent., while the fourth shows a difference of a little more than 1 per cent.

§ 49. The second table given under this subject, being the results obtained from an experiment with beets of very large size, and grown at or near the edge of the patch, with a constant and abundant water supply, suggested an explanation for the general impression that large beets are poor beets. Excessively large sugar beets, 8 to 10 pounds or upwards, are unusual. Such beets are grown under such conditions as above given, at the edge of a patch with abundant water and plant food, or where they stand alone. I have analyzed Kleinwanzlebener beets grown in this manner that were very poor, showing less than half as much sugar as the average of the patch. In other words, very large size and low quality are associated with an almost unlimited feeding ground and abundance of water. There was a single row of beets on the Farm which had practically been grown under these conditions, except that the beets were thick in the row. There were three varieties: Vilmorin, White French and White Imperial. Samples of each of the varieties were taken by digging a piece of the row and sorting the beets into different lots, according to size.

TABLE VII.—EFFECTS OF EXCESSIVE FEEDING GROUND ON QUALITY OF BEETS.

VARIETY.	Number of Beets.	Average Weight of Beets in Pounds.	Percentage of Sugar in Beets.	Coefficient of Purity.	Percentage of Sugar in Beets Grown in Patch. Rows 13 inches, Beets 8 inches.	Coefficient of Purity.
Vilmorin.....	6	2.02	12.78	75.5	.....	.....
	9	0.50	14.30	80.0	13.97	79.2
White French.....	9	1.95	11.50	73.0	.....	.....
	12	0.33	11.82	72.2	13.16	80.3
White Imperial.....	10	1.56	10.31	68.5	.....	.....
	3	0.84	11.50	74.2	.....	.....
	13	0.17	10.59	70.7	11.88	70.9

§ 50. This exhibits the effect of growing free, which would probably have been more pronounced had the beets not been so crowded in the row. The Vilmorins averaged one beet to each 3.4 inches, the White French one to each 3.5 inches, and the White Imperial one to each 2.4 inches. This made the beets so thick that they pressed one another outward from the row, and modified the effect of the row being single and with an excess of room laterally. In the case of the Vilmorin there is a decided superiority shown by the small beets in both percentage of sugar and coefficient of purity, 1.5 per cent. in sugar and 4.5 in purity. The other two are so close that it is not decisive. The average of the Vilmorin is so close to the value found for the sample taken from the patch that it is not clear that the difference is due to the amount of space at the disposal of the beets. In the other two, however, there is a difference of one and one and a half per cent., respectively, in favor of the beets grown in the patch. The two soils in which these samples were grown are equally good, so far as one can judge.

§ 51. My conclusion is that in the case of beets growing side by side, those ranging in weight from one to two pounds are richer in sugar, and of higher purity, than either the larger or smaller, and of the latter that there is a slight difference in percentage of sugar in favor of the smaller beets. But the difference in purity is slightly in favor of the larger beets, and in neither case is the difference great or constant. But large beets, grown under conditions differing from those under which the smaller beets have been grown, cannot be compared with the smaller ones. I also take it, as indicated by the values obtained from the samples from our

single row, that two great a width between the rows tends to have the same effect as permitting the beets to grow singly.

EFFECTS OF OVER IRRIGATION.

§ 52. The difference in the size of the beets, it being smaller, and their sugar content, it being higher, in the west end of one of our patches than in the east end, seemed difficult to explain, as the patch was only 400 feet long, and the soil seems equally good throughout. Our field notes, however, call attention to the fact that the west end is hard and the foliage is yellow, as though water had stood there, puddled the ground and produced the yellowness of the leaves. As this was the only perceptible difference in the conditions at the east and west ends, there remained nothing else to which to attribute the difference in the quality of the beets. There was another patch on the Farm in which this had happened, and we collected samples from this patch also and analyzed them, together with samples taken from the same patch, but which had not suffered from this cause. It appears from the table on page 27 that the average of all the samples taken from the west end exceeds by 0.71 per cent. that of all the samples from the east end. An examination of the table in detail shows how constantly the samples from the west end were better than those from the east end, though the average difference is only 0.71 per cent. The samples obtained from the other patch, consisting of eight beets each, the one yellow from the effects of too much water, the other taken a few feet away but green and healthy looking. The beets of both samples were small. In the green sample they averaged 0.62 pound. This sample showed 13.78 per cent. sugar and 79.1 purity. In the over irrigated sample the average weight was 0.66 pound. This sample showed the presence of 17.20 per cent. sugar and 89.1 coefficient of purity. It was at this time so late in the season that we could not follow this subject, and postponed further observations until the next season, 1899. I was, in a certain sense, thwarted in this part of my work; but in another sense I was not. In making an experiment with irrigating water I had an opportunity to over irrigate my beet plot and subject it to a treatment reproducing the conditions of these over-irrigated patches.

§ 53. My plot did not need water, but wishing to make observations on the changes in the amount of solids, etc., which go into solution and pass into the ground water, I obtained, through the kindness of Capt. Hawley, our Water Commissioner, enough water to thoroughly soak the ground, raising the water plane quite to the surface. This irrigation was made August 31 to September 2 inclusive. The ground was not disturbed, but allowed to settle and become hard. The beets were left to themselves until dug. The ground did become hard, and the beets showed the effect of

over irrigation by turning yellow in places. The average for this plot in 1898 was 13.65, and the average for all samples analyzed at the Station that season was 13.62 per cent. The average for this crop, 1899, which was over-irrigated in early September, was 14.69 per cent. I have no way of judging whether I diminished the yield by treating the crop as I did, but it was the largest yield that I have yet gotten off of this ground. The size of the beets in the over-irrigated patches of the season of '98 give contradictory indications. It seems probable that the yield would be diminished, but it certainly was not materially affected in any of the observed cases.

§ 54. These facts seem to contradict the generally accepted view that a rainfall in the latter part of September or early October may effect the beets unfavorably. I recorded, in 1897, the effect of a rainfall of about .75 of an inch as depressing the sugar content to an extent which the beets did not overcome for three weeks. I think that the explanation is not difficult. A moderate rainfall may do one of two things, according to the condition of the crop at the time of its fall. If the crop is growing slowly, but has not begun its rest period, the rain may very materially increase its rate of growth, and an increase in weight of crop may take place more rapidly than the formation of sugar. This would produce a depression in the percentage of sugar present, but the percentage might be subsequently regained or exceeded. If the crop had already begun its resting period, had begun to ripen, the rain might, as it often does, produce a new growth, that is, a second growth, in which new leaves are produced, a fact familiar to every one. In this case there is a real diminution of the sugar present, and not only an apparent one due to a disproportionately large increase in the weight of the crop. In the over irrigation we have neither of these cases. On the contrary, the effort was to keep the beets growing steadily, but to puddle the soil tightly about them at a period not too much in advance of their normal time of maturing and then to leave them. I do not believe that the same results would follow in all soils, nor if the excessive irrigation should be applied at a time when it would cause the crop to take on a new growth, but there does seem to be enough promise in it to justify a sufficiently extensive series of experiments to determine the exact conditions of soil and time when it will produce advantageous results, as there is no doubt but that such conditions exist.

BEET ASH AND ITS COMPOSITION.

§ 55. In 1897 I endeavored to determine the ash at different periods in the development of the beet, and the effect of the different soil conditions upon the composition of the ash. There was a series of analyses of beet ashes, seventeen in number, made during the

season. Thirteen of these ashes represented varieties of sugar beets, mostly the Kleinwanzlebener variety. The reason that my work was confined to this one variety was that the results obtained showed so little variation that the information to be obtained did not promise to be commensurate with the labor involved. Our conclusion from that series of analyses was, that probably owing to the richness of the soil in the elements of plant food necessary for the beet, the alkali present had exerted but little or no influence on the composition of the ash. The ash in that series which showed the largest amount of soda was one prepared from beets grown on a Farm plot free from alkali, or as much so as any of our soils. The only thing which we observed in the analyses which might be taken as indicating anything characteristic of the soil, was the tendency shown toward a high chlorin percentage. We have not endeavored to study this subject in such detail in the subsequent years, but have reduced the number of samples, enlarging them at the same time, so as to make them thoroughly representative. As we had selected the Kleinwanzlebener variety in 1897, we selected it also in 1898. The samples were not only of the same variety, but were grown on the same ground, so the ashes ought to give us a measure of the influence of the manure applied, and the effect of the cultivation if the composition of the ash is materially affected by these factors. Our conclusion in 1897 in regard to this point, was that the composition of beet ashes was relatively constant, within comparatively narrow limits. The following analyses corroborate this view, though they are not given for this purpose:

TABLE VIII.—GIVING COMPOSITION OF ASHES OF BEETS GROWN WITH AND WITHOUT MANURE.

	Kleinwanzlebener. Chemical Plot Manured. 1898.	Kleinwanzlebener. Chemical Plot. Not Manured. 1898.	Kleinwanzlebener. Chemical Plot. Not Manured. 1897.	Vilmorin Improved. Farm Plot. 1898. Not Manured.	Vilmorin. Farm Plot. Not Manured. 1897.	Vilmorin. Chemical Plot. Not Manured. 1899.	Zehringen. Chemical Plot. Not Manured. 1899.
Dry Matter in Beets.....	19.770	20.822	18.090	23.704	17.500	23.493	24.423
Ash in Dry Matter.....	5.650	5.433	6.491	5.476	5.469	4.000	4.500
Insoluble Ash.....	1.075	0.921	1.389	0.850	1.311	1.350	1.150
Soluble Ash.....	4.575	4.512	5.102	4.626	4.158	2.650	3.350
Ash in Fresh Sample.....	1.117	1.131	1.174	1.298	0.957	0.940	1.099
Carbon.....	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.
Sand.....	1.440	1.079	1.188	1.125	0.931	2.613	2.139
Silica.....	0.946	0.887	1.102	0.652	1.264	1.373	1.234
Sulphuric Acid.....	2.760	3.062	3.476	3.364	2.878	3.747	3.913
Phosphoric Acid.....	9.984	8.434	8.668	6.923	6.088	8.613	9.109
Carbonic Acid.....	18.106	17.092	15.690	22.300	19.177	16.890	15.294
Chlorin.....	10.752	11.857	12.599	6.966	10.887	5.699	9.464
Potassic Oxid.....	40.061	37.923	42.976	38.322	40.065	40.525	38.572
Sodic Oxid.....	8.699	12.184	8.811	12.736	11.161	5.878	9.219
Calcic Oxid.....	2.549	2.612	1.951	2.356	3.409	4.106	2.980
Magnesian Oxid.....	5.745	5.366	5.573	5.156	5.264	7.226	7.242
Ferric Oxid.....	0.273	0.306	0.146	0.238	0.414	0.396	0.707
Aluminic Oxid.....	0.087	0.303	0.538	0.100	0.774	0.184	0.193
Manganic Oxid.....	0.195	0.331	0.195	0.152	0.186	0.310	0.204
Loss on Ignition.....	1.519	1.626	.....	1.532	.....	3.454	2.308
Sum.....	103.109	103.062	102.912	101.922	102.498	101.014	102.498
Oxygen Equivalent to Chlorin.....	2.423	2.672	2.839	1.570	2.441	1.284	2.132
Total.....	100.686	100.390	100.073	100.352	100.057	99.730	100.366

§ 56. This table shows the composition of beet ashes obtained from beets grown on three different soils and under different conditions, both of season and cultivation. The differences in the percentage of dry matter in these samples are, as I have already suggested, to be attributed to seasonal influences rather than to differences due to variety and cultivation. But whether the other differences, such as is observed, for example, in the percentage of the phosphoric acid, is to be attributed to the differences in the soils, season or cultivation, appears open to doubt, though the

higher percentage of this acid in the ash of beets grown on the manured ground indicates that the cultivation has an influence upon the amount of this component of the ash, tending to increase it. On page 48, Bulletin 46, is given an analysis of the ash of a sample of Kleinwanzlebener beets grown in New Mexico, in which we have less than 4 per cent. (3.336 per cent.) of phosphoric acid, showing that ash from the same variety may have a varying composition, due to differences of soil, and it may be that the lower phosphoric acid in the Vilmorin ashes, given in the table, is due to this, and not to variety, for these samples were grown on different plots in 1897 and 1898, while the Kleinwanzlebener samples were grown on the same plot, one half of which, however, had received a dressing of manure. The percentage of chlorin shows the greatest change as a result of the cultivation and continued cropping. In 1897 the ash of the Kleinwanzlebener beets contained 12.599 per cent. of chlorin; in 1898, grown on the portion which had not been manured, the ash contained 11.857 per cent., and the ash of the beets grown on the manured portion contained 10.752 per cent. The highest percentage of chlorin found in the ashes of the Zehringen variety, in 1899, was 9.464 per cent., while the Kleinwanzlebensers showed only 5.699 per cent. chlorin present in the ash. These last two samples were grown on soil which had not at any time received a dressing of manure. These percentages indicate a decrease in the amount of chlorin taken up by the beets, as the soil conditions are improved. There has been, at the same time, an improvement in the quality of the beets. In 1897 the Kleinwanzlebener variety showed 11.76 per cent. sugar, 76.0 purity; in 1898, 13.97 per cent. sugar, 84.6 purity; in 1899, 15.34 per cent. sugar, 80.8 purity. For two years, 1897 and 1898, the percentages of sulphuric acid, phosphoric acid, lime and magnesia remained almost the same. In 1899, however, the percentages of lime and magnesia increased by about 1 per cent. in each case. Previous to 1899, the highest percentage found for the magnesia was 5.74 per cent., but in 1899 it reached 7.25 per cent., an increase of 1.5 per cent. In the case of the lime, the highest percentage found, in 1897 and 1898, was 2.826 per cent.; in 1899, 4.106 per cent.; also an increase of nearly 1.5 per cent. These samples were grown on the same plots, and were of the same variety of beets. The changes observed are toward a closer agreement with other analyses than heretofore. These percentages do not establish permanent changes, but do show the tendency which the continued cropping and cultivation of this soil has to modify its effects upon the mineral matters taken up by the plants. The tables giving the percentage of sugar and the coefficient of purity for these crops show a decided improvement in the three years covered by the experiments, and the analyses of the ashes show the tendency which manuring,

cultivation and continued cropping to the same crop, has to ameliorate the effects of unfavorable soil conditions.

§ 57. Reference was made to the question as whether the manure added to the soil, acted, in this case, as a fertilizer or as a mechanical agent, simply improving the physical condition of the soil. The composition of the ash shows that its action is not merely physical but is well marked chemically, in that the percentage of chlorin is lowered and that of phosphoric acid is increased.

§ 58. Reference to the Tables Nos. I. and II., showing the percentage of sugar, etc., for the years 1898 and 1899, will show that the effect of the manure upon the sugar content and coefficient of purity was not marked until the end of the season, or the period of ripening. This was especially true in 1898; the difference in favor of the not manured plots being greater in 1899 than in 1898. It should, however, be borne in mind that all of the beets in '99 are remarkably high in sugar, and quite up to the average in purity, and while the beets grown on the plots having received no manure were better than those grown on plots which had received manure, it is not to be inferred that the latter were poor beets in regard to either sugar content or purity, for the averages for the two varieties grown on the manured plots in 1899 were 15.06 per cent. sugar, 81.7 purity, and 14.15 per cent. sugar, 77.7 purity, while those grown without manure showed 15.34 per cent. sugar, 80.8 purity, and 16.24 per cent. sugar and 84.5 purity.

The effects of the straw were probably almost wholly mechanical, and this effect was very evident. The effect of the sheep manure was evident in the improvement of the physical condition of the soil, in the germination of the seed, the more vigorous growth of the crop, the shape of the beets, the sugar content of the beets, the coefficient of purity, and in its effects upon the composition of the ash.

§ 59. The effects of the manure upon the vigor of the growth, the percentage of sugar and the coefficient of purity were quite as marked in the second as in the first crop grown on the soil after the application of the manure. The manure being more thoroughly incorporated with the soil the second year, did not produce as marked effects upon the shape of the beets as it did the first year.

COMPOSITION OF THE MANURE APPLIED.

§ 60. It has already been stated that the amount of manure applied was at the rate of sixty-four tons to the acre, also that it was applied broadcast in February and plowed under in May. At the time of the application of the manure, my opinion was that this soil was so abundantly rich in plant food that the only effect of the manure would be mechanical. The results observed show that

its effects were varied, and it apparently produced important chemical changes in the soil, because of its fertilizing ingredients.

§ 61. This manure contained, at the time of its application, 45.14 per cent. of dry matter, or 28.89 tons of dry matter was applied per acre.

§ 62. The ammonia in the fresh manure was equal to 0.926 per cent. of nitrogen. This determination was made by distillation with magnesian oxid, to learn how much of the total nitrogen existed in the manure in the form of ammonia and ammonia salts; also to learn how great a loss might be suffered by the volatilization of this compound under the influence of our winds and sunshine. The loss in our particular case was probably large, as the weather remained clear for some time after the application of the manure, and dried it out until it became very dry. The percentage of the total nitrogen, which was set free as ammonia by the magnesian oxid, was 47.22 per cent., and the amount expelled by drying the manure to a constant weight in a water oven was 60.73 per cent. of the total. I do not know the power of this soil to absorb the ammonia which was ready formed in the manure, but it is evident that the danger of loss was, under the conditions given, greater than one would expect. Had rain fallen immediately after the application, the loss would have been much smaller than it probably was.

§ 63. The total nitrogen present in the manure was 1.940 per cent., or the nitrogen applied was at the rate of 2,483.2 pounds per acre; or if we allow a loss of one fourth of the nitrogen, due to volatilization and failure of the soil to absorb the ammonia, there would remain 1,861.6 pounds to the acre. The phosphoric acid in the fresh manure was 0.654 per cent., or an application of 837.1 pounds, equivalent to 1,573.4 pounds of calcic hydric phosphate per acre.

§ 64. The potassic oxid equaled 2.427 per cent. of the fresh manure, or a dressing of 4,077.36 pounds of potassic oxid to the acre, equivalent to 8,543.11 pounds of potassic sulphate. We have the application of 2,483.2 pounds of nitrogen, 1,573.4 pounds of calcic hydric phosphate and 8,543.1 pounds of potassic sulphate, or their equivalent, together with nearly 25 tons of organic matter, producing the effects recorded in the preceding pages.

§ 65. The most salient question suggested by a comparison of the composition of the manure applied and the results produced, is in regard to the phosphoric acid and potassic oxid, the former being materially increased in the ash of the beets, while the latter, on the contrary, is not effected, or is possibly decreased. The amount of potassic oxid applied is greatly in excess of the phosphoric acid, and the ratio of the potassic salts to the phosphates in the manure is

greater than the ratio of potash to phosphoric acid in the ash. The effect of the manure is probably to be found in the specific action of the nitrogen and the organic matter. I think that the analyses of the soil will tend to establish this view.

§ 66. The nitric acid in the ground water in 1898 is more variable and much higher than it was in 1897, but on the other hand, the water level stood somewhat higher in 1897 than it did in 1898, the difference being about one foot. I think that the smaller quantity of water applied to the surface in 1898, either as irrigation water or as rain, tending perhaps to yield a more concentrated percolate, will not account for the greatly increased amount of nitric acid in the ground water, but that it is to be explained chiefly by the oxidation of the nitrogen added to the soil in the manure.

§ 67. The total solids in the ground water in 1898 were higher, as a rule, than in 1897, but whether they were as much higher as the supply of water was less, I cannot say. I know that it does not hold good that the total solids in the water are larger in amount as the water is lower. The greater the depth of soil the water has to travel through, the less likely we are to find excessively large amounts of the total solids in the water.

§ 68. In 1899 we had a larger amount of water as sub-irrigation water, and it may be doubted whether the total solids contained in the ground water should be used as a criterion of the effect of the manure, *i. e.*, as a measure of the chemical changes induced by the manure. I regret that the relation here is so obscure and involved that it lessens the value of the results obtained, but our observations show that the total solids fell again in 1899 to a lower point than they showed in 1897.

Irrigation or heavy rains which fill the soil with water, raise the water level, and cause an increase in the chlorin contained in the ground water. The manure applied seemed to make the increase more pronounced and of greater duration.

The analyses of the ground water in 1898 do not show a sufficiently marked difference to justify any further inferences than those based upon the nitric acid and chlorin. We shall discuss this part of our work more fully in the succeeding part of our study.

§ 69. The effects upon the crop indicate that the manure applied produced not only mechanical effects upon our soil, but also chemical effects, both tending to improve its condition and eliminate the effect of the alkali in increasing the percentage of ash. But it is not clear what relation exists between the composition of the manure and the general effects produced. The observations made upon the effects of the straw, and the increased amount of nitric acid in the water (it is understood that this nitric acid is present in

the form of nitrates), incline me to the view that the organic matter, including the nitrogen, played an important part in our particular case.

SOAKING EXPERIMENTS.

§ 70. It is a universally acknowledged fact that the maturing of the beet is accompanied by an increase in the coefficient of purity; that is, that the sugar in the juice of ripe beets constitutes a larger percentage of the total solids than it does in the juice of green beets. The percentage of sugar in the ripe beet is also higher than in the same beet when it is green. The increase in the ratio of the sugar to the solids not sugar, might be due to an increase in the amount of sugar, without any change in the amount of the other solids, in which case there would be an increase in the weight of the beets, corresponding to the increase in the amount of sugar and of the dry matter in the beet. There is, however, a disappearance of solids not sugar at this period, which indicates that the percentage of total solids in the beet is not maintained at an approximately constant figure by a proportional increase of crop and sugar content, but a proportional decrease of the one and increase of the other.

§ 71. The following experiments were made in an endeavor to obtain more definite information on this subject, *i. e.*, whether this change of material into sugar may continue after the beet has been pulled; for if we can prove an increase in the amount of sugar, before and after soaking, the probability of such a change in the living beet is strengthened. In 1897 we found that there was a period during which sugar was rapidly formed, but that sugar was present early in the history of the crop, and that there was a slow increase, after the growing season for the crop had passed, even extending up to the early part of January, the beets having been left in the ground and covered with straw.

In 1898 a different experiment was performed. Four varieties of beets were chosen, Vilmorin Improved, White Imperial, White French and Kleinwanzlebener. Sixty-eight beets of the first and sixty of each of the last three varieties were taken, and after washing were paired, according to size, and one of each pair taken for immediate analysis, while the other was taken for soaking. The halves of the samples obtained in this manner varied but little from one another, the maximum difference being six pounds on a sample weighing 132 pounds. One half was analyzed immediately, the other half was packed in galvanized iron tubs, with fine sand, in such manner that the beets did not touch one another; water was added till the tubs were full, and pieces of ice were placed on top of them. The samples were soaked in this manner for seven days. The temperature of the water in the interior of the sand ranged from 41° to 48° F. throughout this time. The results were as follows:

TABLE IX.—SHOWING THE EFFECTS OF SOAKING BEETS ON THE SUGAR CONTENT.

Year.	Variety.	Before Soaking.				After Soaking.	
		Number of Beets in Sample.	Weight of Beets in Pounds.	Pounds of Sugar.	Purity.	Pounds of Sugar.	Coefficient of Purity.
1898.....	Vilmorin Improved.....	34	65.00	8.2435	76.5	9.7657	78.8
	White Imperial.....	30	59.50	6.8960	74.0	7.0420	74.4
	White French.....	30	67.40	8.8698	80.3	8.8797	66.1
	Kleinwanzlebener.....	30	24.70	3.3789	77.0	3.5644	83.5
1899.....	Zehringen.....	30	35.12	5.2020	78.7	5.6451	84.4
	Zehringen.....	15	18.43	2.5913	77.2	2.7628	83.8
	Vilmorin.....	30	42.20	6.6549	82.0	6.8959	82.7
	Vilmorin.....	15	19.25	3.0560	84.2	3.1086	82.5
Average.....				5.6115	78.7	5.9580	82.0

§ 72. The samples taken were large enough to eliminate the errors in sampling, any effects of size of beets, and also any effects which might be attributed to variety. The same experiment was repeated twice in 1899, using two varieties. The series of experiments is wholly consistent in showing an increase in the amount of sugar after the seven days' soaking. I regret that I have not tried this experiment with beets at different periods of their growth. The experiments recorded were all made with mature beets, and the formation of sugar was going on slowly and would probably have proceeded slowly if the beets had remained in the ground with their full growth of leaves intact.

§ 73. The effect upon the coefficient of purity is quite as marked as upon the amount of sugar present. In one case, it is true, the coefficient of purity appears to have been lowered; this may really be the case, but I am inclined to consider it an accident, especially as the seven other experiments agree in showing an increase in the coefficient, while this one alone shows a decrease.

THE REDUCING POWER OF BEET CHIPS.

§ 74. Thinking that some light might be obtained on the preceding subject by determining the reducing power, shown by the beet pulp after the extraction of the sugars, reacting with alpha naphthol, by means of 80 per cent. alcohol, a series of experiments was made, in which the ground dried beets were extracted with

boiling 80 per cent. alcohol so long as the solution continued to react with alpha naphthol. I will observe, in passing, that this alcoholic extract yielded, after the alcohol had been distilled off, furfural, upon distillation with hydrochloric acid of 1.06 sp. gr. The residue thus freed from sugar was boiled for thirty minutes in a flask provided with a reflux condenser, with 1.25 per cent. hydrochloric acid solution. The solution was made to volum, and its reducing power determined. No furfural could be detected as escaping from the condenser. The results were as follows :

Kleinwanzlebener.....	9- 2-97—2.535 per cent. pentoses.
Kleinwanzlebener.....	9-22-97—3.415 per cent. pentoses.
Kleinwanzlebener.....	10-13-97—2.624 per cent. pentoses.
Vilmorin.....	10-13-97—3.445 per cent. pentoses.
Yellow Globe.....	10-29-97—2.673 per cent. pentoses.
Lane's Imperial.....	10-29-97—2.729 per cent. pentoses.
Zehringen.....	11-10-99—5.897 per cent. pentoses.
Vilmorin.....	11-10-99—5.615 per cent. pentoses.
Zehringen—after soaking.....	11-10-99—5.770 per cent. pentoses.
Vilmorin—after soaking.....	11-10-99—5.065 per cent. pentoses.

The total furfural which the samples were capable of yielding was not determined.

§ 75. The two fodder beets, the Yellow Globe and the Lane's Imperial, were included to see whether they contained more or less of these pentose bodies than the sugar beets. In the Zehringen and Vilmorin samples of 1899, we observe that the reducing power of the extracted pulp is high. The sugar content is also high, but the table does not show a decrease in these substances as the beet matures; at best, it is not conclusive, because the series is not extended enough. But three out of four show a lower percentage for pentoses, accompanying a lower sugar percentage, and four out of five show a higher percentage, accompanying the higher sugar percentage. The two soaked samples agree in showing a decrease in the pentoses present, which may be due to transformation of these bodies into others. It seems probable that not only the monosaccharids, such as glucose, may suffer change into polysaccharids, but that the pentoses may also be involved in similar changes.

THE SUGARS IN BEET LEAVES.

§ 76. I have tried four methods in my efforts to prove the presence of sucrose in the leaves and to determine its quantity.

The first one tried was the investigation of the expressed juice of the leaves. This was very unsatisfactory, and led to no conclusion except that there is in the juice of the leaves one or more bodies which yield upon hydrolysis with hydrochloric acid bodies which reduce Fehling's solution, but I did not succeed in establishing the presence of sucrose by this method.

§ 77. The expressed juice of the leaves was subjected to fermentation and subsequent distillation. Two thousand seven hundred and forty-nine grams of juice, expressed from fresh leaves, stems and blades being used, received a quantity of compressed yeast and was allowed to stand 36 hours at a temperature of from 26° to 31° C., after which it was subjected to distillation. A blank test was made as a control. The results showed the probability of fermentable sugars in very small quantities in the juice of the leaves.

§ 78. A larger quantity, 30 pounds, of stems of leaves were gathered October 20, 1899, when the deposition of sugar was supposed to be active, dried quickly, ground, and subsequently extracted with 80 per cent. alcohol. The alcohol was distilled off and the extract concentrated, a little ammonia being added from time to time. The fluid extract was treated repeatedly with ether to remove the chlorophyll, etc.; an aliquot part of it was taken and treated with lead acetate, the sugars inverted by hydrochloric acid, determined by Fehling's solution and calculated as sucrose. The total sugars found corresponded to 0.28 per cent. calculated on the green stems. The inversion was quite difficult to effect, much more so than the inversion of pure solutions of cane sugar.

§ 79. The fourth method followed was that of Brown and Morris, *i. e.*, extraction with ether, and solution of sugars in alcohol; treatment with lead acetate, removal of lead; determination of glucose by means of Fehling's solution; inversion of maltose by means of invertin, and inversion of all of the invertible sugars by hydrochloric acid.

§ 80. A sample of leaves, Kleinwanzlebener variety, gathered September 2, 9 a. m., when the beets were growing vigorously, gave the following results:

Glucose	0.156 per cent.
Maltose	0.030 per cent.
Sucrose	0.000 per cent.
	—————
Total	0.186 per cent.

Kleinwanzlebener, leaves gathered September 22, 9 a. m.:

Glucose	0.801 per cent.
Maltose	0.023 per cent.
Sucrose	0.064 per cent.
	—————
Total	0.888 per cent.

Kleinwanzlebener, leaves gathered October 13, 10 a. m. :

Glucose	0.398	per cent.
Maltose	0.394	per cent.
Sucrose	Lost	per cent.
	<hr/>	
Total	0.792	per cent.

Vilmorin, leaves gathered October 13, 10 a. m. :

Glucose	0.398	per cent.
Maltose	0.186	per cent.
Sucrose	0.000	per cent.
	<hr/>	
Total	0.436	per cent.

These results agree in showing the presence of glucose and maltose, the latter being present in smaller quantity than the glucose, while cane sugar is present in subordinate quantities or absent.

As experiments show that the alcoholic extract of beet leaves yields furfural when distilled with hydrochloric acid, indicating the presence of pentoses in this extract, which are susceptible of hydrolysis, it cannot be considered as rigorously proven that there is any cane sugar present, though the probability of its presence seems quite strong. But it is much less than has been found in the leaves of other plants which do not store sugar as a supply for the future use of the plant.

SUMMARY.

§ 81. The effect of the alkali is noticeable, but to a less extent than in 1897, and the area in which its effects appear are more restricted.

The application of straw, as well as of manure, improved the condition of the ground and perceptibly mitigated the effects of the alkali.

The application of manure improved the stand of beets, but did not prevent a failure to germinate in some spots.

The amount of water received by the crop of 1898, rain and irrigation water together, was about eight inches.

The water plane varied from three to six feet below the surface in different portions of the patch at various times during the season.

The force of capillarity caused water to rise 45 inches as a maximum, the surface of the soil being protected from wind and sun.

The plot receives subirrigation, though there is a drain and an open ditch, supposed to intercept this water.

The cultivation in 1897 differed in one respect from that given in 1898 and 1899. In 1897 the crop received two irrigations and more cultivations than in the latter years. The soil was kept more mellow. In 1899 it was purposely firmed about the beets in September, and no effort was made to mellow it after this. The percentage of sugar in 1898 and 1899 was higher than in 1897. This was in part caused by the condition of the soil produced in 1899 by intentional over-irrigation.

The effects of the manure upon the crop was to produce ill shaped, rooty beets, also to slightly lower the percentage of sugar and the coefficient of purity. Its effect on the shape of the beets was far more serious than that on the percentage of sugar and coefficient of purity.

The conclusion reached in 1897, relative to the effect of the alkali condition of the soil upon the percentage of sugar in the

crop, is corroborated by the observations of the years 1898 and 1899, *i. e.*, that the alkali *per se* is not injurious in such quantities as it is present in any part of our plot.

The effect of the manure upon the shape of the beets was noticeable the second season after its application, but it was less marked than it was the first season. But its effect upon the percentage of sugar and the coefficient of purity was almost as marked the second year after its application as it was the first year. The peculiar soil conditions are in part the cause of this, for they retard the rotting and complete incorporation of the manure with the soil.

The marked increase in the percentage of sugar at the period of ripening, observed in 1897, was not observed in the years 1898 and 1899. The difference in the manner of maturing is attributed to the difference in the seasons. It is possible, though not probable, that such increase had already taken place before we took our first samples, September 27. The beets did not show any signs of having ripened at this time.

The beets from the Farm plots and our alkali ground showed no difference in this respect, corroborating the observation of 1897, that the alkali was without influence on the maturing of the beet.

Cut straw was applied to one section in order to compare its effects with those of the manure, as a measure of the extent to which the manure might act as a mechanical agent. It benefited the soil greatly, its mechanical effect being nearly as great as that of the manure, but the effects of the manure were in other respects much greater.

The percentage of dry matter in the beets of the years 1898 and 1899 was higher than in 1897, due, probably, to seasonal differences. The average difference for beets from my plot was 4.9 per cent. in 1898 and 3.8 per cent. in 1899.

The average percentage of sugar in the crop for 1898 was, after making allowance for some drying out of the samples, 13.62 per cent. The average of the crop grown on alkali soil was 13.65 per cent.

Medium sized beets are apt to be better than either large or small beets, but the size is less determinative of the quality of the beets than the conditions under which they grow. Beets weighing two pounds and upwards are quite as rich as those weighing less than one pound, if they have been grown under the same conditions.

The effect of excessive free space was studied on a row planted singly, with unoccupied ground for several feet on either side. The beets were very close to one another in the row. The average percentage of sugar was lower than shown by the same varieties grown in rows twenty inches apart.

Over irrigation applied at the proper time, produces, in some soils, an increase in the percentage of sugar, without materially, if at all, decreasing the crop.

The continued cropping and cultivation of our plot has slightly decreased the percentage of ash in the beet and changed its composition, particularly lowering the percentage of chlorin.

If fresh beets be soaked for seven days in water cooled by ice, an actual increase of sugar takes place, indicating the formation of sugar in the beet root.

The substances in beet chips hydrolized by dilute hydrochloric acid, are, as a rule, higher in beets rich in sugar than in stock beets, or in those having a lower percentage of sugar.

The leaves of the sugar beet contain some glucose and maltose, but only small quantities, if any, sucrose.

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