THE SUGAR-BEET IN AMERICA

BY

F. S. HARRIS

The Rural Science Series

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PLATE I.

A good field of sugar-beets.

THE

SUGAR-BEET IN AMERICA

BY

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PREFACE

SUGAR, which was once a luxury, has become a necessity in modern dietaries. The civilized nations have become so accustomed to its use as an important food that great inconvenience is experienced if it cannot be had or if the supply is reduced. This has made sugar-producing plants almost as staple as those from which bread is derived. As a result, sugar-beets, in the past century, have won an important place among the profitable crops of the temperate zone. In most of the European countries they have been raised extensively, whereas in America their growth has been confined to a comparatively few localities. In recent years, however, the area has been greatly extended, and increased interest has been taken in establishing a domestic beet-sugar industry.

Much has been written about sugar-beets in America within the last thirty years, but most of this material is scattered through numerous bulletins and reports of experiment stations and the United States Department of Agriculture, and is not easily available. For some time a book containing the important facts regarding sugar-beet production has been needed. This has become more apparent since the beginning of the European war, which caused a sugar shortage in western Europe and America. In response to this need the present volume is prepared. It is hoped that it may be useful to farmers who are raising sugar-beets, to agriculturists of the sugar companies, and to students of sugar-beets in agricultural colleges as a text. Those who do not find in the volume sufficient information for their needs will find references to additional material in Appendix A.

The author wishes to acknowledge his indebtedness to the many individuals who have been helpful in the work of preparing the manuscript. He is under special obligation to Prof. George Stewart, Dr. E. G. Titus, Mr. J. W. Jones, Dr. G. R. Hill, Jr., Prof. G. B. Hendricks, Dr. George Thomas, Dr. W. E. Carroll, Prof. O. W. Israelsen, Mr. D. W. Pittman, Prof. H. R. Hagan, Prof. M. H. Greene, Mr. L. A. Moorhouse, Dr. M. C. Merrill, Mr. W. K. Winterhalter, Mr. H. Mendelson, Mr. A. M. McOmie, Mr. J. A. Brock, Dr. N. Kopeloff, Dr. C. O. Townsend, Mr. Truman G. Palmer, Dr. E. D. Ball, Dr. O. E. Baker, and Mr. W. H. Wallace, who have read chapters and offered valuable suggestions; to Mrs. F. S. Harris, Mr. K. B. Sauls, Miss O. Blanche Condit, and Miss Carrie Thomas for assistance in preparing the material for publication and in proof-reading; and to the various sugar companies who have furnished photographs, statistics, and other valuable material. He wishes to make particular mention of the assistance rendered by Mr. N. I. Butt, who did much laborious work on the literature and helped in collecting statistics and preparing diagrams.

F. S. Harris.

Logan, Utah,
Oct. 1, 1918.

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THE SUGAR-BEET IN AMERICA

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CHAPTER I

GENERAL VIEW OF THE INDUSTRY

THE beet-sugar industry in America has but recently passed out of the experimental stage. It was undertaken nearly a century ago by men who had more enthusiasm than knowledge concerning the raising of beets and the methods of extracting sugar from them. Early attempts to establish the industry on the Western Hemisphere were not successful, partly because of the lack of scientific methods and partly because beet-growing was first tried in unfavorable localities. It also required time to train farmers to grow beets and experts to make beet-sugar. Legislation, also, has been a factor. When regions well adapted to beet-culture were chosen, when farmers became familiar with methods of raising beets, when methods of extracting sugar from the beets were improved, and when legislation was favorable, then was the industry able to establish itself and to pass beyond precarious infancy. This stage being passed, the industry has now entered the period of vigorous youth — the time of greatest virility and growth. The beet-sugar industry is now firmly established in America; it is ready to take its place in the sisterhood of great American industries.

The key to successful beet-sugar manufacturing is a supply of good beets at a reasonable price. The actual making of sugar can be conducted about as well in one place as in another if the beets are available. The growth of the industry, therefore, depends on an extension of the beet-producing area and on perfecting the methods of growing beets in sections where they are now produced.

Those persons familiar with the conditions necessary to beet production, and those acquainted with American geography, are convinced that only a small part of the land well adapted to beets is at present planted to the crop. Figure 1, which shows the relative number of sugar factories in Europe and in the United States, indicates that in America the area devoted to beets may be increased many times before it will reach the limits that have been found profitable in Europe. Reference to Chapter IV, wherein the conditions for raising beets are considered in detail, will show that many parts of the United States are well adapted to the production of sugar-beets. Now that the industry is well started, it seems probable that it will grow rapidly in the next few years.

This growth will be fortunate for American agriculture, which needs stimulation of more intensive methods. Experience has shown that wherever a beet-sugar factory has been established in a community, the price of all farming land has risen. This has resulted not alone because beets themselves make a profitable crop, but because raising them promotes better farming and consequently a higher return to each acre of land. The deep plowing and the thorough tillage, so indispensable to beet-culture, increase the yield of subsequent crops on the same

FIG. 1. — Relative number of beet-sugar factories in Europe and the United States. Maps drawn to the same scale. The factories in Europe, however, are smaller than those in the United States.

land. The cost of these tillage operations is met by the beet crop, the increase in yield of the other crops usually coming as a net profit.

Beets make an excellent crop to fit into the rotation. On account of the tillage required, they permit the eradication of weeds that persist in other crops; they furnish, through their by-products, a large quantity of stock feed; they are deep-rooted, and consequently bring from considerable depth plant-food that is later made available to shallow-rooted crops; the period when work is required by beets fits well with the raising of grain and alfalfa; and, finally, they furnish a cash crop, which should be found in every rotation. Because of these conditions, beet-raising is a help to the individual farmer.

The community as a whole is also benefited by the beet-sugar industry. Considerable ready money is thereby brought into the region and the farmer is enabled to know before the crop is planted that he has a sure market at a definite price. This tends to stabilize all phases of business in the community; it gives a standard market value to all land capable of raising beets profitably. The factory furnishes work to farm hands who would otherwise be idle in winter; boys and girls find employment in the beet fields when school is not in session. This employment of the people of the community makes the industry valuable even when direct profits of beet production are small.

Perhaps the greatest reason for encouraging the domestic production of beet-sugar is the greater national independence that results from having at home a supply of such an important food. In times of peace the advantage of this condition is not strikingly apparent, but war forces the situation home.

Within the last century the world's use of sugar has increased from about one million tons in a year to twenty million, an increase of two thousand per cent. There are many reasons for expecting this increase to continue until the world's requirement will be several times what it now is. At present the United States uses about five times as much sugar as it produces from beets. It is evident, therefore, that beet-sugar is still only a minor factor in supplying the home demand.

In view of the increasing importance of sugar as a food, that great areas of land in the United States are well adapted to beets, that only a small percentage of the sugar consumed in the country is produced at home, and in view of the many benefits of a domestic beet-sugar industry, it seems imperative that greater attention be given to the sugar-beet in America.

CHAPTER II

DEVELOPMENT OF THE BEET-SUGAR INDUSTRY

The beet-sugar industry has grown in a century from nothing to its present enormous proportions. It is a significant example of the application of science to the needs of mankind. With the demand for sugar exceeding the supply and increasing faster than could be satisfied from known sources, new and better methods of securing sugar were sought. By applying the principles of plant-breeding to the sugar-beet — a plant formerly having only a low percentage of sugar — the quantity of sugar that can be extracted from a ton of beets was increased several fold. The same incentive has also led to the application of the principles of chemistry and physics to the manufacturing of sugar. When the industry first began, beets low in sugar were the only kind obtainable, and even this little sugar had to be extracted by imperfect processes; but as time went on the beets were improved and the processes perfected, until at present sugar can be obtained from the beet at a fraction of the cost of a hundred years ago.

EARLY USE OF SUGAR

The use of sugar as an important food is confined to modern times; formerly it was known only as a medicine sold by apothecaries. In ancient times, honey was the chief source of sweet. This was supplemented by sweet fruits and sirups, but no refined sugar was extracted from any source to be used as ordinary food.

It is not certain whether the first sugar was obtained from sugar-cane or from the bamboo, which belongs to the same family. Early Greek and Roman writers mention it as a rare product. Theophrastus, in the third century B.C., refers to it as honey which comes from bamboos, and Pliny tells of sugar in Arabia and India. Very little sugar-cane was found in Bengal before the fifth century A.D., but about this time it was introduced into the Tigris Valley and soon after into the Euphrates Valley. In 627 A.D. it was found in Persia and carried westward. About the middle of the eighth century the Moors carried it to Spain, this being its first introduction into Europe. It is known to have been raised in China at an early date and has been grown there continuously ever since.

By the tenth century, sufficient sugar was produced in the valleys of the Tigris and Euphrates to attract traders, and it was sometimes used as food in special feasts. It was not until the middle of the seventeenth century, however, when Queen Elizabeth of England introduced it into her household, that sugar could be considered as part of the diet.

Sugar-cane went from Spain to Sicily and Cyprus in the thirteenth century. The King of Portugal in the fifteenth century sent cuttings from Sicily to Madeira and the Canary Islands, from where it went to Brazil during the early part of the next century. About the same time it also became important in the Island of San Domingo. By 1518 there were twenty-eight mills on this island. It reached Mexico in 1520, Guadalupe in 1644, and Martinique in 1650. The first sugar mill in Cuba was built in 1547. Sugar-making was brought to Louisiana in 1751 by the Jesuit fathers, but after about twenty-five years' trial it was abandoned, not to be tried again till 1791. Thus with the introduction of sugar into the diet of the people of Europe, the colonies of the European countries furnished an abundant supply. At that time the consumption was very low compared with that of the present.

When sugar first became an article of commerce, the high price prohibited its general use. As late as 1482 it sold for as much as $275 a hundred pounds on the London market, although it had been considerably cheaper a century before. By the close of the fifteenth century the price had fallen to $53 a hundred pounds in London. Competition became very keen among the English, Dutch, French, and Portuguese traders for the sugar trade of Europe in the early part of the eighteenth century. Each country was anxious to have its colonies furnish the chief supply of sugar, most of which was at that time produced by slave labor.

EARLY HISTORY OF BEETS

The first use of beets as a cultivated crop is not known. Theophrastus, in the third century B.C., describes two varieties of beets grown in Greece — the deep red and the white. The barbarians who conquered Rome carried beets back and planted them in Bohemia on their return. Oliver de Serres, in 1590, seems to have been the first to record the sweet properties of the beet. He said that "the juice yielded on boiling is similar to sugar sirup." He believed that alcohol could be made by fermenting the beet. The red beet was introduced into England in 1548, but the white variety was unknown there until 1570. Four varieties were known by 1782, the small and large red, the yellow, and the white. In 1786 Abbé Commerel published a book on the value of beets as feed for stock.

Discovery of sugar in beets.

Although De Serres had suggested the sweet properties of beets, he did not obtain pure sugar from them. It was left to the German chemist, Andrew S. Marggraf, a member of the Berlin Academy of Sciences, first to obtain sugar from the beet. This he accomplished in 1747, but it was a half century before this discovery was put to any practical use. The methods used by Marggraf in extracting sugar in the laboratory are described as follows: "After having cut the beets into thin slices, he dried them carefully and reduced them to a powder. On eight ounces of beet thus pulverized, he poured six ounces of alcohol rectified as highly as he could obtain it, and placed the mixture over a gentle fire in a sand bath. As soon as the liquid came to a boiling point he withdrew it from the fire and filtered it into a flagon, which he stoppered and left to itself. After some weeks he perceived that it had formed crystals, which presented all the physical and chemical characters of the crystals of sugar from cane. The alcohol which remained contained sugar in solution and also a resinous matter which he abstracted by evaporation."

First commercial extraction of beet-sugar.

Karl Franz Achard, son of a French refugee in Prussia, was the first to extract sugar from beets on a commercial scale. He had been a student of Marggraf, who had turned his attention to the beet as a source of sugar. After the death of his teacher in 1782, Achard devoted himself faithfully to perfecting methods of extracting the sugar. The laboratory methods were too expensive to be used on a large scale. In 1797, after fifteen years of work, he announced his methods, and two years later presented them and samples of sugar to the Institute of France. His statements brought forth considerable ridicule, but the Institute was sufficiently aroused to appoint a commission of nine leading scientists of France to investigate the whole problem of extracting sugar from beets. On January 25, 1800, the commission made its report, which, on the whole, was favorable to Achard, although it doubted some of his claims.

In the meantime, the producers of cane-sugar had become alarmed and feared that some of their profits might be lost. It is reported that in 1796 a society in England offered Achard $30,000 if he would abandon his work and make the world believe his attempts had not been a success. Two years later a new offer of $120,000 was made and refused. An attempt was then made to destroy interest in beet-sugar through Sir Humphry Davy, the celebrated English chemist. He said that while sugar could be obtained from beets, it was too sour for food.

The early work of Achard was encouraged by financial assistance from Frederick the Great, but after his death in 1786 the work was somewhat interrupted until his successor, Frederick William III, came to the rescue. Through the aid of the latter, the first beet-sugar factory in the world was built on Cunern Estate, near Steinau in Silesia, in 1799–1801. In 1802 a factory was built near Paris for experimental purposes. These first factories experienced many difficulties in purifying the sugar. This, together with the low sugar-content of the beets, discouraged all but the most enthusiastic.

Assistance from Napoleon.

The establishing of the beet-sugar industry on a paying basis really came as an incident in the wars of Napoleon. As a measure against England he established in 1806 a blockade in which any merchandise from England and her colonies was not allowed on the continent. This cut off the chief source of sugar; as a result the average price from 1807 to 1815 was thirty cents a pound. At times it went much higher than this. In 1806 the French Government offered a bounty on beet-sugar, but it was not until 1811, near Lille, that the first commercial factory in France was established.

On January 12, 1812, Napoleon issued a decree providing that one hundred select students should be sent from schools of medicine, pharmacy, and chemistry to the six special beet-sugar schools that he had established the year before. He also set aside large tracts of land to be devoted to beet-raising and compelled the peasant farmers to plant sugar-beets. The decrees of Napoleon to encourage the beet-sugar industry were so liberal and the price of sugar was so high that by 1812 forty factories were in operation. These factories handled 98,813 tons of beets produced on 16,758 acres and manufactured them into 3,300,000 pounds of sugar. This may be called the real beginning of the beet-sugar industry.

From France the industry spread rapidly to the other countries of Europe, especially to Germany and Russia. In Germany, Achard established a school which was attended by students from all parts of Europe. These students carried back to their respective countries technical information which, encouraged by the success of the French manufacturers, led to the establishment of many factories.

Decline of the industry.

With the downfall of Napoleon in 1815 and the return of peace, the ports of Europe were thrown open to the cheap sugar from the colonies. As a result, the newly established industry was not able to hold its own. The quality of beets was still poor and the processes used in the manufacture of sugar were so imperfect that it was impossible to compete with cane-sugar produced by slave labor. Only one factory in Europe survived the reconstruction that followed the overthrow of Napoleon. This was the factory of M. Crespel at Arras, France.

Revival of the industry.

For some time in France the beet-sugar industry fluctuated according to the laws that were passed. In an effort to revive beet-sugar production during the period from 1822 to 1825, over one hundred new factories were built. The processes of manufacturing were improved so greatly that 5 per cent of sugar could be extracted instead of 2 per cent, as formerly.

Researches of Pelouze in 1821 led to better methods of breeding, which made progress more rapid. By 1836 there were 436 factories in operation. This alarmed the importers of cane-sugar and led to legislation which was unfavorable to beet-sugar producers. This legislation caused the abandonment in 1837 and 1838 of 166 factories. In 1840 and 1843 attempts were made by the cane-sugar interests to have the government buy the beet-sugar factories and close them, but this failed. In 1847 colonial cane-sugar and beet-sugar were taxed equally, which made it difficult for the beet-sugar to compete, because the cane-sugar was nearly all produced by cheap slave labor. The abolition of slavery in 1848, however, helped the beet-sugar industry. From 1851 to 1873 the making of beet-sugar in France was very spasmodic, since it depended almost entirely on the attitude of legislation.

In Germany, where legislation was more consistent, the industry grew slowly but surely. Considerable attention was given by scientists to the improvement both of the quality of beets and of the manufacturing processes. In 1836 Germany had 122 factories which used 25,346 tons of beets and produced 1408 tons of sugar. The average percentage of sugar extracted that year was 5.5, while in 1886 it averaged 12.18 per cent. The per capita consumption of sugar in Germany was 4.4 pounds in 1836, but had risen to 7.14 pounds in 1856, and in 1906 it was 41.08 pounds. The factory price of sugar in Magdeburg fell from 9.4 cents a pound in 1854 to 4.2 cents in 1886.

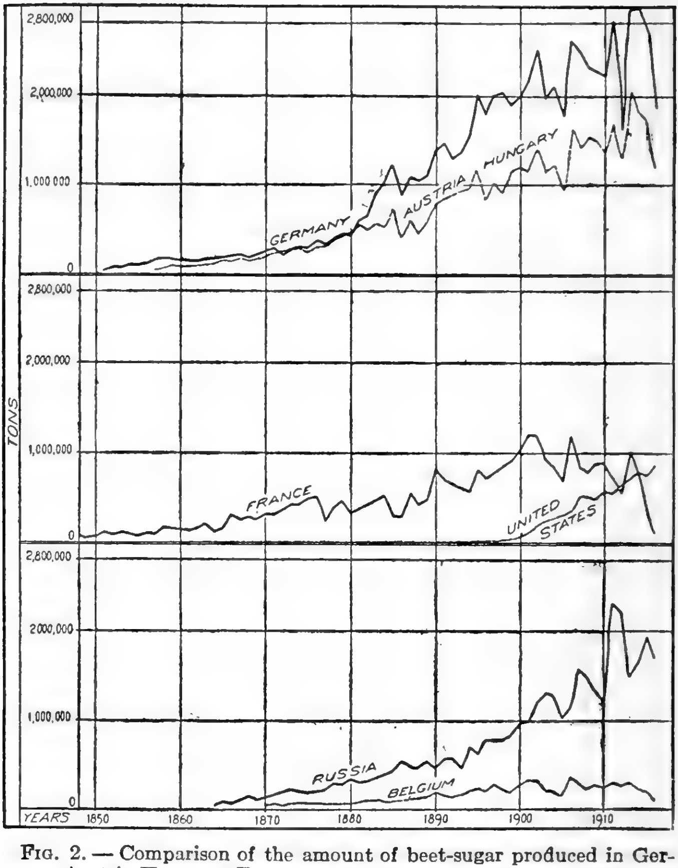


Fig. 2. — Comparison of the amount of beet-sugar produced in Germany, Austria-Hungary, France, United States, Russia, and Belgium, in different years.

In 1877 Germany had 286,000 acres of beets, which produced 378,000 tons of sugar, while in 1886 the output of sugar was more than 1,000,000 tons. Germany did not equal the sugar production of France until 1878, but since that time she has led the world in beet-sugar. She produced 2,223,521 tons of sugar in 1906. The average percentage extracted that year was 15.69.

In other countries of Europe the beet-sugar industry followed rather closely the lead of France and Germany (see Fig. 2). At present there are beet-sugar factories in all the European countries except Norway.

Ware[1] shows in the following table the relative importance of the industry in 1877–78. By this time the beet-sugar industry had become thoroughly established:

TABLE I. — NUMBER OF SUGAR FACTORIES IN EUROPE, IN 1877–78, WITH THE TOTAL PRODUCTION AND THE PER CAPITA CONSUMPTION OF SUGAR IN EACH COUNTRY

COUNTRIES	KILOGRAMS PRODUCED 1877–78	APPROXIMATE CONSUMPTION PER CAPITA, KILOGRAMS	FACTORIES EXISTING
Germany	375,000,000	6	330
France	325,000,000	9	513
Austria-Hungary	245,000,000	2	248
Russia, Poland	250,000,000	2	288
Belgium	50,000,000	6	153
Holland, Sweden, Denmark	25,000,000	8	42

[1] Ware, L. S., "The Sugar Beet," p. 40 (1880).

THE INDUSTRY IN THE UNITED STATES

The first effort to grow sugar-beets in the United States was made about 1830 at Ensfield near Philadelphia. In 1836 a number of citizens of Philadelphia became interested in sugar-beet culture and sent James Pedder to France to study the business. A company known as "The Beet Sugar Society of Philadelphia" was organized with James Donaldson, the chief promoter, as president. Pedder sent home about 600 pounds of seed to be distributed among the farmers for trial. No evidence is available that a factory resulted from this effort.

The first factory was erected at Northampton, Massachusetts, in 1838, by David Lee Child, assisted by Edward Church and Maximin Isnard, who had played an important part in establishing the industry in France and who was at this time French vice-consul at Boston. The seed was imported from France. It gave a satisfactory yield — from thirteen to fifteen tons to the acre — but the beets were low in sugar. In 1839, 1300 pounds of sugar were produced and several prizes were taken. The industry could not be made to pay under the circumstances, and the factory never ran after 1840.

Soon after the settlement of Utah, in 1847, the Mormon pioneers began to establish different home industries in order to make themselves as industrially independent as possible. Since at this time all manufactured goods had to be hauled from the Missouri River to Salt Lake City by team, sugar was worth from forty cents to one dollar a pound. John Taylor (Plate II), who was laboring as a missionary in France, studied the beet-sugar

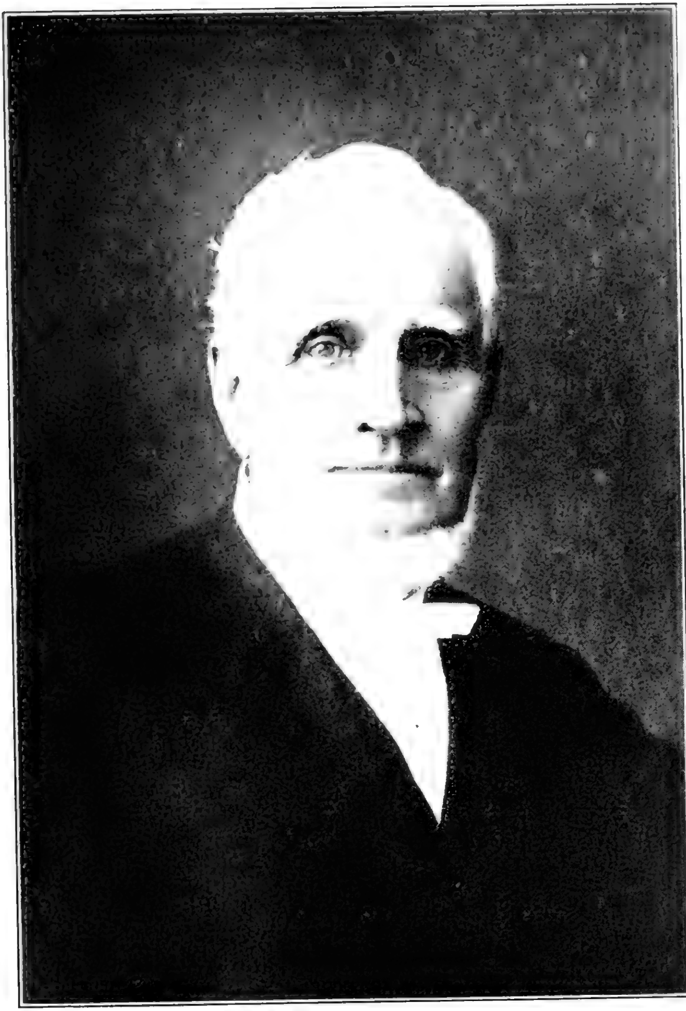


PLATE II.

John Taylor, who introduced the beet-sugar industry into Utah in 1852.

(Courtesy of Frank Y. Taylor.)

industry, and in 1852 purchased from Faucett, Preston, and Company of Liverpool, for $12,500, a complete outfit of machinery for making beet-sugar. This arrived at New Orleans in April, 1852, from where it was taken on another boat to Fort Leavenworth, Kansas. It took fifty-two ox teams four months to haul the machinery from Fort Leavenworth to Provo, Utah, where it had been decided to erect the factory. Five hundred bushels of beet seed came with the machinery. The Deseret Manufacturing Company, the corporation that was promoting the industry, was unable to carry it on because of the many unexpected expenses. The machinery was, therefore, purchased by the Mormon Church and moved to Salt Lake City, where it was installed in an adobe building at Sugar House Ward, where additional machinery was received in 1853. On account of the difficulty that was experienced in getting sugar to crystallize, sirup only was made and the project was finally abandoned in 1855.

In 1864 the Gennett Brothers, Germans living in New York, became interested in the beet-sugar industry. One of them went to Europe to study the conditions on that continent. On his return, 2300 acres of prairie land were purchased at Chatsworth, Illinois, and the Germania Beet Sugar Company was organized with a capital of $200,000. The mill had a capacity of fifty tons a day, but it was able to extract only a small part of the sugar from the beets. In 1866, 4000 tons of beets were raised on 400 acres. A series of unfavorable years induced the company to move the plant, first to Freeport, Illinois, and later to Black Hawk, Wisconsin, but it was never a success. Some of the machinery was finally taken to

California. Failure was due in part at least to a lack of interest on the part of farmers in raising beets.

Two Germans, by the name of Otto and Bonestell, erected a plant of ten tons daily capacity at Fond du Lac, Wisconsin, in 1868. After two years of partial success, the enterprise was abandoned. Otto went to Alvarado, California, in 1870 and associated himself with Klineau and E. H. Dyer, who the year before had raised 150 acres of beets as an experiment. The $125,000 factory which they erected produced 250 tons of sugar in 1870, 400 tons in 1871, 560 tons in 1872, and 750 tons in 1873. The average cost of producing sugar was about ten cents a pound. The plant did not pay and later was moved to Santa Cruz County. In 1871 the Sacramento Beet Sugar Company began the operation of a small plant. It made sugar and molasses for several years and was finally sold to E. H. Dyer. This was the first plant in the country to use the diffusion battery system of extracting the juice.

Other unsuccessful attempts to establish the industry were made at Portland, Maine (1896), Edgemoor, Delaware (1877), Franklin, Massachusetts (1879), and Rio Grande, New Jersey (1879). These failures were due to various causes: (1) lack of experienced beet-raisers, (2) poor quality of beets, (3) imperfect machinery, (4) mistakes in locating factories, and (5) general lack of interest in the industry.

Commercial success in the United States.

The successful commercial production of beet-sugar in the United States may be said to date from about 1890.

Plate III.

E. H. Dyer, father of the American beet-sugar industry.

(Courtesy of E. F. Dyer.)

Previous to this time, E. H. Dyer (Plate III), after years of experimentation and after four complete financial failures and reorganizations, succeeded at Alvarado, California, in establishing a factory on a paying basis, in 1879. This was the first beet-sugar factory that had been made to pay in the United States. In 1888, Claus Spreckels built at Watsonville, California, a factory which the first year made 1000 tons of sugar. Thus, in 1889 there were but two beet-sugar factories operating in the United States, both in central California.

About this time the Oxnard Brothers interested themselves in the industry. They went to Europe and made a careful study of it there. In 1890, they built a factory at Grand Island, Nebraska, and in 1891 one each at Norfolk, Nebraska, and at Chino, California. This served to arouse interest in the industry over a wider section of the country. In the intermountain region a factory was established at Lehi, Utah.

From this time on, the growth of the industry has been constant and at times rapid, stimulated largely by favorable legislation. The Sugar Bounty Act of 1890, on which McKinley worked, gave two cents a pound bounty on domestic beet-sugar. This was to run fifteen years (1890–1905), but in 1894 it was repealed and the Wilson Act, which was not so favorable to the industry, was enacted. "Development was more rapid following the passage of the Dingley Act of 1897, according to which imported sugars were taxed as follows: refined sugar, \$1.95 per 100 pounds; 96° sugar, \$1.68 per 100 pounds, with a reduction of 3½ cents for each degree below 96 and an increase of 3½ cents for each degree above 96.

During 1899 fourteen new factories were constructed." In 1892 there were only a half dozen factories with an

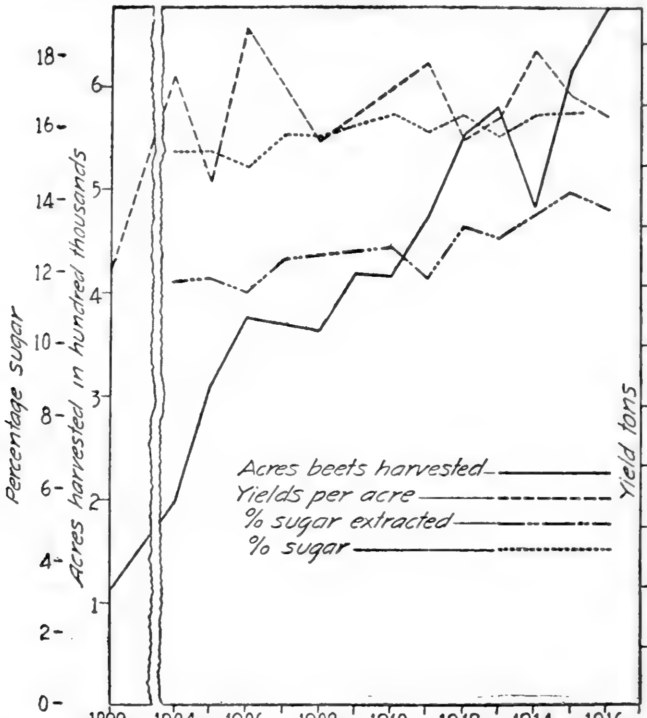


FIG. 3. — Growth of the beet-sugar industry, with the yield and quality of beets, in the United States since 1899.

output of 13,000 tons of sugar, but by 1902 there were forty-one factories, yielding 2,118,406 tons.

Later developments.

Since 1890, growth of the beet-sugar industry has in the main been regular and constant (Fig. 3). During periods when legislation has been favorable it has been more rapid than at other times. This has been the history of the beet-sugar industry the world over. In 1912, seventy-seven factories operated in the United States, and by 1915 the number had increased only to seventy-nine. This slowness in factory building was caused largely by the uncertain effect on the industry of reducing the tariff on imported cane-sugar. The passage of the Underwood-Simmons Tariff Bill reduced the tariff on imported sugar 25 per cent after March 1, 1914, and provided that all the duty should be removed after May 1, 1916. The latter provision was, however, amended before it went into effect.

The retention of the tariff, taken with the effect of the European war, greatly stimulated the erection of sugar factories in 1916 and 1917. In 1917, fourteen factories, with a daily slicing capacity of 11,000 tons of beets, were erected in the United States. The high price of sugar resulting from the war also made it possible to pay farmers more for beets. This in turn greatly stimulated the raising of beets, — and the acreage of beets rather than the number of factories is the real limiting factor determining the sugar production in America.

CHAPTER III

THE SUGAR-BEET PLANT

It is through the remarkable organizing capacity of the sugar-beet plant that nature is able to take unusable substances and by combining them properly produce the useful product, sugar. The whole beet-sugar industry rests on giving to this plant the conditions necessary to do its work most effectively; then after it has produced and stored its precious nectar, to extract and prepare it for the use of man. The important agent in the whole process is the plant — the greatest of nature's laboratories.

BOTANICAL GROUP

The sugar-beet belongs to the goosefoot family, or Chenopodiaceae. The chief cultivated members of this family are beets and spinach. Many weeds belong to the family, among which are goosefoot, pigweed, lamb's quarter, Russian thistle.

The species *Beta vulgaris* includes sugar-beets, mangel wurzels, common garden beets, and leaf-beets. There is a wild form of the same genus (*Beta maritima*) which grows as a perennial along the coast of southern Europe. The cultivated forms of Beta are thought by some to have originated from "a variety growing wild on the western coast of the Mediterranean and on the Canary Islands, and known as *Beta vulgaris L., var. maritima Koch.*

Whether this plant is really distinct, or is itself a variety of *Beta maritima*, is not certain."[1] Those who hold that the cultivated forms and the wild coast plant are the same species, use the name *Beta vulgaris* (which is the older) for the entire group. Those who prefer to keep them botanically separate, use the names *B. vulgaris* for the cultivated plant and *B. maritima* for the wild Beta.

HABIT OF GROWTH

The sugar-beet is ordinarily a biennial, storing food in the root during the first year, and sending up seed stalks the second. In some climates there is a tendency for many plants to produce seed the first year, particularly if there has been a period of drought or other conditions causing a temporary rest in the growth of the plant. The plant may also live and produce seed during a number of successive years if it is kept alive during the winter.

Many beet plants do not produce seed even during the second year but continue throughout the season to send out an abundant growth of foliage without sending up root-stalks. This condition is probably due, in part at least, to environmental facts, since the percentage of beets failing to produce seed varies greatly during different seasons. Some years this lack of fruiting is rather serious in fields producing beet seed.

The *Beta maritima*, in its native habitat along the Mediterranean, completes its cycle of growth in one year. The self-planted seed germinates in the fall and produces considerable growth before its activity is reduced by the

[1] Percival, "Agricultural Botany," p. 352.

mild winter. In the spring growth is resumed, and by early autumn the seed is ripe and again ready for planting.

PARTS OF THE PLANT

The enlarged root is the predominating part of the beet plant. The first year the stem consists of the crown on

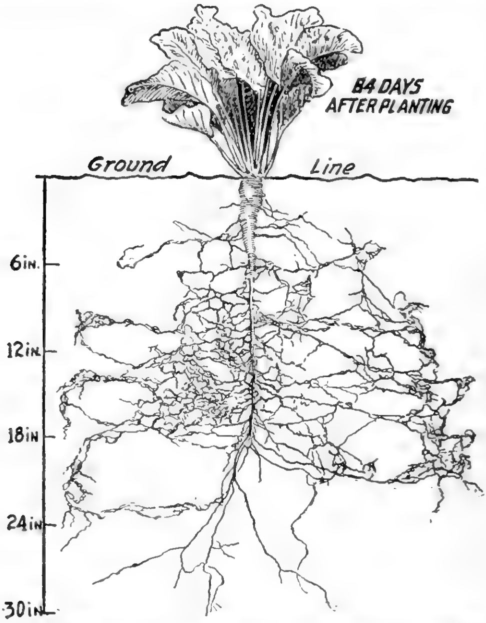


FIG. 4. — The sugar-beet has a very extensive root system.

top of the root from which the leaves spring. It is very much shortened and scarcely distinguishable from the fleshy root. The second year seed-stalks are sent up two

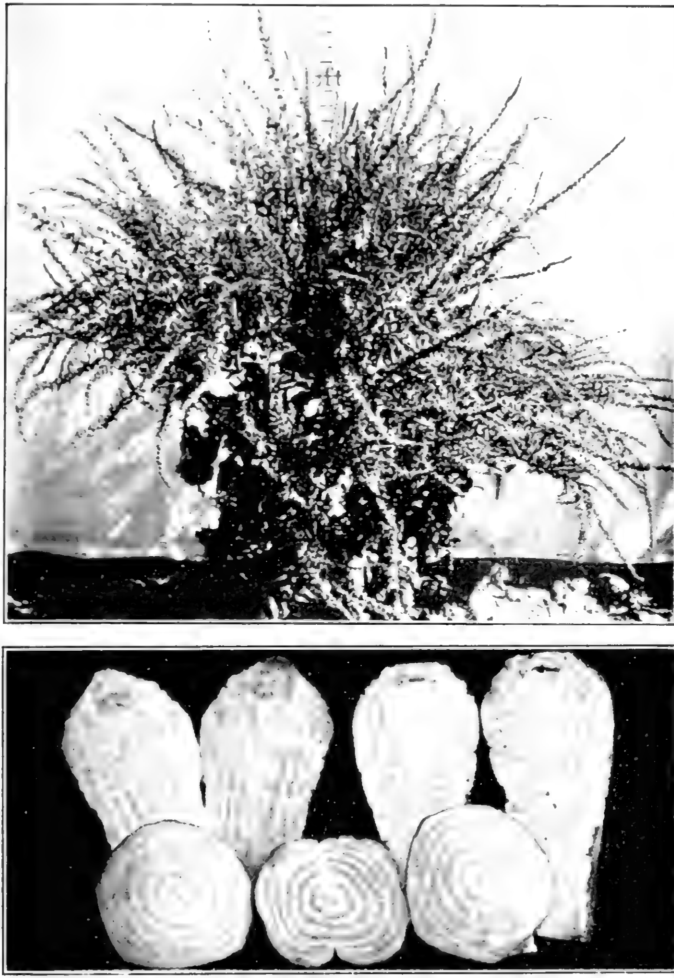


PLATE IV. — *Above* a mature sugar-beet plant two years old, showing the method of growth of seed stalks; *below*, cross and longitudinal sections of sugar-beets; the cells of the dark rings are richer in sugar than those of the light ones.

to four feet tall. They bear the flowers and seeds and most of the leaves. The first year the leaves are large and usually erect, although they sometimes form a sort of rosette on the ground. This varies with the strain of beet and also with the conditions of growth. The weight of the leaves is about one-half that of the root. The proportion of leaves is greater for small than for large beets. The leaves on the seed-stalk the second year are much smaller than those growing from the beet crown the first year.

The fleshy root (Fig. 4) is an enlarged taproot, thickest just below the crown and gradually tapering into a slender root which may extend several feet into the soil. Branching from the taproot are numerous secondary roots that extend as feeders throughout the soil. These secondary roots are clustered in two rows extending down the beet usually in a spiral direction, although frequently straight. The upper six or eight inches of the old beet are almost free from the secondary roots. One examination showed the greatest branching between eight and fourteen inches in depth. Attached to the secondary roots are numberless root-hairs which absorb water and plant-food from the soil.

The beet is made up of a series of concentric rings of alternating lighter and darker color shown in Plate IV. These rings are composed of two kinds of parenchyma cells, the ones with a denser finer structure being richer in sugar and dry matter. The larger coarser cells are richer in water. For this reason, beets with a larger number of small compact cells are richer in sugar than those in which the larger water-storage cells predominate. Although small differences in sugar-content cannot be distinguished by an anatomical examination, there is a rather definite correlation between structure of the beet and sugar-content.

HOW THE PLANT FEEDS AND GROWS

The development of the plant from a tiny germ through the various stages to maturity is an interesting and complex process. When the seed is planted, it absorbs moisture and swells. Part of the starch stored in the seed is changed into sugar by the action of enzymes, and the cells composing the germ enlarge and divide till the germ becomes a seedling. At first the germ must depend entirely on the food stored in the seed, but a few days after germination the rootlets penetrate into the soil and leaves appear above ground. The plant is now ready to begin gathering and making its own food.

The feeding of the plant goes on in two distinct processes: the gathering of soluble salts and water from the soil and the taking of carbon from the air through the leaves. After these two kinds of raw materials are gathered, the plant in the wonderful laboratory of its own cells produces all the compounds necessary to its life and to the performance of its very complex functions.

From the soil the plant absorbs various materials that are dissolved in the soil solution. The materials like nitrogen that are used extensively by the plant are absorbed in much larger quantities than such unnecessary elements as sodium. These materials must be dissolved before they can be taken up by the plant. The root-hairs, which are minute, single-cell extensions of the root system, reach to all parts of the soil and come in close contact with the individual soil particles. (Fig. 5.)

By a process known as osmosis, water passes from the soil through the cell-wall of the root-hairs into the root, and finally from cell to cell throughout the plant wherever it is needed, or it may pass directly to the leaves where it is lost by transpiration. Each day during rapid growth, the plant in this way takes up and loses several times as much water as its weight. Water is used as a carrier of all foods within the plant. It also helps in regulating the plant as well as entering into many of the compounds of which it is made up. More than half of the weight of sugar comes from water which is combined chemically with carbon.

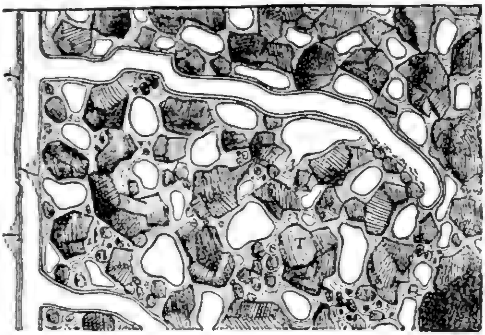


Fig. 5. — Root-hair extending through the soil in close contact with the soil particles.

The mineral compounds which the plant obtains from the soil are: the salts of calcium, magnesium, potassium, iron, phosphorus, sulfur, and nitrogen. These, together with hydrogen and oxygen from water and carbon from the air, make up the ten elements essential to the life of all ordinary plants. If any of these are entirely absent, the plant cannot grow. Many other elements are also taken up by plants, but while they may be used in various plant processes, they are not essential to growth.

These various soil compounds are also taken up by osmosis, each one independent of the other. If the plant-cells are low in one of the required substances that are present in the soil solution, it passes through the cell-wall of the root-hairs and from cell to cell to the place where needed. The movement continues as long as the compound is used by the plant if the supply in the soil is maintained. If this supply becomes depleted, the growth of the entire plant is retarded by a shortage of this one element. This explains the importance of keeping the soil well supplied with all the necessary plant-foods.

The processes taking place in the leaves are even more interesting. The leaf is made up of layers of cells of various kinds. On the surface of the leaf are tiny openings called stomata through which air and other gases pass freely. These stomata are much more numerous on the under side of the leaf. The air, containing carbon-dioxid gas, enters the leaf through the stomata and circulates between the loose sponge cells, where a transformation takes place. The cells of the leaf contain chlorophyll, or leaf green, which, through the action of sunlight, is able to cause a union of carbon dioxid and water with the final formation of sugar. By this process the greater part of the plant material is made. In this laboratory the food of man and beast is prepared. If a process similar to this did not take place in plants, it would be only a short time till practically all animal and plant life would disappear.

After the sugar is made in the leaves, it is transferred from cell to cell to all parts of the plant, where it is used in the formation of starch, cellulose, and the other compounds. Thus the greater part of all plants comes from water and the air and only a comparatively small amount from the soil. An especially large part of the sugar-beet is made of air and water. As the leaves grow older, the percentage of ash in them increases and the nitrogen decreases. The old practice of stripping part of the leaves from the beets is harmful, since it reduces the formation of sugar.

THE STORAGE OF SUGAR

Although the sugar-beet plant begins the manufacture of sugar and other compounds almost as soon as the first leaves are formed, very little material is stored at this time, since all the food gathered is needed for growth. The plant is adding to itself rapidly and is sending out new roots and leaves; hence none of the sugar manufactured in the leaves is available for storage. It goes into the production of more leaves and roots and to the general growth of the plant.

After the sugar-beet has produced most of its growth and approaches maturity, it stores sugar very rapidly. Practically all the sugar manufactured by the leaves during the latter part of the season is stored in the root in order that the plant may use it the next year in producing seed. The storage is not uniform in the various parts of the root. This is shown in Fig. 6, which was taken from analyses reported by Briem.[1] This drawing shows that

[1] "American Sugar Beet Growers' Annual," 1908, p. 67.

the beet is richest in sugar slightly above the middle of the beet and that the sugar decreases toward the two ends. The tip of the root is lower in sugar than any other part except the center of the crown. The section of the beet down through the center has appreciably less sugar than the section directly opposite toward the outside. The part of the beet lowest in sugar has only about two-thirds as much as the highest.

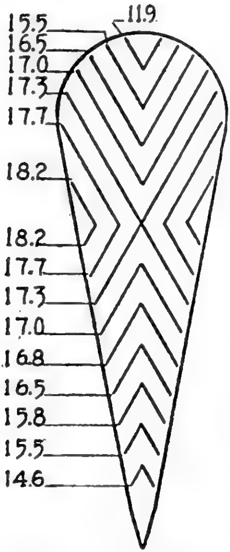


FIG. 6. — Diagram showing distribution of sugar in different parts of the sugar-beet.

The ideal condition would be to leave all the beets in the ground till completely ripe, which is the time when the highest percentage of sugar is stored. This is not always practical, however, when a large acreage must be harvested. Some of the beets must be dug before they are entirely ready, and the digging season must be extended beyond the best time in order to harvest all the crop. After sugar has been stored in the beets, it may again be transferred to other parts and used. This storage and later transfer of sugar are dependent largely on soil and climatic conditions. The storage of a high percentage of sugar in the root while the leaves are comparatively low in sugar is made possible by the fact that sucrose diffuses out of the cells with difficulty, whereas the glucose and fructose of the leaves move rapidly from cell to cell and are distributed independent of the amount of sucrose present.

FACTORS AFFECTING PERCENTAGE OF SUGAR

The amount of sugar contained in the beet is of the highest importance to the manufacturer of beet-sugar. The same expense is attached to handling the beets and running them through the mill if they contain 10 per cent sugar as if they contain 20 per cent. The expense of refining and handling the larger quantity of sugar is only slightly greater in the latter case, whereas the returns would be almost double. Beets low in sugar cannot be handled at a profit; the life of the industry depends on getting roots sufficiently rich in sugar to justify its extraction.

A number of factors modify the amount of sugar present. Probably the most important of these is the breeding, or heredity, of the strain. When Marggraf first extracted sugar from beets in 1747 the amount of sugar contained was low, but a hundred and fifty years of careful breeding has increased the amount by several times. One reason why the beet-sugar industry was not able to continue after protection was removed following the downfall of Napoleon was that strains of beets were not available with a sufficiently high sugar-content. Only after better varieties were developed in Germany was it possible to extract sugar from the beet at a profit.

The commercial strains now on the market differ widely in the amount of sugar they produce under the same climatic and soil conditions. It is necessary to continue a rigid selection in order to keep the beets up to as high a production of sugar as possible. With no crop are the requirements more exacting.

Climatic conditions affect very much the amount of sugar stored in beets. Seed out of the same bag may one year produce beets having but 14 per cent sugar, and another year 18 per cent. Some of the factors entering into seasonal effects may be controlled; others cannot. Moisture, which greatly affects not only the yield but also the quality of the beets, may be controlled by irrigation. This is discussed more fully in Chapter X.

Many attempts have been made to point out correlations between the shape of beet and its sugar-content, but these have not been very successful. If there were correlations of this kind it would save a great deal of chemical work in selecting beets with a high sugar-content.

RELATION OF SIZE OF BEET TO SUGAR-CONTENT

The relation between size and percentage of sugar has long been a subject of study. Observations have shown that often very large beets are low in sugar and the small ones high. In order to determine the exact correlation between these two factors the Utah Experiment Station[1] made tests extending over several years and including nearly seven thousand individual beets. The results of that test are summarized in Table II, which shows the number of beets of each weight and sugar-content. A definite negative correlation is shown, although it is not

[1] Harris, F. S., and Hogenson, J. C., "Some Correlations in Sugar-Beets," Genetics, Vol. I, July, 1916, pp. 334–347.

Table II. — Correlation of Weight of Beet with Percentage Sugar

	Per cent sucrose: Below 6.5	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	21.5+	Total
2.1											1							1
2.0				2		2	12	14	11	6	4	2	1					54
1.9							4	4	5	4	5	5	1					28
1.8				1	1	3	3	14	8	16	9	4	2					61
1.7					2	5	7	9	10	13	13	7	6	1				73
1.6			1		1	3	5	19	28	32	22	20	8	2	1			142
1.5					4	3	7	20	32	39	38	29	25	8	1			206
1.4		1		3	2	3	11	31	46	51	38	42	34	13	4			279
1.3		1		4	3	6	20	27	57	55	88	67	53	25	4	1		411
1.2	2	1	2	1	4	11	15	31	60	72	79	69	63	37	19	2	2	470
1.1	3	1	5	2	7	6	20	42	48	88	112	91	116	49	27	5		622
1.0	2	2	2	3	13	14	22	24	65	98	113	133	105	68	32	5		701
.9	5	6	3	5	8	7	18	40	57	96	108	167	138	115	41	10	1	825
.8		1	6	8	13	16	17	26	60	80	81	141	134	105	51	11	1	751
.7	7	1	2	5	9	7	17	24	35	60	84	135	124	65	55	6		636
.6	3	2	2	7	6	8	14	20	21	45	69	97	106	60	42	4	2	508
.5	1				14	4	4	6	23	30	49	90	105	44	43	8	9	430
.4					4	3	5	4	12	28	49	57	85	69	42	16	11	385
.3					3		3	5	8	25	28	35	72	50	31	12	11	283
.2							1	6	3	6	10	15	33	14	14	6	10	118
	23	16	23	41	94	101	205	366	589	844	1000	1206	1211	725	407	86	47	6984

Correlation = − .2877 ± .0074.

Mean weight of beets .9133 ± .0297; standard deviation 3.681 ± .0210.

Mean per cent sucrose 16.3278 ± .0205; standard deviation 2.537 ± .0145.

large. This means that, while there is a tendency of the large beets to be low in sugar and the small ones to be high, this relation does not always hold. In some districts large beets may have a very satisfactory sugar-content, whereas in others this may not be the case.

FLOWERS AND SEEDS

The sugar-beet produces perfect flowers. The arrangement of parts is shown in Fig. 7. The stamens are partly attached to the perianth ring. Pollen is readily carried

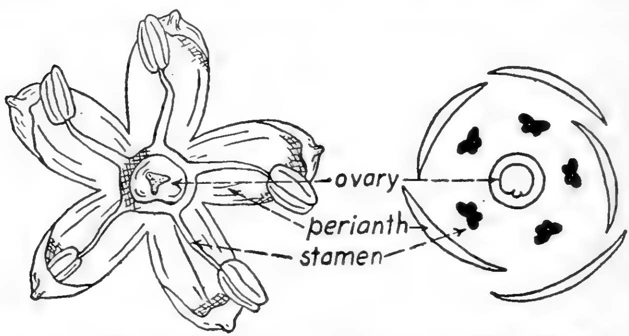


Fig. 7. — Diagrams showing parts of the sugar-beet flower. Much enlarged.

from flower to flower by insects, thrips playing an important part in cross fertilization. The ovary is partially imbedded in the flesh of the receptacle and contains from one to three seeds. The flowers are produced in dense clusters along an axis, resulting in the formation of seed-balls containing a number of seeds or germs. Much extra work is required by this arrangement, since hand thinning is made necessary. If but one germ were contained in each seed-ball, the work of thinning would be greatly reduced. Attempts have been made to produce strains of seed having a single germ, but these have not proved to be successful. The seed-ball is hard, similar to the shell of a nut, and completely covers the tiny seeds it holds.

In germination the primary root first appears. Very soon the cotyledons may be seen. The seedling consists of a short hypocotyl, two fleshy cotyledons, and a primary root from which a few fibrous laterals arise.

CHAPTER IV

CONDITIONS FOR GROWING SUGAR-BEETS

PROBABLY no other common crop should be more closely confined to regions adapted to its growth than should sugar-beets. This is due in part to the great expense required to raise an acre of beets, and where natural conditions are unfavorable, the returns for this expense and labor are small. Another important item to be considered is that sugar-beets are not raised by isolated farmers; there must be a sufficient number of beets in a region to justify the erection of a factory. Thus, a large amount of capital is tied up in a manufacturing plant. This will be wasted if beets cannot be raised successfully.

In raising a crop like potatoes, adaptation is not so important. The individual farmer may raise a few potatoes for his own use even though the country is not well adapted to potato-growing. If at any time he wishes to raise some other crop, he is perfectly free to change and no one is injured. With sugar-beets, on the other hand, there may be a great loss if the industry is established in a region not adapted to it; hence the importance of knowing the conditions contributing to the success of sugar-beet production. These conditions may be grouped as: (1) climatic conditions, (2) nature of the soil, and (3) economic conditions. Of the climatic factors, temperature, sunshine, moisture, and wind are of greatest consequence.

CLIMATIC CONDITIONS

Temperature.

The sugar-beet will grow in most parts of the United States and Canada where the ordinary crops of the temperate climate thrive; but the region maturing beets of desirable sugar-content, purity, and yield is confined to a rather narrow strip across the continent. It lies largely in a wedge-shaped area including California, Oregon, and Washington on the west, and tapering irregularly to the east, with Michigan and the states to the east as the sharp end of the wedge.

So far as sugar is concerned, the best sugar-beet regions are those with an average temperature of about 70° F. during the three summer months — June, July, and August. The distribution of the heat over the summer period as well as the daily variations in temperature affects the average temperature required. Unlike corn, beets are not injured by cool nights during the warm part of the growing season. A great amount of heat is not required when the beets are young; neither will they thrive if the weather is cold and damp just after planting. This condition retards germination and causes part of the seeds to decay in the soil. The young plants that emerge are also likely to be attacked by disease, such as that caused by the damping-off fungi. With a protracted cold spring, the young beets sometimes receive a set-back from which they never fully recover.

Beets should do well in most localities where the sum-

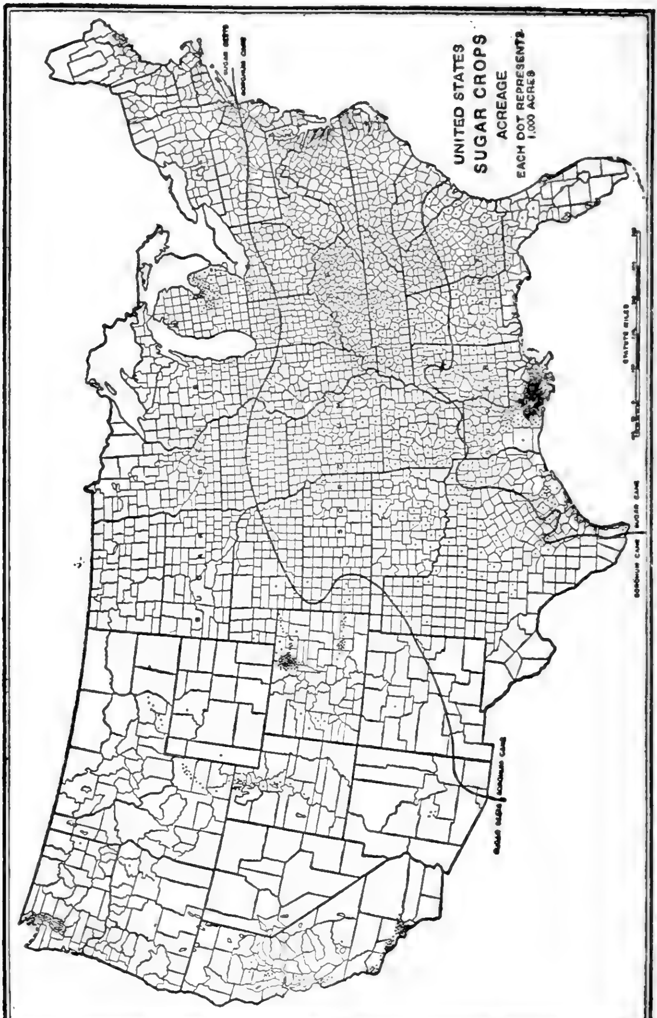


FIG. 8. — Map showing the areas of the United States where sugar-beets, sorghum, and sugar-cane are raised.

mer temperature is suitable, provided planting is not begun until the soil is warm enough to insure good germination and a rapid growth while the plants are young and tender. Hot weather during this period is undesirable, since this condition makes the young plants less able to overcome the shock resulting from the disturbance they receive at thinning time.

A severe frost just as the plants are coming up is almost fatal, and replanting is usually necessary. At this time they are most sensitive to frost. Later, after a few leaves have been developed and a number of healthy roots sent into the soil, they become much more hardy. In the fall of the year the beet can stand rather severe frost without injury, very much more than can be endured by corn.

Severe freezing in the fall is likely to cause trouble by freezing the beets in the ground, in which case it is very difficult and sometimes impossible to harvest them, and almost complete loss results. In order to be entirely safe, an area raising sugar-beets should have about five months in which severe freezing does not occur. Slight frosts during this time, particularly in the fall, may do no damage. The short season in the cooler parts of America prevents the proper ripening of the beets, resulting in a low sugar-content and consequently poor milling quality.

The high temperatures of the southern part of the United States have a tendency to cause a vegetative growth producing good yields, but the beets are poor in quality. In some regions having a high temperature at certain seasons, beets are planted at a time that will enable them to make the greater part of their growth during the cooler part of the year.

Sunlight.

Sugar is made by the action of sunlight on the chlorophyll of the beet leaf; hence the storage of a large amount of sugar requires a great deal of light. In northern latitudes where days are long, the beet is able to store sugar faster than farther south where the summer days are shorter. For this reason, the growing period of the north does not need to be so long.

Workers in the United States Department of Agriculture [1] as a result of experiments were led to the conclusion that the sugar-content of the beet is not dependent on direct sunshine. Diffused sunlight from a cloudy sky seemed to be practically as good as direct sunshine. Sunshine probably has a sanitary effect, however, since attacks of diseases are much greater during damp, cloudy weather than during periods when the sun is shining brightly. The effect of sunlight is so closely related to temperature and moisture that it is rather difficult to discover just what its effects are.

Moisture.

Favorable soil moisture conditions are essential to success in beet-raising. A crop costing less to produce may be raised where it is too wet or too dry for maximum yields without the results being serious, since little is involved. With sugar-beets it would not pay to go to

[1] Wiley, H. W., *U. S. Dept. of Agriculture, Bur. of Chem. Bul. No.* 96.

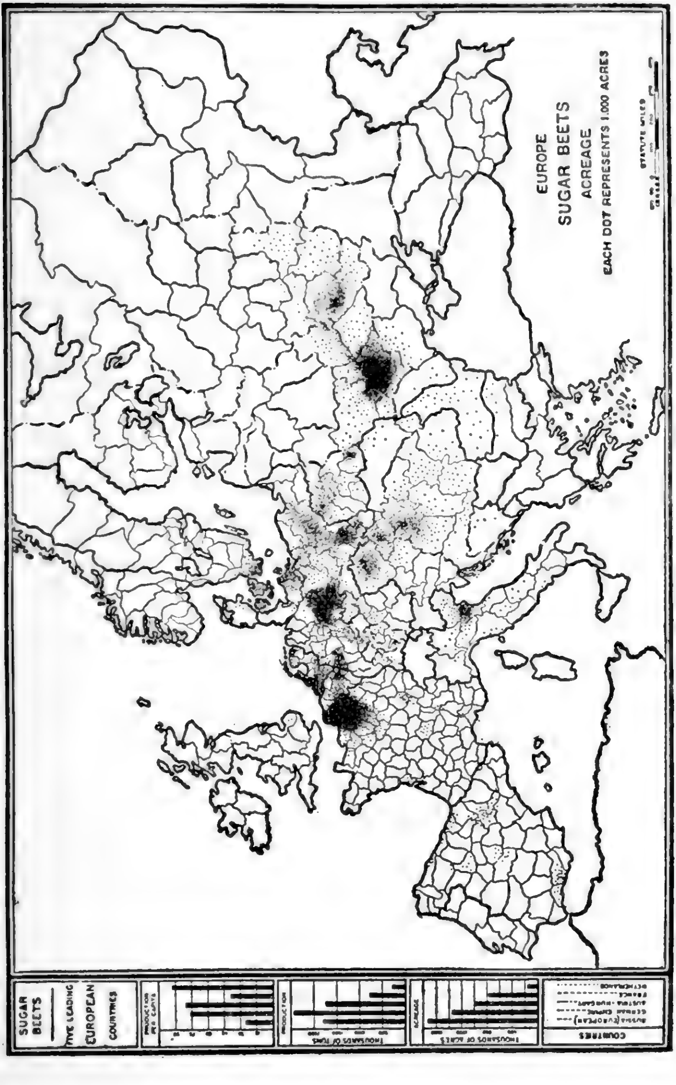


Fig. 9. — Map showing areas in Europe where sugar-beets are raised.

all the trouble necessary to produce the crop if the yields were greatly reduced by unfavorable conditions.

The use of irrigation water makes possible an easy control of soil moisture, and as a result the beet-sugar industry of America is largely an industry of irrigated districts. Michigan is the only important sugar-beet state where irrigation is not practiced. The methods of maintaining proper moisture relations by the aid of irrigation are discussed in a later chapter.

In non-irrigated regions, the production of sugar-beets follows the zone with a favorable distribution of rainfall as closely as the zone of favorable temperature. The time and manner in which the precipitation is received, as well as the total amount, must be considered. In a district having heavy soil that packs or crusts, a heavy rain at the time the plants are sprouting may cause trouble. A region having the greater part of its rain during the period when the beet is growing most rapidly and ceasing before harvest time is fortunate. Regions having a continuously rainy and damp summer, however, do not raise good beets.

Small showers at the right time may be beneficial, but usually they do not wet down far enough to do any good. If the precipitation comes in heavy rains, there may also be considerable loss due to run-off from the surface of the land. Such storms also have a tendency to pack the soil and cause crusting. It is desirable, therefore, in considering a region for sugar-beet production, to study the nature of the rainfall as well as the total amount. Hail-storms are not so injurious to beets as to crops having the marketable portion above ground.

Wind.

In many beet-producing sections winds at certain seasons are rather serious. This is particularly true with spring winds that come about the time the seed is planted or immediately before or after. Winds coming before the seed is planted are likely to dry out the seed-bed so much that it is necessary to plant the seed too deep in order to find sufficient moisture. Winds about the time of planting may blow the seed out of the ground and make the stand very irregular. When the young plants are coming up, winds often cause injury to the seedling by the cutting action of shifting sand. Hot winds may also completely dry up the young plants even when sufficient water is present deeper in the soil.

The bad effects of winds may be overcome in part by a number of methods. Windbreaks, an abundant supply of humus, plowing, cultivating, keeping the rows at right angles to the direction of the wind, and the formation of a mulch of small clods at the surface of the land all help. Sometimes it is necessary to shift the period of seeding in order that the plant will not be in a critical stage at the time of regular winds.

THE SOIL

For the production of good sugar-beets, the soil should be fertile, deep, and of a texture that is easy to work. No particular kind of soil is absolutely necessary. Any good soil adapted to the raising of general crops such as potatoes, corn, and the small grains will also produce beets, which are raised on soils of every texture ranging from a sand to a clay. A coarse sand is not good because it does not hold sufficient water, and it is not usually strong in available plant-food. A clay is not the best, since it does not furnish the root a medium in which to expand readily. It is, moreover, not adapted to the great amount of working necessary in beet-raising. A medium loam is, on the whole, most satisfactory. It should be deep enough to allow an easy penetration of the feeding roots.

A fuller discussion of the relation of beets to the soil is given in Chapter V.

ECONOMIC CONDITIONS

Competition with other crops.

Many districts adapted to the culture of beets do not produce them because beets cannot compete with other crops in these sections. Some of these crops yield greater returns to the acre and will, as a result, shut out beets in districts where land is limited and the highest returns must be secured. Other crops, because they use little labor, prevent beets from getting a foothold where labor is the limiting factor.

Beets would thrive in many of the districts that grow truck crops near large cities, but greater returns are obtained from the latter than could be had from beets. Likewise, many orchard districts give a return to the acre of land with which beets cannot compete. Attempts have been made to introduce sugar-beets into the corn-belt, but corn is so well adapted to these regions that no competing crop has been able to displace it. Beets require attention at the same time corn must be cared for, and since corn in this section brings more money for the labor, sugar-beets will probably not gain much of a foothold unless economic conditions change. A decided advance in the price of sugar or a decline in the price of corn might change this balance entirely.

Sugar-beets have not secured a strong foothold in the great wheat sections of the country, partly because the farmers can earn more money with less labor by handling a large acreage of wheat than by handling a few acres of beets. The farmer who has been used to raising 500 or 1000 acres of wheat and doing most of the work by machinery is not likely to be satisfied to spend all of his time over fifteen or twenty acres of beets, particularly if he has to do most of the work by hand.

It takes time for sugar-beets to come into active competition with long-established crops, even though conditions are highly favorable to their growth. Farmers have to learn how to raise the crop, and they are limited in their markets to regions having a sugar factory. This means that the industry is usually extended gradually and not rapidly; but where it is well established, sugar-beets usually have little difficulty in competing with most of the ordinary farm crops.

Labor.

More than ten times as much hand labor is required to raise an acre of beets as to raise an acre of wheat, over five times as much as to raise an acre of corn, and more than twice as much as to raise an acre of potatoes. The horse labor required for beets is over three times that for wheat, oats, and barley, and about one and one-half times as much as for potatoes. If only four to eight acres of beets are raised, the amount hardly justifies bringing in expert contract labor; but if the farmer attempts to do all the work himself, other crops are greatly interfered with. If he has children of his own or if he can hire school children, he may be able to get along. From fifteen to twenty-five acres are necessary in order to make it pay to take advantage of contract labor for thinning and harvesting.

New growers should not attempt to raise too many acres of beets, since they are not familiar with the requirements of the crop and great waste may result from their inability to do work at the proper time. After a few years of beet-raising, the farmer learns to adjust the acreage to the labor he can command during the busy season. On the small irrigated farms in the thickly settled regions, the labor question is not so acute as in the newer regions that have small population. A survey in Utah showed that as the size of farm decreased, the percentage of the land raising beets increased.

Where beets are raised on a large scale, the labor problem is solved by hiring foreigners to do the hand work. Some of these are permanent farm hands; others may have had experience working in beet fields in their native land but are doing city work in this country. This class of labor may be induced to go to the farms for a few months during the busy part of the beet season. The most satisfactory way when possible is to keep the hands on the farm throughout the year, having other means of employment when they are not needed in the beet fields.

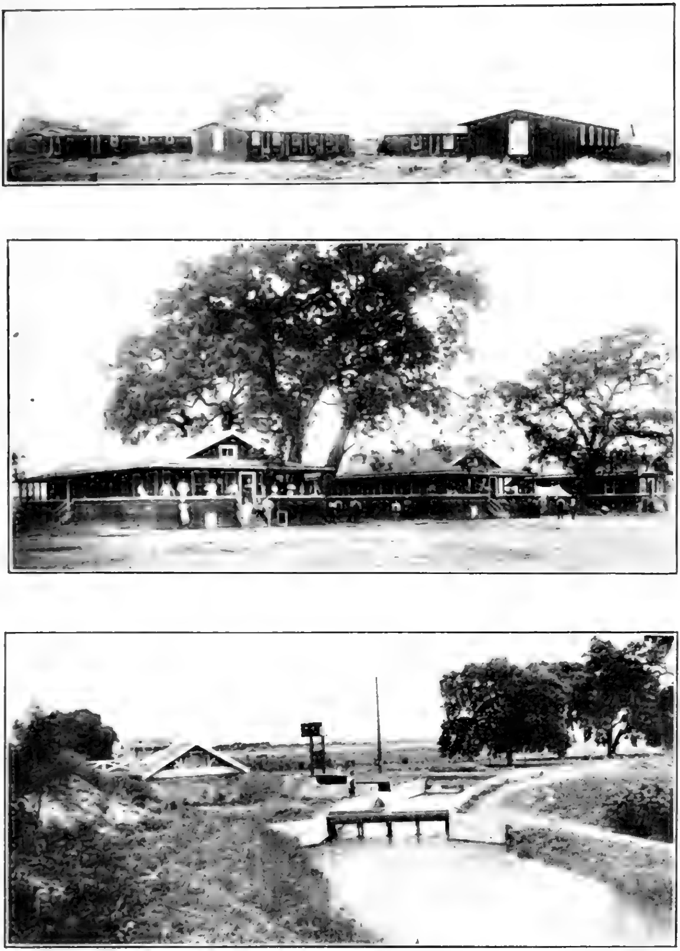


Plate V. — *Above*, cheap houses of this kind are often constructed to care for foreign labor; *center*, houses of this kind attract labor which is an important item for success in raising sugar-beets; *below*, pumping water for irrigation. (Courtesy Pacific Sugar Corporation.)

To get this result, it is necessary, or at least desirable, that small houses be built near the fields. Plate V shows desirable houses for this purpose. Provision for suitable living conditions for those who must do hard manual labor is a greater factor in getting and keeping hired labor than is realized by many farmers. Many suitable workers could be induced to move to the farms to meet the labor situation if more suitable living conditions and better pay were provided.

Where gangs of foreign laborers are imported, they are much more contented and do better work if they work together in colonies rather than as individuals. To satisfy this condition requires large acreages. In some communities movable houses are used by the contracting laborers, the houses being moved from field to field as necessary. These houses are very desirable where the individual fields in a district are too small to make it worth while to build permanent houses.

The labor question is probably the most difficult general problem with which the sugar-beet growers have to contend. It is a problem that must be handled by community action or by the sugar companies who are generally well prepared to secure and distribute this labor, since they can determine through their field men the approximate labor situation throughout the territory contributing beets to their factory. If the farmers can be induced to report their probable labor needs to these field men in advance, the proper amount of imported labor usually can be secured.

The United States Government is attempting to keep in touch with the labor situation in all parts of the country in order that the best possible distribution of the laborers may be made. In some communities where there is insufficient labor, farmers bid against one another for the labor that is available, resulting in prices out of all proportion to the service obtained. Such action does not improve the labor situation; it merely raises wages without increasing the efficiency of the labor. An appeal to the sugar companies or the government for additional workers might bring the required labor at prices satisfactory to both the growers and the workers.

When labor must be hired, it is much more satisfactory to have the work done by contracts based on tonnage than merely to contract by the piece or by the acre. Time labor, though usually slower than piece contracting, results in better work if properly supervised. Since man labor constitutes nearly half the total cost of growing beets, and since more than two-thirds of this labor comes at the time of thinning and harvesting, it is imperative that as many labor-saving devices as possible be used. Relief at the harvest season seems to be in sight, for a number of mechanical toppers are proving successful. No practical method has as yet been devised for lessening materially the labor of blocking and thinning. Up to the present time machines designed to do this work have failed to give satisfaction.

Capital.

The raising of sugar-beets requires much more capital than do most other crops. In the first place, good sugar-beet land is usually high-priced. Special planters, cultivators, harvesters, and racks are required in handling the crop. The chief item to consider is the expense of raising the crop. It costs more to produce an acre of beets than is required to purchase outright several acres of the cheaper wheat lands. This money must all be spent before any returns are obtained.

In the older districts where beets are known to do well, this item is not so serious, since the banks are willing to advance money on the prospect of the crop; but in districts where the success of beets is uncertain, the amount of money required to produce a crop may be a serious matter. Under conditions of this kind, it is often necessary for the sugar company to furnish implements on "time" and to render other financial aid during the growing season.

Transportation.

The transporting of beets is one of the deciding factors in determining whether or not the crop can be raised in a given district. Because the crop is bulky, there is a decided limit to the distance it can be hauled profitably. There are many small areas that can produce excellent beets, but are not of sufficient size to support a factory and are too far from any factory to justify hauling the beets. There are also good beet districts that are large enough to support a factory, but the whole district is so far from a railroad that it would not be practical to attempt establishing a factory. It costs about thirty cents a ton to haul beets a mile by team; hence it is not practical to have beet fields at great distances from dumps. Ordinarily, beets cannot be hauled more than three or four miles by team. This depends somewhat on the kind of roads and on how busy the farmer is with other work at the time beets are to be hauled.

The whole beet-sugar industry is closely tied up with the question of transportation. Each prospective sugar-beet area must be considered from this viewpoint as well as from its adaptability to the raising of beets.

Special troubles.

A number of special troubles must be kept in mind in considering conditions for beet-raising. Among these are diseases and insect pests. A number of factories have failed because beets in the district have been so greatly infested by curly-leaf and other serious troubles. For this reason it would not be advisable to invest hundreds of thousands of dollars in a mill where external conditions only seemed to be favorable to the industry. It is much safer to raise beets for a number of years first in order to see whether any of these serious troubles develop. Hot winds, severe drought at a critical period, and many other unfavorable conditions may completely outweigh other favorable ones.

Kind of farmers.

Successful sugar-beet growing requires good farmers. Every operation from the plowing of the land to the delivery of the beets is particular and calls for skill and painstaking care. There is no operation that can be slighted without reflecting itself in the returns. Many farmers fail because they are not willing to look after details. They want to apply wheat-growing methods, and these methods simply will not succeed with sugar-beets. The farmer who does not want to bother with the crop from the time it is planted until it is ready to harvest had better devote himself to extensive crops; he certainly cannot make a success in raising beets, — at least not until he changes his methods.

The sugar-beet is sensitive to the attention it receives. It does not thrive under "horse-back" methods of farming. The farmer who would succeed with it must get down on his knees and use his fingers, almost fondling each plant. If he is not willing to do this, he will not be a good beet farmer.

The people of some communities are not adapted to the raising of beets. They are not willing to give the personal attention and the work that is required. If their chief thought is to do as little work as possible and to make their profit by selling the farm instead of tilling it, they are not good beet farmers. In order for a community to be successful at beet-raising, it must have the attitude that a farm is a place on which to raise crops and not a place that is just held to be sold at the first opportunity. For this reason new communities rarely succeed with beets. Usually it is necessary to wait until those on the land feel that they are established in a permanent home. The period of good beet-farming does not come until the days of boom and land speculation have passed.

The high sugar-content and purity of sugar-beets are artificial characters produced by years of special cultivation, selection, and breeding. The quality of the crop is, therefore, subject to modification by cultural methods. It responds readily to good treatment, and as quickly deteriorates under bad. A good farmer will succeed with beets, whereas his neighbor who is a poor farmer will fail miserably.

In considering the advisability of establishing a factory in a region, considerable attention should be given to the kind of farmers who will raise the beets.

The factory.

The first consideration in attempting to introduce the sugar-beet industry in a district is, of course, a guarantee from the farmers that they will grow a sufficient acreage of beets to assure a reasonably long run for a factory. Many of the factories that have failed would have continued had the supply of good beets been large enough. Quality of beets is perhaps more important than quantity, because if the proper quality can be secured, the prices can usually be regulated so as to make it profitable for the farmers to produce the necessary quantity. If beets testing 12 per cent or more of sugar and with a purity coefficient of at least 70 per cent cannot be obtained, the success of a factory is doubtful. The price paid by the manufacturers for beets constitutes over two-thirds of the total cost of manufacturing beet-sugar; and the cost is relatively much less for good beets than for poor ones. Factories that must work beets from which only 220 pounds of sugar can be extracted from each ton are distinctly at a disadvantage when compared with those that can extract 300 pounds with practically the same expenditure for manufacturing, even if the better beets cost considerably more.

With a given quality of beets, it is very desirable that the quantity grown be as great as the economic conditions will justify. For a good run of an average-sized factory, 3000 to 5000 acres or more of beets should be grown. It has been found that factories with a slicing capacity of 800 tons daily are materially more efficient in sugar manufacturing than are those handling less than 500 tons daily. It is a mistake, however, to build a factory with a large daily capacity in a district not capable of furnishing beets to supply the daily tonnage for a run lasting in the neighborhood of ninety to one hundred days. Since it is impossible to determine accurately beforehand just what acreage a new region will grow, it is usually better to build a medium-sized factory capable of being enlarged than to build a large one that may need to be removed.

In choosing a location for a factory, one of the first considerations is an abundant supply of pure water. Large quantities of alkali salts or other foreign matter in the water make the extraction and purification of the juices much more difficult than with pure water. Cheap fuel must be available as well as a good quality of cheap limestone. With much bulky material such as beets, coal, and limestone to be moved, transportation costs run high unless the lowest possible rates are secured. For this reason it is an advantage to locate a factory where there is competition from two or more railroads. It is also better to locate the factory in a position as nearly in the center of the beet-growing area as possible rather than to favor a position near a village. The closer the factory is to the beet fields, the better is the condition of the beets when they reach the factory.

CHAPTER V

SOILS

SUCCESSFUL sugar-beet production, as well as every other phase of agriculture, is dependent on the intelligent handling of the soil. All farm profits ultimately go back to the land. Live-stock, important as it is, merely furnishes a means of marketing what the soil produces. Every effort should be made to understand the needs of the soil in order that it may be made to yield bounteously and permanently.

RELATION OF SOIL TO BEET-CULTURE

Sugar-beets are not so sensitive as to require a special kind of soil. They will grow on any good agricultural land on which the ordinary field crops thrive. As with other crops, however, beets do better on some soils than on others. This is reflected much more in the yield than in the quality of beets. Wiley,[1] after making a rather exhaustive study of beets raised on soils in many parts of the United States, reports:

[1] Wiley, H. W., *U. S. Dept. of Agr., Bur. of Chem. Bul. No.* 96, p. 34.

"The data show in a general way what has been observed before, that the quality of the soil has but little to do with sugar content of the beet. It is true that if the soils be so very poor that the beet is very much stunted in its growth, reaching a weight of only two or three ounces at maturity, the poverty of the soil would act in this way to increase the percentage of sugar in the beet; but this is only incidental, since any unfavorable condition would act in the same way, as, for instance, a deficient rainfall or imperfect cultivation. It is quite certain that a very rich soil, in the presence of an environment otherwise favorable to a large growth, would have the opposite effect, for the overgrown beet is prone to have an excess of cellular tissue, to become pithy and be less sweet. In this case, also, the effect is largely fortuitous, for it is evident that in any condition of over-fertility the beets may be grown so close together as to prevent large size, and thus their percentage of sugar may be largely conserved.

"It is undoubtedly true that the use of certain fertilizers in definite proportions may tend to increase the percentage of sugar. This is particularly true of potash and phosphoric acid. On the contrary, an abundant supply of nitrogenous fertilizer may tend to depress the content of sugar. In the latter case the effect is probably due to a tendency to increase the growth, while in the former case it may be partly due to securing a proper ripening of the beet and thus avoiding overgrowth, and partly to actual saccharigenic influences of the fertilizers themselves. Whatever the physiological action may be, it is evident that neither soil nor fertilizer is the dominant or even important factor affecting the percentage of sugar in the beet."

Even though, as pointed out above, the soil does not affect greatly the sugar-content of the beet, it is of the highest importance in determining yield; and after all it is yield in which the farmer is most interested. The factory is also interested in securing a high tonnage of sugar to the acre. Every phase of the soil should, therefore, be given consideration by the producer of sugar-beets.

ORIGIN OF SOILS

The material of which the soil is made has been derived largely from the rocks and minerals composing the crust of the earth; but in some soils a considerable part is made up of vegetative matter from the bodies of dead plants. All agricultural soils contain a small quantity of organic matter which is intimately mixed with the mineral matter. It is difficult to tell in all cases just the kind of rock from which a given soil is derived, since a great amount of weathering and mixing often cause it almost to lose its original identity.

Numerous minerals may be isolated from every soil, but in the finer soils the minerals are separated only with difficulty on account of the minuteness of the particles. Among the most common minerals making up the soil are quartz, the feldspars, hornblende, pyroxene, mica, chlorite, calcite, dolomite, gypsum, apatite, and the zeolites. Each of these brings to the soil some plant-food that helps to nourish the crop. Some of them make much better soils than others, but all contribute their part.

Few of these minerals occur separately; they are usually combined to form the different igneous and sedimentary rocks, which, on decomposing, form soils. Each one has its effect on the resulting soil. Granite, containing a potash feldspar, gives a soil rich in potash and also high in phosphoric acid, which comes from small apatite crystals. Eruptive rocks as a class decompose slowly, but usually form highly productive soils. Hard limestone dissolves slowly, but the softer varieties go into solution readily. Limestone soils, from which much of the lime has been leached, form some of the richest soils. Many of the better sugar-beet sections of America have soil high in lime. Sandstone soils are often poor, but this depends on the material cementing the grains together. Claystone soils are usually rich in plant-food, but are too heavy for the best growth of sugar-beets. Hardpans are formed where an excess of alkali accompanies the clay.

Soils are formed from minerals and rocks by the various chemical and physical agencies of rock decay known as weathering. The most important of these agencies are: (1) heat and cold, (2) water, (3) ice, (4) the atmosphere, and (5) plants and animals. Their action is both mechanical and chemical, the mechanical causing the breaking up of the rock into finer fragments, and the chemical causing a change in the actual composition of the material.

CLASSIFICATION OF SOILS

Soils may be classified according to their origin as either sedentary or transported. Sedentary soils are of two kinds: those that overlie the rock from which they were formed, and those formed in place largely by the accumulation of organic matter, as in swamps. Transported soils vary with the agent used in carrying the materials of which they are composed. Those transported by running water are called alluvial; by ice, glacial; by wind, æolian; and by the ocean, marine. Each of these kinds of soils has its own peculiar properties, although the composition is dependent largely on the rock from which it is formed. Probably more sugar-beets are raised on the alluvial soils than on any other group, although good beet sections are found on all the groups.

In addition to classification according to origin, soils are sometimes classified by their chemical composition, by the native vegetation growing on them, by the crops to which they are suited, by the size of particles composing them, and by a number of other properties. For our purpose the classification according to the crop adaptation is probably most interesting.

SOIL AND SUBSOIL

(Plates VI and VII)

For practical purposes, the soil layer is divided into the surface soil and subsoil, the subsoil being the part below the plowed zone. Soils vary greatly in their general make-up; some are but a few inches deep and overlie rock, whereas others are hundreds of feet deep and fairly uniform throughout. Every gradation between these two is found, including clay surface soil with gravelly subsoil or gravelly surface with clay below. In arid regions the

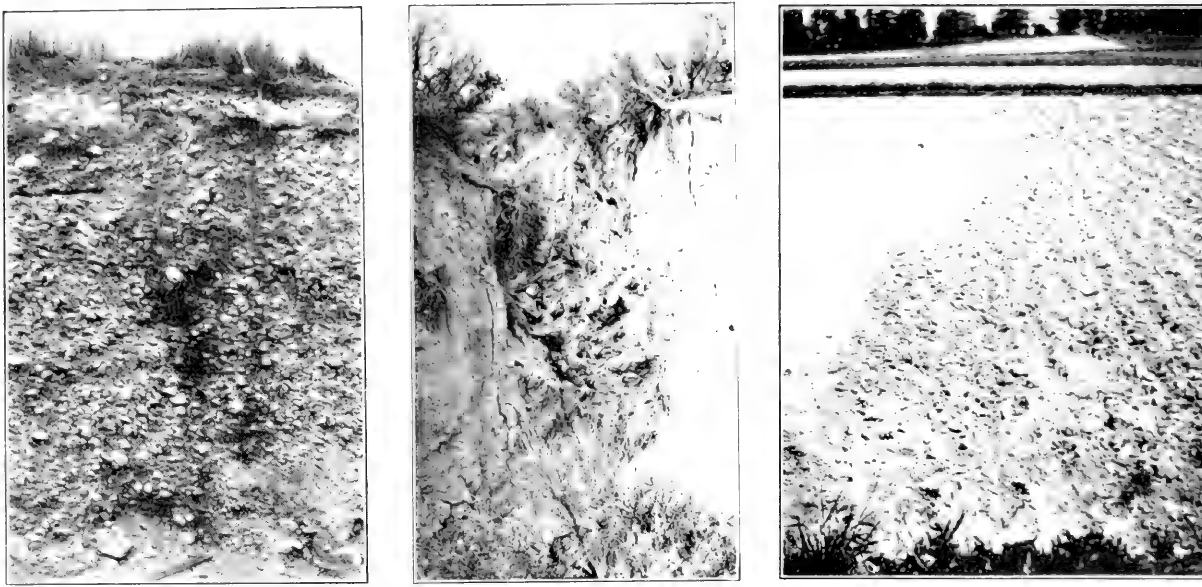


PLATE VI. — *Left*, gravelly soils are unsuited to sugar-beets; *center*, section of deep uniform fine-texture soil desirable for sugar-beets; *right*, a mellow soil that is crusted. Harrowing puts this in good condition. (Courtesy R. A. Moore.)

difference between the surface and the subsoil is not great, the subsoil being in many cases just as fertile and mellow as the upper layer. In humid regions, on the other hand, the subsoil is often compact and, on account of its lack of aëration, seems "dead" when brought to the surface. Such soils sometimes require a number of years to become fertile. Sugar-beets, on account of their deep penetration of roots and their high air requirement, find their best growth only in soils having a subsoil condition that is favorable. Any hardpan layer is particularly detrimental.

SOIL TEXTURE

Soils vary greatly in the size of particles composing them. Some are made up almost entirely of coarse particles; others are composed entirely of fine. Most soils, however, contain some fine and some coarse grains, the relative number of each determining the texture, which cannot be modified by the farmer. The texture of the soil has a great influence on the method of tillage as well as on a number of its properties, such as the water-holding capacity, the circulation of air, and the availability of plant-food. These all help in determining the kind of crop that should be grown. For example, peaches and cherries thrive on a soil having a coarse texture; the small grains prefer a "heavier" soil; sugar-beets and most other crops do best on soils of intermediate texture, such as the loams.

The various sizes of particles composing the soil have been classified by the United States Department of Agriculture, Bureau of Soils, as follows:

TABLE III. — NUMBER OF SOIL PARTICLES IN A GRAM OF SOIL OF DIFFERENT TEXTURES

Name	Diameter in Millimeters	Number of Particles in a Gram of Soil
1. Fine gravel	2.000–1.000	2.52
2. Coarse sand	1.000–0.500	1,723
3. Medium sand . . .	0.500–0.250	13,500
4. Fine sand	0.250–0.100	123,600
5. Very fine sand . . .	0.100–0.050	1,687,000
6. Silt	0.050–0.005	65,000,000
7. Clay	Less than 0.005	45,500,000,000

A soil composed entirely of particles of a single size is never found; hence the name given to a soil type depends on the relative mixture of these various sizes. The terms most commonly used for these mixtures are: (1) coarse sand, (2) medium sand, (3) fine sand, (4) sandy loam, (5) loam, (6) silt loam, (7) clay loam, and (8) clay. Farmers, speaking in a general way, usually call their soil sand, loam, or clay.

Of the properties of the soil affected by texture, probably none is of greater practical importance than the water-holding capacity. Moisture is held in thin films around the soil particles and the quantity that can be retained depends largely on the surface area of the particles, which, in turn, depends on the size of the particles. This is illustrated by the fact that a coarse sand will hold scarcely 15 per cent of water, whereas a clay may hold 45 per cent.

SOIL STRUCTURE

Structure refers to the arrangement of the soil particles, which may be wedged tightly together or so arranged that there is considerable air space between. The numerous sizes of particles present in any soil make possible a great difference in structure, particularly in fine soils. Soil tilth, which has such great practical importance, is determined largely by its structure, or the grouping of particles. Soil grains packed tightly together form a soil of poor tilth. When plowed, such a soil breaks up into clods instead of falling apart in granules or floccules. A loose structure gives lines of weakness extending in every direction through the soil. When this condition exists, the soil crumbles readily, but when the opposite condition is found, much work is necessary to put the soil in good condition. The facts that sugar-beets in growing expand greatly and that they require considerable air make very desirable a soil with a good structure.

IMPROVING SOIL TILTH

The tilth of a coarse-grained soil cannot be greatly affected, since it is always fairly good, but a clay requires constant care to prevent its becoming puddled. Many farmers have learned through experience that by cultivating a clay soil when too wet, they can so injure the tilth that several years are required to get it back into good condition. Almost anything causing a movement in soil may affect its tilth. Among the common factors are: (1) tillage, (2) the growth of roots, (3) alternate freezing and thawing, (4) alternate wetting and drying, (5) organic matter, (6) soluble salts, (7) animal life, and (8) storms. The tilth of the soil is the result of a combined action of a number of these factors, all of which improve it, except certain kinds of storms and certain soluble salts like sodium carbonate.

AIR IN THE SOIL

Oxygen is as necessary for the growth of plants as it is for that of animals. It is, therefore, impossible to have a fertile soil unless there are spaces through which air can circulate. Seeds in germinating, and roots in growing, require oxygen which is absorbed while carbon dioxid is given off. The decay of organic matter uses oxygen and forms carbon dioxid which accumulates in the soil air. If conditions in the soil do not favor a free movement of air, the oxygen supply soon becomes reduced to a point at which plant growth is retarded. The aëration of the soil is dependent on texture, structure, drainage, and a number of other factors. In a coarse sand, air moves readily, but in a clay, especially if it is compact, the movement is slow. Puddling greatly reduces aëration, whereas flocculating the soil particles into groups promotes the ready movement of air.

A water-logged soil, on account of the lack of oxygen, usually has a low crop-producing power. A free circulation of air, resulting from placing drains under such a soil, is in part responsible for the increased yields that follow drainage. The beneficial nitrifying and nitrogen-fixing bacteria require an abundant supply of oxygen for their best growth; their action is practically discontinued when the air supply is reduced greatly.

SOIL HEAT

The temperature of the soil is important because of its influence on the germination of seeds and on the growth of plants, and also because of its effect on chemical changes and bacterial action in the soil. When a soil is cold, life in it is dormant and chemical action is reduced. The earlier a soil is warmed in spring and the later it is kept warm in fall, the longer is the growing season. This is very important for sugar-beets, since there is not time during a short season to store large quantities of sugar.

Soil heat is derived largely from the sun, the rays of which are most effective when striking perpendicularly. A south slope, therefore, is considerably warmer than one facing the north. A sandy soil is also warmer than a clay. On account of the high specific heat of water, a wet soil is much slower to warm up in spring than a well-drained soil. The high evaporation from a wet soil also reduces the temperature. Such factors as colors, specific heat, and tillage play an important rôle in regulating soil temperature.

ORGANIC MATTER

The chemical, physical, and biological conditions of the soil are greatly influenced by organic matter because it reacts favorably on the tilth, the water-holding capacity, and the temperature of the soil. Through its decay, organic matter increases the availability of mineral matter and hastens desirable chemical changes in the soil. It also makes possible the work of bacteria by furnishing them food.

The organic matter of the soil is derived largely from the decay of roots, leaves, and stems. If the beet tops and crowns are left in the field, a considerable amount of organic matter is furnished. In arid regions, where the growth of native vegetation is light, the organic content of the soil is low and requires special attention. Indeed, the getting of a good supply of humus into the soil is one of the chief problems in the management of most soils. Organic matter is maintained by the addition of farm manure and other plant and animal refuse and by the raising of crops to be plowed under. The wise sugar-beet farmer will use large quantities of stable manure and, in his rotation, will arrange to plow under some leguminous crop or the manure resulting from it. On new land, it is often necessary to raise clover or alfalfa and turn under a crop before beets can be made to thrive.

SOIL MOISTURE

No factor in crop production is more important than soil moisture. Every plant and animal requires water for its life and growth. Plants may live a considerable time without receiving mineral food, but if water is withheld they soon wilt and die. The yield of beets in any particular year usually is a reflection of the moisture conditions during the growing season. Even in humid regions, the lack of available moisture often is responsible for a failure in the beet crop. On more than half of the tillable surface of the earth, the shortage of moisture is the chief limiting factor concerned in crop growth, while in parts of the humid regions an excess of water in the soil prevents the cultivation of vast areas of otherwise fertile land. It is apparent, therefore, that soil moisture is worthy of the most careful consideration.

The quantity of moisture in the soil is not so stable as the mineral constituents, but it varies from season to season and from day to day. More is being added from time to time, and losses occur through a number of channels. Even if for a short period no water is added or lost, a constant movement is going on with a tendency to establish an equilibrium which is seldom or never reached. Many forces are at work, making it difficult to determine all the laws by which soil moisture is influenced. The conditions of the moisture depend largely on the quantity present and the nature of the soil, which is able to hold only about a certain amount of moisture. When more is added, it percolates rapidly. As the quantity decreases, the tenacity with which it is held increases. A sandy soil reaches the point of saturation with much less water than does a clay. The condition of the moisture, therefore, is not always the same with a given percentage, but varies with the texture of the soil. The water of the soil is usually divided into three classes, determined by the percentage present. These are: (1) free, or gravitational, (2) capillary, or film, and (3) hygroscopic water. The maintenance in the soil of the proper moisture content for the best growth of crops is one of the most difficult phases of farming. The practical side of this question is discussed more fully in Chapter X.

SOIL ALKALI

In many of the sugar-beet areas of America, a condition known as alkali in the soil is met. This condition is found in practically all arid regions and results from the presence of large quantities of soluble material in the soil, which is rendered valueless by these salts if they are present in quantities that inhibit crop growth. Many soils containing considerable alkali will raise good crops until stronger concentrations are brought near the surface by evaporation of large quantities of water. In fact, some farmers contend that sugar-beets do better if a small amount of alkali is present. It is well known that after beets get a good start they are able to endure more alkali than many other common field crops. Experiments,[1] however, have shown that young beet seedlings are rather tender, and if much alkali is present near the surface when the seed is planted, germination will be poor.

In considering a tract of land for sugar-beet production, a careful survey of alkali conditions should be made, since new land is not likely to show the salt so much as is old, particularly when careless methods of irrigation are used. In the management of soils containing rather large quantities of soluble salts, even though toxic limits have not been reached, the farmer should know how to prevent accumulation at the surface. He should also make provision to reclaim the land when such a step becomes necessary.

[1] Harris, F. S. "Effect of Alkali Salts in Soils on the Germination and Growth of Crops." *Jour. Agr. Research.* Vol. V, pp. 1–52 (Oct. 4, 1915).

PLATE VII. — *Top*, an alkali spot, showing a soil condition unfavorable to sugar-beets; *center*, a full crop of alfalfa being plowed under to prepare the land for sugar-beets; usually corn or potatoes follows alfalfa a year before beets are planted; *below*, plowing beet land, Colorado. (Photo L. A. Moorhouse.)

Any soluble salt present in sufficient quantities may be considered an alkali. The salts most commonly causing injury are sodium chloride, or common salt; sodium sulfate, or Glauber's salt; sodium carbonate, or salsoda; and magnesium sulfate, or epsom salt. In addition to these, sodium nitrate and a number of other salts cause injury in some districts. Sodium chloride is injurious to beets when present in lower concentrations than any of the other salts mentioned; sodium carbonate, or black alkali, injures the soil when present in low concentrations by dissolving the organic matter and causing a hard crust to form. Beets will grow in relatively large quantities of the sulfates.

The injury done to crops by alkali salts results largely from the shutting off of water from the plant on account of the soil solution's having a greater concentration than the plant-cells. By the law of osmosis, water passes from the dilute to the more concentrated solution. In a normal soil the root has a cell-sap with a higher concentration than the soil solution; hence water passes from the soil into the plant. When the soil solution is made too concentrated, water passes out of the roots into the soil and the plant dies.

The permanent reclamation of alkali lands rests on the removal of the excessive salts by drainage. The methods of accomplishing this are discussed in Chapter X. Where the accumulation of alkali results from the over-irrigation of higher lands, the remedy is obviously the prevention of percolating water, which carries soluble salts from the higher and concentrates them in lower lands. Any practice that reduces evaporation, such as cultivation, cropping, or the use of farm manure, tends to reduce the accumulation of these salts.

ACID SOILS

Soil acidity is not nearly so serious a problem in the sugar-beet areas of the country as is alkali, but in some districts it occurs. Sugar-beets, in common with most ordinary crops, require for their best growth an alkaline, or basic, reaction of the soil. This is not the condition mentioned above as alkali, but refers to the chemical reaction. Such important crops as alfalfa can hardly be made to grow on an acid soil, since the bacteria that fix nitrogen in connection with growth on the roots of these plants require a basic reaction. Acid soils are most often found in humid regions where the basic elements of the soil minerals have been leached out, leaving the acid part behind; in swamp lands where the decay of large quantities of vegetable matter also results in an acid condition due to the accumulation of organic acids.

An acid soil is indicated by the growth of a number of plants, among which are common sorrel, sour dock, and horsetail, also by the failure of alfalfa and other legumes to do well. Blue litmus paper and a number of other laboratory tests may be used in determining acidity and the amount of lime necessary to correct the condition. The kind of lime to use depends on conditions; burned lime and ground limestone both accomplish the result. Ground limestone, however, is usually cheaper and, if fine enough, is effective.

PLANT-FOOD IN THE SOIL

The method by which plants secure their food from the soil has been known less than a century. From the time of the ancient Greeks and Romans down to the beginning of the nineteenth century, investigators sought to find some one substance in the soil that was the real food of plants. At different times it was thought to be fire, water, niter, oil, and many other materials. During this period all plant-food was supposed to come from the soil; it was not known that the greater part of it comes from the air.

Of the ten elements required by plants, seven, in addition to those obtained from water, come from the soil. These are potassium, phosphorus, calcium, magnesium, iron, sulfur, and nitrogen. A number of non-essential elements, including sodium, chlorine, and silicon, are also taken up by most plants. All crops require the same elements for their growth, although they do not use them in the same proportion. Sugar-beets and potatoes use relatively large quantities of potassium, the grain crops require considerable phosphorus, while alfalfa and clover use more calcium.

Soils are made up largely of insoluble material of no food value to plants. The amount of actual plant-food in the soil is comparatively small, but since plants do not use large quantities of this food, the supply of most of the elements is sufficient for crop production. Only a small part of the total plant-food of the soil is available during any one year. Roots penetrate every part of the surface soil, but they can absorb only the material that is in solution. The carbon dioxid given off by roots assists in dissolving the minerals of the soil.

The making available of reserve plant-foods as fast as needed by crops is one of the chief problems of soil management. This is done: (1) by tillage, which aids the weathering agencies in their action on soil particles; (2) by drainage, which allows air to circulate more freely through the soil; (3) by plowing under organic matter, which in decaying helps to make the minerals soluble; and (4) by numerous other less important means. The nitrogen present in the soil is made available by nitrification, which is favored by tillage and by a desirable moisture-content. Plant-foods that are likely to be scarce are discussed in Chapter VI.

SOIL BACTERIA

The soil is not a mass of dead matter, but is filled with myriads of living organisms, which are constantly transforming its compounds and renewing its productiveness. These organisms work on the bodies of plants and dead animals and make the material composing them useful to growing plants. All life on the earth is dependent for its continuance on these unseen organisms, but for whose renewing action the available plant-food would in time be consumed, all plant life would then cease, and animals would soon follow.

The most important of these organisms of the soil are the bacteria, the existence of which was discovered in 1695. They are so small that it would take about 25,000 of them placed side by side to reach an inch. They increase very rapidly when conditions are favorable. Many of the diseases of plants and animals are caused by bacteria. This does not mean that all are harmful; many are decidedly beneficial.

These germs cause the decay of the coarse organic matter of the soil and assist in the formation of the more useful humus. They are exceedingly important in connection with the nitrification, that is, with the transformation of nitrogen from the unavailable form to the nitrates, which are taken up by crops. Certain forms of bacteria also assist in fixing the nitrogen of the air and in making it into a food for plants. This is done mainly in connection with the legume crops, although some forms fix nitrogen without the aid of legumes.

SELECTING A SUGAR-BEET SOIL

As previously stated, sugar-beets do not absolutely require any given kind of soil; they are successfully raised on almost every type of soil when other conditions are favorable. This does not mean that all soils are equally well suited to raising the crop. Usually it does not pay to raise beets on any but well-adapted soils.

A number of conditions must be strictly avoided. One of these is a hardpan near the surface that would interfere with the deep rooting of the beets. Another condition to be avoided is a water-logged soil. Of course this can usually be overcome by drainage, but as a rule beets should not be planted until after the drain is in operation.

So far as texture is concerned, a loam is best adapted to beets, for it is easy to work and allows a ready movement of air. At the same time, it will hold sufficient moisture to meet the needs of the beet plant. A sand, although easy to work, is likely to be lacking in fertility and water-holding capacity. A clay, though having a high water-holding capacity, is likely to be difficult to work and is usually not sufficiently well aërated. Depth, proper texture, fertility, and desirable water relations deserve careful attention.

CHAPTER VI

MANURING AND ROTATIONS

THE fact that sugar-beets may often be raised for several years on the same land without a decrease in yield has led many farmers to believe that the productivity of the land can be maintained without either the application of fertilizers or changing the crop. The opposite point of view, that beets are very hard on the land, is sometimes held. Neither of these extremes is true. Where sugar-beets are raised continuously, a certain amount of food is carried away. Particularly is this the case if the tops and crowns are removed, since they contain the great part of the mineral salts of the entire plant. An unreplenished deposit of money in the bank, no matter how large, will in time be exhausted if continually drawn on. The plant-foods in the soil may be considered in much the same way.

Fortunately most soils on which sugar-beets are raised in America are high in mineral plant-foods; further, very little of this mineral matter is lost if the by-products are returned to the land. Nevertheless, maintaining the fertility of the soil and thereby insuring a high yield is one of the chief problems of sugar-beet production.

PLANT-FOOD REQUIREMENTS OF BEETS

As previously stated, all crops use the same foods, but they do not use these foods in the same proportion, and as a result, the various crops have different fertilizer needs. Of the seven mineral foods used by crops, all are present in most soils in sufficient quantity to meet the needs except nitrogen, potash, and phosphorus. In a few exceptional soils other minerals are lacking, but they form no important need. The following table gives the amount of these scarce plant-foods used by sugar-beets in comparison with other crops:

TABLE IV. — MINERAL FOODS REMOVED FROM THE SOIL BY CROPS

Crop	Yield	Nitrogen	Potash	Phosphoric Acid
Sugar-beets	10 tons	30.0 pounds	70.0 pounds	14.0 pounds
Potatoes .	6 tons	47.0 pounds	76.5 pounds	21.5 pounds
Wheat . .	30 bushels	48.0 pounds	28.8 pounds	21.1 pounds
Barley . .	40 bushels	48.0 pounds	35.7 pounds	20.7 pounds
Oats . . .	45 bushels	55.0 pounds	46.1 pounds	19.4 pounds
Corn . .	40 bushels	56.0 pounds	23.0 pounds	21.0 pounds
Meadow hay . .	1.5 tons	49.0 pounds	50.9 pounds	12.3 pounds
Red clover	2.0 tons	102.0 pounds	83.4 pounds	24.9 pounds

This table shows that sugar-beets use relatively large quantities of potash but not so much nitrogen or phosphoric acid.

Studies of the effect of the various fertilizers on growth have shown that excessive nitrogen stimulates leaf growth.

Potash is closely associated with photosynthesis in the formation of sugar in the leaves, whereas phosphoric acid is required in large quantities in the formation of seeds. This may explain in part the high potash requirements of sugar-beets, since work must be carried on in the leaves in producing sugar.

WAYS OF MAINTAINING SOIL FERTILITY

Various means may be used in maintaining the productivity of the land. Probably no system is complete that does not provide for the return to the land of at least a part of the mineral matter removed by the crop. This may be accomplished by the use of barnyard manure or by the addition of the substances in the form of commercial fertilizers. The plowing under of green-manure may also help in making available elements contained in the soil in large quantities, but in a condition that the crop cannot make use of them. In cases in which legumes are used for green-manure, there is also a direct addition of plant-food in the shape of nitrogen. Every good system of keeping the soil productive will include a rotation so arranged that the maximum returns will be secured and that will, at the same time, maintain the soil in good condition. Under most conditions, the practical method of maintaining the fertility of sugar-beet soil will combine all the ways mentioned. Farm-yard manure will be supplemented by the wise use, in a commercial form, of elements necessary to balance the needs of the crop on any particular soil; and crop rotations will be practiced in which some legumes will be plowed under as a green-manure. With this combination, the productivity of the soil should not only be kept up but should actually be increased.

HOW TO DETERMINE FERTILIZER NEEDS

In order that there may be no waste of material, it is important to know just what are the fertilizer needs of the soil. This problem is not so simple as it might at first seem to be. Soon after the methods by which plants feed and the elements they require from the soil were discovered, it was thought that by making a chemical analysis of the soil, its fertilizer requirements could be determined at once. It soon was found, however, that so many factors entered into the problem that this method could not be relied on. For example, an analysis may show a soil to be rich in potassium and at the same time this soil may give a marked response to the addition of potash fertilizers. This is true for all plant-food elements. In some cases, the elements shown by a chemical analysis to be lowest in the soil are the ones that give least returns when added as fertilizers. Numerous experiments have shown that an analysis of the soil is useful when taken with other tests, but that alone it is not sufficient.

Field tests carried over long periods of time have been found necessary in making a thorough diagnosis of the needs of a soil. These may be supplemented by pot tests and by chemical analyses. A complete understanding of a soil cannot be obtained without a combination of field and laboratory tests. When all this information is brought together and carefully studied, a fairly accurate judgment of the soil requirements may be made. The practice of applying any kind of fertilizer the dealer may have for sale, without making a thorough investigation, cannot be too strongly condemned.

COMMERCIAL FERTILIZERS FOR BEETS

In some regions where an abundance of farm manure is available, little or no commercial fertilizer may be needed for beets. There are many sections, however, where the supply of manure is insufficient. In these places commercial fertilizers will find increased use. The kind of fertilizer will of course depend largely on soil conditions. From Table IV it is evident that the sugar-beet plant uses relatively large quantities of potassium, which means that sugar-beet fertilizers should be well supplied with this element. After this requirement is satisfied, an effort should be made to supply a well-balanced fertilizer for the average soil. Voorhees [1] shows that sugar-beets grown on light soils often require potash, while on heavier loamy soils this element is not needed. He brings out the fact that fertilizers that produce too rapid or too prolonged growth tend to reduce the percentage of sugar. Phosphoric acid is one of the most necessary constituents to produce a large and rapid leaf growth in the early part of the season when the plant is preparing itself for the storage of sugar. This fertilizer should, therefore, be present in comparatively large quantities in the soluble form during the early period of growth.

[1] Voorhees, E. B., "Fertilizers," pp. 235–240.

While applying nitrogen in a form to encourage steady and continuous growth would result in a large yield, it would also produce beets low in sugar. In order to encourage the desirable early growth, nitrogen should be supplied largely in the readily available form in the spring before planting; organic, or slow-acting, forms should not be applied at that time.

When beets are raised for stock feed, fertilizing should be done in such a way that rapid and continuous growth is secured. This is accomplished by large applications of nitrogen and phosphoric acid throughout the season, especially the former. The liberal use of farm manure would be desirable in this connection, especially on heavy soils. On light soils all the fertilizer elements could be supplied as commercial fertilizers.

A discussion of the sources of the various fertilizer elements follows.

Nitrogen.

The most expensive of all the fertilizer elements is nitrogen. The supply of this element is also limited. Formerly, it was obtained in the form of guano, which is manure and decayed bodies of birds, but this supply is now practically exhausted. At present the chief source is the beds of sodium nitrate, or Chile saltpeter, found in Chile. It lies near the surface of the ground in great beds, but is so mixed with rock and earth that the leaching out of the salt is necessary before it is ready for market. Nitrogen in the form of sodium nitrate is directly available to plants.

Ammonium sulfate is another important source of nitrogen. In making coal-gas by the distillation of coal, a quantity of ammonia is given off. The gas is passed through sulfuric acid in which the ammonia is removed and ammonium sulfate formed. This salt is about 20 per cent nitrogen.

By means of electricity and in other ways, it is possible to combine the nitrogen of the air in such a manner that it can be used as a fertilizer. The chief products of these processes are calcium nitrate and calcium cyanamid. The main difficulty in the way of using these fertilizers more widely is the lack of cheap power which is required in their manufacture.

Many animal products are used for their nitrogen. Dried blood, dried flesh, ground fish, tankage, hoof-and-horn meal, and wool and hair wastes are all used. The availability of nitrogen in these compounds decreases about in the order named. The nitrogen of dried blood is available at once, whereas in leather and hair it becomes available slowly.

It is probable that the future supply of nitrogen will come more and more from the use of leguminous plants rather than from the addition to the soil of material from the outside. The supply of these materials is diminishing, but there is no limit to the use that may be made of these nitrogen-gathering crops.

Phosphorus.

Fertilizers yielding phosphorus are obtained from both organic and mineral sources. Bones in various forms are extensively used. Formerly they were used chiefly raw, both ground and unground; now most of the bone is steamed or burned to remove fat and nitrogenous materials which are used for other purposes. The fine grinding of bone makes its phosphorus more readily available. Tankage relatively high in bone is used largely for its phosphorus; if high in flesh scraps it is valuable for its nitrogen. Bone is sometimes treated with sulfuric acid to render its phosphorus more available.

Mineral phosphorus is found in several kinds of rock, which usually have the phosphoric acid in combination with lime, iron, and aluminum. The presence of the last two elements reduces the availability of the phosphorus. Rock phosphates are used in various ways. Formerly practically all of the rock was treated with sulfuric acid to form super-phosphate, or acid phosphate as it is often called; but of late years the use of finely ground raw rock-phosphate has increased, especially in soils rich in organic matter. The acid phosphate is doubtless more immediately available than the raw rock, but it is also much more expensive.

In the manufacture of steel from pig-iron, much phosphorus is removed with the basic slag, called Thomas slag. It is often ground and used as a fertilizer.

Potassium.

Most of the potash fertilizers used in the world have in the past come from the Stassfurt deposits in Germany. Here many minerals rich in potash are found. Some of these are ground and put directly on the land; others are leached with water to concentrate them before being used. Kainit and silvinit are among the most common of these minerals.

Wood ashes have for generations been known to be high in potash. They are often applied directly to land, but are sometimes leached to obtain the potash in a more concentrated form. In some countries where sunshine is abundant, sea water is evaporated and potassium obtained by fractional crystallization. During the last few years much potash has been obtained from kelp, which is harvested in the sea with special boats. This is a promising source of potash.

The mineral alunite is also being used to a considerable extent as a source of potash. Rather extensive beds occur in Utah and other parts of the West. Other minerals, such as orthoclase feldspar, have a rather high potash-content, but cheap methods of making it available have not yet been developed.

INDIRECT FERTILIZERS

Many soils, particularly in humid regions, have an acid reaction which is not conducive to the best growth of most crops. It is necessary to neutralize this acidity before sugar-beets will thrive. This is best done by the use of some form of lime. Burned lime has been used extensively, but it is gradually giving way to finely ground limestone which is much easier to handle and much cheaper. The effectiveness of limestone depends to a great extent on the fineness of grinding.

Many substances are added to the soil because of their stimulating action. Among the most common of these are common salt, gypsum, iron sulfate, soot, and manganese salts. It may be advisable to use some of these materials in special cases, but their general use is not recommended, since they add no plant-food and their temporary benefit may have a later and undesired reaction.

HOME-MIXING OF FERTILIZERS

Many farmers would rather pay more for fertilizers that are already mixed than to take the trouble of mixing them. This is largely because they do not realize how much more they have to pay for the various elements when purchased in the commercial brands of fertilizer than if obtained as the simple fertilizing materials, such as sodium nitrate, acid phosphate, and potassium sulfate.

Fertilizer manufacturers possess no special secrets that cannot be learned by any farmer who will study the subject a little. It is a poor policy to pay hundreds of dollars every year for a fertilizer about which nothing is known except what is told by a salesman. Better economy would lead the farmer to spend a few dollars buying books on the subject, as the information obtained from any good book on fertilizers may make possible a saving of 25 to 50 per cent of the fertilizer bill. Any farmer can, with but little expense, prepare a place in which to mix fertilizers. Then by purchasing the materials best suited to his conditions, he can mix them himself and thereby obtain a much more effective fertilizer at the same cost.

FARM MANURE FOR SUGAR-BEETS

In every beet-producing section an effort should be made to utilize fully all farm manure that can be obtained.

This is the surest means of preserving soil fertility. Practically every farm produces a quantity of this by-product of animal husbandry, and a wise use of it is fundamental to permanent agriculture. Since the very dawn of history the excreta of animals have been used as fertilizer. Although for a long time little was known of the way in which it improved the soil, the increased yield of crops was evident. Manure is now known to benefit the soil by adding directly a quantity of plant-food, by increasing the organic matter, and by aiding the work of desirable organisms. It may not in all cases be a complete and well-balanced fertilizer for beets in all soils, but it can always be recommended with safety. Where sugar-beets have been raised for any length of time, farmers have learned the great value of manure. Probably no other common field crop has done more to promote a careful use of farm manure.

The amount to apply depends on that available, the nature of the soil, and the rotation used. When beets are raised in a regular rotation, the manure can usually be applied with greater profit to the sugar-beet crop than to almost any other crop in the rotation. An application of five to twenty tons to the acre usually gives good results; ten tons is a fair application. The amount depends in part on the kind of manure. Quality is influenced by the kind of animal producing it and by a number of other factors. Manure produced by poultry and sheep is concentrated and dry; that produced by cattle and horses contains more moisture and coarse material. The manure of any kind of animal is influenced by the kind of food it eats and by its age and work. Old animals that do but little work and eat much rich food produce the best manure.

Liquid manure is richer in plant-food elements than the solid, but it lacks the organic matter so beneficial to most soils. Good husbandry requires the saving of both the liquid and the solid manure, which can easily be kept together if sufficient bedding material is used to absorb the liquid.

Handling farm manure.

Experience has demonstrated that the best way to handle manure is to haul it out and spread it on the land while it is fresh. This prevents any serious loss from leaching or fermentation, which are the methods by which manure deteriorates. When left carelessly exposed to the weather for six months, manure loses about half its value. This loss can be overcome in a large measure by proper storage without expensive equipment. The plant-foods contained in manure are readily soluble and but little rain is required to dissolve and carry them away. If manure is left scattered in the open yard, it is wet through by every rain and the greater part of the plant-food is washed out before the season is over. If manure has to be stored for any length of time, it should be piled so that it cannot be leached. This may be done by putting it under cover or by making the pile of proper shape.

Manure is filled with bacteria and fungi which are constantly at work. Some of these make the manure heat, causing a loss of considerable nitrogen. Since these destructive organisms work best in manure that is fairly loose and dry, their action is most easily prevented by compacting the manure to exclude air and by keeping it moist. Many farmers haul manure to the field and leave it standing for months in small piles. This practice allows destructive organisms to work rapidly. Moreover, the leaching of the piles causes an irregular distribution of plant-food in the soil. The idea that the manure should not be spread until the farmer is ready to plow it under is erroneous.

Manure must be stored during a part of the year if no vacant land is available for spreading it. Storage may be in special manure-pits, under sheds, or in the open yard. Expensive pits probably do not pay, but simple devices to assist in handling manure are doubtless good. When an open yard is used, the neatest and most sanitary kind of pile, as well as the one allowing least loss, is one with vertical sides and with edges slightly higher than the middle. The manure that is produced each day should be put on the pile and should be kept compact and moist. A manure-spreader is a great time-saver and makes possible a more even distribution than can be made by hand.

GREEN-MANURES

The plowing under of growing plants to increase the organic content of the soil has been practiced for generations. This practice has been found favorable, particularly in preparing new land for sugar-beets. The decay of plants helps to make available the mineral foods of the soil, and to correct physical defects. Plate VII.

Legumes make the best green-manure crops, since they increase the nitrogen supply by taking this element from the air and combining it in such a way that it can be used by other plants. The clovers, vetches, cowpeas, soybeans, field peas, and alfalfa are all plowed under as green-manures. The small grains are also much used for this purpose. A worn-out or poor soil will usually produce a fair growth of rye which, when plowed under, puts the soil in a condition to raise other crops. For beet land under irrigation, probably no crop will be better as a green-manure than alfalfa which is used in a rotation wherein the last crop of alfalfa is plowed under.

ROTATIONS

Reasons for crop rotations.

Some sort of crop rotation has been practiced for many centuries. The reasons for this practice were probably not at first understood; even today all the effects of alternate cropping are not known, but so many reasons are now evident that no good excuse seems to exist for not practicing some kind of rotation on almost every farm. As pointed out in Table IV, all crops do not require the various foods in exactly the same proportions: some use more potash or nitrogen; others need relatively more phosphorus or lime. If one crop is grown continuously on the same land, the available supply of scarce elements is reduced and the yield will finally decrease; but if crops with different requirements are alternated, the food supply of the soil is kept in a more balanced condition. Each kind of plant has a different rooting system and manner of growth. If shallow-rooted crops are grown continuously, only part of the soil is used; an alternation of deep- and shallow-rooted crops overcomes this difficulty.

The improvement of the soil furnishes one of the chief reasons for crop rotation. This improvement is made possible by the use of legume crops, which fix nitrogen from the air. The nitrogen fixed by these crops can be used by others which follow in the rotation, but it would be lost practically if legumes were raised continuously. The control of plant diseases, insect pests, and weeds is made possible by the rotation of crops; indeed, such considerations often compel a farmer to change his crops when he would not otherwise do so. Economy in the use of man-labor, horse-labor, machinery, and irrigation water results from the raising of a number of crops on the farm. These considerations alone, without any other benefits, would be sufficient for practicing rotations.

Sugar-beets require a great deal of tillage. The land must be plowed thoroughly and deeply; cultivation during the growth of the crop is practiced; and finally at harvest time, the land must be stirred to considerable depth to get out the beets. The large roots go deeply into the soil and promote thorough aëration, and when the beets are topped a large quantity of organic matter is added to the land from crowns and tops. All these practices promote a desirable condition in the soil. It is also highly desirable to have part of the results of these intensive methods of cultivation reflected in later crops. This end is achieved by rotating the crops. The crop that follows beets in the rotation is benefited by the tillage given to the beet crop, even though beets add no plant-food to the soil as do legumes.

Principles of good rotations.

No one rotation is good under all conditions; soil type, climate, markets, and many other factors must be considered when planning a rotation. A number of cardinal principles, however, if kept in mind, will be of considerable assistance.

It is first necessary to decide what crops can best be grown under the conditions and what area of each crop it is best to grow. The following principles should then be observed: (1) raise about the same acreage of each crop every year; (2) have at least one cash crop; (3) include a legume crop in the rotation; (4) alternate tilled and non-tilled crops; (5) alternate deep- and shallow-rooted crops; (6) alternate exhaustive and restorative crops; (7) include crops that together will make the best use of irrigation water, labor, and equipment; (8) a forage crop should be included; (9) follow the best sequence of crops; and (10) add manure to the right crop in the rotation. It is not always possible to conform to all these rules, but they may serve as useful guides.

Rotations with sugar-beets.

The rotation that should be practiced varies with so many conditions that the naming of any particular one to include sugar-beets may be misleading. It must be remembered, therefore, that no rotation is best for all conditions. Some of the factors that influence the rotation are: (1) kind of soil, (2) the kind of crops that can be raised profitably in the region, (3) the proportion of the farm that is to be planted to beets, (4) the amount of fertilizer available, (5) the number of live-stock kept on the farm, (6) the presence of pests and diseases, (7) the amount of labor that is available, and (8) many other conditions.

In several of the beet-producing areas where beets have been raised almost continuously for many years, the nematode has made it impossible to continue the crop unless a rotation is introduced. In planning a rotation for these conditions, it is necessary to eliminate plants that will foster this pest. Crops available for this purpose are listed in Chapter XIII.

In several districts land has become so high-priced that it is impossible to raise at a profit many of the crops that would ordinarily be included in rotations with sugar-beets. Where a condition of this kind is found, the planning of a good rotation becomes a real problem. The plant-foods removed by the beet crop may be added in commercial fertilizers, but this does not keep out injurious diseases and pests, neither does it provide the proper balance in the farm business. A short rotation used in some of the areas of California having high-priced land consists of beans and sugar-beets.

In the Arkansas Valley of Colorado and western Kansas, the cucurbit group of crops forms an important part of the rotation with sugar-beets. Cantaloupes are the principal of these; cucumbers are also important. These crops, with alfalfa and in some cases potatoes, make the principal crops to alternate with beets.

In northern Colorado and in parts of Utah, several canning crops, such as peas, beans, and tomatoes, enter into the rotation. These crops, taken with alfalfa, potatoes, sugar-beets, and grain, enter into most of the rotations. Under these conditions, it is a rather common practice to allow alfalfa to grow until the latter part of May, then plow under the crop and after thoroughly working down the land, plant potatoes or corn. The next year beets are planted. The organic matter plowed under with the alfalfa adds to the humus supply of the soil and enriches it in nitrogen.

A farmer having eighty acres of land and wishing to raise twenty acres of beets and having as other possible crops, alfalfa, potatoes, tomatoes, peas, beans, and the small grains, might arrange his crop in a rotation something like this: alfalfa, four years; followed by potatoes, corn, or tomatoes, one year; beets, one year; peas or beans, one year; beets again, one year; grain as a nurse crop with alfalfa, one year. This would give an eight years' rotation with the following acreage each: alfalfa, forty acres; corn, potatoes, or tomatoes, ten acres; beets, twenty acres; peas or beans, ten acres; and wheat, oats, or barley, ten acres.

A variation of this rotation would be to put the two beet crops together and let the peas or beans follow; or if it was desired to have as large an acreage of beets as possible, the peas and beans could be eliminated and the beets raised three years continuously if well manured, giving a total of thirty acres of beets. If the farm were small, the same general arrangement could be maintained, only it is probable that the relative area planted to beets would be larger. The rotation could readily be extended or shortened a year or two by increasing or decreasing the length of time the land was in alfalfa.

Where alfalfa does not thrive, the same general plan could be carried out with some other sod crop, such as clover or grass. In a rotation of this kind the use of manure is usually most effective if applied just previous to the beet crop. In plowing up alfalfa, it is usually better to plant the land to some crop such as corn or potatoes for a year before planting beets because of the interfering action of the coarse alfalfa crowns. Clover and grass land may often be planted to sugar-beets at once, especially if fall-plowed.

CHAPTER VII

CONTRACTS FOR RAISING BEETS

It seems desirable both for the sugar company and for the farmer to have a contract on the raising of beets signed before the crop is planted. The farmer would have no market for the crop of beets if the sugar company did not buy them. He might feed a few to stock, but on the ordinary beet farm only a comparatively small number could be used in this way. He should be sure, therefore, before planting the crop, that the sugar company will take it; otherwise, he runs the risk of a heavy loss. Likewise, the sugar company needs to know early in the season the approximate tonnage of beets that it will have to slice in order that necessary equipment and supplies may be secured. These conditions have led to the universal practice of contracting in advance all beets that are raised for the factory.

ADVANTAGES OF CONTRACTING

Farming is one of the most uncertain of all businesses. This is partly because of the irregularities in prices. One year potatoes or hogs will be high and the farmer thinks he should produce more of these commodities; but by the time he has a large number of potatoes or hogs to sell, the price has gone so low that he makes nothing. The same condition is repeated to an extent with most products of the farm that are marketed in the usual way.

The farmer should have some crop that he can depend on, with the selling price known at the beginning of the season. This condition is found in contracted crops like sugar-beets. They may not give such high returns every year as some other crops, but the fact that a known price can be depended on tends to stabilize the entire farm business. With crops that are contracted, the farmer can depend on getting his money soon after harvest. Probably all crops should not be contracted in advance, but a desirable arrangement is to have some contracted crop raised in connection with others that are marketed in the usual way.

ITEMS INCLUDED IN THE CONTRACT

The contracts used by different sugar companies vary greatly in their content. Some go into considerable detail and specify every point; others cover only the more important questions. Items included in some contracts for raising beets are the following: amount of seed to be planted to the acre, price of seed, price of seeding, price of beets, provision for the supervision of growing by the factory agriculturist, specific directions regarding cultural methods, time of digging, methods of topping, method of weighing, method of taking tare, standards for condition and composition of the beets, time of payment, provision for furnishing labor, and a number of other points.

No single contract includes everything. In one region one item is important and is mentioned; in another region this item may never cause disagreement and would, therefore, probably not need to be mentioned.

TYPES OF CONTRACTS

Most beet contracts are similar in their wording and in the points they include but vary in such details as the price paid for beets, the time of performing the different kinds of work, and rates for sliding scales, and profit sharing. The flat rate contract, wherein the farmer receives a definite price for a ton of beets regardless of their sugar-content or the price of sugar, is popular in many districts because of its simplicity and because no laboratory tests and complex systems of accounting are involved.

The flat rate contract, however, is not likely to be so fair to all concerned as either the sliding scale, based on sugar-content of beets, or the profit-sharing plan, based on the price of sugar or the net profits from the manufacturing of it. Although these systems of setting the price of beets are rather difficult to handle, they make it possible for the sugar company to pay more on the average for beets, because the farmer takes part of the risk. Why should not both parties share the hazards of the business and also share in its profits?

Most companies also have a labor contract by the provisions of which they assist the farmer to secure the hand labor required in thinning, hoeing, and digging. The sugar company is able to get in touch with this labor much easier than the individual farmer and it, therefore, maintains a labor department whose duty it is to assist the farmer to get help when he needs it.

Often contracts call for some special bonus based on the total quantity of beets in the district or some other condition that will boost the industry. These are usually local and, therefore, call for no particular discussion.

SAMPLE CONTRACTS

The following contract gives a flat rate for beets, but allows the farmer to share the benefits of a rise in price of sugar:

No. . .

Acres . .

. . . . Sugar Company

SUGAR-BEET CONTRACT

. . . . (Locality)

1918

THIS AGREEMENT, in duplicate, this . . day of 191 , by and between . . . . SUGAR COMPANY, a . . . . Corporation, hereinafter called the Sugar Company, and . . . . of . . . . , County of . . . . . , . . . , hereinafter called the Grower.

WITNESSETH: The Grower agrees to grow in the year of 1918, from seed to be supplied by the Sugar Company . . . . . . acres of sugar-beets, and to deliver and sell the entire crop therefrom to the Sugar Company, and the latter agrees to buy and pay for the same, upon all and singular the terms and conditions hereinafter set forth, to-wit:

1. The Grower will prepare and cultivate the said land and harvest the beets grown thereon in a husbandlike manner, and deliver all beets with the tops closely cut off at the base of the

bottom leaf, and will use reasonable effort to protect the same from frost and sun. The Sugar Company will furnish the seed at 15 cents per pound to the Grower, and plant the same, when so requested, at the rate of 65 cents per acre.

2. Delivery of beets shall be made as follows: Until and including October 15th, only as required by the Sugar Company; and after October 15th, the Grower shall deliver without further notification all unharvested beets, the Sugar Company reserving the right to reject beets containing less than 12 per cent Sugar. The Sugar Company, at its option, may accept or reject any beets not delivered on or before November 30th.

3. All such beets to be delivered at the expense of the Grower in a manner and condition satisfactory to the Sugar Company, in the sheds or on cars at the . . . . factory, or at the receiving station at . . . . . . In case of no care, the Grower agrees to unload in piles as directed by the Sugar Company and shall receive ten cents per ton for such piling.

4. The Sugar Company shall not be bound to accept diseased, frozen, damaged, and improperly topped beets, and beets which do not otherwise meet requirements hereof.

5. The weight of dirt delivered with beets shall be deducted in the customary manner, and such deductions shall be conclusive.

6. The Sugar Company, on the fifteenth day of each month, will pay $9.00 per ton for all beets delivered and received during the preceding calendar month in accordance with the terms, specifications and requirements of this contract, that shall test over 15 per cent in sugar content. In addition to the aforementioned payment, the Sugar Company will pay the Grower his proportion of one-half the increase in the price of sugar, if any, above $7.45 per cwt., Seaboard Refining point, based on the quantity of sugar sold at such increased basic price. The latter payment to be computed and made when all the sugar manufactured from the beet crop of 1918 has been sold.

7. The Growers shall have the privilege of selecting, at their expense, a man of reliable character, satisfactory to The Sugar Company, to check the tares and weights of the beets grown under this contract, at the receiving stations where such beets may be delivered.

8. The Sugar Company, at its pleasure, during the growing, harvesting and delivery of the beets, shall have the privilege and shall be accorded the opportunity, by the Grower, of sam-

pling the beets, in order to ascertain the quality thereof, by polarization and analysis. It is agreed that the polarization and analysis by the Sugar Company shall be accepted as conclusive.

9. This agreement shall bind both the Grower and his legal representatives, and the Sugar Company and its successors, and shall not be transferable by the Grower without the written consent of the Sugar Company, its successors and assigns.

. . . . SUGAR COMPANY,

By . . . .

Witness: . . . . Agent.

. . . .

. . . .

Grower.

P. O. Address . . . . .

The following contract provides for a sliding scale of prices based on the sugar-content of the beets.

ORIGINAL

MEMORANDUM OF AGREEMENT

Between

. . . . Grower

and

. . . . Sugar Company

. . . . (Locality)

1. THE GROWER agrees to prepare the land for, plant, block, thin, cultivate, irrigate, harvest, and deliver during the season 191 , in compliance with the directions of . . . . SUGAR COMPANY, hereinafter called THE COMPANY, as may be given from time to time, ... acres of sugar-beets on the following described lands, to-wit: . . . . quarter-section, ... Township, ... Range,

. . . . County, (State); but in no event shall THE COMPANY be held liable in damages for any failure or partial failure of crop or any injury or damage to beets.

2. That the seed used shall be only that furnished by THE COMPANY, for which the grower shall pay ten cents (10¢) per pound, and twelve (12) pounds per acre shall be planted, the same to be paid for out of the first beets delivered. Seed-bed must be approved by the duly authorized agents or field men of THE COMPANY, before the seed is planted.

3. THE GROWER agrees that all beets grown by him will be harvested and delivered to THE COMPANY as directed, at the factory, or in cars at designated receiving stations of THE COMPANY, properly topped at base of bottom leaf, and that knives will not be used for lifting beets; but hooks may be used, provided they are properly driven into the top of the crown of the beet only. THE GROWER further agrees that all beets grown and delivered by him shall be free from dirt, stones, trash, and foreign substance liable to interfere with the work at the factory, and shall be subject to proper deductions for tare, and that he will protect the beets from sun or frost after removal from the ground. THE COMPANY has the option of rejecting any diseased, frozen or damaged beets, beets of less than twelve per cent (12%) sugar or less than eighty per cent (80%) purity, or beets that are not suitable for the manufacture of sugar. It being agreed and understood that THE COMPANY shall not be obliged to receive any beets prior to October 8th containing less than fifteen per cent (15%) sugar. It also being understood that THE COMPANY will commence receiving the crop as soon as the beets are thoroughly matured.

4. In the event that any portion of the beets grown under this contract (except that portion of the crop which is to be siloed as herein provided) shall not by the 8th day of October of said year be ordered delivered by THE COMPANY, then in such case it shall be the duty of THE GROWER to promptly commence and proceed with the harvesting and delivery of such beets as come within the contract requirements after the said 8th day of October without further notice from THE COMPANY, and to fully complete delivery of all of said beets on or before the first day of December of said year.

5. THE GROWER agrees to silo, if so directed in writing by THE COMPANY prior to harvest, any portion of the tonnage

produced on the above contracted acreage not to exceed twenty-five per cent (25%) of the entire crop grown hereunder.

6. Beets delivered and accepted will be paid for by THE COMPANY, as follows:

$8.375 per ton for beets	testing not less than 12 per cent sugar and under 14 per cent
$8.50 per ton for beets	testing not less than 14 per cent sugar and under 14.5 per cent
$8.625 per ton for beets	testing not less than 14.5 per cent sugar and under 15 per cent
$8.75 per ton for beets	testing not less than 15 per cent sugar and under 15.5 per cent
$8.875 per ton for beets	testing not less than 15.5 per cent sugar and under 16 per cent
$9.00 per ton for beets	testing not less than 16 per cent sugar and under 16.5 per cent
$9.125 per ton for beets	testing not less than 16.5 per cent sugar and under 17 per cent
$9.25 per ton for beets	testing not less than 17 per cent sugar and under 17.5 per cent
$9.375 per ton for beets	testing not less than 17.5 per cent sugar and under 18 per cent
$9.50 per ton for beets	testing not less than 18 per cent sugar and under 18.5 per cent
$9.625 per ton for beets	testing not less than 18.5 per cent sugar and under 19 per cent
$9.75 per ton for beets	testing not less than 19 per cent sugar and under 19.5 per cent

And twelve and one-half cents (12½¢) per ton additional for each one-half per cent above 19.5 per cent.

For all beets siloed one dollar ($1.00) per ton extra will be paid. It being distinctly understood, however, that none of such siloed beets shall be delivered until THE COMPANY sends written instructions to THE GROWER to make delivery of "siloed beets"; also that all of said siloed beets shall be ordered and delivered prior to January 31st.

Payment to be made the 15th of each month for beets delivered and received during the previous calendar month.

7. THE GROWER shall have the privilege of selecting, at his expense, a man of reliable character, satisfactory to THE

COMPANY, to check the tares and weights of the beets grown under this contract, at the receiving stations where such beets may be delivered, and to check in the tareroom laboratory the polarization of his beets.

8. It is further agreed in the event of a shortage of cars after October 8th, causing serious delay to THE GROWER, said GROWER shall be allowed to fork his beets into piles, providing he piles them eight (8) feet high, under the direction of THE COMPANY, at the receiving stations where large elevated dumps are established; and no loose dirt shall be removed from the wagon box until after having been weighed back.

9. To ascertain the quality of said beets, THE COMPANY shall have the privilege at various times during the growing and harvesting season of causing the beets to be sampled and polarized.

10. THE GROWER agrees not to assign this contract without written consent of THE COMPANY.

The Silo clause of this contract will not be enforced for the year 1918:
(Place) . . . . 191 .

. . . . GROWER
. . SUGAR COMPANY
By . . . .

The following is a contract between the sugar company and laborers it secures for the farmers.

LABOR AGREEMENT

IT IS HEREBY AGREED Between Mr. . . . . . . of No. . . . . Street, City of . . . . . . , and The . . . . Sugar Company of . . . .

That the said laborer and . . . . . associates agree to take care of . . . . . acres of sugar-beets; for certain farmers who have contracted with The Sugar Company to grow beets; the labor to consist of blocking and thinning, once hoeing, and pulling, and topping. Sufficient number of men are to be furnished to do the work in a careful and efficient manner that shall be satisfactory to the farmer.

The Sugar Company agrees that the farmer will make settlement with the laborers when each part of the work is done, as follows:

$12.00 per acre when the thinning and hoeing is completed.

$10.00 per acre when the pulling and topping is done.

It is also agreed that The Sugar Company is to furnish for the farmer a comfortable home in which the laborer is to live, and transportation from his present city to the house in which he is to live.

As a guarantee of the performance of the above contract it is agreed that The Sugar Company is to retain for the farmer two dollars per acre from the first settlement until the work is completed in the fall.

It is further agreed that on arrival at the place of labor, a contract will be entered into between the laborer and the farmer whose beets he is to care for, which shall supersede and cancel this agreement but will describe more specifically the work to be done.

THE . . . . SUGAR COMPANY

Per . . . .

Dated . . . . 191 .

. . . . Laborer.

A form of labor contract between the sugar company and the farmer is given below.

ORIGINAL

GROWERS' APPLICATION AND AGREEMENT FOR BEET WORKERS, 1918

. . . . SUGAR COMPANY,

I, ... , of . . . . County of . . . . . , State of . . . . . , hereby make application to the . . . . Sugar Company (hereinafter called the company), for hand laborers to care for . . . . acres of sugar-beets, planted in rows . . . . . inches apart, to be grown by me for said Sugar Company on Section . . . . , Township . . . . . County. . . . . . , State of . . . . . , during the season beginning with the spring of 1918; the cost of such labor to be Twenty-three Dollars ($23.00) per acre for beets planted in rows Eighteen (18) to Twenty-two (22) inches apart inclusive; Twenty-one Dollars ($21.00) per acre for beets planted in rows Twenty-four (24) to Twenty-six (26) inches apart inclusive; and Nineteen Dollars ($19.00) per acre for beets planted in rows Twenty-eight (28) inches apart.

I hereby agree that, in consideration of the said Company securing beet workers for me, and furnishing them with railroad transportation, I will sign a contract with such beet workers, at prices above mentioned.

I further agree to transfer the laborers from the railroad station to and from the land to be worked for me, or to pay the cost of such transfer, and to furnish such laborers with a suitable dwelling place and water, and to haul fuel while they are employed under this agreement.

In case the Sugar Company furnishes a house for the laborers, I agree to pay for rent of said house fifty cents (50¢) for each acre of my beets worked by said laborers.

I further agree that for all money advances made by the said company, to care for the growing crop under the terms of this agreement, I will give to the said company my promissory note, bearing seven per cent annual interest, payable November 15, after date of note.

It is understood that the said company will undertake to furnish the best laborers obtainable, but I will not hold the said company responsible for the efficiency of said laborers or failure to secure same.

Dated . . . . , 191 .

(Signed) . . . .

Grower.

Witness: . . . .

The phraseology of any of these contracts might be varied, but they illustrate the type of agreements entered into in the production of sugar-beets.

CHAPTER VIII

PREPARATION OF SEED-BED AND PLANTING

THE seed-bed is the home of the young plant. If that home is favorable, the plant gets a good start and has a fair chance to make a satisfactory growth; if it is unfavorable, the plant is doomed. No matter how good the seed or what provisions are made for caring for the crop later on in its life, a satisfactory yield cannot be obtained unless the plant has a favorable condition in which to begin its life and to grow during the period when it is tender. In outlining methods of obtaining a good seed-bed, it must be remembered that conditions differ widely and that no practice will fit all conditions. The object is to make the soil a suitable home for the young plant. The practice that will produce this result in any locality is the one to use. In discussing the question for all conditions, only general suggestions can be offered; the details must be worked out locally.

EFFECT OF PREVIOUS CROP

The methods of preparing land for sugar-beets cannot be discussed independently of the previous crop. If a sod crop is followed by beets, every effort must be made to kill the sod plant and to promote the decay of roots and crowns. Considerable attention must also be given to stirring the land deeply in order that the beet root may have a mellow soil in which to grow. If potatoes or a root crop have been grown on the land, the soil will already be loosened to considerable depth and there will be no coarse plant residues to care for. Under these conditions, the preparation of a seed-bed for beets is comparatively simple. In planning a rotation in which sugar-beets are included, this question should be given due consideration, particularly in arranging the order in which the crops should follow each other. This is discussed more fully in Chapter VI.

REASONS FOR PLOWING

The most fundamental operation in the preparation of the seed-bed is plowing. One of the distinguishing features between the agriculture of the savage and that of civilized man is the difference in plowing: the one merely scratches the land sufficiently to get the seed planted; the other stirs and pulverizes the entire surface layer of soil. In this process many desirable results are obtained: the structure, or tilth, of the soil is improved; air is better able to penetrate to the roots; undesirable plants and weeds are killed; manure, stubble, and other plant residues are covered and decay is thereby hastened; and moisture is conserved.

Every plant requires for its best growth that looseness of soil which permits a free passage of air and an easy penetration of roots. This is particularly true of sugar-beets. When left undisturbed for a number of years, the soil becomes compact and is not in the best condition for crop growth. It is necessary, therefore, to loosen it by the use of some tillage implement, preferably the plow. In cultivating the soil to improve tilth, attention must be given to the amount of moisture present. A soil plowed when too wet will become more compact than it was before plowing.

Plowing should mean more than the mere turning over of the soil. If plowing is well done, every clod will be shattered and every particle have its relation to every other particle changed through the shearing action that should take place when the plowed slice is turned over. As the soil falls into the furrow, it should be a granular mellow mass of loose particles. The kind of plow that will best produce this condition varies with each soil. Sand or loam may be made mellow with any kind of plow, but a heavy clay without organic matter can be given a good tilth only when every condition is favorable.

Organic matter accumulates at the surface of any soil that is cropped. In the orchard, leaves fall; in the grain field, stubble is left after harvest; and in meadows that are to be followed by another crop, a sod must be turned under. These plant residues cannot decompose readily if left at the surface; they need to be turned under and mixed with the soil in order to decay and give up their plant-foods as well as to assist in making available the mineral matter of the soil. Farm manure is constantly being applied to the land, and must be covered and mixed with the soil if it is to do the most good. Practically all of this covering must be done with some kind of plow, although the disk harrow finds occasional use where the land has been plowed recently.

One of the most important reasons for cultivating the soil is to conserve moisture. Even in regions of abundant rainfall it is often necessary to save soil moisture, and in arid regions the very life of agriculture depends on conserving the scant supply of water. If the soil is compact and hard, rain water will run off the surface rather than penetrate the soil where plants can use it. The soil must, therefore, be loosened in order that it may absorb moisture. The water that is in the soil moves from particle to particle, and if the surface particles are pressed tightly together the water will rise to the surface where it is lost by evaporation. This loss can be prevented by stirring the surface and forming a loose, dry mulch of earth which retards the escape of moisture.

TIME OF PLOWING

Many factors must be considered in determining the best time to plow, such as the amount of moisture in the soil, the rush of other work, the climatic conditions during the winter, the time of harvesting the preceding crop, and the time at which the land is to be seeded. As a rule, it pays to plow for sugar-beets in the fall rather than in the spring. This is probably more true for this crop than for any other, although fall-plowing is usually considered good for practically all crops; there are, however, a few conditions in which spring plowing seems to give better results.

Fall plowing is desirable because it allows the turning up and mellowing of deep soil which winter-freezing will make congenial to crops; it secures a more complete decomposition of organic matter; it breaks up a cloddy and compact condition; it allows more of the winter rainfall to be stored; it allows time to establish capillary connection between the plowed portion and the subsoil; it makes possible the earlier use of sod land for the beet crop; it exposes and kills many insects and fungous pests; and by giving better conditions for decay it allows the best use to be made of manure applied in the fall.

The mellowing frosts of winter bring about changes in the soil that would require a great amount of labor to accomplish. This is especially true on heavy land that is made friable only with great difficulty.

One decided advantage of fall plowing in regions having heavy winter and spring rains is that the beet crop can be planted much earlier with fall than with spring plowing. If the farmer has to wait in the spring till the land is well dried before plowing, the season is far advanced before seed can be planted. Harrowing should follow plowing, after which enough time should elapse for the soil to settle before seed is planted. By this time the surface soil is dry and the seeds have to be planted deep in order to obtain the moisture necessary for germination.

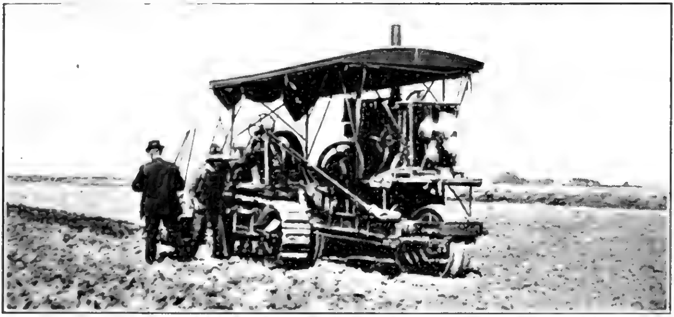
In many regions it is the custom to plow beet land shallow in the spring after fall plowing. This has the advantage of killing weeds that come up early in the spring, and it leaves a mulch on the surface. It has the disadvantage of drying out the surface; it also entails considerable extra expense. Farmers in many of the leading sugar-beet areas find that spring plowing can well be dispensed with, particularly on heavy soils.

In many regions it has been found that heavy land planted to beets or potatoes the previous year may be put in good shape without plowing, by giving the surface a thorough treatment in the spring. This is done by "taking [1] a fine tooth harrow, riding it and running it as deeply as possible, following with a float which will form a fine mulch on top and prevent crusting. Then take a spring-tooth harrow and run it as deeply as possible the same way the rows of beets are to run at least three or four inches deep. Next follow immediately with a fine tooth harrow in order to keep the land worked down and retain the moisture and not allow clods to form. The same process should be repeated crosswise, running the spring tooth an inch or two deeper if possible. Go over it again with a roller or leveler to get the surface firm enough for planting." While this method seems to eliminate plowing, it does not in reality do so, since the digging of the potatoes or beets is practically equivalent to a fall plowing and the treatment is not recommended except for heavy land that has raised these crops.

DEPTH OF PLOWING

The proper depth of plowing has always been a topic of discussion among farmers. One will say that the deeper the plowing the better; another will affirm that shallow plowing is best. It may be that neither has

[1] Austin, Mark, *Utah Farmer*, Vol. 12, No. 31, Mar. 3, 1917.



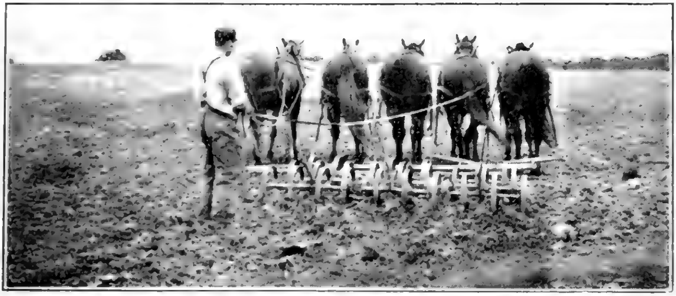


PLATE VIII. — *Above*, (Photo by J. A. Brock) culti-packer preparing land for sugar-beets in Colorado; *center*, (Photo by J. A. Brock) preparation of land for beets with a tractor, Colorado; *below*, (Photo by T. H. Summers) the spring-tooth harrow is an excellent implement to prepare land for sugar-beets.

made any careful investigations in which costs have been figured. All seem agreed that for beets deep plowing is desirable, since the expanding roots require a soil that may be moved readily; but just what deep plowing is seems to be entirely a matter of local judgment. In one place twelve inches would be called deep plowing; in another locality nothing less than eighteen or twenty inches would be so designated.

Ordinarily where mechanical traction power is available, the land is plowed deeper than where horse power is depended on. In some sections an attempt is made to plow all beet land twenty to twenty-four inches deep. Other sugar-beet areas find half this depth ample. The nature of the soil and other local conditions are doubtless important considerations in this connection. The length of time the land has been cultivated must also be taken into consideration. It would most likely be unwise to plow land twenty inches deep when it had previously been plowed only eight inches. The amount of raw soil thus turned up would probably render the land almost wholly unproductive the first year, particularly if the deeper soil were heavy and compact.

The use of the subsoil plow was highly recommended for sugar-beets in the early days of the industry in America, but now there is little said of it. In some areas it doubtless pays to subsoil, but usually subsoiling cannot be recommended as a regular practice in connection with plowing. In digging beets the land is in reality subsoiled; this is ordinarily all that is necessary. In some soils that have never produced beets, a subsoiling would probably be beneficial, but it certainly is not necessary to success in raising beets and it is an expense that should, therefore, be eliminated.

Conditions in each locality must determine what depth land should be plowed, but for a great part of the sugar-beet area a thorough plowing to a depth of twelve to fifteen inches is ample. When experience demonstrates that deeper plowing will pay for the extra expense it entails, greater depth should be practiced, but the extra cost should always be considered.

FINAL PREPARATION

(Plates VIII, IX)

Much depends on the final preparation of the land for planting. Good plowing counts for little if it is not followed by tillage methods that put the seed-bed in a condition that will favor a quick germination of the seed and a rapid growth of the young plant. This means that the top few inches must be fine and mellow and at the same time firm and moist. This preparation should be done early in order to make possible early seeding.

If the land is too dry in the spring to respond well to tillage, it may be irrigated, but this irrigation must be given early. Usually irrigation will not be required before seeding, but when necessary it should be given before the seed-bed is finally prepared, since it enables the farmer to make a much finer, more moist, and better bed for the germinating seed.

Definite directions cannot be given regarding the implement to use. The tool that does the best work is the one to employ. The nature of the soil will determine

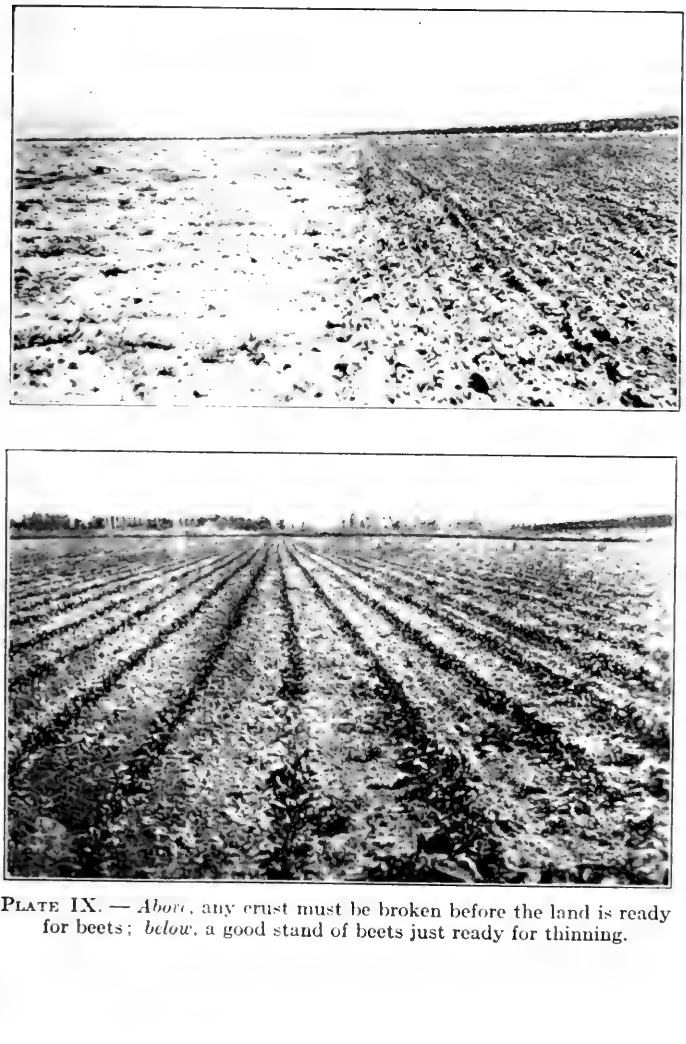


PLATE IX. — *Above*, any crust must be broken before the land is ready for beets; *below*, a good stand of beets just ready for thinning.

whether disk harrow, spring-tooth harrow, spike-tooth harrow, float, or roller should be used. Often a combination of several of these implements is required to secure satisfactory results.

It must be remembered that the young beet seedling is extremely tender, and too much care cannot be given to prepare the land for its initial growth. Thorough disking, harrowing, and floating are the successive steps usually followed. The float may often be followed to advantage by some implement to firm the soil just below the surface, for sugar-beet seed is not planted deep. A number of good implements are available for this firming. Finally, a light harrowing makes a thin surface mulch and kills the weeds that are newly germinated. The weed problem must be kept definitely in mind in this final preparation, because if all the weeds are not killed about the time the beet seed is planted, they will get ahead of the beets and cause much trouble. Weeds are most easily killed just when they are starting. The land cannot be harrowed after the beets are planted; and by the time they are high enough to cultivate, the weeds may have a good start.

Rolling the land is often practiced to make the surface smooth and to break clods. Compacting the surface soil with the roller increases capillary movement toward the surface, thereby hastening the loss of moisture. The fact that the soil seems more moist after a roller is used often misleads farmers into thinking they are actually saving water. Probably the farmer is, under certain conditions, justified in sacrificing part of the moisture in the soil in order to secure a better germination than is likely to follow compacting the soil around small seeds. If the land were compact in its original unplowed condition, the loss of moisture would result without the benefits of placing the seed in close contact with a firm soil.

THE SEED

With no crop is greater care necessary to secure good seed than with beets. It is so highly important that the sugar companies have taken the matter in hand and furnish seed to all farmers contracting to raise beets for them. Beet seed to be good must have the proper breeding; its sugar-producing quality must be up to the standard by actual demonstration. This is a matter that cannot be guessed at by the seed grower; he must know just what the seed will do. The seed must be up to standard in power to germinate, since poor germination means a poor stand and this is a serious matter for the sugar-beet grower. The seed should have a bright appearance; if it is dark colored, it may have been wet and the germinating power thereby reduced.

A number of treatments to improve germination have been tried with varying success. Treatment with sulfuric acid increases germination, but the trouble and expense of this treatment will probably prevent its general use. Scarifying the seed with a special machine hastens the germination of hard seeds, but this is not widely practiced. For the present, the farmer's effort should be centered on securing good seed instead of trying to revive poor seed by special treatment. A fuller discussion of the seed question is given in Chapter XV.

TIME OF SEEDING

The date of planting seed varies with the region and with the season. In the Mississippi Valley and the East, the time of planting is between April 1 and June 1. In Colorado, Utah, Montana, Wyoming, and Idaho, it is two or three weeks earlier. Adams [1] gives the time for planting in California as follows:

Sacramento and San Joaquin Valleys	January 15 to March 15
Southern California	October 1 to April 1
Central Coast Counties	February 1 to June 1

In most regions the season of planting is late March, April, and early May. Seeding time should not be determined by the calendar, but by soil and weather conditions. The soil should be warm and moist and the period of severe frosts should be past.

Early seeding has many advantages and some drawbacks. If the seed is planted early and for any reason the stand is poor, there is still time to re-seed. There is also the advantage that the young plant can use the early spring moisture to germinate and get up before hot weather causes a crust to form. If seeding is done too early, there is danger of the seed remaining in the cold soil so long that it rots before there is sufficient heat to germinate.

In some localities the time of planting is determined by seasonal winds which dry the land and cause it to crust or in other ways injure the newly planted seed or the seedling. Dates of planting must be chosen so that the seedlings will not be at a critical stage during the season when regular unfavorable winds occur.

[1] Adams, R. L., *Calif. Exp. Sta., Cir. No.* 160. 1917.

METHOD OF PLANTING

(Plate X; Fig. 10)

The distance between rows varies from eighteen to thirty inches; twenty inches is the ordinary distance. If land is poor or if water is scarce, the beets must be planted farther apart or they do not continue a vigorous

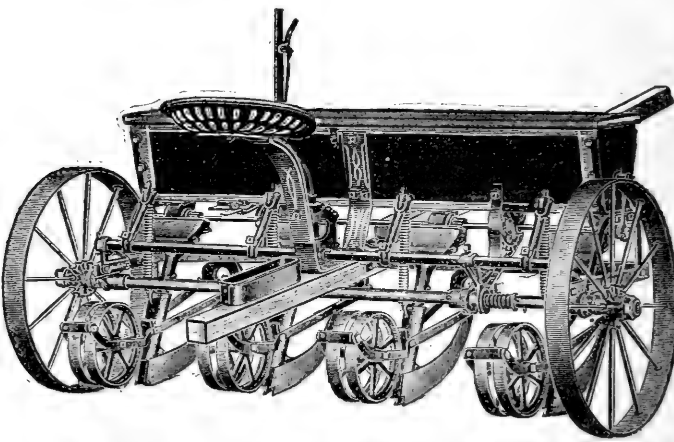


FIG. 10. — Four-row beet seeder. Rear view.

growth throughout the season. Under any conditions the rows must be far enough apart to permit horse-drawn cultivators to go between them. In each locality the distance is usually uniform in order to allow an interchange of machinery. Tillage implements are made to cultivate a number of rows at a time; consequently, the spacing should be regular.

The amount of seed planted varies from about twelve

PLATE X. — *Above*, (Courtesy Truman G. Palmer) planting sugar-beets, Colorado; the extending arms are used as markers; *center*, (Courtesy Union Sugar Co.) two engines with connecting cables pulling machinery in beet fields, California; *below*, (Courtesy Facts About Sugar) cultivating and hoeing sugar-beets, Iowa.

to twenty pounds to the acre. More seed is required if the land is not in a condition to hasten germination. The size of seed also affects the amount to be used. It is poor economy to save unnecessarily on beet seed, since a good stand is so indispensable to a good yield. For the average soil that has been well prepared, about fifteen pounds of average seed to the acre gives excellent results.

The depth of planting is very important. It is easy to plant the seed too deep and thereby to reduce its vitality. The seed of the sugar-beet has little food stored in it. If it is planted deeply, this reserve is used up before the plant is able to manufacture its own food. The depth of moisture necessary to germinate the seed must also be considered. Seed planted in dry soil will not germinate, and it is better to have a plant that is weak due to deep planting than to obtain no plant at all, because of planting in dry soil. Usually seed is planted between three-fourths of an inch and one and a half inches deep. If the condition of the soil permits, shallow planting is to be preferred. This is particularly true on heavy land that is likely to crust.

Many types of beet drills are on the market. No type is best for all kinds of soils. In some cases the seed is planted one seed in a place and scattered regularly along the row. In some sections a type of drill that drops the seed in hills to facilitate thinning is finding favor.

THE STAND

A good stand of beets is so important that every means should be used to secure it. If, for any reason, the first seeding does not produce a uniform stand, it is often desirable to re-seed. It may be that the crop will have to be planted several times. One of the chief causes of a poor stand is a crust which forms at the surface after the seed is planted and before it comes up. If the seeding is light, the single plants may have difficulty pushing through, whereas a heavier seeding would place several plants near each other and together they could break through the crust.

Many kinds of mechanical devices are used to break the crust. The roller is often employed. A very effective implement consists of special wheels running directly over the rows. These have spike points or knives which penetrate the crust sufficiently to enable the tender plants to come through without disturbing the soil enough to injure the seedling.

CHAPTER IX

CULTURAL METHODS

THE acre-yields of sugar-beets are lower in America than in the European countries, largely because cultural methods here are not so thorough. The higher price of hand labor, together with the availability of land, has made the American farmer less inclined to give to his farming operations the painstaking care necessary for high yields. This condition made him slow to take up beet-raising in the first place, and it makes him remain a little behind the European farmer in the care he gives to the crop. In regions in which sugar-beets have been raised longest, farmers are learning that they are well repaid for the extra work they give to the beet crop. They are finding that for every dollar spent on better culture, they may obtain several dollars in return. The operations deserving most attention in this connection are thinning and cultivation. The practices are suggested in Plate X, and in the test figures.

THINNING

(Plate XI)

Preparation for thinning.

The first requisite to good thinning is an even stand of beets. If this can be secured from the first seeding, so much the better; but if not, re-seeding should be resorted to. A satisfactory crop cannot be raised if only half the beets come up. In some soils no treatment is necessary from the time the seed is planted till the beets are ready to thin. In some sections, however, it is advisable to roll the land soon after the beets come up and before they are thinned. Some disagreement exists as to the value of this rolling, but many farmers believe it to be of decided benefit on some soils.

The practice of beginning cultivation as soon as the beets are up enough to show the rows has many advantages. It helps to conserve the moisture; it keeps in check weeds that come up so abundantly at this season of the year; it gives to the rapidly-growing young plants the supply of air needed by their roots; and it facilitates thinning.

Blocking and thinning.

No operation in the entire process of beet-raising is more important than thinning. Losses resulting from poor thinning are not easily apparent; for this reason the danger is greater. At the time the beets are thinned, the farmer is rushed with other work, and since this operation is very slow and tedious, the tendency is to hurry over it. If each farmer could perform his own work, sufficient care would probably be taken, but most thinning is done by contract labor or by children, and as a result it is usually far from perfect.

When the work is contracted, at least part of the pay should be based on the acre-yield of the crop instead of entirely on the area thinned. When a flat rate for an acre is paid, it is difficult to secure satisfactory work. When

PLATE XI. — *Above*, thinning sugar-beets, Utah (Photo by U. S. Dept. of Agr.); *below*, cultivating young beets; continual cultivation is necessary for the best growth of beets.

children are employed, careful supervision is necessary, since they do not realize the difference in yield resulting from careful and slovenly work.

Beets should be thinned about the time they have four leaves. Before this time, it is impossible to tell which will be the strong plants. Later, the shock to the plants that are left is so great that they do not easily recover. Much more damage is done by leaving beets too long before thinning than by thinning them too early. When the farmer has a large acreage, he must begin a little too early and continue a little too long in order to thin most of the plants when they are the proper size. Planting on two or three dates is necessary with large acreages in order to make thinning at the proper time possible.

The distance apart to leave plants depends on a number of conditions. If the land is rich, the beets may be closer together than if it is poor. If the season is short, they may also be left closer in order to hasten an early maturity. Under some conditions, the highest yield and sugar-content are obtained where the beets have from 144 to 160 square inches of surface to the plant. With the rows twenty inches apart, the plants would be about eight inches apart in the rows. This would give 39,200 plants to the acre. If the beets weighed one pound each, a perfect stand would give a yield of 19.6 tons to the acre. In some places the beets are left as much as eighteen inches apart, but so great a distance usually results in a decreased yield. In a few places where the beets grow exceptionally large, this distance may be justifiable.

When the beets are close together the yield may be higher, but the extra work of handling the smaller beets often makes the farmer satisfied with the lower yield. The whole question of distance of spacing is so much dependent on local conditions that the farmer is safer in following local practice than any general advice. It is probable that the distance is more often too great than too small, since in thinning more ground can be covered if the beets are far apart and the tendency is to stretch ten inches to twelve or fourteen. Under average conditions, from ten to twelve inches is about the correct distance.

After deciding on the time to thin and the distance between beets in the row, the next thing is a sharp hoe with which to do the blocking. This is accomplished by cutting out all plants in the row except bunches that are left as far apart as the beets are to grow. From these bunches all plants but one are removed. In blocking the beets, it is well to lay out a strip of land containing sixteen to twenty rows and proceed much as in plowing the land so as to leave a back furrow with soil hoed from the furrow as seldom as possible. Later in cultivating the rows with the back furrow, the soil and clods are thrown on the young plants and may injure them. Expert blockers with the right kind of hoe can make the proper width with a single stroke.

Next comes the tedious process of thinning (Plate XI), in which all the plants except one are removed from the bunch. In every case the most vigorous plant in the bunch should be left. Experiments have shown an appreciable difference in yield where a comparison was made between leaving the weak and the strong plants. If two beets are left at a place, each interferes with the other, producing two under-sized and undesirable beets at harvest time.

Losses from poor thinning.

The United States Department of Agriculture,[1] as a result of three years' experiments carried on in Utah, showed the importance of having a good stand. The differences in treatment were hardly noticeable by a casual observation, but were easily seen when actual measurements were made. Although the beets were considerably larger where the stands were thin, the extra size did not nearly make up for the thin stand; the correlation between stand and yield was remarkably close. Poor stands were almost entirely due to careless thinning, spacing, hoeing, and cultivation. Leaving the beets in pairs had a bad effect on the yield. Planting deeper than is customary resulted in more damping-off in the young beets and consequently in a poorer stand.

The loss in stand before thinning was over 19 per cent, that during thinning over 21 per cent, and the loss between thinning and harvest almost 7 per cent, or a total of 47.55 per cent loss in stand, so that the average showed only one beet to every 16.4 inches. Some farmers who were able to maintain a stand averaged a beet to each ten to twelve inches in the row. These farmers harvested a crop not only larger in proportion to the better stand, but the beets with a thicker stand averaged higher in sugar. When the stand at harvest was 76.8 per cent perfect, the yield was 30.5 tons to the acre; when it was

[1] Shaw, H. B., *Dept. of Agr., Bul. No.* 238. 1915.

60.3 per cent perfect, 17.2 tons; and when but 29.6 per cent perfect, 10.3 tons to the acre.

In addition to the losses in stand due to poor cultural methods, there were losses caused by imperfect germination which might be attributed to the following causes: poor preparation of seed-bed, imperfect operation of seed drills, late frosts, damping-off disease, blowing of light sandy soils, flea-beetles, cutworms, and wireworms.

Losses due to delayed thinning are shown from the following yields obtained in Germany:

Time of Thinning	Yield — Tons	Loss at $5 a Ton
At proper time	15.0	$ —
One week later	13.5	$ 7.50
Two weeks later	10.0	$25.00
Three weeks later	7.0	$40.00

HOEING

Two hoeings by hand are usually required; three are sometimes necessary. This is the chief item of expense after thinning and topping. Much depends on hoeing at the proper time in order that weeds do not get started and take the nourishment and moisture that are needed by the young beet plant. It is likewise important that the hoeing be thorough. This is much more important for sugar-beets than for a crop like corn that grows rapidly and soon shades the weeds. In the beet field it is the weeds that do the shading. Hoeing is often contracted in connection with thinning. This is very satisfactory since it

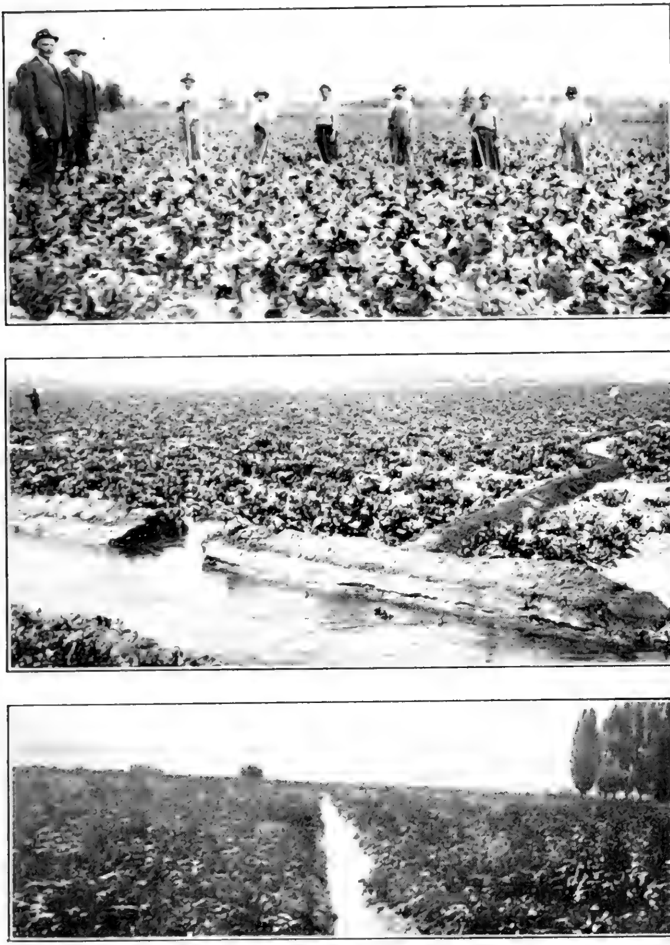


PLATE XII. — *Above*, (Courtesy Facts About Sugar) hoeing sugar-beets, Michigan; *center*, (Courtesy Union Sugar Co.) irrigating sugar-beets, California; *below*, ditch used to sub-irrigate beets; this method of irrigation is used rather extensively in parts of California and Utah.

gives opportunity to require a re-thinning when the work was done carelessly the first time.

CULTIVATING

As previously stated, cultivation should begin as soon as the rows can be seen and should be continued till the

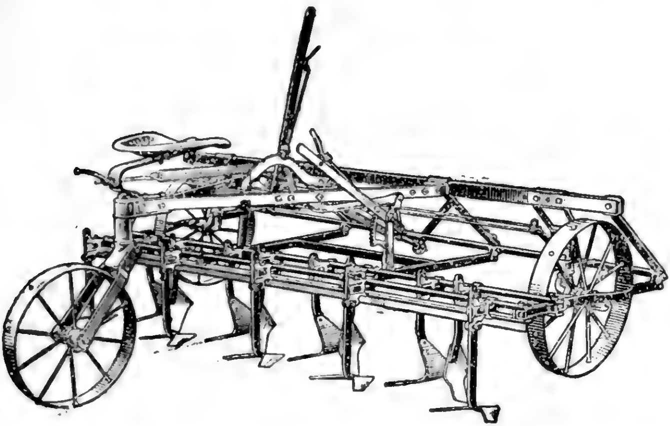


Fig. 11. — Four-row beet cultivator with pivot axle and frame leveling lever.

leaves become so large that they are injured by the cultivator. Probably the most important single cultivation is that given immediately after the beets are thinned. If properly done, it enables the young plants to revive better from the shock they receive when their companion plants are removed and the soil is moved away from their roots. Under ordinary conditions the cultivations will be repeated about every ten days. This time may, however, be modified somewhat by rains or by irrigation.

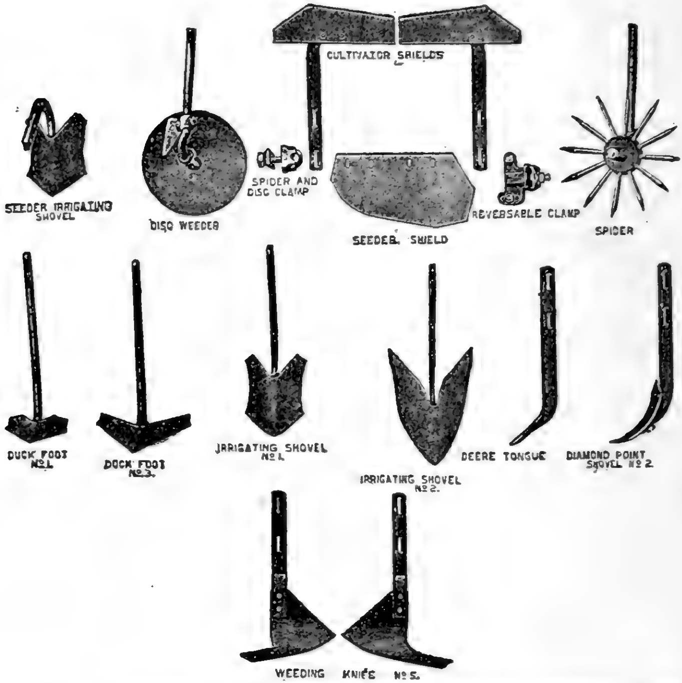


Fig. 12. — Cultivator attachments to be used at different stages in the growth of the beet.

Several good cultivators are on the market. These provide a number of attachments, varying from the "spider" to the weeding knife, to be used at different stages in the growth of the crop and for different conditions. Two-rowed and four-rowed cultivators are both employed. The larger one is used almost exclusively for the larger acreages. Plates XI and XII and Figs. 11 and 12 indicate some of the methods.

Specific directions as to just when and how to cultivate are almost useless, since practices vary so much with conditions. The best method is the one that will most surely accomplish the ends sought: the aërating of the soil, the conservation of moisture, and the control of weeds. Each one of these would be enough to justify frequent cultivation; combined they make it imperative. Few farmers cultivate too much; many cultivate too little. A crop may be raised with very few cultivations, but every time the soil is properly stirred the yield of beets is increased. Just before the leaves cover the ground, the final cultivation should be given and it should be thorough but not deep.

CHAPTER X

IRRIGATION AND DRAINAGE

THE sugar-beet plant responds readily to a favorable moisture condition in the soil. It cannot be classed as either drought-resistant or a water lover; it requires an intermediate amount of moisture similar to that demanded by such crops as potatoes and the grains. The amount of labor expended on a crop of beets is so great that every effort should be made to maintain the most favorable moisture-content in the soil in order that the yield of the crop may justify the expense necessary to raise it. The practical methods of affecting the soil moisture are by irrigation water where the rainfall is not sufficient, and by drainage on land that is too wet.

IRRIGATION

(Plates XII, XIII; Figs. 13–22)

Beets adapted to irrigation farming.

Most of the sugar-beets raised in America are produced with the aid of irrigation water. Michigan is the only important beet-producing state in the United States that is not in the irrigated region. The beet-sugar industry was started in the humid part of the country, but it made no great success till it was carried to irrigated lands. The yield of beets is greater under irrigation than where water is not supplied. This is probably because irrigation makes possible the maintaining of a more desirable moisture-

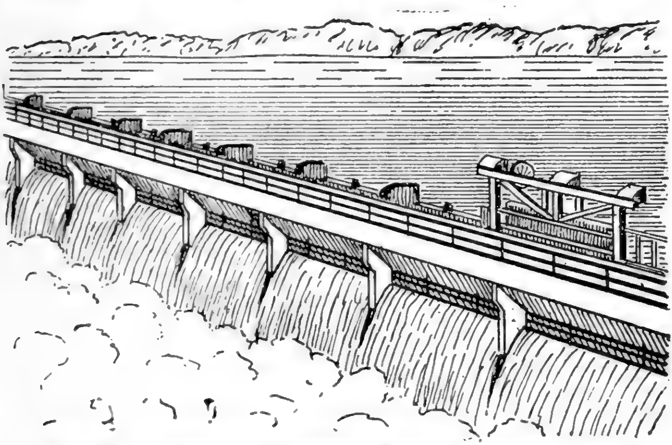


Fig. 13. — Reservoir for irrigation water, and diversion dam.

content in the soil than can be relied on from the rainfall alone.

Sugar-beet culture is adapted to intensive farming on account of the great amount of man-labor that must be spent on each acre in thinning and harvesting. This condition fits well into the small farms of the irrigated district.

Sources of irrigation water.

The most common and least expensive source of water for irrigation is found in running streams. A suitable dam is placed across the bed of the stream to turn water into the canal which carries it to the land to be served. The head of such a canal is sometimes many miles from the farm; at other times the land to be irrigated is along the banks of the stream.

When irrigation water is secured directly from a river, only part of the water can be used, since the irrigation season occupies but a few months out of the year, whereas the stream flows continuously, often having its greatest flow when the water is not being utilized. In order to make more water available, storage reservoirs are built. These receive the water at times when it is not being used and hold it until the irrigating season. As more land is farmed and as water becomes less plentiful, increased provision for storage is made.

The pumping of water for irrigation from wells and ponds is increasing rapidly. The depth from which it can be pumped economically for beets depends on the expense of fuel, or power, and a number of other factors. Many beets are raised with water pumped from a depth of fifty feet; and in some cases a part of the water used for beets is pumped more than one hundred feet.

Measurement of water.

Irrigation water, as well as land and crops, should be measured. In the past, guessing at the amount of water used has been more common than making accurate measurements. This has led to endless disputes and trouble concerning water rights. In the future, those concerned with the use of water will need to be familiar with methods of making measurements and expressing quantities. This will be especially true on sugar-beet farms where land and water are usually high-priced.

The two principal devices for measuring flowing water are the weir and the current meter. With the former, a measuring gate of known size is placed in the stream and the height of water flowing over it determined. From standard tables the discharge is found. When the current meter is used, the velocity of the stream-flow is obtained, together with its cross-section; from these the amount of water is calculated.

Of the many methods of expressing quantities of water, the ones in most common use are the second-foot and the acre-foot. A second-foot represents one cubic foot of water flowing each second. An acre-foot is the amount of water required to cover an acre of land one foot deep, that is, 43,560 cubic feet. A second-foot flowing for twelve hours will flow almost exactly an acre-foot. If a weir is placed in the ditch, it is very easy to compute the depth of water applied at each irrigation.

Preparing land for irrigation.

Considerable care should be taken in preparing land for irrigation. This often calls for a great expenditure of money to make smooth a surface that is rough and to give a uniform slope to the land; but since a single leveling will serve for many years, the expenditure is usually justified. Too often farmers, not wishing to spend so much money during any one season, leave the land uneven year after year, and as a result each crop is diminished. It may be that the loss each year would not be sufficient to pay for grading the land, but many years would not be required to do so.

Losses result from an uneven soaking of the land in which the beets on low places receive more water than they need before those on the higher land have received as much as they should have. Scalding of plants on the lower spots, due to their being covered with water, is not uncommon. Excessive slope to the land should be avoided; more than five feet fall in one hundred will result in considerable washing.

Methods of irrigating beets.

Although check and border irrigation is used in parts of California and in a number of other sections to a less extent, most of the beets in the country are irrigated by the furrow method. In a few sections sub-irrigation is practiced. The checks are usually rectangular in form and not larger than an acre in extent; a half acre is better. The checks near the head of the ditch are filled first and the water is moved from one to the other in regular order. The levees are seeded with the remainder of the field, but the beets planted here have less moisture than the others. Care must be exercised in irrigating by this method not to scald or to drown the beets.

In furrowing out the beet field for furrow irrigation, several implements are used. Each community has its preference for some special implement. The main thing is to be able to make a good, clean, smooth channel. With the proper implement five to ten acres can be prepared in a day by one man and team.

The permanent field laterals should be arranged so as to allow the freest preparation and cultivation of the fields without interference. By making the field laterals conform to the contour of the land, the water may be distributed evenly through the furrows. On light soil difficulty is likely to be experienced with the banks' cutting, causing more water to run down one furrow than another. When this difficulty occurs, some form of permanent outlet may be provided to advantage. This insures fairly even streams. In many places small lath or galvanized iron tubes are put through the bank at the head of each row. These are long enough to protrude a little on both sides of the bank. Though these tubes are often helpful, they are not without objections. In a heavy soil devices of this kind usually are not required.

To run water the entire length of a long field is a mistake even where the slope of the land permits. On flat fields, cross ditches usually should be not more than two or three hundred feet apart; even on sloping ground the distance should rarely exceed five hundred feet. Waste ditches at the bottom of the land should always be provided, in order that use may be made of all the water that does not soak into the land. Allowing water to go to waste where it does no one good, but causes injury, cannot be condemned too strongly.

When sub-irrigation is practiced, water is allowed to stand in deep ditches from which it soaks laterally till all the land is moistened. This method can be used only where a rather open surface soil covers a layer that prevents the water from percolating rapidly. Where these conditions prevail, sub-irrigation offers an ideal method of applying water.

Water requirements of beets. (Plate XII)

The amount of irrigation water required to produce a maximum crop of beets varies with the sunshine, wind, rainfall, type of soil, and a number of other factors. It is impossible, therefore, to say that any given amount of water should be applied.

Widtsoe [1] and his associates working at the Utah Station found that on a gravelly loam from twenty to twenty-seven inches of water gave higher yields than either more or less. On a deep fertile soil there was an increase in yield with increased application of water up to fifty inches. There was a gain of nearly five tons to the acre when the amount of water was increased from five to ten inches, but when more than ten inches were given, the increase in tonnage was slight. One acre of land with thirty inches of water applied produced 20.28 tons, but when this amount of water was spread over six acres of land it gave a total yield of 82.68 tons.

Investigations carried out in Colorado by Mead [2] and his co-workers, covering twenty fields irrigated in the usual way, showed that the average amount of water applied during the season was 15.6 inches. Most farmers irrigated from one to four times with about 5.8 inches to the application. The same investigations showed that for Montana and Arizona the irrigation season lasted from July 13 to August 17, during which time an average of 25.8 inches of water was applied.

Roeding,[3] from experiments in Colorado, concluded that a higher yield to the acre was produced from about 11.3 inches of water applied in two irrigations than from

[1] Widtsoe, J. A., *et al.*,*Utah Exp. Sta.*, *Buls. Nos.* 80, 116, 117, 118, 119, and 120.

[2] *U. S. Dept. of Agr.*, *Off. Exp. Sta.*, *Bul. No.* 158.

[3] Roeding, F. W., *U. S. Dept. of Agr.*, *Farmers' Bul. No.* 392.

larger quantities in three or four irrigations. Irrigating every row was found to be much superior to running the water down alternate rows. Keeping the soil constantly wet was also found to be detrimental to the crop. Beckett,[1] in California, ascertained the yield of beets to increase with the increase of water. This was, however, affected by the time of planting.

The author [2] determined that when weekly irrigations were given, one inch each week gave a higher yield than when more was given. These results are shown in Fig. 50. It will be noted from the variation in the water requirements of beets under different conditions that it is impossible to give a definite duty of water for beets under all conditions.

Time to apply water.

No set rule can be given as to the time to irrigate beets, except to say that when the land becomes too dry for favorable growth, it is time to add water. This condition will come at different times in the life of the plant under different conditions.

McClatchie,[3] working in Arizona, found that if seeding was done during the cool part of the year, the crop needed no irrigation for a month or so after planting, but if grown during the time of warm weather of early fall, it needed frequent watering till the weather became cool. If the beets were planted in the warm spring weather, irrigation was necessary during the entire period of growth. Where

[1] Beckett, S. H., *U. S. Dept. of Agr., Bul. No.* 10.

[2] Harris, F. S., *Utah Exp. Sta., Bul. No.* 156.

[3] McClatchie, A. J., *Ariz. Exp. Sta., Buls. Nos.* 31 and 41.

the land was so dry as to necessitate irrigating the seed-bed, it was judged better to irrigate before seeding than immediately after.

Knight,[1] in Nevada, concluded that "fall-plowed land sometimes requires an application of water before seeding," but a poor stand generally results from an irrigation immediately after planting. Where spring watering is necessary, it should be done as early as possible, and when the land is sufficiently dry, should be deeply cultivated. He found that where beets received no irrigation until they failed to revive at night from the wilting of the day, an unsatisfactory crop resulted.

Knorr,[2] at Scottsbluff in Nebraska, secured the best results when beets were irrigated at such times as to keep the plants in good growing condition from the time of thinning until about three weeks before harvest. The irrigations should be in moderate amounts and the soil never so dry that the plants suffer for lack of moisture. He found it desirable to cultivate the beets to break the crust by irrigating as soon as the soil became dry enough. Sugar-beets receiving three irrigations during the growing season gave a yield of 1.6 tons to the acre more if they also received an irrigation the previous fall, than those receiving water only in the growing season.

The author,[3] in order to determine the critical periods in the life of the sugar-beet for water, divided the life of the plant into four stages of growth and added water in

[1] Knight, C. S., *Nev. Exp. Sta., Bul. No.* 75, and *Ann. Rpt.* for 1915.

[2] Knorr, F., *Neb. Exp. Sta., Bul. No.* 141.

[3] Harris, F. S., *Utah Exp. Sta., Bul. No.* 156.

five-inch irrigations to these various stages both singly and in various combinations. The results are shown in Fig. 15, which gives the average yield of roots and tops for the various treatments. The lowest yield was obtained when the land was irrigated after the seed was planted and before it came up. The yield with this treatment was decidedly less than it was when no water was given.

Comparing the various periods in which but one five-inch irrigation was given, it will be seen that the third period, when the beets averaged two inches in diameter, was the most favorable; the last period, when the beets were nearly ripe, was the least favorable. The second period was decidedly more favorable than the first. It will be noted further that the yield of tops was greatest with the very late irrigation. This means that the farmer by looking at his beet field will doubtless be deceived into thinking that the very late irrigation is increasing his yield much more than it really is.

Upon examining the plants receiving two, three, and four irrigations, the greater value of irrigation water during the third stage is clearly evident. The highest yield was received where a total of fifteen inches was applied. It will be remembered that in the weekly irrigations a higher yield was obtained for 12.8 inches than for 32 inches. It seems, therefore, that the total requirement of sugar-beets for irrigation water is not large, but that the period of application is important.

The old ideas, that it is necessary to withhold water until the beets suffer before giving the first irrigation and that irrigation should be discontinued five or six weeks before harvest, have been proven to be false. If the plant suffers for water either early in the season or late, the yield of the crop will be reduced. The soil auger will be found valuable in determining the moisture condition of the subsoil, and will thereby assist the farmer in judging when to irrigate.

Size of irrigation.

The amount of water to apply in each irrigation is a subject of constant discussion among irrigators, who seem unable to come to any definite agreement. This must

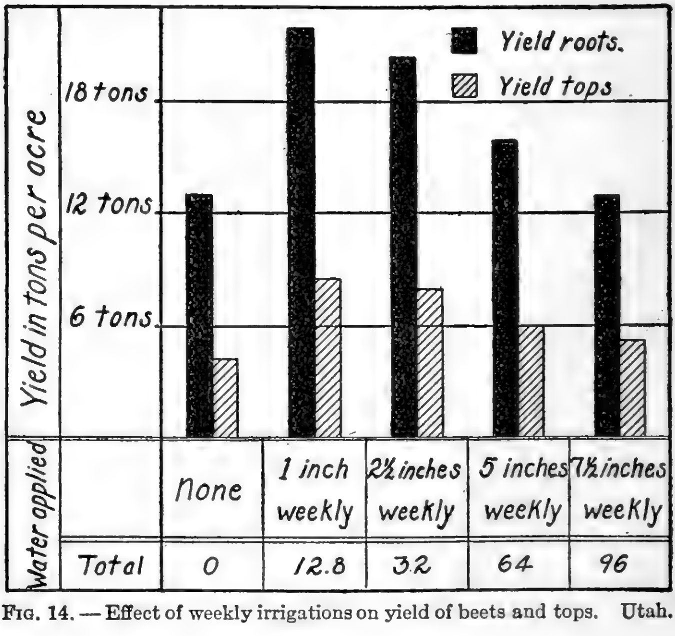


FIG. 14. — Effect of weekly irrigations on yield of beets and tops. Utah.

vary with a number of factors, the most important of which are the depth and texture of the soil. A light irrigation of one to two inches would be ample for a shallow sandy soil, whereas five or six inches might well be given a deep loam or clay. It must be kept in mind that the beet is a deep-rooted plant and that sufficient moisture should be added to moisten the land as deeply as the roots penetrate. Where the soil is suitable, a few rather heavy irrigations have given better results than many small ones. The reverse is true for potatoes.

Relation of irrigation to size, shape, and quality of beets. (Figs. 14–21.)

Many tests have been made to determine the effect of irrigation water on the nature of the beets. These tests

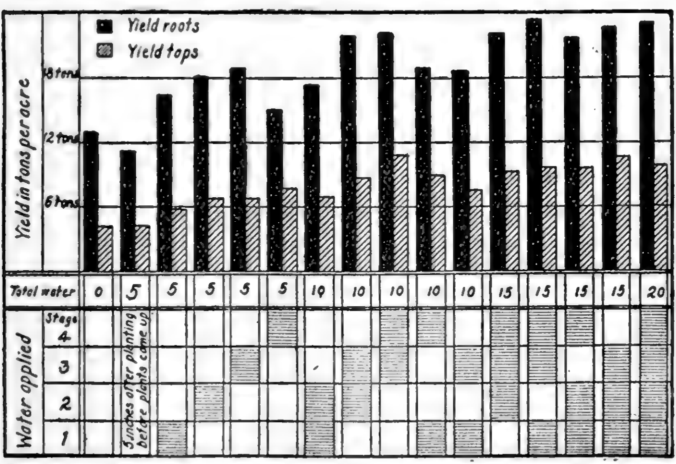


FIG. 15. — Effect of irrigation at different stages on yield of beets and tops. Utah.

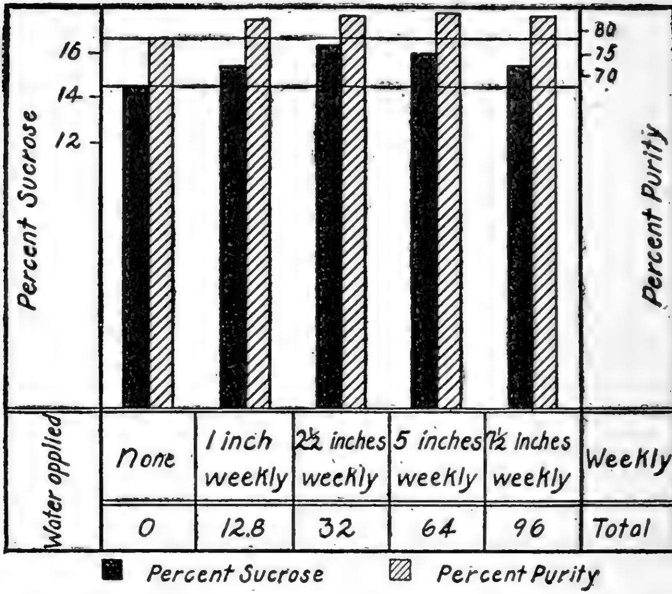


Fig. 16. — Effect of weekly irrigations on percentage of sucrose and purity. Utah.

have given rather conflicting results. Observations by Schneidewind [1] and others in Germany in the period from 1896 to 1906 showed that, although the yields are smaller, root crops are richer in carbohydrates and protein in dry years than in wet ones; hence the net influence of weather is not so great as it is ordinarily thought to be. High-bred, resistant strains showed less variation in dry and wet years than did common varieties.

[1] *Landw. Jahrb.* 36 (1917), *No.* 4, pp. 474–581.

Widtsoe and Stewart[1] found that although there was only a slight increase in the percentage sucrose with the water applied up to thirty-five inches, the percentage of carbohydrates increased with increased quantities of water used. Starch and cellulose, therefore, increased with heavier applications. The application of fifty inches in every case decreased the sucrose-content. The purity was lowest with the smallest quantities of water and was highest with intermediate applications up to twenty

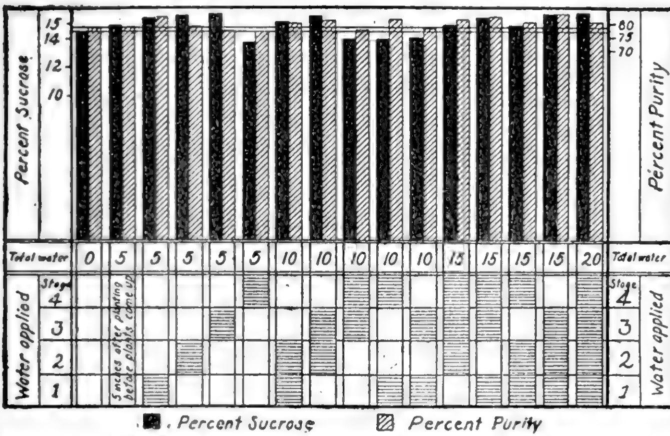


FIG. 17. — Effect of irrigation at different stages on percentage of sucrose and purity. Utah.

inches. The percentage of sucrose and the purity were higher in October than in September.

Investigations made by the author[2] on the effect of irrigation water on the quality, size, and shape of beets

[1] Widtsoe, J. A., and Stewart, R., *Utah Exp. Sta., Bul. No.* 120.
[2] Harris, F. S., *Utah Exp. Sta., Bul. No.* 156.

are illustrated in Figs. 16 and 17. In Fig. 16 both the percentage sucrose and the purity are shown to be some-

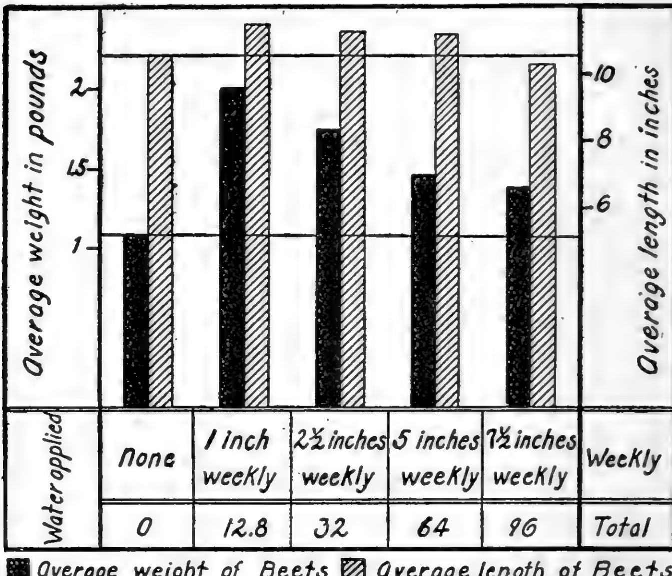


FIG. 18. — Effect of weekly irrigations on average weight and length of beets. Utah.

what higher in all the beets that were irrigated weekly than in those receiving no irrigation. The highest sugar-content was in the beets receiving two and one-half inches of water each week. Figure 17 indicates the lowest sugar-content, as well as the lowest purity, to have been produced on the plat receiving water only when the beets were approaching maturity. The highest sugar-content with a single irrigation was in the beets irrigated when about two inches in diameter.

The average weight of beets under the different treatments is given in Figs. 18 and 19, which show that the size of beets follows closely the relationships that have already been pointed out for yield. This was to be expected, since the stand on all plats was practically the same in the spring and yield was largely, but not entirely, an expression of size. The size of beets irrigated only at the fourth state was proportionately smaller than the yield would indicate.

The length of beets is also given in Figs. 18 and 19. Figure 18 illustrates that when seven and one-half inches of water were given each week, the length of beets averaged slightly less than those receiving no water. The longest

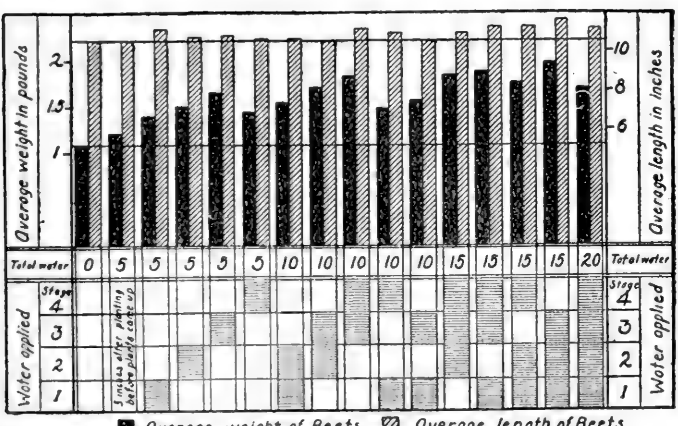


FIG. 19. — Effect of irrigation at different stages on average weight and length of beets. Utah.

beets under the weekly irrigations were produced by one inch of water each week, but the differences due to the treatments were very slight.

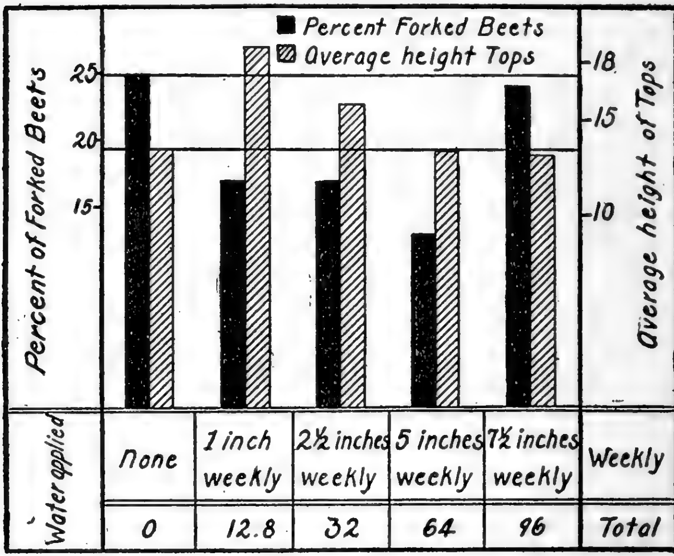


FIG. 20. — Effect of weekly irrigations on percentage of forked beets and height of tops. Utah.

Figure 19 shows that five inches of water applied at any period made the beets longer than those that were not irrigated. The longest beets were those irrigated at the first three stages. The very late irrigation had but little effect in lengthening the beets.

There is a popular idea among farmers that the first irrigation should be delayed just as long as possible in

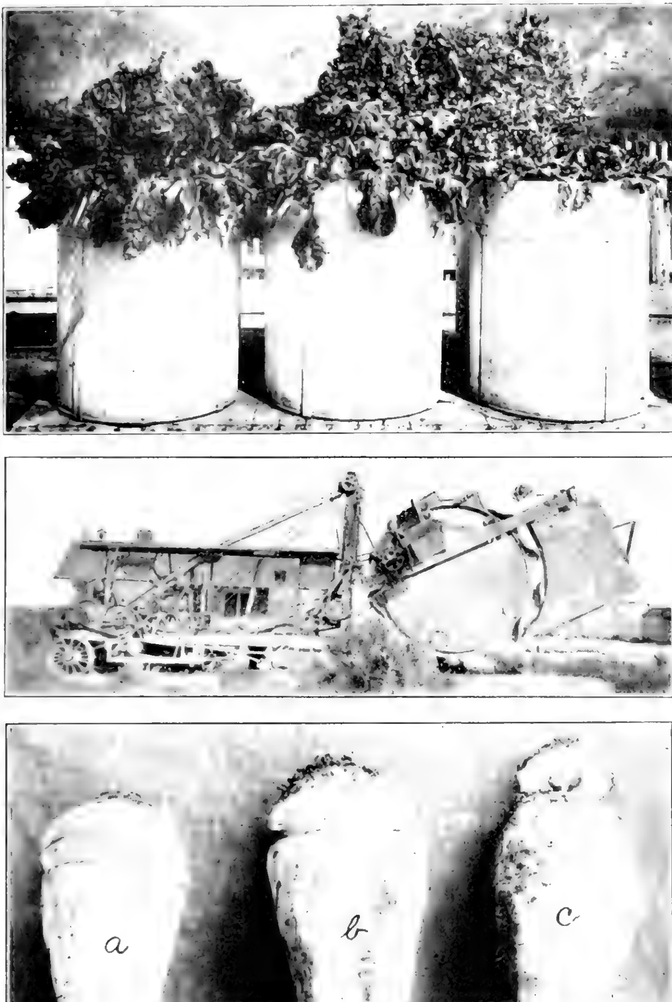


PLATE XIII. — *Above*, tanks used in determining the amount of water used by sugar-beets, Utah; *center*, machine for digging drain ditches; much drained land is planted to sugar-beets; *below*, (*a*) topped too low, (*b*) topped at proper place, (*c*) topped too high.

order to induce the beets to go deeply into the soil. In order to increase length, some farmers even allow their beets positively to be injured by drought before applying water. The results reported here, which represent many thousands of careful measurements during five years, show that this idea is wrong. In the ordinary good beet soil that is well-drained, an irrigation does not decrease the depth of penetration of beets; it rather assists them to go deeper. Of course this does not contradict the well-known fact that beets are likely to be shorter on a soil that is water-logged, such as that in which a total of 96 inches of water was applied. In view of these experiments, it seems folly to let beets suffer for water and be injured permanently in order to make them root deeply.

The percentage of forked beets is shown, by Figs. 20 and 21, to bear no consistent relationship to the amount

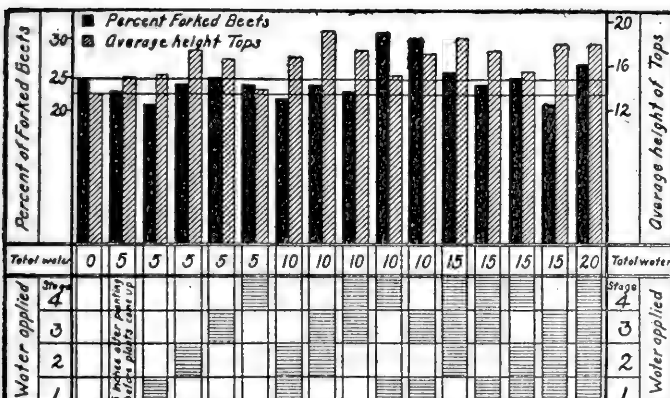


FIG. 21. — Effect of irrigation at different stages on percentage of forked beets and height of tops. Utah.

of water or to the time of application. In the weekly irrigation tests, the beets that were not irrigated had the largest number of forked roots, whereas in the plats that had water applied at different periods, the plat receiving water only at the first stage had the least number of forked roots. The greatest number was on plats irrigated early and late. The differences, therefore, are not consistent and the idea that any method of irrigation greatly increases the tendency toward forkedness seems unwarranted.

An examination of Figs. 20 and 21 for the effect of treatment on the height of tops reveals a rather close relationship between this and the yield of tops, but not the yield of beets, which has already been discussed in connection with Figs. 14 and 15.

DRAINAGE

Reasons for drainage. (Fig. 22.)

Many millions of acres of land in the United States contain so much water that crops cannot be raised successfully. Part of this land is in permanent swamps; some of it is dry during a part of the year, being water-logged only at certain seasons. Much land, having a dry surface appearance, contains ground-water so near that roots cannot penetrate to any great depth. The chief difficulty in the way of successful agriculture in all such places is the surplus of water. The only way to make this land suitable for crops is to drain it.

In most arid regions, much of the land contains a high percentage of soluble salts. These often accumulate near the surface in such large quantities that the growth of plants is prevented. Drainage, which gradually removes these salts, is the only method of reclaiming alkali land permanently. Much land that is at present valueless on account of its high alkali-content would be of excellent quality were its excess salts removed. In fact, some of the highest yields of sugar-beets are obtained on land thus reclaimed.

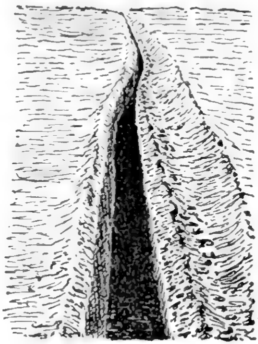


FIG. 22. — Drainage trench dug with a machine. It is ready for the tile.

Effects of drainage.

The drainage of wet land improves it in many indirect, as well as direct, ways. Lowering the water-table gives plants a larger zone from which their roots can draw plant-food and moisture. This lessens the need of fertilizers and the susceptibility to drought. The increased aëration of the soil resulting from drainage promotes the growth of desirable organisms, increases favorable chemical action, and makes the soil a much more desirable home for plants. It warms the soil earlier in the spring, thereby increasing the length of the growing season of crops.

Drainage improves the sanitary conditions of a region by drying the breeding places of disease germs and disease-carrying insects. It lessens the winter-killing of crops by reducing heaving of the soil, and it decidedly improves structure and tilth. All of these benefits working together result in a good net profit in almost every case in which drainage is properly done. It is a common experience that when twelve or fifteen dollars are spent in drainage, the value of the land is increased from twenty-five to fifty or more dollars.

Kinds of drains.

Any one method of drainage is not suitable for all conditions, nor is it always practicable to employ the method that might seem best. The entire set of conditions must be taken into consideration before deciding just how to drain a piece of land. Open ditches are probably the cheapest method of carrying away the water. They are used to advantage in draining ponds and other surface accumulations. The chief advantages of the open drain are: (1) the cheapness with which it can be constructed, and (2) the ease with which it can be cleaned. Some disadvantages are that it renders waste the land occupied and cuts the land area into small fields that are difficult to get at. The open ditches become filled with falling earth and weeds, and are a constant source of danger to farm animals.

Some form of covered drain is usually preferable for ordinary purposes. With the covered drain, a trench is dug and some material that will allow water to pass through is placed in the bottom. This is covered later with earth. Some of the materials used for such drains are rocks, brush, lumber, clay tile, and cement tile. The last two are by far the most common. Where clay tile can be secured, it is recommended under almost all conditions, especially for land high in alkali.

Installing the drainage system.

The first step in draining land is to lay out the system. Some kind of instrument for getting levels must be used to determine the contours and to decide where to place the drain lines. A level is also necessary to find the proper depth for the trenches. After the system is laid out, the ditches are dug either by hand or by machinery. In early days they were practically always dug by hand, but modern machinery now does the work much more cheaply. Tile should probably not be placed nearer the surface than two feet or deeper than six or eight feet except in unusual cases. Usually five feet is a good depth.

The bottom of the ditch should have a uniform grade; otherwise, the flow of drainage water will be uneven and silt will be deposited in low places. In sections where springs of fresh water occur, there is a tendency for roots to clog the drains. They must then be placed deeper than would otherwise be necessary. Care should be taken to have the joints of the tile fit well together to avoid filling with dirt. The work of covering can usually be done with a team and scraper. The outlet should be screened to keep out small water-loving animals, and should be constructed so that it will not be clogged easily. If an extensive drainage system is to be laid out, an engineer should be consulted.

CHAPTER XI

HARVESTING

On the returns of the harvest depend the profits of the year. It is not sufficient to raise a good crop; it must also be gathered and husbanded. The farmer's responsibility does not cease till he has delivered the result of the harvest to the purchaser and secured his pay. It would be folly indeed to take great care in preparing a seed-bed, in planting, in cultivating, in irrigating, and in conducting the other operations involved in raising beets, and then be less vigilant in harvesting the crop. The harvest time is a very busy season and help is often scarce. For this reason, there is a constant temptation to rush the work and thereby to slight it. Giving way to this temptation means the giving away of part of the season's profit.

TIME OF HARVEST

The proper time to harvest beets varies greatly with conditions. In parts of California and in other warm climates, digging may begin early in July and extend for two or three months. In most of the other sugar-beet areas, digging starts in September and continues till the time the land usually freezes hard. The time to begin in any locality will be affected somewhat by the area in beets. If the acreage is large and the mill will have a long run, digging may begin before the beets are entirely ripe in order that the farmers may be able to get all the beets dug before they are frozen in the ground. Since it is impossible to predict the kind of autumn, mistakes are often made in the time to commence digging. For example, in 1916 over some sugar-beet areas the land froze solid very early and thousands of acres of beets rotted in the ground. If this condition could have been predicted, digging would have been started earlier and pushed faster. In 1917 the previous year's record was fresh in the minds of all and probably hastened digging somewhat. As it happened, however, the fall remained open till late and all the beets were harvested before it was necessary.

Beets should usually be harvested when they are mature. This is not an absolutely definite point, but the general condition of maturity can be told rather easily. It is indicated by the browning of the lower leaves and a yellowing of all the foliage. The leaves also lose their vigor and have a drooping appearance. Ripeness is also indicated by the sugar-content and purity, but it cannot be told by analysis alone, since the composition of the beets is variable under different conditions. A beet may be said to be ripe when the foliage has the appearance just described and when analysis shows a satisfactory sugar-content and purity.

The sugar company contracting for beets reserves the right to say when they should be dug. This is necessary in order that the beets may be received regularly during the slicing season and also because the company's agriculturists, aided by chemical analyses, are better able to judge the proper time to dig than the individual farmer, who might allow the date of digging to be influenced more by personal convenience than by the condition of the beets. It is easy for the farmer, desiring to close off his fall work as soon as possible, to make the mistake of digging too early. It is difficult for him to realize that it is during the last few weeks of growth that the greater part of the sugar is stored in the beet, and that the tonnage is also materially increased at that time. During its early stages of growth the beet plant is sending out roots and leaves and most of its food is used in growth. Only when growth is nearly complete is the plant in a position to do any large amount of storing.

Under a number of conditions the beet plant may begin to ripen and store sugar, then later begin another period of growth and the sugar-content be reduced. These conditions are to be avoided. Every effort should be made to keep the plant growing up to the time of final ripening. A period of drought in the early fall may promote ripening; and if followed by warm rains or by an irrigation, the plant may send out new leaf and root growth and use a part of the sugar that has been stored. It is, therefore, a mistake to let the beets become dry any great period before the time of digging. Some of the conditions bringing about this reduction in sugar are beyond the farmer's control, but he should be watchful to make favorable the conditions of which he is master.

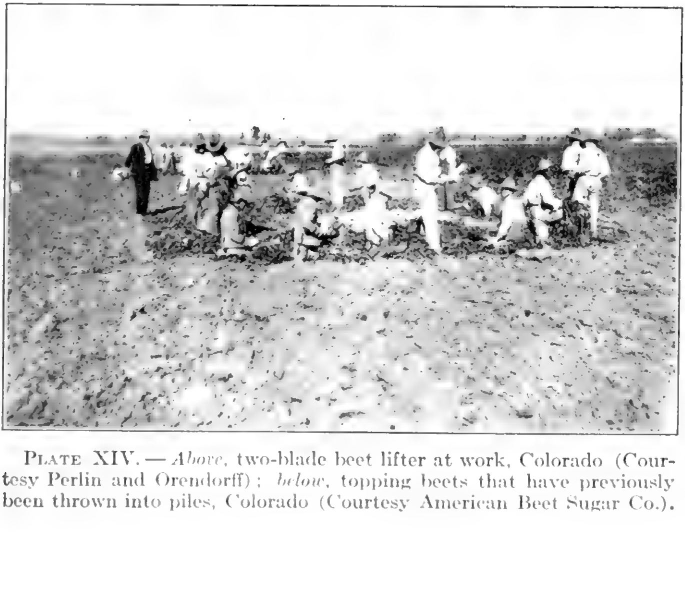


PLATE XIV. — *Above*, two-blade beet lifter at work, Colorado (Courtesy Perlin and Orendorff); *below*, topping beets that have previously been thrown into piles, Colorado (Courtesy American Beet Sugar Co.).

DIGGING

Two processes may be included under digging: namely, "lifting" and "pulling." The lifting is done by means of some sort of implement especially made for the purpose. The ordinary plow can be used, but it is very

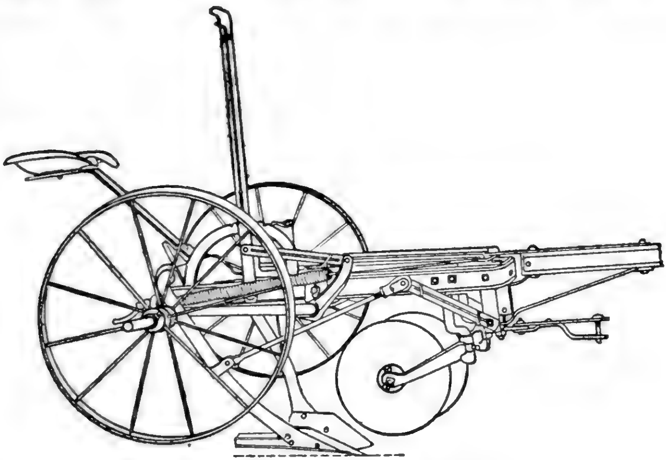


FIG. 23. — Two-blade riding beet lifter.

wasteful of power and it causes considerable damage to the beets.

One type of lifter is made on the plan of a subsoil plow with a single point that is pulled along the beet row to break the beets loose from the soil. It also raises them slightly. This is the simplest kind of implement. It is cheap and effective, but has to be operated by hand, and the operator walks.

A type of lifter that is probably in greater use consists of two points parallel to each other, one on each side of the row. Fig. 23, Plate XIV. As it moves along the row, the beets pass between the two points, being slightly raised but remaining standing in the soil. Some of these are operated by a man walking; others are arranged on a sort of cart and are controlled by a man who rides. Several companies manufacture implements of this type that give satisfaction. Probably no one type is best for all conditions.

After the beets are lifted in this way, they are pulled by hand and thrown into piles for convenience in topping. Sometimes the piles are made without regard to any order of piling; at other times the beets are placed in such a way that all the tops lie in one direction. Without doubt this arrangement makes topping easier. If the beets are not taken from the ground immediately after lifting, there is a tendency for the soil to become compact again around the roots and increase the work of pulling.

Two beets are knocked together when they are pulled to remove as much of the dirt as possible. The dirt when handled several times with the beets adds considerably to the work involved, and it does no good since it is taken off as tare when the beets are finally delivered to the sugar company. Unclean beets are a source of annoyance to all concerned in handling them. Sometimes the beets are pulled and topped in one operation, but this practice is not common.

TOPPING (PLATES XIII, XIV, XV)

Topping is one of the important operations, and unless properly done results in considerable loss. It is an ad-

PLATE XV. — *Above*, topping beets that have been laid in rows with the tops all one way, California (Courtesy Union Sugar Co.); *center*, beet silo in field, showing, a common form of beet rack (Courtesy Truman G. Palmer); *below*, rack containing net to assist in unloading, California. (Courtesy Union Sugar Co.)

vantage to both the farmer and the sugar company to have the beets properly topped. The cut should be made just at the sunline as shown in Plate XIII. This is indicated by the coloring in the part of the beet that protrudes above the surface of the ground.

The crown is low in sugar, as shown in Fig. 6. It is also high in salts, which interfere greatly in the purification of the sugar. These salts must be removed before the sugar can be made to crystallize. The salts so troublesome to the sugar makers are some of the very ones that are desirable for plant-food in the soil; it is to the interest of the farmer to have them retained on the land. The sugar company wants only the sugar, which is the part that comes from the air; the farmer needs the salts in order to maintain the fertility of his soil. Proper topping serves the interests of both farmer and factory.

When the beets are piled in windrows with the leaves all one way, the toppers can go along the windrows on their knees and do the topping without much bending. When the person doing the topping stands, he must do considerable bending in picking up the beets. This is in part overcome by having a hook fastened to the knife near the point. The hook is driven into the beet, which is thereby picked up without the operator having to stoop so far. Some object to the use of the hook since the wound it makes in the beet doubtless results in a slight loss of sugar. Whether this loss is enough to make up for the advantage is not known.

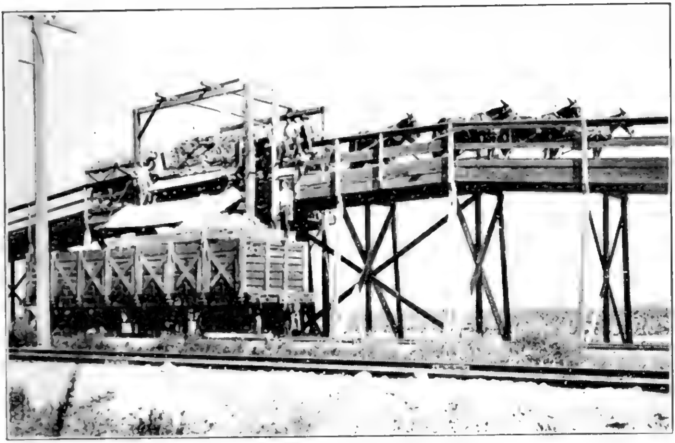
After the beets are topped, they are piled on a place that has been cleared of tops. They are now ready to be hauled. If hauling is delayed, the pile should be covered with tops to prevent evaporation of moisture, which amounts to considerable weight on a hot day. Care should be taken that tops are not mixed through the pile of beets, as they are very troublesome later on at the mill.

MECHANICAL HARVESTER

Many attempts have been made to secure machines for the digging and topping, but these machines have not been widely used in the past. It seems, however, that at present machines are available to do as good topping as can be performed by hand and more quickly and at much less expense. Many of these are being manufactured and it is hoped that hand-topping may soon be relegated to the past. If these machines are entirely successful, the labor question in sugar-beet raising will be greatly simplified.

There are two general types of harvesters: one that tops the beets and leaves the root in the ground to be lifted with another implement; after the tops have been raked into windrows, the ordinary lifter is used. An attachment that is fitted to the lifter has been devised and its use facilitates the lifting process. This attachment also removes most of the dirt that would otherwise attach to the root.

The other type of harvester first lifts the beet and then tops it. This type of machine is fitted with equipment that delivers the roots in piles at one side, or with an extension of the delivery carrier, the roots are elevated directly into a wagon that is driven alongside the har-



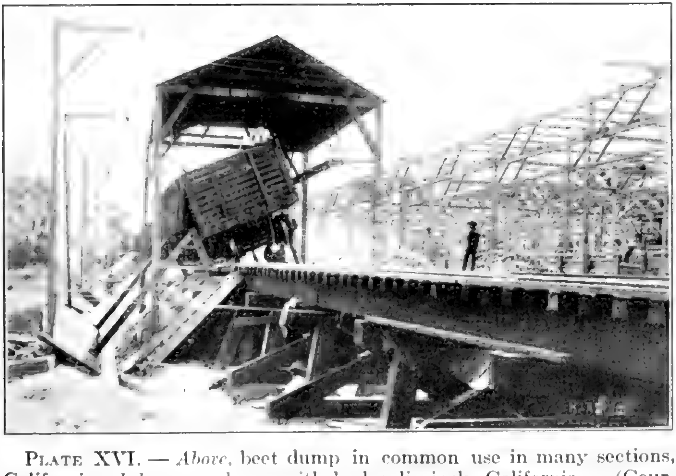


PLATE XVI. — *Above*, beet dump in common use in many sections, California; *below*, car dump with hydraulic jack, California. (Courtesy Truman G. Palmer.)

vester. The tops are delivered, separate from the roots, and left in windrows or piles.

This latter type of machine moves under its own power, using a light-weight, high-speed gasoline engine. The first type described is drawn by a team and requires about the same power to propel it as does a mowing machine that is cutting alfalfa.

HAULING (PLATES XV, XVI)

Beets are taken to the factory or to the railroad loading stations in wagons which are usually fitted with special racks. The ordinary wagon box can be used, but much labor is saved by having a rack made for the purpose. The beets are thrown from the field piles into the wagon by hand or with a beet fork. If no dumps are available, the beets must be thrown from the wagon into cars or into pile silos with a fork. Hand unloading involves considerable hand labor, but fortunately it has to be resorted to in a few places only. In most of the beet-producing sections, conveniences for lessening hand labor are at hand.

A number of types of beet racks are used: some merely let down the sides; others provide for the entire rack to turn on an axis and dump out the beets. These racks are made to hold from two to seven tons and average about four tons. Nets are sometimes used to help in unloading. These are placed in the rack before the beets are loaded, and with their aid the entire load may be lifted off at once.

Different companies have various methods of handling beets at the receiving stations and different arrangements for weighing. One method is carried out as follows: When the farmer arrives at the dump with his load, the wagon and beets are weighed together, and he is given a ticket showing the weight. Several beets of average size are taken from the load as a sample from which to determine sugar-content and purity. He then drives to the dumping place and dumps his load into a hopper. From there the beets go into a revolving screen where most of the dirt is shaken off. It drops on a belt and is carried to a dirt hopper under which the farmer drives and gets his dirt back. This is taken to the scales and weighed with the wagon. From ten to fifty pounds of the beets that have passed over the screen are weighed, and after all dirt is removed, weighed again. From this, the percentage of dirt is determined and the net weight of beets calculated.

The problem of ascertaining the proper percentage of tare is one on which there is constant friction unless both the farmers and the factory are willing to give as well as take. At best, the amount of tare is only an approximation, and every method that can be used to simplify its determination will result in more agreeable relations between the farmer and the sugar company.

The providing of inadequate dumping facilities often leads to friction in regions where the industry is newly established; but in the older regions dumps are being built, so that most farmers can be accommodated without having to haul great distances. A number of convenient types of dumps are being used.

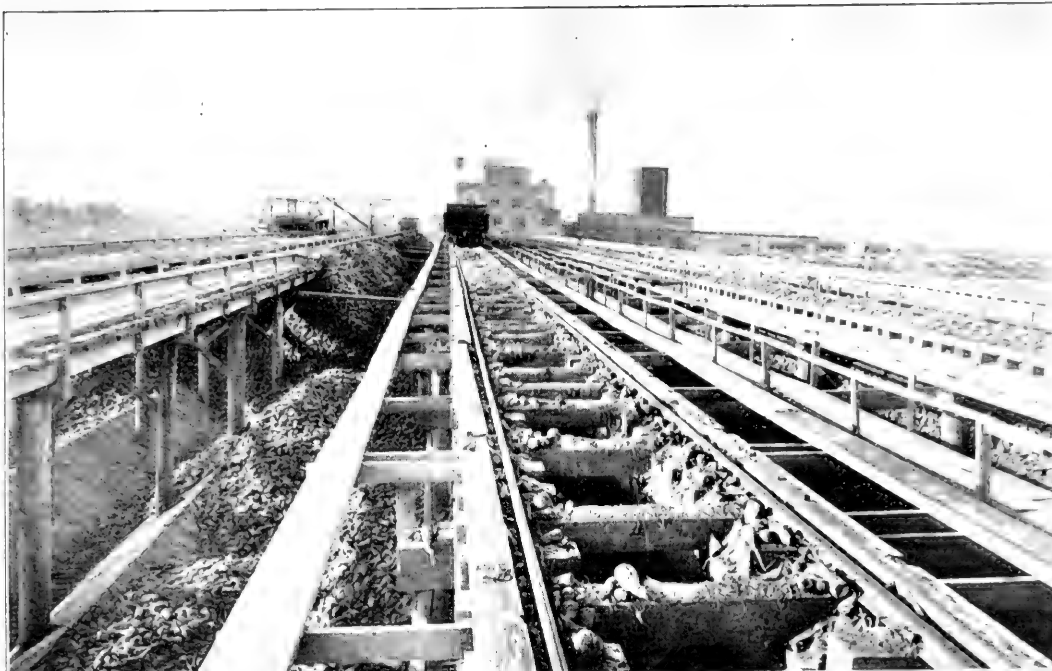


PLATE XVII. — Beet bins at a factory with V-shaped bottom, showing where boards are removed to allow beets to fall into a flume through which they are carried to the factory, Idaho. (Courtesy Truman G. Palmer.)

SILOING (PLATE XVII)

In many places where the land freezes, it is necessary to remove the beets from the ground several weeks before they can be sliced by the factories. This means that they must be stored during this time. In California and other warm sections, the beets cannot be dug many days before they are run through the mill or they will decay; but under these conditions there is no danger of the beets being frozen in the ground, and they are not dug until they can be used. In storing beets, care must be taken to prevent heating, evaporation, and alternate freezing and thawing. This means that the piles must be so built that ventilation is possible without the evils resulting from open exposure. These conditions are met differently under different conditions, depending on the length of time the beets are to be stored, the temperature, and the quantity of beets to be handled. A high temperature is the greatest enemy to stored beets.

In Colorado, Idaho, and Utah, the beets that cannot be handled in the bins at the factories are stored in large flat-topped piles several feet deep. These are carefully watched, and if any begin to spoil the pile is opened where the heating begins. In some places beets are stored on the individual farms. This is usually done in covered ricks similar to those described in Chapter XV. In these piles, as in the larger ones, the main things to guard against are heating and freezing. Provision must always be made for ventilation. Heat is much more likely than cold to cause loss.

CHAPTER XII

BY-PRODUCTS

In some of the live-stock communities, sugar-beets are becoming one of the most important crops because of the large quantity of inexpensive stock feed produced as by-products of the beet-sugar industry. It is the opinion of some experienced beet-growers, especially dairy-men, that beets would be a profitable crop to raise in order to secure the tops for stock feed, even if no profit were obtained from the beets themselves. In addition to the tops, sufficient cheap feed in the form of pulp and molasses is annually available to fatten thousands of cattle and sheep. Sugar-beet regions are usually profitable live-stock sections. Each acre of sugar-beets yielding a good crop furnishes nearly as much feed in the form of by-products as is obtained from most ordinary forage plants. The best beet-growers are generally good stock-men and receive considerable of their income from live-stock.

SUGAR-BEET TOPS

In topping the beets, there remains in the field from one-third to two-thirds as much weight as is hauled away. This consists of beet tops and crowns. The quantity varies considerably with the soil, climate, water received,

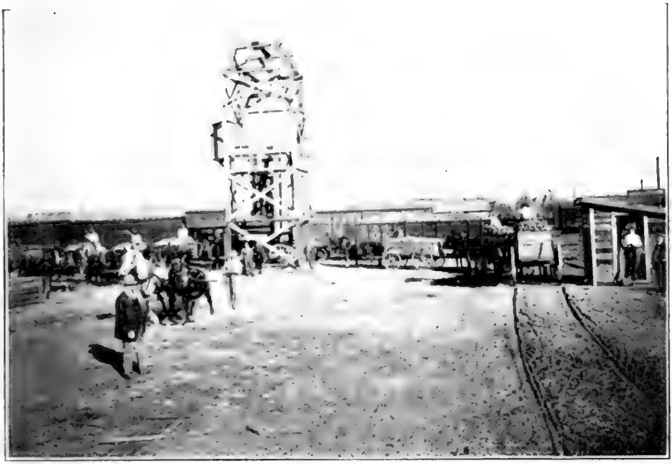


PLATE XVIII. — *Above*, type of beet dump in use in Nebraska (Courtesy American Beet Sugar Co.); *below*, sugar factory with beet-pulp drier and alfalfa-meal mill at the right, Kansas. (Courtesy Garden City Sugar and Land Co.)

and maturity of the crop; but under ordinary conditions about one-third of the total weight of the crop is left as tops. This would mean eight tons of tops for sixteen tons of beets. The green weight varies much more than the dry weight. Between one and two tons of dry matter to the acre in the beet tops can be depended on from an average yield of beets, or to put it more definitely, 10 to 15 per cent of the net weight of the roots.

Much more has been done to utilize beet pulp than tops; but the tops furnish a cheaper feed than the farmer can obtain from any other source. The reason for carelessness in utilizing the tops is probably due to the fact that they are a by-product and their true value has been underestimated. When dried in the field, beet tops contain about the same amount of nutrients as an equal weight of alfalfa hay; their feeding value is about the same except that they are lower in nitrogen and contain a comparatively large amount of potash and organic acids, which cause animals to scour when they have unlimited access to the tops.

Composition of the tops.

The composition of tops is shown in Table V. The ash consists of potassium, sodium, calcium, magnesium, chlorine, sulfuric acid, silica, and phosphoric acid, which are valuable fertilizers and should not be taken from the land. The tops consist of two to three parts of leaves containing about 2.2 per cent ash, to one part of crowns containing 5.6 per cent ash. Because of the high ash-content of the tops, it is often advocated that they be plowed under just as they are topped in order not to

TABLE V. — FEEDING VALUE OF SUGAR-BEET BY-PRODUCTS

(*Adapted from* "The Scientific Feeding of Animals" *by Kellner*)

	1	2	3	4	5	6	7	8	9	10
	SUGAR-BEET ROOT	LEAVES AND CROWN			SUGAR-BEET PULP					SUGAR-BEET MOLASSES
		Wet	Siloed	Dried	Fresh	Pressed	Siloed	Dried	Dried with Molasses	
Crude Nutrients										
Water	75.0	83.8	77.0	14.0	93.0	85.0	88.4	11.2	10.0	21.9
Protein	1.3	2.3	2.4	9.1	0.6	1.3	1.0	8.1	8.7	(10.5)
Fat	0.1	0.4	0.7	0.8	—	0.1	0.2	0.6	0.3	—
N. Free Extract . .	21.4	7.4	9.1	34.8	4.7	9.9	72.0	58.5	60.8	60.4
Fiber	1.5	1.6	3.4	11.1	1.4	3.0	2.3	17.6	13.8	—
Ash	0.7	4.8	7.4	30.2	0.3	0.7	0.9	4.0	6.4	7.2
Digestible Nutrients										
Protein	0.9	1.7	1.5	3.8	0.3	0.7	0.5	4.1	4.6	5.4
Fat	—	0.2	0.3	0.2	—	—	0.1	—	—	—
N. Free Extract . .	20.3	5.9	7.2	28.4	4.0	8.5	5.4	50.4	52.0	54.9
Fiber	0.5	1.1	2.5	7.5	1.0	2.2	1.2	12.7	8.2	—
Starch Equivalent										
Per 100 lbs. . . .	15.8	7.2	9.5	27.0	5.0	10.6	6.5	51.9	50.5	48.0

disturb the fertility of the soil; but this practice is not economical when live-stock can be fed and the manure returned to the land. It would be better, however, to plow the tops under than to allow them to be taken away from the farm and have no manure returned. It is a much more profitable practice to buy stock to eat the tops than to sell the tops, because the price obtained for them is usually much below their feeding value, which may generally be considered as equal to about one or two tons of alfalfa hay for each acre of beets. Besides, if their fertilizer value has to be replaced by commercial fertilizer, the loss is considerable.

Feeding and storing beet tops.

There are three general methods of feeding beet tops. The most common consists in turning the stock into the fields to pasture the tops just as they were left when removed from the beet. Although this is the easiest way, it is very wasteful; it is estimated that from one-third to two-thirds of the tops are tramped into the ground or soiled by manure and dirt. There is also danger that the stock will over-eat if allowed to run freely to green tops after they have been eating dry feed. When this occurs the cattle scour excessively and fattening is delayed. This danger is somewhat lessened if the tops are allowed to become dry. Tops, when left in the open, sometimes tend to mold and cause trouble in feeding. This is especially true in humid sections. If pasturing is regulated somewhat for the first three or four days, the stock may be trusted safely to feed on the tops without injury. This method is less desirable than drying the tops and feeding as hay or than making them into silage. When labor is expensive and feed cheap, this may be the most economical method of feeding.

When hay is more expensive and when labor is available shortly after the beet harvest, it is common to gather the tops after they have cured in the field and stack them like hay. Whether it is more profitable to dry-cure the tops or to silo them is a difficult question to answer in arid regions where curing is easy, but in humid regions siloing is unquestionably to be preferred. In case the beets were thrown in piles before topping, the tops are usually in piles that can be gathered easily; but when topping is done directly from rows or by a mechanical topper, it is usually necessary to gather the tops with a hay rake before hauling them. A large part of the tops is always lost in handling them dry; hence it is usually advisable to gather while they are still green or only partly dry. Piling green results in a smaller loss than does curing in the open field. Usually there is considerable dirt gathered with the tops. This could be avoided by using care in gathering.

Under ordinary conditions in a sugar-beet region, live-stock feeding is an important industry and feed is rather expensive because land that might otherwise produce forage crops is planted to beets. It is important, therefore, that as much cheap feed be used as possible. Since tops are a good and also a cheap live-stock feed, much more attention should be given to their preservation than is usually done in this country.

Methods of handling by-products are shown in Plate XX.

Siloing beet tops.

The greatest feed value can be obtained from beet tops by siloing. This practice also proves beneficial by freeing the leaves from pests, such as the leaf-spot and crown-rot organisms, and by removing the favorable hibernating places for insects. Siloing has the serious drawback that it requires considerable labor at a time when hands are most needed. To make good silage, the tops should be

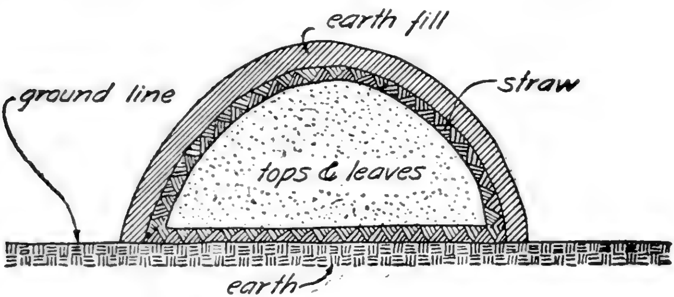


FIG. 24. — Beet-top silo above ground.

put into the silo within two or three days after being removed from the beet. It usually pays to silo the tops if conditions are favorable; but the supply and wages of local labor and other economic considerations make the problem one that each farmer must solve for himself.

The usual method of siloing beet tops consists in digging a trench six to ten feet wide, four to five feet deep, and as long as necessary in a well-drained soil, as convenient as possible to the feeding yards (Fig. 25). Silos are sometimes made on top of the ground, as in Fig. 24, but the depth is governed to some extent by the nearness of the water-table to the surface; the depth of the pit is frequently less than given above and the thickness of tops made up by extending the pile above ground. Less work is required in covering the silage if the trench is not too wide. Sufficient width, however, should be given to allow the wagon carrying the tops to be driven freely

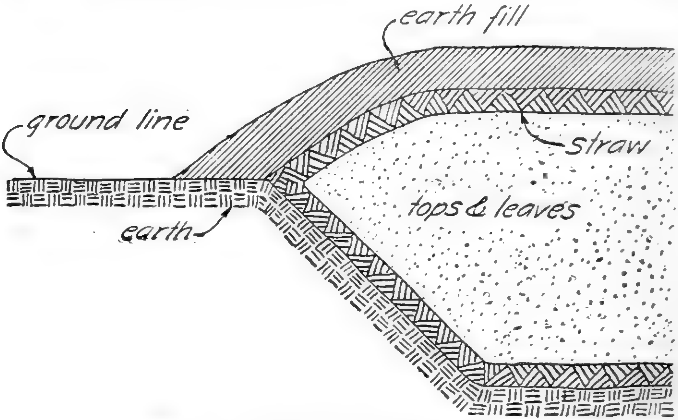


FIG. 25. — Beet-top silo below ground.

over them. This aids in compacting the tops. In scraping the trench out, the ends are left sloping enough to allow the wagon to pass easily in and out. In estimating the size of the excavation, usually it is assumed that the yield of silage will be about one-half the weight of the roots and that a ton of the green tops will occupy thirty-eight cubic feet.

In order that as small a proportion as possible of the tops shall spoil, six to eight inches of straw are spread on the bottom and sides of the excavation in which the tops are to be siloed. To absorb a part of the moisture and to make the best use of the straw on the farm, a six-inch layer of tops is often alternated with a three-inch layer of straw as illustrated in Fig. 26, although the results are entirely satisfactory when no straw is used.

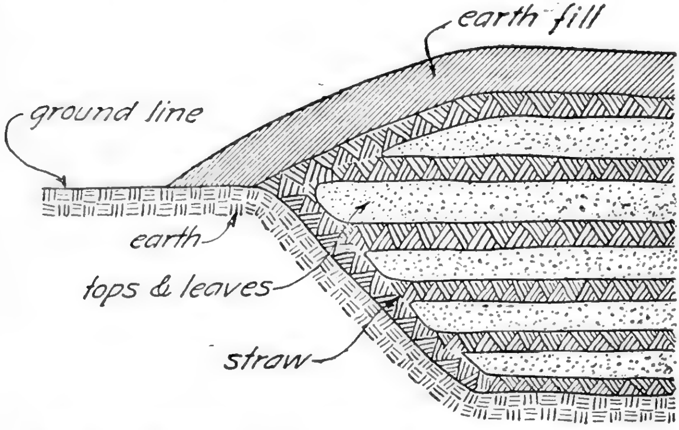


Fig. 26. — Beet-top silo with alternating layers of tops and straw.

From three to seven pounds of salt for each ton of silage is sometimes added while the silo is being filled. The value of this practice is questioned by some feeders. When all the tops are in the silo, a layer of straw is spread over the top and eight to ten inches of earth thrown over this to exclude the air as much as possible. In filling, it is essential that each layer be rather firmly packed both by the wagon delivering the tops and by a roller or by horses led over the tops near the edges. The drier the leaves when put into the silo, the more the packing that is needed. When layers of straw are alternated with layers of tops, greater care will need to be used in packing to exclude the air more thoroughly.

A cheaper but more wasteful manner of siloing, practiced by some, consists in piling the tops in large heaps without the excavation and allowing the surface few inches to decay, thus forming a protective covering for the interior of the stack. Obviously, the larger the pile the smaller the proportion of tops that will decay.

After a period of about four to six weeks, the silage fermentation has progressed far enough to correct the cathartic, or scouring, effect of the tops, and they are ready to be fed. This silage is handled and fed in much the same manner as corn silage; all kinds of live-stock readily eat it when they become used to it.

Use of beet silage.

A large part of the beet tops is fed to beef cattle, and it probably serves best when used for this purpose. Beef fed on tops command as high a price as any on the market. Cattle-men ordinarily figure that for each acre of beets raised there will be sufficient tops to feed one steer at least one hundred days, allowing about twenty-seven to thirty pounds of dry matter to the steer each day. When used as pasturage, not more than a month to the acre is counted on to each steer. Usually some hay, and often pulp and grain, are fed in addition to the silage. By feeding twenty to thirty pounds of the beet-top silage a day, the hay eaten will be about half what it is without the silage.

With dairy cattle the quantity of tops fed should be much smaller than with beef, because the former should have more concentrates and less bulky feed. Fed in moderate quantities, equaling about one-third of the total ration, the silage increases the yield of milk; but with unlimited access to the tops, cows do not maintain their milk flow. Each acre of beets should furnish from one hundred fifty to two hundred days' feed for an ordinary dairy animal. About the same quantity of siloed tops may be used as of corn silage.

Sheep do well on beet tops, but care must be taken that they eat only moderate quantities at first. Because of the desirable flavor and color of their flesh, sheep fed on beet tops are in great demand. Pasturing sheep on the tops is perhaps the most common practice, but it is dangerous not only because of the scouring effect of large quantities of tops on the animals but also because sheep tend to pack the soil, and thereby to destroy its tilth, particularly if the land is wet. Sheep are usually fattened on beet by-products during the winter, and it is more desirable that the tops be siloed than pastured or fed dry, since the silage is always warm and convenient to handle in winter. Satisfactory, rapid, and economical gains have been realized from feeding three to four pounds of beet-top silage a day together with a lessened quantity of hay or other supplementary feeds.

If the land is not so wet that it causes the soil to pack, either sheep or hogs may be pastured on the remaining tops after the siloing or stacking has been done. Considerable feed is left in the form of undug beets and scattered tops that these animals relish. Since pork from hogs fed on beet tops is of a desirable quality, feeding tops to them is recommended. Experiments[1] show that hogs pastured on beet tops and receiving one-third normal grain rations did well. Horses should not be fed large quantities of tops.

SUGAR-BEET PULP

After the beet has been sliced into shreds and most of the sugar extracted, pulp remains as a by-product. A great many experiments in this country as well as in Europe have been conducted to determine the value of this pulp. The interest in it seems to have been due not so much to its value as to the difficulty of disposing of such a great quantity of material at the factories. Approximately 85 per cent of the original weight of the roots is discarded as fresh pulp, but by the time the water has been well drained from it and it has gone through the siloing process, only 25 to 35 per cent of the original weight of the roots remains. The tops can be dried easily into a rich hay in the more arid parts of the country, whereas it is rather expensive to dry pulp. The dried pulp is less than twice as valuable for feed as the cured tops. When time cannot be spared to silo the tops and when a succulent feed is desired during the winter, the pulp may be the more economical even though it is usually necessary to pay a small sum for it. Table V shows the relative value of tops and pulp.

Only a small part of the pulp is fed just as it comes

[1] Shaw, R. S., *Mich. Exp. Sta., Bul. No.* 223.

from the mill. Most of it goes into huge lumber-lined earth silos six to ten feet deep, where it ferments into the pulp that is ordinarily fed. An increasing number of factories is being equipped with drying plants into which the pulp goes after a part of the water is expressed by pressure. In a few minutes the pulp is reduced to a moisture-content of about 10 per cent, after which it is sacked for shipment, or is mixed with molasses before being sent to market.

By drying pulp, the loss due to fermentation is avoided and a concentrated feed is made. About 5 to 6 per cent of the original weight of the beets is recovered in drying. Dried pulp is somewhat similar to corn or to cornmeal in composition and in feeding value. In this form it is worth about ten times as much as the fresh pulp and about eight times as much as the siloed pulp.

Uses of beet pulp.

It is often necessary to starve stock for a few days in order to induce them to eat siloed pulp for the first time; but once they acquire the taste for it, all classes of livestock eat it readily. Although siloing gives to pulp a disagreeable odor, it is a better feed after fermentation than before. The value of pulp lies not only in its succulent nature, as with corn silage, but it also has a desirable hygienic effect. Brood animals and dairy cattle are especially benefited by the laxative properties of the pulp. It has a stimulating effect on the digestion of all animals and enables them to make the most of their feed. Wet pulp is almost an ideal feed in sections where alfalfa forms the roughage part of the ration. Where grain can be obtained at a moderate price, alfalfa, grain, and pulp put a fine finish on stock; but thousands of animals are fattened without the grain, especially where it is high priced. By varying the amount of pulp in proportion to other feeds, it is possible to make excellent rations for fattening animals, producing growth and milk, preparing for maternity, and for merely wintering the animals cheaply without their losing weight. The combination of feeds and the amount of each is altered according to the purpose. Likewise, the value of the pulp to the feeder is determined by the object of the feeding, the character and amount of supplementary feed, the condition of the animals to be fed, and the value of the finished product.

Being close to the great stock ranges, the western beet-sugar companies are able to make good use of pulp. With rations made up largely of the siloed pulp and alfalfa hay, thousands of steers are fattened annually on these feeds. The stock fresh from the ranges are at first fed largely on alfalfa hay with only a comparatively small amount of pulp. This is increased gradually until the daily ration consists of about fifteen pounds of alfalfa and one hundred pounds of siloed pulp. When fed alone, pulp is a poorly balanced feed which will endanger the lives of the animals, and will not fatten stock that are in poor condition. Grain and some roughage must supplement it. The best feeders begin with alfalfa hay and a small amount of pulp, increasing the pulp until the full ration is given, then toward the close of the feeding period a small quantity of grain is added. Where grain can be fed economically, the amount used is gradually increased and the pulp decreased until the grain entirely supplants the pulp for a short period just before the steers are put on the market. In spite of the economy of feeding grain, thousands of steers are placed on the market without it. The Colorado Station,[1] in a one-hundred-day period, found that if the steers were in poor condition when the fattening period commenced, adding about half of an ordinary ration of corn to the pulp and alfalfa hay caused

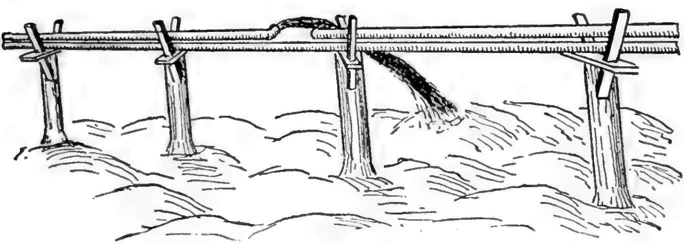


Fig. 27. — Pulp being piped from factory to silo.

the steers to gain nearly half as much again as without the grain. With the same type of animals, the gain was about three-fourths greater when grain and pulp were fed than when only hay was used. The animals fed on pulp were also more thrifty than those not receiving it. For two-year-old fattening steers, nine pounds of wet pulp was equal to 2.8 pounds of alfalfa hay or to one pound of ground corn. In computing the amount of pulp necessary for steer fattening, stock-men consider one and one-half tons of pulp a month to be sufficient for each steer. From four to seven tons of wet pulp and one ton of alfalfa,

[1] Carlyle, W. L., and Griffith, C. J., *Colo. Exp. Sta., Bul. No.* 102.

together with the supplementary feeds, if any is used, will finish one steer for the market. About forty-one pounds of beef is produced from a ton of pulp under average conditions. The daily amount fed is about 6 to 10 per cent of the weight of the animal. Figure 27 shows a method of transporting sugar-beet pulp. Other methods are illustrated in Plate XIX.

For wintering steers, the amount of pulp fed is often greater and the roughage may be straw instead of hay. Cattle will come out of the winter in fair condition on pulp and oat straw; but they are not so thrifty and do not make the growth they should without a little nitrogenous food such as alfalfa hay or grain. Dried pulp is generally considered too expensive to feed to steers, although at some periods it has been found to be about equal to cornmeal for fattening them and is somewhat cheaper.[1] At Michigan it was ascertained that dried pulp tended to produce growth rather than fat; hence, it is recommended that it be fed during the early part of the feeding period and dropped from the ration later. From three to five pounds of the dried pulp a day is a common amount, although some feeders allow as much as ten to fifteen pounds to the animal.

Used in moderate quantities, pulp is desirable for dairy cattle. Milch cows need considerable nourishing feed, but they will not eat enough to bring best results when they receive only dry feed. The stimulating effect of a succulent feed such as corn silage is well recognized. The dry matter in wet beet pulp is equal to that in corn silage

[1] Shaw, R. S., and Norton, H. W., Jr., *Mich. Exp. Sta., Buls. Nos.* 220 and 247.

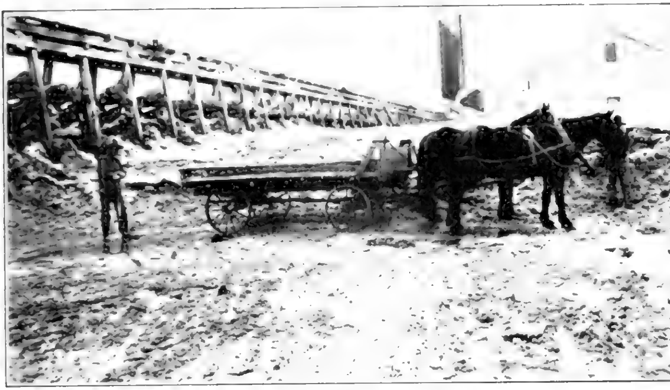


Plate XIX. — *Above*, cured pulp being hauled from the silo; *center*, pulp silo almost empty; the pulp remaining in the silo till the end of the season, due to evaporation and fermentation is much more concentrated than when fresh; *below*, (Courtesy National Sugar Manufacturing Co.) pulp silo and feeding yards joining a sugar factory, Colorado.

for milk production,[1] so that by feeding enough more of the pulp to make up for the extra water it contains the same effect is obtained by the two feeds.

If properly fed, no ill effects on the milk result, and there is a stimulating action which causes the cow to consume more dry roughage and to produce milk more economically. With no other succulent feed in the ration, the benefits of siloed pulp are very marked. Since the cow should not have too large a quantity of bulky feed, it is not advisable to feed more than twenty to forty pounds of pulp a day, although fifty to one hundred pounds would be eaten if placed before the cow in unlimited quantities. Dried pulp finds great favor with dairy-men, especially with those who are feeding for high milk production. The stimulating effect is obtained in the dry pulp without the bulk, although it is better to soften with a little water before feeding.[2] Replacing forty-five pounds of corn silage with nine pounds of dried beet pulp and five pounds of mixed hay increased the milk yield 11 per cent. Experiments show dried pulp to have a value as a dairy feed equal to two-thirds that of wheat bran,[3] and it frequently takes the place of bran, oil meal, and the like, in the dairy ration.

There is some diversity of opinion as to the value of mixing the beet molasses with the dried pulp. In New Jersey the addition of the molasses had little influence when compared with the dried pulp without the molas-

[1] Wing, H. H., and Anderson, L., *Cornell Exp. Sta., Bul. No.* 183.

[2] Billings, G. A., *New Jersey Exp. Sta., Bul. No.* 189.

[3] Woll, F. W., and Humphrey, G. C., *Wis. Exp. Sta. Ann. Rpt.*, 1905, pp. 108–117.

ses, either of them being about equal to hominy meal. Comparing three pounds of molasses beet pulp with two pounds of wheat bran, it was found that the pulp produced 12 per cent more milk than the bran.[1] In other experiments [2] these two feeds were determined to be about equal. Molasses pulp is usually considered to be more laxative than the pulp without the molasses.

In addition to cattle, thousands of sheep are fattened on siloed beet pulp and alfalfa hay near the sugar factories of the West. Pulp has proved to be an excellent feed both for fattening and breeding animals. The meat is of excellent quality and much sought for in the larger markets. As in the case of steers, it is advisable gradually to increase the pulp ration until the finishing-off period, when the pulp is substituted by a less bulky feed. The addition of four-tenths of a pound of grain a day to a full pulp and alfalfa-hay ration was found to reduce the amount of pulp and hay, respectively, by about five and about two times the weight of the grain. It was not considered advisable to feed more than four-tenths of a pound of grain to sheep on pulp and alfalfa, and whether it should be fed at all or not depends on the prices of the feed.[3] Colorado experiments [4] show that a ton of wet pulp has about the same feeding value as 200 pounds of corn for fattening lambs. Dried beet pulp has been found [5] to produce larger gains with growing lambs on

[1] *Wis. Exp. Sta. Ann. Rpt.*, 1905.
[2] Hills, J. L., *Ver. Exp. Sta. Ann. Rpt.*, 1904, p. 484.
[3] Merrill, L. A., and Clark, R. W., *Utah Exp. Sta., Bul. No.* 90.
[4] Griffin, H. H., *Colo. Exp. Sta., Bul. No.* 76.
[5] Shaw, R. S., *Mich. Exp. Sta., Bul. No.* 220.

clover hay and bran or oats than does cornmeal, although for fattening cornmeal was the better feed. Trials with sheep have failed to show that the dried-molasses beet pulp is any better for a feed than plain dried pulp. One hundred pounds of fresh pulp absorbs about six pounds of molasses; this will produce from fifteen to eighteen pounds of dried-molasses beet pulp. The usual amount of wet pulp to feed sheep is from seven to ten pounds a head each day, and of dried pulp about the same weight as the grain they would have received. It is usually accepted by stock-men that eight sheep or twelve lambs should receive the same quantity of feed as one steer.

Although wet fermented pulp is ordinarily considered too bulky and too laxative for horses, it has been concluded that when fed in limited quantities it is not harmful. Farm work horses eating as much as twenty pounds daily did well on this feed when combined with oats and alfalfa hay.[1] When thus fed, the pulp displaced about one-sixth of its weight of oats. Perhaps more of the pulp is fed to horses in the dried form, and especially molasses-dried, than in any other form. In any form, pulp is not extensively used for horses, except for young growing animals and for brood mares when a rather laxative feed is desired.

During their growing period, swine make good use of pulp, as do also sows without pasture. When fed in moderate quantities, young pigs relish it and make good gains, although grass answers the same purpose by acting as a mechanical agent to stimulate digestion. Pulp

[1] Clark, R. W., *Utah Exp. Sta., Bul. No.* 101.

is so bulky that only a small part of the ration should be supplied in this form. Pulp and molasses sometimes take the place of part of the shorts or of similar feeds.[1]

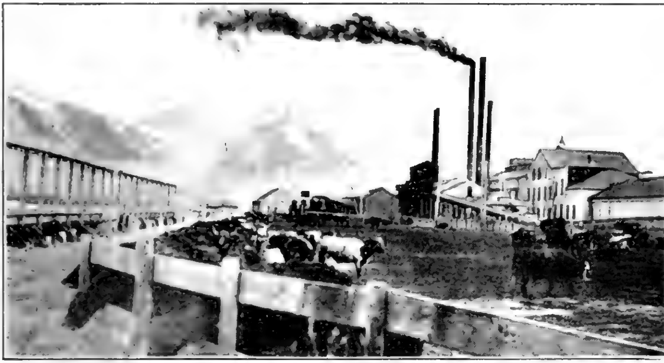
To winter brood sows cheaply, pulp and a small quantity of grain have been used with good results. For hogs, the quantity of pulp recommended is between one and two pounds for each pound of grain fed in fattening. If dried pulp is used, it is usually softened with milk before being fed.

WASTE SUGAR-BEETS AND ROOT-TIPS

The feeding of roots left from the production of sugar-beet seed is growing in importance. These beets contain from 6 to 14 per cent of sugar and frequently yield from eight to ten tons to the acre. Since their woody fibrous nature prevents their being used for sugar-making, feeding seems to be the only way of obtaining a profit from them. The great amount of fibrous material makes them somewhat dangerous for stock, which are sometimes killed by accumulations of this material in the digestive tract. If fed in moderation and in connection with other feeds, it seems possible to utilize this rapidly increasing by-product. Formerly, only a few acres of beet seed were grown in America, but in the future thousands of acres will be devoted to seed production.

A product that merits more attention for feeding purposes than it is receiving is that which remains after the

[1] Clark, R. W., *Utah Exp. Sta., Bul. No.* 101.



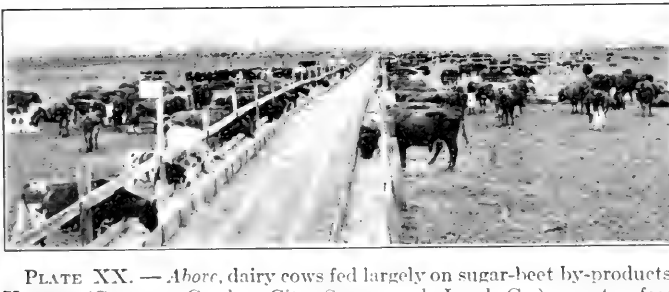


PLATE XX. — *Above*, dairy cows fed largely on sugar-beet by-products, Kansas (Courtesy Garden City Sugar and Land Co.); *center*, feed yards near factory, Utah; *below*, beef cattle being fattened on sugar-beet by-products, California. (Courtesy Union Sugar Co.)

beets are washed at the factory. Quantities of root tips, leaves, and stems are flushed into the sewers and go to waste. If the water in the flumes carrying the beets to the factory were made to run over a screen just below the device for elevating the beets to the washer, considerable valuable feed might be saved. Various feeding practices are shown in Plates XX and XXI.

SUGAR-BEET MOLASSES

In factories not equipped with the Steffen process of removing additional sugar from the molasses, there remains from 3 to 5 per cent of the original weight of the beet as a bitter molasses. Factories turning out molasses as a by-product vary the quantity according to whether the price of the sugar minus the cost of extracting is greater than the price for which the molasses can be sold. The ordinary amount that is sold as a by-product is about forty to sixty pounds for each ton of beets sliced. The purity of the juice, which in turn is modified by climatic, soil, and other conditions, such as the manner of topping, also modifies the quantity remaining after the sugar is made. Formerly, it was almost impossible to make a satisfactory disposition of the molasses, but today it is highly valued both as a stock feed and for manufacturing such products as alcohol, fusel oil, vinegar, and certain kinds of fertilizer. Reference to Table V shows molasses to contain about 60 per cent of digestible nutrients. A large part of this, 50 per cent of the total weight, consists of sugar that cannot be extracted except by the Steffen process because of the high percentage of salts, about 7.2 per cent being present. These salts, together with organic substances, give the molasses a disagreeable taste and a laxative action, which makes it unsuitable for human use and for animals when used in large quantities. When properly combined with other feeds and slowly introduced into the ration, it furnishes a desirable nutrient for fattening animals. For most stock, molasses is first diluted with water and then sprinkled on the roughage with which it is to be fed. In Europe, peat, which has no food value in itself, is sometimes used as roughage. Stock will eat large quantities of straw when sprinkled with molasses and do well on it. When purchased in combination with other feed, it is usually in the form of dried-molasses beet pulp. Molasses is a valuable material to feed with alfalfa hay because its high carbohydrate content balances the high protein of the alfalfa.

Alfalfa leaves and molasses are about equal to grain for feed and cost much less. To begin with, only about one-fourth of the full amount of molasses should be fed. This may be increased gradually to the full ration. It is a violent purgative when fed in excessive quantities or when introduced too rapidly into the ration; but if properly fed, its tonic action allows the best use to be made of a large quantity of rough food that might not otherwise be utilized. It should not be fed to brood animals in quantities large enough to cause great activity of the bowels, as this is likely to cause abortion. For fattening purposes, it is worth six to eight times its weight of wet pulp.

The use of molasses for fattening beef cattle is increasing in the western states. Many factories must raise stock as a side line in order to make a satisfactory disposal of pulp and molasses. Some of the larger feeders chop alfalfa hay or straw and sprinkle molasses over it with satisfactory results. About twenty pounds of molasses to each one hundred pounds of straw is a common proportion. Molasses increases the appetites of stock, resulting in their eating more feed at a time; fattening is thereby hastened.

The Great Western Sugar Company, in experiments on a large scale in which they used ordinary range cattle, found that for each one hundred pounds gain it required about 7500 pounds of pulp, 240 pounds of molasses, 760 pounds of alfalfa hay, and 90 pounds of grain. It is usually aimed to feed three to four pounds of molasses a day along with the other feeds, although some give larger quantities. A ration recommended for a hundred fifty day feeding period with steers in ordinary condition is one ton of alfalfa, 400 pounds of molasses, 500 pounds of grain, one-half acre of beet tops, and one-fourth acre of oat straw. Steers on this ration made a gain of about 1.7 pounds a head each day and were marketed in the best of condition.

Without concentrates, it takes a little longer to get steers in good marketable condition; the flesh is not so firm, neither will the stock stand shipping so well without a great shrinkage; but practically the same total gain is obtained from feeding a ton of alfalfa, five to seven tons of pulp, and four-tenths of an acre — or about 500 pounds — of dry beet-top hay. With less pulp available, molasses and grains should make up the deficiency according to the amount of nutrients lacking in the pulp.

Dairy cows are favorably influenced by small quantities of molasses. Each cow can use to advantage from two and a half to three pounds a day. When other laxative feeds are not present in the ration, it is especially good as a tonic and results in an increased yield of milk.

Sheep make good gains on molasses, fermented pulp, and alfalfa hay. In some sections, molasses is used to fatten old ewes and less valuable sheep, the only additional feed being the hay or straw with which it is mixed. Molasses beet pulp and dried beet pulp are about equal to corn and cause the same gains. It is not, however, extensively used in this way.

In some parts of America, molasses has met with considerable favor for feeding horses. When used in quantities not to exceed two quarts — 5.6 pounds — daily, it has been found possible to substitute it for grain pound for pound. Because of its laxative effect, most horsemen prefer not to feed more than one to one and one-half quarts a day. Horses at hard work, receiving this quantity of molasses mixed with twenty pounds of alfalfa or clover hay, and receiving six to seven pounds of rolled barley a day, kept in better condition than horses with a full grain ration. It is advisable to begin feeding horses with only one-fourth to one-half quart of molasses a day until they become used to it.

Hogs have been fed successfully as much as one pound of molasses a day while on pasture without causing digestive troubles. Feeding in larger quantities (2.4 pounds or more) for fattening quickly has sometimes proved

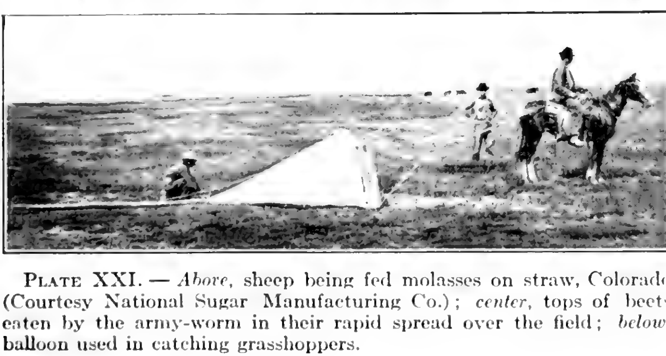


PLATE XXI. — *Above*, sheep being fed molasses on straw, Colorado (Courtesy National Sugar Manufacturing Co.); *center*, tops of beets eaten by the army-worm in their rapid spread over the field; *below*, balloon used in catching grasshoppers.

rather unsatisfactory.[1] Shorts, beet pulp, and beet molasses when combined produced nearly as large gains as the full ration of shorts alone. By feeding one hundred pounds of molasses, thirty-two pounds of shorts and one hundred fifty-three pounds of beet pulp were saved.[2] Over-feeding with molasses causes excessive scouring and often results in death to pigs. Molasses is not generally considered to be a good pig feed; if it is used, only small quantities should be given, and this must be introduced gradually into the ration.

WASTE LIME AND MINOR BY-PRODUCTS

Considerable lime is used to purify the juice in the manufacture of beet-sugar. After the lime has combined with the impurities, it is of no more value to the manufacturer. Some factories run this refuse lime into the sewer; others run the lime water into large reservoirs where the water is allowed to evaporate, leaving the lime as a residue. Lime to the extent of 2 to 6 per cent of the weight of the beets is required; hence, the quantity of waste product is large. No satisfactory commercial use has been found for it, although it has been used to some extent as a fertilizer. Its value for this purpose varies with the quantity of water in it, the quantity of valuable constituents it contains, and the nature of the soil on which it is to be used. The following is an analysis of samples from a Michigan factory:

[1] Clinton, L. A., *Cornell Exp. Sta., Bul. No.* 199. 1902.
[2] Clark, R. W., *Utah Exp. Sta., Bul. No.* 101.

Water	44.40	
Insoluble matter	23.37	
Iron and alumina (Fe_2O_3, Al_2O_3)	4.05	
Lime (CaO)	34.90	
Magnesia (MgO)	1.16	
Carbon dioxid (CO_2)	26.00	
Phosphoric acid (P_2O_5)	.48 to	1.53
Potash (K_2O)	.07 to	.11
Organic matter	9.06 to	10.76

The product from different factories varies considerably in composition. It will be seen from the analysis that the fertilizing value depends almost entirely on its lime-content, the other valuable plant-foods being present in almost negligible quantities. This makes the material of value to the farmer only in case his land is poor in lime. Most of the beet lands of the country are fairly rich in lime and the demand for this waste product is not so great as it would be in regions having acid soils. There is no doubt, however, that on clay or acid soils greater use should be made of the waste lime. Many of the less friable and unworkable soils would require much less work and would produce better crops if lime were applied. An ample supply of lime makes more available the phosphorus, potassium, and other plant-foods in the soil. When possible it is flooded over the land with irrigation water, thereby saving hauling and distributing.

A few conditions occur which make the use of the waste factory lime unpopular. Being wet and mucky, it is very difficult or impossible to spread it evenly over the ground. In districts infested with certain pests, the use of the lime, together with the other refuse that is usually found with it, endangers the greater spread of these troubles. The disagreeable odor that accompanies most sugar-factory by-products makes them nauseating to handle. Its bulky nature makes its use uneconomical at great distances from the factory.

In addition to lime, a small amount of potassium and ammonium fertilizer is made from by-products of the manufacturing process in factories equipped with the Steffen process. After all possible sugar is extracted from the molasses, there remains a slop containing comparatively large quantities of inorganic salts and organic compounds that may be utilized for making fertilizer. The slop must be evaporated to dryness to obtain the fertilizer. This is profitable only when potassium brings a high price. Under normal conditions the slop can best be used on local farms with the irrigation water. Under more intensified farming, it may become profitable to evaporate and return it to the land from which it came; but at present it seems improbable that this material can compete commercially with the cheaper sources of fertilizer.

Besides the products mentioned, there are a number of others, such as filter cloth and rubber belting, that are sometimes made of use for various purposes by the local community.

CHAPTER XIII

PESTS AND DISEASES

WITH the increase in sugar-beet production, it is only natural that there should also be an increase in the pests that attack the plant. The gradual introduction of the enemies of the crop into sections is continually making the sugar-beet more difficult to raise. Because the various troubles are likely to appear at almost any locality, it is imperative that growers should be able to recognize them in order that they may be checked as completely as possible. Profitable sugar-beet production has practically ceased in certain sections because the seriousness of the pests was not recognized and control measures taken in time. It is not within the scope of this book to give a complete discussion of all the pests and diseases affecting sugar-beets. Those who wish more detailed information should consult the special publications dealing with the various troubles.

INSECT PESTS

Extent of pest injury.

There are at least one hundred and fifty species of insects known to feed on beets; of these about forty are of economic importance.[1] It is the leaves and not the marketable part of the beet that usually suffer; therefore, unless proper functioning of the leaves is prevented, the injury passes without notice.

Ordinarily, injury is not great if proper methods are taken to prevent the incoming of pests; but if no attention is given to them and if farm practices are followed without regard to pest troubles, the damage is likely to be considerable. For example, the nematode when introduced into a region is usually unheeded, because of which it gradually infests the soil, making beet-growing impossible until suitable rotations are adopted. Insect difficulties vary greatly from year to year. One year grasshoppers or army-worms may devour everything in their way, but the next year they may be absent almost entirely.

Whenever there is a serious outbreak of any pest or disease in a locality, the State Agricultural College should be called on for help and every agency should coöperate. The sugar factory agriculturist and the county agricultural agent will be able to give assistance with ordinary troubles. When a new pest or disease appears, experts from the State Experiment Station or the Department of Agriculture should be summoned.

Preventive measures for controlling pests.

A few general precautions known and utilized by all beet farmers would prevent a great part of the loss occasioned by insects. Weeds, especially those belonging to the same family as the sugar-beet, such as the dock,

[1] Forbes, S. A., and Hart, C. A., *Ill. Exp. Sta., Bul. No.* 60.

lambsquarter, and cocklebur, are breeding plants of many of the most serious pests. Clean culture that would eliminate these weeds greatly lessens the injury due to insects. Rotation of crops is practiced by many of the beet-farmers, but a few maintain the one-crop system until the enemies of the beet become so numerous that the crop no longer can be grown. Much loss is occasioned by planting beets after grass or similar crops that harbor some of the worst beet enemies, such as the cutworms and wireworms. Fields are not ordinarily kept as clean of insect-harboring rubbish over winter as might be wished. In sections where cutworms give difficulty it should be known that plowing either in the fall or in the spring lessens injury from this insect. When attacks of insects become acute, sprays and insecticides save much injury.

Two general classes of insecticides are available: (1) contact solutions for insects such as plant-lice and leaf-hoppers, which obtain their food by piercing the plant and by sucking its juice; and (2) poisons applied in solution to the leaves of the plant to kill such insects as caterpillars, beetles, and grasshoppers, which feed on the outside of the leaves. The most effective contact spray is made of a solution of tobacco. For biting or chewing insects, sprays containing a poison such as the arsenicals are employed, the insects being killed by eating a part of the plant covered by some of the poison. The latter type of spray should contain a very active poison which will not easily run off the leaves of the plant and be wasted, as frequently happens when not properly applied; hence arsenate of lead is one of the best sprays.

Insect troubles vary from section to section; some of the most serious in one locality are not known in others. Certain insects, though present in a locality, may do very little damage even when serious elsewhere. Such insects as the leaf-hopper are greatly affected by geography. In some places they have rendered successful beet-culture practically impossible, though in other sections the injury is but slight. Treatments must, therefore, be applied locally. No general description will suit all conditions.

Blister-beetles (*Meloidae*). (Plate XXI.)

These insects sometimes descend in swarms on field and garden crops, destroying the foliage and ruining the crops. No less than a dozen species of blister-beetles work on crops. The insect is a long, narrow beetle with a distinct head and "neck." In color it is black, gray, or mottled, with a black or yellow stripe running the length of the wings on most species. The grubs, or larvae, of the blister-beetle feed on grasshopper eggs, and when the grasshoppers are more injurious than the beetles, it may pay not to disturb the beetles. The beetles may be kept from the leaves by applying bordeaux mixture. When this spray is made up with paris green as a constituent, it may be beneficial. When the attack is sudden, the usual method of control is to drive the insects from the field by a number of men swinging branches over the crop. The beetles move ahead of such a disturbance and do not return quickly after once having been expelled.

Army-worms.

The beet army-worm (*Caradrina* [*Laphygma*] *exigua* Hbn.) occurs in disastrous abundance on beets at certain periods. Outbreaks of this pest in the beet fields of the western states have at times nearly ruined the crop. With the exhaustion of its usual food in years when it is worst, it migrates from field to field devouring everything in its course as shown in Plate XXI. The larvae which do the injury are naked, dull-striped worms resembling cutworms and closely related to them. Except when moving in armies, the worm is not noticed, because it usually remains concealed in the daytime, feeding mainly at night. When full grown, the worm is about one and one-half inches long, of a dark color except for a yellowish stripe down the back and one down each side. The second brood makes its appearance in the latter part of the summer; as a result, late plantings suffer most. Its normal food plants are certain weeds; hence clean culture will prevent a number of the pests from developing. Poisoning with paris green or arsenate of lead offers much relief when there are a great number of the insects. The poison should be applied as soon as injury is noticed.

The common army-worm (*Leucania unipuncta* Haw).

This species is similar to the above except that it has three yellow stripes instead of one down its back and it winters as a half-grown larva in the ground, emerging in the spring as a dull brownish moth. It more often attacks cereals and grasses, but also eats sugar-beets. This worm does its injury in early summer, whereas the beet army-worm is most troublesome in late summer. This insect troubles more crops than the beet army-worm and is more widely distributed. Ordinarily, it is held in check by its natural enemies, but when it becomes excessively abundant, control methods are necessary. One method of control is by plowing three or four furrows with the vertical edge facing the direction from which the army is approaching and dragging a log down these furrows to make a loose dust mulch. If the dust is warm, many of the insects perish by suffocation when they fall into this dust, but it is better to drag the pole down the furrow often during the invasion in order to kill as many as possible. If the attack is severe, it is often a good policy to spray the furrows with kerosene emulsion in case there is not sufficient time to do the dragging. The best method of control consists in applying a heavy dose of lead arsenate to the crop around the edge of the field. Poisoned bran mash is often effective in preventing a severe attack. By fall-plowing fields in which worms were numerous in late summer, many of the hibernating larvae are destroyed.

The fall army-worm (*Laphygma frugiperda* S. and A.). This species is rather similar to the above insect, but its destructive period is usually later in the summer. In appearance it is very similar to the beet army-worm and is distinguished from it by the number of dots on its segments. It does not develop the army instinct so readily as the common army-worm and is not ordinarily so destructive. It feeds on a wide variety of crops. Arsenical sprays are frequently successful in controlling this pest. Often on large fields, such as alfalfa stubble before the beet field is reached, many of the worms are crushed by running a heavy roller over the field. Plowing and disking, together with cultivation, kill many of the overwintering forms.

Sugar-beet webworm (*Loxostege sp.*).

These insects were introduced into this country before 1869, when they were observed in Utah, having probably come to the Pacific coast from the Orient. It is an inhabitant of Western and Central Europe and Northern Asia. Its wild food plant is pigweed (Amaranthus) and injury is greater to beets when this weed is allowed to grow abundantly.

The worms spin webs over the leaves of the beet and eat out the portions between the veins. The larva is an inch long when full grown, brownish in color, with a narrow dark stripe edged with white down the middle of the back, and a light stripe along each side. Small dots cover the surface of its body.

The worms burrow into the ground in the fall and spend the winter in white silken cocoons which they spin around themselves. In the spring the moth comes out and lays eggs on the leaves of pigweed and alfalfa. A second generation comes in July in some regions and a third in August. The last brood is likely to do most injury to sugar-beets.

Control measures consist of poisoning and late fall plowing, which breaks up their winter cells in the soil. Arsenate of lead is sprayed on the beet leaves. Since the worms destroy the plants rapidly, the poison must be put on as soon as the injury is observed.

Cutworms (*Noctuidae*).

Every gardener is familiar with the work of this group of insects. The several species going under the name of cutworms are the larvae of night-flying moths. The worms are smooth and of a mottled brown color, the species having a slightly different appearance. They work most vigorously in spring about the time the garden is coming up. They attack practically all crops, doing most damage by cutting off the young plants just as they are coming through the ground. When they are present in large numbers and take on the army habit, almost everything in their way is destroyed. They feed at night and hide during the day.

The moths lay eggs in July and August in fields that have grown up to weeds. The eggs hatch early in the fall and the young worms feed a few weeks before hibernating in the soil. In the spring they come out with a full-grown appetite ready to eat almost anything. If poisoned bran, clover, or alfalfa is spread over the field just before the young beets come up, the worms will devour sufficient of the bait to be killed before injury is done to the crop. Arsenate of lead is used for poison. In large fields thorough cultivation in the late summer and keeping the land free from weeds, together with deep fall plowing and early spring cultivation, help to control the pest.

White grubs (*Lachnosterna spp.*).

The larvae of several species of June bugs or May beetles pass under the name of white grubs. As high as 15 per cent of the fields of beets in some districts has been reported destroyed by this pest, although it is not usually considered to be serious. Its action is worse in crops following sod, since grass land is its natural breeding place. Its life history is similar to that of the wireworms discussed below, about two years being required for the grub to complete its cycle.

The presence of this pest is usually indicated by the dying of plants throughout the field. Examination of the soil near the plants shows the soft-bodied white worm curled up. It is from one inch to an inch and a quarter in length, and has a brown head and an enlarged abdomen.

Nothing added to the soil is practical in killing the grub. Fall plowing, proper rotation of crops, and avoiding the use of infected manure are all helpful in controlling the pest. Chickens and hogs are very fond of the grub and will help to eradicate it. Care in handling manure in which it develops may also help.

Wireworms (*Elateridae*).

The larvae of several species of "click beetles" or "snapping beetles" are known as wireworms on account of their tough and wiry appearance. These slender, cylindrical worms vary from one-half inch to one inch in length. They vary from a shiny yellow to a shiny yellowish brown color, with their segments showing plainly. They move about by means of three pairs of dark legs close to the front of the body.

"The life history of the injurious subterranean species is in some respects similar to that of the white grubs, the beetles being among the earliest spring arrivals, occurring in April and May, and flying rapidly in the heat of the day. The eggs are generally deposited in moist places grown up with grassy vegetation, weeds, or corn, and the larvae upon hatching feed, like the white grubs, upon the roots, developing slowly and requiring about the same period for the completion of the life cycle — about two or three years. Like the white grubs, the wireworms trans-form to pupae in autumn and the change to the beetle form takes place before winter, the beetles usually remaining in a quiescent state until their emergence the following spring."[1]

Wireworms do not affect sugar-beets nearly so much as they do some other crops. They are always worse after sod, corn, beans, or potatoes. When once they get into the land, they are difficult to eradicate by ordinary treatments. Nothing put on the land will kill them without also injuring the soil. One of the best ways is to starve them out by summer fallowing or by growing crops on which they do not feed. The elimination of trash from the field also helps.

Flea-beetles and leaf-beetles (*Chrysomelidae*).

Several small leaf-feeding beetles, known as flea-beetles and leaf-beetles, do considerable damage to sugar-beets. The most severe injury is to young beets when they have from two to eight leaves. Some of these insects cause injury both in the adult and larval stage. The beetles skeletonize the leaf by eating out the pulp between the veins. These insects are sometimes poisoned by the use of paris green, london purple, and paragrene applied dry mixed with flour and dusted on to the leaves. Arsenate of lead is an effective spray. Clean culture is also helpful.

Grasshoppers.

Grasshoppers are among the most common and the best known of crop pests. They eat almost all kinds of plants

[1] Chittenden, F. H., *U. S. Dept. of Agr., Bur. of Ent., Bul. No.* 43.

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and attack sugar-beets only incidentally. Grasshopper injury varies greatly from year to year, usually increasing gradually up to a climax year and then dropping off suddenly to begin the gradual ascension again. At least a dozen species are known to attack sugar-beets.

Grasshoppers are commonly kept within normal numbers by natural enemies, among which are birds, fungous diseases, and other insects. Mechanical means of coping with them, such as that shown in Plate XXI, are also used. Plowing under the eggs before they have had time to hatch is probably the most effective means of controlling them when the breeding grounds can be handled in this way. Several types of catchers are also used with success. Arsenic-bran mash is the most economical and effective poison.

Beet-root aphis (*Pemphigus betae* Doane).

Within the last few years the beet-root aphis has spread rapidly over the beet-growing sections of the United States. Attention was first called to it in 1896. It is similar in appearance to its relative, the woolly aphis of the apple. The insect lives on the small roots of the beet, sucking juice from it and thereby dwarfing the plant. It protects itself by means of its woolly covering and is consequently not injured by irrigation water. At intervals a generation of winged individuals appears; these fly to other fields, where they settle down and begin a new colony. In the fall, winged females fly to cottonwoods and lay eggs on the trunks. These hatch in the spring and migrate to leaves, where they pass one or more generations before going to the beet fields. In Colorado, another species (*Tychea brevicornis* Hart.) has done considerable damage. This species also works on corn roots.

No direct method of control is known for either of these insects. Sprays are impractical since the insects work under the ground. Prevention, the only known method of coping with the pest, can be practiced, however, in crop rotation and clean cultivation. Thorough tillage early in the spring is thought to help in controlling aphids.

Sugar-beet nematode (*Heterodera schachtii* Schmidt).

One of the pests that has done most damage to sugar-beets during the last few years is the nematode. This is not a true insect, but is an exceedingly fine, threadlike, colorless worm, so small that it is difficult to see with the naked eye. When these worms hatch from the egg, they enter the nearest rootlet and feed on the plant juices. This results in the formation of a dense mass of rootlets which cling to the beet when it is pulled up (Plate XXII). This has resulted in calling the trouble "bearded roots," "hairy roots," and other similar names.

The first evidence of the pest is a change in the color of the foliage, which takes on a lighter tint when the beet is injured. The outer leaves gradually wilt and finally die. The inner ones are small and do not thrive. Often the plant dies and the infected land is left bare. Usually this condition appears as a spot in the field which gradually enlarges. Since the pest is readily carried about in the soil, when it once becomes established in a district, it is likely to extend to all the fields unless its spread is checked.

Rotation of crops seems to be the best method of combating the difficulty. Many farmers, who have for several years raised sugar-beets on the same land, are being forced by the nematode to practice rotations. Shaw[1] has proposed dividing the sugar-beet states of the country into the following four groups and has given crops to be included in rotations in each group:

Group (1) California and Arizona.
Group (2) Oregon and Washington.
Group (3) Utah, Montana, Nevada, Colorado, Kansas, and South Dakota.
Group (4) Nebraska, Wisconsin, Indiana, Michigan, Ohio, New York, and West Virginia.

Crops for the groups:

Group (1) Cowpeas, soybeans, sweet clover, rye, the millets, tomatoes, asparagus, lettuce, cantaloupes, strawberries, barley,[2] corn,[2] Lima beans,[2] and wheat.[2]
Group (2) Cowpeas, soybeans, sweet clover, rye, the millets, truck crops (such as lettuce and asparagus — but not celery), barley,[2] and wheat.[2]
Group (3) In addition to the crops mentioned in Group (2), cantaloupes, cucumbers, and potatoes.[2]
Group (4) Clover, cowpeas, sweet clover, soybeans, rye, the millets, tobacco, flax, peppermint, cucumbers, strawberries, melons, lettuce, asparagus, some other truck crops, the grasses with the exception of tall oat-grass, barley,[2] corn,[2] Lima beans, potatoes, and wheat.[2]

When only small areas are infested, the pest may be prevented from spreading by pulling and destroying with quicklime beets for several feet around the infested area. When there might be a possibility of carrying the pest

[1] Shaw, H. B., *U. S. Dept. of Agr., Farmers' Bul. No.* 772.
[2] Occasionally slightly infested with beet nematode, but may be used in a rotation series.

PLATE XXII. — *Above*, beets injured with nematode in comparison with a normal beet of the same age; *below*, spot in beet field affected by nematode.

on seed, heating that seed to a dry temperature of 145° F. will kill any nematode without injuring the seed.

The beet leafhopper (*Eutettix tenella* Baker).

This is probably the most serious pest of the western sugar-beet. Plate XXIII. It causes injury through the disease curly-leaf, which it transmits. This disease, together with all other similar leaf troubles, has gone under the general name of "curly top." For many years the cause of this important disease was not known, but the discovery that it is due to punctures made in the leaf by the beet leafhopper makes clear the source of the difficulty.

"Attention [1] was first called to the trouble in 1899 and 1900, when it appeared throughout the entire western region from California to Nebraska. Another serious outbreak occurred in 1905. Over the large part of the area it has only appeared two or three times in twenty years. In smaller areas it has usually appeared in three-year attacks, cumulative in nature, after which it has almost totally disappeared for a time. In still other areas it has appeared the greater part of the time, and in these areas beet-raising has not been successful.

"This insect is single-brooded, hibernates as an adult, flies to the beet field in late spring, and lays eggs in beet stems — a few at a time until mid-summer. The larvae mature in summer and the adults disappear in early fall. It is found on shadscale, greasewood, Russian thistle, and fine-leaved annual salt bushes. Swarms of these insects appear suddenly in beet fields previously uninfested. Much evidence points to the conclusion that these

[1] Ball, E. D., *Utah Exp. Sta., Bul. No.* 155 (1917).

swarms fly from their breeding grounds on wild plants for long distances over mountain chains and other barriers. Sometimes there will be only one flight into a particular region; if so, beets coming up later will not be infested.

"Leafhoppers taken from wild plants do not transmit the disease until they feed on diseased beets. Three hours on a beet rendered them pathogenic, but they could not transmit until after an incubation period of one or two days. It is probable that some wild plant carries the disease and leafhoppers coming from this plant are able to transmit it to the beets.

"A large number of leafhoppers, early attack, hot weather, and clean cultivation are favorable to the curly-leaf development. The converse of these factors, together with frequent cultivation, early irrigation, and shade or weeds, are unfavorable. Seed growing is doubly hazardous in curly-leaf areas.

"Loss from curly-leaf may be largely prevented by avoiding dangerous areas, by planting small acreages in a 'blight cycle,' by controlling the time of planting, by not thinning just as the leafhoppers appear, and by knowledge of conditions on breeding grounds. Parasites doubtless assist somewhat in controlling the leafhopper, but to be at all effective should be introduced into the permanent breeding grounds."

DISEASE INJURY

The losses due to beet diseases have not been great in America, probably because beets have been grown here only a few years and the diseases have required time for their spread. New beet areas have each year been opened up and these have been free from disease. The American beet-raiser has come to regard the crop as being free from disease and requiring no attention in this matter. The time of complete freedom from disease, however, has passed. Already the fields in the older districts are infested; the fight must be taken up in earnest. We may feel thankful for past immunity, but now precautions must be taken to keep in check the diseases that menace the industry. Many fungous and bacterial organisms live on the sugar-beet plant, but only a few are of great economic importance. There are also a number of troubles that seem to be physiological. Forms of rot on tubers in storage are shown in Plate XXIII.

Leaf-spot (*Cercospora beticola* Sacc.).

This fungous disease is one of the best known and widely distributed of the sugar-beet. It is found in all American beet-growing districts. The amount of injury depends on the number of the fungous plants present and the period in the beet's life when the attack begins. Late plantings are as a rule less affected by the disease than early. It is more injurious to sugar-beets than to the red garden variety.

It begins as tiny white spots scattered over the leaf, which later develop into small brown spots with a reddish purple margin. There may be from ten spots to several hundred on each leaf. As the spots become older they turn ashen gray at the center and gradually increase in size until the entire leaf may be covered, when it becomes black and crisp. The outer, or older, leaves are the ones first affected.

Townsend,[1] in summarizing methods of control, says: "(1) Leaf-spot may be controlled on a commercial scale and in an expensive manner by a carefully planned and thoroughly executed system of crop rotations or by deep fall plowing. The best results are obtained by combining these two methods.

"(2) A proper and uniform supply of soil moisture, spraying, and proper disposition of beet tops and stable manure are important aids in the control of the leaf-spot.

"(3) The principal agencies in the distribution of the leaf-spot fungus are wind, water, insects, and man and other animals.

"(4) Leaf-spot tends to reduce either the tonnage or the sugar content of the beet, or both, depending on the time, duration, and severity of the attack.

"(5) Leaf-spot seriously injures the feeding value of beet tops."

Bordeaux mixture is used as a spray. The fungi are killed when the beet tops are siloed.

Heart-rot (*Phoma betae* Frank).

This disease, which is one of the most serious of the sugar-beet in sections of Germany, Austria, and France, has recently been introduced into the United States where it will probably become rather serious in the next few years. It has already gained a strong foothold in several beet-growing sections.

[1] Townsend, C. O., *U. S. Dept. of Agr., Farmers' Bul. No.* 618 (1914).

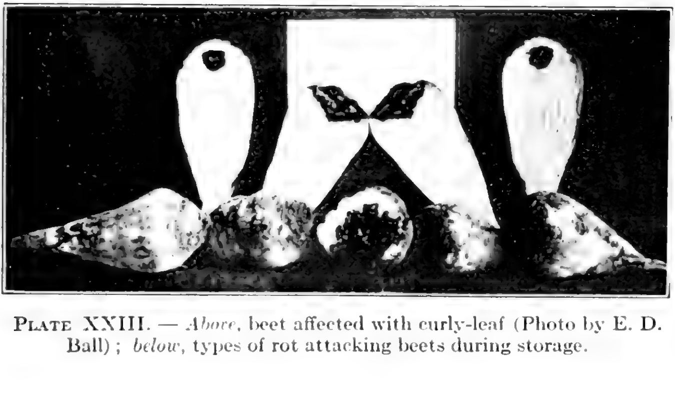

PLATE XXIII. — *Above*, beet affected with curly-leaf (Photo by E. D. Ball); *below*, types of rot attacking beets during storage.

Duggar[1] describes it as follows: "It begins to manifest itself as a rule in August by blackening and drying of the younger heart leaves, and later older leaves also succumb, so that before the period of harvesting all the leaves may be dead and merely the beet stub remain. In cases where the beets are grown for seed, the fungus may also be found upon the seed stalks and cases. It is thought that this is one means by which the fungus may pass over from one year to the next. From affected leaves, particularly along the course of the fibrovascular bundles, the browning and general discoloration of the tissues extend into the tissues of the root, and there rot sets in. If the disease begins early in the season great injury may be done.

"Spraying experiments have not yet given complete satisfaction. Care should be taken to destroy such remains of the previous crop as is practical, and the treatment of seed with Bordeaux mixture is desirable where disease abounds."

One company has adopted the practice of treating the seed where more than 25 per cent shows infection. The entire question of treating seed for this disease is at present somewhat unsettled.

Scab (*Oospora scabies* Thaxt.).

In some sections sugar-beets are affected by a scab similar in appearance to that on the potato and caused by the same organism. It usually covers the beet more completely than it does the potato. The disease begins as small irregularities on the surface of the beet in which a corky, or spongy, appearance is seen. These small patches

[1] Duggar, B. M., "Fungous Diseases of Plants." (1909), p. 3.

spread and unite till a great part of the surface of the beet may be covered.

On potatoes the disease may be controlled by treating the tubers, but this treatment is not applicable to beets. Beets should not be planted on land known to be infected with scab, and particular care should be taken not to follow scabby potatoes with beets.

Soft-rot (*Bacterium teutlium* Met.).

This rot has done considerable damage in Nebraska and in a number of other states where beets are grown. "It [1] consists of a rotting away of the lower portion of the root, the crown and leaves remaining normal except in the most severe cases, when the outer leaves may fall. The rotted portion is honeycombed with cavities which are filled with viscous, colorless, sour-smelling fluid which exudes on pressure. The decayed tissue is usually yellowish gray. The rot seldom appears above the surface of the ground. Young beets are not susceptible. The disease is favored by damp surroundings, as poorly drained soil. In some cases, large damage is known to result, sometimes fully 90 per cent of the crop being affected. It is inadvisable, if the disease is noted, to grow beets in wet soil."

The moisture condition of the soil seems to have great influence on soft-rot.

Beet-rust (*Uromyces betae* Kuhn).

This rust, which has been known in Europe for a half century, is found in some American beet fields, particularly

[1] Stevens, F. L., and Hall, J. G., "Diseases of Economic Plants." (1910), p. 209.

in California. It has the appearance of the true rusts. The leaves contain pustules of yellowish brown powder. Cold damp weather favors the development of the disease, which may be controlled by a bordeaux mixture spray, should it become sufficiently serious to justify this measure. Affected leaves fed to stock may carry the disease through the manure to plants the following season.

Rhizoctonia.

The group of fungi called Rhizoctonia by De Candolle seems to be responsible for injury to beets as well as to potatoes. The beet Rhizoctonia has gone under the name *Rhizoctonia betae* Kuhn, and has been popularly known as root-rot. This disease works principally in the seedling stage of the plant. At this time, on account of its girdling action, which is typical of Rhizoctonia, it shuts off the movement of food to the roots and the plant dies.

No effective preventive measure for controlling this disease is known. General sanitary conditions — draining the land and keeping the surface of the soil aërated and in a good sanitary condition — help in retarding its growth. One precaution in handling the trouble is to delay planting until the soil is warm enough to enable the seed to germinate rapidly and for the seedling to get a good start.

Sugar-beet mosaic.

This disease is increasing from year to year. In some places it affects a high percentage of the plants. It causes the leaves to turn a mottled yellow and to have a patched appearance. The shortened petiole resulting from it makes the plant resemble one having curly-top, although the two diseases are easy to distinguish. The roots of plants having the mosaic disease are likely to be dwarfed and are often hairy.

Damping-off.

The damping-off of seedlings near the surface of the ground when they first come up results in considerable loss in some districts. This may be caused by a number of organisms, among which are Rhizoctonia, Phoma, and Pythium. The conditions which favor damping-off are heat, abundant moisture, and a weakened condition of the seedlings. The elimination of any of these conditions greatly reduces the difficulty from this cause. Plants on heavy clay soils are more subject to the disease than those raised on lighter soils. Improving the tilth of these soils also reduces the likelihood of injury from damping-off.

CHAPTER XIV

FACTORS AFFECTING QUALITY OF BEETS

Success in the beet-sugar industry depends on the maintenance of high quality in the beets. The industry was made possible only by improving the quality of the crop; in the first years of beet-sugar making, profits were realized only in the more favorable seasons. Since the quality of beets has been so much improved, the industry has gained a foothold that places the raising of sugar-beets as one of the important phases of agriculture in many sections. As the success of the industry is so closely related to the quality of beets, everybody connected with their raising or the manufacture of sugar from them is interested in conditions that affect quality.

WHAT ARE GOOD BEETS

In choosing desirable types of beets, several definite ideas should be kept in mind. Chief attention must be given to high sugar-content combined with high yield. These two characters are somewhat antagonistic, yet neither can be neglected. The end sought is the highest acre-yield of sugar. At the same time, it is desirable to have beets of a size and shape that can be harvested and handled at the lowest possible labor cost to the farmer as well as beets from which the manufacturer can extract the sugar efficiently. This calls for beets of a high-yielding strain, high in sugar and purity, and having a desirable size and shape.

The qualities of good beets are summarized by Newlands[1] as follows (cf. Plate XXIV):

"1. They have a regular pear-shaped form and smooth skin. Long, tapering carrot-like roots are considered inferior to pear-shaped Silesian beets.

"2. They do not throw out forks, or fingers or toes.

"3. They have white and firm flesh, delicate and uniform structure, and clean sugary flavor. Thick-skinned roots are frequently spongy, and always more watery than beets distinguished by a uniform firm and close texture.

"4. They weigh, on an average, one and one-half to two and one-half pounds apiece. Neither very large nor very small roots are profitable to the sugar manufacturer. As a rule, beets weighing more than three and one-half pounds are watery and poor in sugar; and very small roots, weighing less than three-fourths of a pound, are either unripe or too woody, and in either case yield comparatively little sugar. As the soil and season have a great influence on the composition of the crop, it is quite possible, in a favorable season, and with proper cultivation, to produce beets weighing over four pounds, which, nevertheless, yield a good percentage of sugar. Speaking generally, good beet roots in average seasons seldom exceed two and one-half pounds in weight.

"5. Good beets show no tendency to become necky,

[1] Newlands, J. A. R. and B. E. R., "Sugar, a Handbook for Planters and Refiners," p. 395.

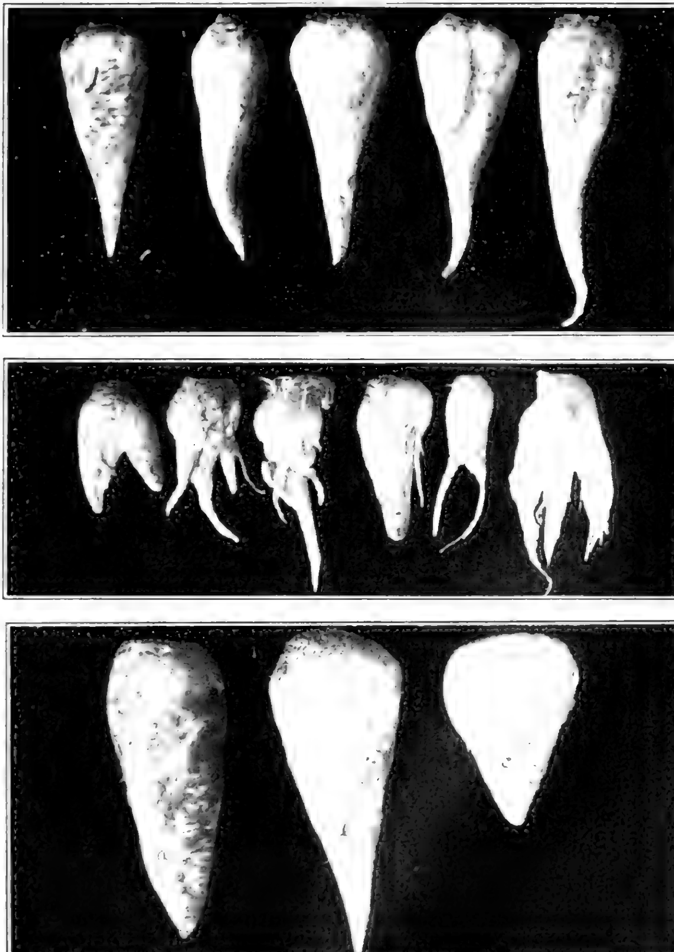

PLATE XXIV. — *Above*, well-shaped beets; *center*, beets of poor shape; such beets grow on water-logged land and also result from great quantities of coarse manure in the soil; *below*, three types of beets; *b* has a more desirable shape than *a* or *c*.

and their tops are always smaller than those of inferior beets. Cornwinder has shown that beets with large leaves are generally richer than those with smaller leaves, and he always prefers the former for seed.

"6. Good beet roots are considerably denser than water, and rapidly sink to the bottom of a vessel filled with water. The specific gravity of the roots affords a pretty good test of their quality, for the greater their specific gravity the richer they will be found in sugar as a rule. A still better test than the gravity of the root is the specific weight of the expressed juice. The juice of good roots has usually a density varying between 1.06 and 1.07. When very rich in sugar the gravity of the juice rises above 1.07, even reaching 1.078 in English-grown roots, indicating over 14 per cent of crystallizable sugar. Juice poor in sugar always has a density below 1.06.

"7. In a well-cultivated soil, the roots grow entirely in the ground, and throw up leaves of moderate size. This tendency to bury itself in the soil is characteristic of good sugar beets, but it may be greatly frustrated in thin stony soil and in stiff clay resting on impervious subsoil."

Sugar-beets raised under irrigation do not conform entirely to the above standards, since there is a tendency for them to grow larger than when irrigation water is not applied; good beets are often much larger than Newlands' figures indicate. It must be remembered, however, that very large beets are usually lower in sugar than the smaller ones. A definite correlation between size and sugar-content has been observed when other conditions are the same.

CONDITIONS PRODUCING GOOD BEETS

Climate is one of the most important agencies affecting the quality of beets. Wiley,[1] after several years of

TABLE VI. — TABLE OF GENERAL AVERAGES OF AGRICULTURAL AND ANALYTICAL DATA FOR THE FIVE YEARS, 1900–1904

Stations where Irrigation Was not Used

STATION	ESTIMATED YIELD PER ACRE	SUGAR IN THE BEET	PURITY COEFFICIENT	AVERAGE TEMPERATURE	
				June to August	May to October
	Tons	Per Cent		° F.	° F.
Lexington, Ky.	8.4	9.0	71.2	75.2	69.6
Washington, D. C.	15.7	9.1	71.3	74.2	68.9
Blacksburg, Va.[2]	13.3	12.9	77.7	69.9	64.4
Madison, Wis.	18.2	13.0	81.4	69.3	63.3
Lafayette, Ind.[3]	7.5	13.2	83.2	72.4	67.4
Ithaca, N. Y.	13.3	13.2	79.0	67.7	62.1
Ames, Iowa[2]	14.2	13.8	79.6	73.0	66.6
Agricultural College, Mich.[3]	13.4	14.2	83.6	68.0	62.3
Geneva, N. Y.	16.1	14.6	85.1	69.3	64.0

Stations where Irrigation Was Practiced

STATION	ESTIMATED YIELD PER ACRE	SUGAR IN THE BEET	PURITY COEFFICIENT	June to August	May to October
Logan, Utah[2]	18.9	13.2	81.2	69.5	62.4
Pomona, Cal.[4]	8.0	14.2	82.5	70.5	68.9[5]
Fort Collins, Colo.[2]	20.4	14.7	83.9	65.1	59.4

[1] Wiley, H. W., *U. S. Dept. of Agr., Bur. of Chem. Bul. No.* 96.
[2] Data for 3 years. [3] Data for 4 years.
[4] Data for 2 years.
[5] 1904; data for March to September.

experimentation, has pointed out how the weather, particularly the temperature, affects the percentage of sugar in beets. In this connection, he shows that a high sugar-content usually indicates a high purity also.

Tables VI and VII summarize the results of five years' experiments with sugar-beets raised under widely different climatic conditions in the United States. The author points out the fact that temperature, or, in other

TABLE VII. — GENERAL AVERAGES OF METEOROLOGICAL DATA (May to October) FOR THE FIVE YEARS, 1900–1904

Stations where Irrigation Was not Used

STATION	TEMPERATURE	PRECIPITATION	CLEAR DAYS	SUNSHINE
	° F.	Inches		Per Cent
Lexington, Ky.	69.6	14.9	90	71.6
Washington, D. C.	68.8	21.5	83	62.9
Blacksburg, Va.	64.4	21.9	57	53.7
Madison, Wis.	63.3	21.1	56	—
Lafayette, Ind.	67.4	20.8	71	64.7
Ithaca, N. Y.	62.1	18.8	48	60.4
Ames, Iowa	66.6	25.0	107	64.2
Agricultural College, Mich.	62.3	19.8	63	59.6
Geneva, N. Y.	64.0	20.0	—	—

Stations where Irrigation Was Practiced

STATION	TEMPERATURE	PRECIPITATION	CLEAR DAYS	SUNSHINE
Logan, Utah [1]	62.4	5.90	126	78.7
Pomona, Cal. [2]	68.9	3.65	124	73.8
Fort Collins, Colo. [1]	59.4	11.00	80	63.8

[1] Three years' data.

[2] Two years' data; 1904 data for March to September.

words, latitude, is the most potent element of environment in the production of beets rich in sugar.

It has already been indicated in Chapter V that the soil does not have so great an effect as some other factors in modifying the percentage of sugar in the beet. It does, however, have some effect and it has a decided influence on the size and shape of beets as well as on the purity of the juice. Headden[1] found that an excess of nitrates in the soil has a decidedly detrimental effect on the quality of beets. He[2] showed earlier that the amount of ash in the beet is increased by the presence of alkali. Voorhees[3] has pointed out that the kind of fertilizer and the time it is applied influence the sugar-beet. This has been discussed more fully in Chapter VI. It has often been observed that beets high in sugar have a lower percentage of ash than have poor beets.

Soil moisture during the growing season is one of the most important factors influencing the quality of beets. This has been discussed in Chapter X on irrigation and drainage.

There is a great difference in the quality of individual beets raised under the same conditions. This results from the ordinary variation found among all plants and animals. Part of this variation is due to heredity and is transmissible, but part of it cannot be transmitted to its progeny. There is, of course, considerable difference in the quality of beets of different strains, the same as there is a variation in the amount of milk given by different

[1] Headden, W. P., *Colo. Exp. Sta., Bul. No.* 183 (1912).
[2] Headden, W. P., *Colo. Exp. Sta., Bul. No.* 46 (1898).
[3] Voorhees, E. B., "Fertilizers," p. 344.

breeds of cows. The relation of breeding to quality is discussed rather fully in the next chapter.

The storage of beets may have considerable effect on their quality, although if they are stored properly the quality is not affected materially. A normal amount of respiration goes on in all beets; hence there is a gradual loss of sugar. This may be slight if the temperature is near the freezing point; but it increases rapidly as the temperature rises. Claassen [1] says that the rate of respiration does not seem to be affected by the percentage of sugar in the beets, but that it is much more rapid in unripe than in ripe beets. Breaking the beets into pieces and also any other mechanical injury tend to hasten respiration.

Freezing does not seem to injure the quality of beets, particularly if they are allowed to thaw slowly. Repeated freezing and thawing, however, has a detrimental effect, especially if the beets are allowed to become warm between the freezings. Headden [2] found that though simple freezing does not change the sugar-content of the beet, the distribution of the sugar is affected if only part of the beet is frozen. Sugar moves from the frozen to the unfrozen part.

Drying increases the percentage of sugar in the beet, but the total amount is not increased; in fact there is a loss of sugar when the beets are allowed to lose moisture. The purity is also reduced by drying. It is also more difficult to extract sugar from wilted beets. The factory, as well as the farmer, loses when beets are allowed to wilt.

[1] Claassen, H., "Beet Sugar Manufacture," p. 8.
[2] Headden, W. P., *Colo. Exp. Sta., Bul. No.* 46.

When beets have to be stored before they can be sliced, the pile should be given as smooth a surface as possible in order to reduce the relative amount of surface exposed, and thereby reduce evaporation. It is neither necessary nor desirable to cover beets piled in this way when the piles are large.

CHAPTER XV

PRODUCTION OF SUGAR-BEET SEED

In obtaining sugar from the beet there are three distinct enterprises: the production of seed, the raising of beets, and the manufacturing of sugar from the beets. In America, only the last two have been given special attention; America has depended on Europe for seed. The time has now arrived to forge the third link in the chain necessary to make the American beet-sugar industry secure. The uncertainty of a foreign supply of seed during war times, endangering an enterprise having a hundred million dollars invested, has demonstrated that all three phases of the industry must be developed at home.

IMPORTANCE OF GOOD SEED

To say that good seed is desirable is simply to re-state one of the commonplaces of all sound agricultural teaching. In the case of sugar-beets, however, this doctrine has a special significance. All the reasons for good seed with any crop apply to beets; in addition the entire success of the industry depends on having seed that will produce beets of a standard quality. With wheat, if the quality of seed is poor, the worst that can happen is that the yield of the resulting crop may be reduced by a few bushels. All the crop that is produced will serve the purpose for which it is raised. With beets, on the other hand, unless sufficient sugar is present to permit extraction at a profit, the crop is practically valueless for sugar-making.

The farmer and the sugar manufacturer are both interested in seed, for unless the factory can be made to pay, the business will have to be discontinued and the farmer will not have a market for his crop. The interests of the sugar factory have been so great that it has taken charge of the seed situation and has assumed the responsibility of furnishing seed to farmers contracting to raise beets. The factory could better afford to give the farmers free seed that would produce good beets than to allow them to plant inferior seed, for the cost of seed is negligible in comparison to other costs. If two grades of seed were obtainable, one that would produce beets having 14 per cent sugar and the other beets with 16 per cent with equal yield, it would pay the sugar company to take the better seed if it sold for a dollar a pound and the poorer seed could be secured for nothing. This shows how absolutely necessary it is to have nothing but the best seed.

HIGH GERMINATION

From the farmer's point of view, seed that is high in germinating power is essential. The yield of beets to the acre is directly dependent on the rate of germination of the seed. With some other crops, such as wheat, if the stand is poor, this condition can be overcome in part by the plants stooling and producing many heads from a single seed. More than a hundred heads of wheat have been reported to come from a single seed. In this way the plant tends to use all the food and moisture that is available in the soil even with a comparatively thin stand.

Beets have no such power to make up for a thin stand. The roots may be somewhat larger where they are not crowded; but if many of the seeds fail to germinate, it is impossible to secure a satisfactory yield. If there are blank spaces in the beet rows, the yield will be reduced by just that much. For this reason it is important to make careful germination tests of every lot of seed that is offered for sale. Particularly is this true of seed that is stained and dark in color, indicating that it has been wet.

SOURCES OF SEED

Until the last few years, practically all of the sugar-beet seed used in America was imported from Europe. This was not because it could not be raised in America, but because foreign seed could be obtained at a low price and it was much less trouble to secure it in this way than to produce it at home. The sugar companies arranged for the seed; they were in the business of making sugar and not of producing seed; hence they took the line of least resistance and purchased the seed where it could be obtained easiest. For this reason, a home seed industry was never developed. This method of procuring seed was satisfactory as long as everything went well, but it had its decided disadvantage.

The seed requirements of the United States for the next few years probably will reach nearly 15,000,000 pounds a year. For a number of years, in the neighborhood of 10,000,000 pounds of seed have been used annually. Prior to 1911, practically all this seed came from Germany, Austria-Hungary, Russia, and France. Since that time the home production has grown, and since 1914, when the European war made it impossible to depend on the old supply, the industry has developed very rapidly in America. Palmer [1] states that 90 per cent of all the beet seed used in the world is produced in Germany and Russia; 69 per cent is from German-grown seed; and 78 per cent of all the beet-sugar produced outside of Russia and Germany is from German-grown seed.

The amount of seed produced in the United States in 1916 and 1917 is given by the Department of Agriculture [2] as follows:

TABLE VIII. — SUGAR-BEET SEED PRODUCED IN THE UNITED STATES

STATES	BEETS GROWN FOR SEED			
	1916		1917 (Preliminary)	
	Area	Production of Seed	Area	Production of Seed
	Acres	*Pounds*	*Acres*	*Pounds*
California, Idaho, Utah	2,178	1,628,000	2,523	2,458,000
Colorado, Kansas, Montana, Nebraska	2,725	3,455,000	1,978	3,030,000
Michigan and Ohio	365	128,000	78	58,000
Total	5,268	5,211,000	4,579	5,546,000

[1] Palmer, T. G., "Sugar Beet Seed" (1918), p. 101.
[2] *Monthly Crop Report*, December, 1917, p. 128.

These figures show that between a third and a half of the seed required was produced in the country during 1916 and 1917. Considerable of the remainder came from Russia through Siberia. Since the reserves of seed stored in the country have gradually decreased, it will be necessary to rely entirely on the home supply until seed can be obtained from Europe.

DISADVANTAGES OF IMPORTING SEED

The importation of seed is attended by many disadvantages. In the first place, the entire beet-sugar industry is threatened in times of war, when, for any reason, it would be impossible to import seed. This condition cannot fail to detract to a great extent from the stability of the industry. Perhaps the most important disadvantage of imported seed is that the breeding has been done for conditions unlike those in which the beets are to be raised. Since the climate and soils of Europe are different from those of the beet-growing sections of the United States, there is doubtless a great loss in yield and sugar-content due to the foreign seed not being entirely suited to local conditions. When the source of supply is not near at hand, there is likely to be difficulty in adjusting any little business differences, which at times may become annoying. In times of scarcity of good seed, there is also a likelihood that the best will be held in Europe for home-planting and inferior seed sent to America.

Tests made at Schuyler, Nebraska, as early as 1893, gave better yields of beets with higher sugar-content from domestic than from imported seed. The same result has been obtained in many other places since that time. At the Utah Experiment Station,[1] tests were made to compare imported seed with that produced on the Station farm. The results given for imported seed represent the average of seed received from a number of foreign seed companies. In all cases, it was represented to be superior seed. The home-grown seed is from strains raised at the Experiment Station for ten years:

TABLE IX. — COMPARISON OF BEETS RAISED FROM IMPORTED AND FROM UTAH EXPERIMENT STATION SEED

Year	Utah Seed		Imported Seed	
	Per Cent Sugar in Beets	Yield Beets Tons per Acre	Per Cent Sugar in Beets	Yield Beets Tons per Acre
1912 . . .	18.97	22.68	18.25	25.15
1913 . . .	16.40	21.28	15.58	26.08
1914 . . .	16.25	25.06	15.45	29.03

The table shows that although the beets from home-grown seed were higher in sugar-content in each of the years than the beets from imported seed, the yield was somewhat higher for the imported seed.

Germination tests were conducted to compare the imported and the home-grown seed with the following result expressed in number of sprouts to 100 seed-balls: Imported seed — *a*, 53; *b*, 79; and *c*, 124; the average of six samples of home-grown seed was 126. Since each

[1] Harris, F. S., *Utah Exp. Sta., Bul. No.* 136 (1915).

seed-ball contains a number of germs, there are often more sprouts than seed-balls. It will be noted that of the three samples of foreign seed, not one was equal to the home-grown seed in germinating power.

The climate of the irrigated section of the West seems well adapted to the production of sugar-beet seed. The use of irrigation to control the soil moisture and the warm dry weather during the season when seed is growing make an almost ideal combination. In the sixteen years since the Utah Experiment Station began raising sugar-beet seed, there has not been a single failure.

TYPES OF BEETS

America has produced no distinct varieties or types of sugar-beets. An examination of almost any commercial field reveals a great diversity in shape and manner of growth. Some roots are long and of small diameter; others are short and turnip-like. The tops vary from erect plants with big leaves to plants with small leaves spreading out near the ground. These conditions show a great admixture of strains.

All of the sugar-beets belong to the same botanical species, *Beta vulgaris*. The differences have arisen from selection of special characters and have given rise to variation in shape, color, and size of beet, amount and manner of growth in foliage, as well as in sugar-content and yield. Selections were always made to improve the beet, and these selections resulted in considerable variation in appearance. Trade names have been given to the various types. Among the most common are: Vilmorin, Kleinwanzlebener, Excelsior, Imperial, Simon-Legrand, Florimond, Bultean-Desprez Richest, Schrieber, Heine, Brabant Demesmal, Electoral Elite, Imperator. The two first-named varieties are most widely known in this country.

If America is to establish a permanent sugar-beet-seed industry, one of the first steps will be the production of strains of beets suited to the needs of the country. Without doubt, some of the better European strains will furnish the basis for selection. In any event the work should be seriously undertaken and continued as long as necessary. This will require many years of careful work, but the returns probably will justify all the work that is done.

SINGLE-GERM SEED

The fact that the seed-ball contains several germs, each of which may produce a beet plant, makes the work of thinning laborious. Even though the seeds are scattered at intervals in the row, the young plants are found in such clusters that the extra plants can be removed successfully only by hand. This means that the number of acres of beets a farmer can raise is usually limited by the amount of help he can secure at thinning time. It also means that the expense of thinning is high.

These conditions led the United States Department of Agriculture, in the early days of the beet-sugar industry, to conduct rather extensive experiments on the breeding of strains of beets producing seed-balls that contained but one germ. Though some progress was made, the results were not altogether satisfactory and the work was

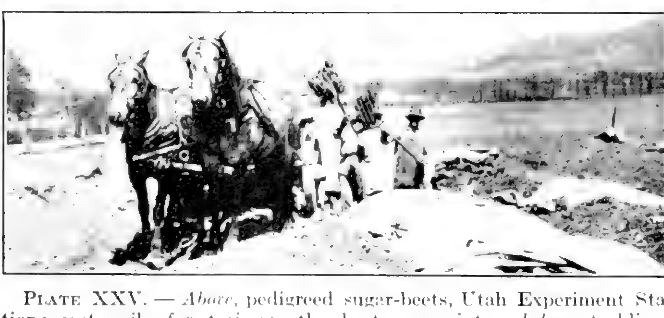

PLATE XXV. — *Above*, pedigreed sugar-beets, Utah Experiment Station; *center*, silos for storing mother beets over winter; *below*, stecklinge being taken from the silo to the field for planting.

abandoned. Whether or not the single-germ beet seed is practical, only the future can demonstrate. There can be no doubt, however, about the desirability of having seed of this kind.

BREEDING (PLATE XXV)

There are two distinct phases to the sugar-beet-seed business: (1) the breeding of desirable strains, and (2) the commercial production of seed. This is true to an extent in every branch of plant and animal production. The man who is engaged in that phase of dairying which deals with commercial milk production may be entirely dependent on some breeder of dairy stock for his cows; likewise, the man who is breeding some new and desirable type of plant may not be interested in the general seed trade. The ordinary individual farmer probably will never take an important part in breeding sugar-beets; he may, however, engage in the commercial production of sugar-beet seed, using as his start "mother seed" that has been produced by a professional breeder.

Chemical test of mothers.

The breeding of sugar-beets is not so simple as that of most other crops, the quality of which can usually be determined by examination. With beets, the important factor, the sugar-content, can be determined only after making a chemical analysis. Some selection of beets has been made by specific gravity as determined in a brine solution. This method, while it indicates to a certain extent the amount of sugar, is so inexact that it finds very little use. In the standard method of selection the chemical analysis is used.

The beet to be tested is cleaned and the sample to be analyzed is obtained by boring a hole diagonally through the beet near the thickest point in such a way that the various zones of high and low sugar will be represented. A given weight of the pulp obtained from the boring is placed in a dish and the sugar extracted by any one of a number of methods. The solution containing the sugar is then placed in a tube which is inserted in a polariscope by aid of which the percentage is read directly. The process is not difficult, but it requires skill in laboratory manipulation and is not adapted to use by the average farmer. Removing the core does not interfere with the growth of the beet if it is stored properly.

Steps in selection.

It is not safe to save all beets that are high in sugar without making further tests to see which ones transmit this quality. The individual beet may be high in sugar because of its environment and may not be of a high-producing strain. For this reason, several years of selection are required before one can be sure of quality of seed that will be produced. It is not the mother beet with high sugar-content that is desired, but the mother whose progeny will be high in sugar. In testing strains, it is a good plan to have for comparison standard seed for growing in different parts of the test field.

The procedure usually carried out is somewhat as follows: The first year a great many beets of desirable size and shape are analyzed for sugar. The better individual beets are siloed; the second year these are planted separately and the resulting beets analyzed. From this analysis it is possible to determine which of the original beets with a high sugar-content are able to transmit to their progeny this necessary quality. The poor strains are discarded and the good ones siloed, to be used the fourth year in producing the "mother seed." The mother seed is planted the fifth year and the beets obtained from it produce the commercial seed the sixth year. The part of the work requiring skill and patience is the obtaining of dependable mother seed.

In planting beets from which the commercial seed is produced, the roots are left considerably closer together in the rows than when regular beets are to be raised. About eight pounds of seed are used to the acre and the plants are not thinned in the ordinary way. Sometimes the plants are thinned to three or four inches apart in the row and sometimes they are left unthinned. This method is used in order to save labor in handling the beets. Less storage space is required for the small beets than for those of full size. Being small does not seem to reduce materially the amount of seed produced. These small beets are called "stecklinge." Beets that are large are sometimes split lengthwise into two or three pieces, each of which will grow if part of the live buds in the crown are retained.

COMMERCIAL PRODUCTION OF SEED

Siloing.

One of the most important operations in connection with seed production is the storing over winter, or siloing, of the beets that are to be used the next year in raising seed. At the Utah Station several methods of siloing have been tested; a number of these have given good satisfaction. The important precautions to be kept in mind are that the beets must not be allowed to dry, to freeze, or to heat. Sufficient ventilation must be provided to allow the carbon dioxid produced by normal respiration to escape and at the same time not enough to dry the beets. Sufficient covering must be given to prevent freezing, but not enough to cause heating.

Beets stored in moist sand kept better than by any other method used, although this method is not practical except for the comparatively few mother beets that have been individually analyzed and are more likely to decay on account of the wound caused when the core is removed for analysis.

For the great number of beets used in producing commercial seed, perhaps the best way is to silo them in the field. This is done by piling the beets on top of the ground or in a shallow trench in ricks four or five feet wide, and then covering them with soil. Only a light covering is given at first and more is added as the weather becomes cooler. In very cold weather manure on top of the silo is helpful.

Ventilators should be placed in the ricks every few feet to allow carbon dioxid to escape and fresh air to enter. Less ventilation is necessary if the remainder of the silo is left open a few weeks after the beets are placed in it. If a long rick is made, the beets should be divided every twelve or fifteen feet in order that if decay begins at any point it will not destroy all the beets in the silo. Before placing the beets in the silo it is a good plan to remove the tops, leaving enough of the crown and tops to permit growth to begin the next spring. If mother beets are allowed to wilt before they are planted, the yield of seed is greatly reduced. Likewise, if they are not put into the silos fresh, the keeping quality is not so good. Beets to be siloed should usually be left in the fields as long as possible before digging, keeping in mind the injury that may result from frost.

The methods of siloing vary considerably with the intensity of the winter cold. In some climates beets live over winter in the field and will produce seed without being dug and siloed. This is not the case, however, in most of the best seed-producing sections. The temperature of the beets in the silo should be taken at intervals during the winter to serve as a guide to the amount of covering needed.

Planting mother beets.

The stecklinge can be planted considerably earlier in the spring than the best seed, since the old beets are not as sensitive to frost as are seedlings. It is probably needless to say that the land should have been plowed deeply. Experiments with a number of methods of planting and distances between plants have been made and the following method adopted as a result:

The land is marked each way about thirty inches apart and a beet dropped at each crossing of the marks. The best distance apart will, of course, depend on conditions. A long spade is pushed into the ground and the beet put in behind or in front of the spade when it is moved for-ward. It is important to plant the beets well below the surface of the soil. The crown should be covered with a small quantity of soil to protect the budding top. The rows being the same distance apart each way, the cultivator can be run in two directions and much hand labor thereby saved. In many cases no attempt is made to provide for two-way cultivation; the beets are merely planted every twenty to thirty inches apart in rows that are about three feet apart. Sometimes a furrow is made with a plow or deep cultivator and the beets planted in it.

The South Dakota Station [1] reports using a machine for transplanting beets in 1916. It was an adapted planter similar to those used in transplanting tobacco; it was also used in transplanting alfalfa roots. "This is a two-wheeled machine with one shovel to open the furrows, two boxes to hold the beets and three seats, one for the driver and two for the beet droppers. Wings draw the dirt around the beets as they are dropped. A pair of rollers to firm the dirt around the beets would make a great improvement. About two or two and a half acres a day was the rate achieved in the trials." It seems probable that some machine will be devised to reduce the great amount of hand labor required in planting mother beets.

Care of seed crop during growth.

When seed is raised under irrigation, it seems advisable to apply water very soon after the beets are planted in

[1] Shephard, J. H., *South Dakota Exp. Sta., Bul. No.* 173. (1917), p. 615.

PLATE XXVI. — A good crop of sugar-beet seed, Utah.

order that the soil may be firmed around the roots and also to insure an early starting of growth. Two or three additional irrigations are usually ample to mature the seed crop. The soil should have sufficient moisture while the seed is forming. Early cultivation is desirable to keep weeds in check as they are much more easily killed at this time. After the seed-stalks become too large, it is difficult to get through the field with a cultivator; unless weeds have been kept in check up to this time, they may prove troublesome and may need to be removed by hand. In any case, late hoeing may be desirable.

Harvesting and threshing. (Plate XXVI.)

Since the seed does not ripen evenly, it is necessary to go over the field and cut some of the plants before all are ripe. This is not practical when seed is raised on a large scale. The ripening period may extend over a number of weeks. The cutting is done with a sickle and the seed-stalks piled in the field to dry before threshing. It usually pays to go over the field after harvest with a brush and dustpan to glean seed that has fallen to the ground in cutting. Threshing can be performed with an ordinary grain thresher with the speed retarded, special screens, and certain adjustments. Special threshers may also be procured. From fifteen to twenty tons of seed can be threshed in a day.

After the seed is threshed, some dirt and stems always remain. These are best removed by running the seed over a revolving canvas, which allows the seed to roll off and at the same time carries the stems away. The dirt and chaff are removed with a fanning mill before the seed is run over the canvas. The seed-cleaning machines may be purchased, or one may be made at home for about $100. A good machine will clean about a ton of seed in a day.

By-products.

After the seed crop is harvested, the beets and part of the stems and leaves still remain in the field. The beets contain considerable sugar, although much less than at first. They have, however, acquired a woody texture that renders them much less palatable to stock than the fresh beets. A number of cases have been reported of animals dying as a result of accumulated balls of this fibrous material in the digestive tract when fed too many of these beets. They have been used in many other cases without any apparent ill effects. The method of utilizing these beets most economically is not known, but it is probable that the cheapest way is to have stock pasture on these old roots directly in the field similar to hogging-off corn. They can be used safely and economically in this way to supplement other feeds.

Yields and profits.

The amount of seed produced varies greatly under different conditions. If all the plants give a normal yield, the amount of seed that would be expected theoretically would be several times the yield actually realized in practice. One of the chief causes for this is that a large number of the plants never send up seed-stalks, but throughout the summer merely develop a dense growth of leaves.

At the Utah Station tests running for nine years gave the following yield of seed from the individual plants:

TABLE X. — AVERAGE WEIGHT OF SEED PRODUCED BY MOTHER BEETS

YEAR	NUMBER MOTHERS TESTED	AVERAGE WEIGHT OF SEED PER BEET (grams)[1]
1905	309	368.9
1906	66	356.5
1907	178	714.6
1908	200	722.6
1909	395	405.0
1910	348	282.3
1911	470	374.3
1912	135	393.4
1913	53	263.7
Average		431.2

An acre of land contains about 7000 mother beets. If each one produced as much as the average reported above, nearly 7000 pounds of seed to the acre might be expected. This, however, is not approached in practice. The yield is usually between 1000 and 2000 pounds to the acre. A yield greater than 2000 pounds is exceptional. The average yield of seed for the United States for 1916 and 1917 was about 1100 pounds to the acre.

The fields of commercial seed raised by the Utah Experiment Station at Logan have given the following yields during the years 1912 to 1917 inclusive:

[1] There are 453 grams in one pound.

Table XI. — Yield to the Acre of Sugar-Beet Seed, Logan, Utah

Year	Pounds of Beet Seed to the Acre
1912	1,190
1913	1,354
1914	1,571
1915	1,868
1916	1,558
1917	1,223
Average	1,461

At a price of fifteen cents a pound for the seed, the return for an acre is $219.15.

The cost of producing this seed varies so much with conditions that definite figures are almost useless, but the following figures for cost are suggestive:

Table XII. — Estimated Cost of Raising One Acre of Sugar-Beet Seed

Rent of land (value $250 an acre)	$ 20.00
Plowing and preparing land	5.00
Hauling stecklinge from silo and planting	15.00
Cultivating and irrigating	6.00
Hoeing	2.00
Cutting seed	5.00
Threshing and cleaning	15.00
Cost of mother seed and stecklinge	40.00
Total	$108.00

A comparison of these figures for cost with the price obtained for seed shows that a good profit may be made. This profit, taken with the fact that domestic seed is better than the imported, surely justifies the establishment of a sugar-beet-seed industry in America.

CHAPTER XVI

COST OF PRODUCING BEETS

No phase of the beet-sugar industry is more elusive than the cost of producing beets. The costs involved in slicing the beets, extracting the sugar, evaporating the juice, and handling the sugar can be determined with considerable accuracy; under normal conditions, these manufacturing processes are fairly constant in their cost. The cost of raising beets, on the other hand, is exceedingly variable from field to field and from year to year. Cost determinations are usually made on the basis of an acre of beets; but a much more useful figure would be the cost of a ton of beets, or even better, the beet-cost entering into a hundred pounds of sugar. The costs reported thus far have been worked out largely from the standpoint of the dollar basis. They have been arrived at without making a detailed study of the hours of man and horse labor that enter into the production of the crop or without including in every case definite information with reference to other items of cost that form a part of the account.

NEED FOR LOW COST

The permanency of the beet-sugar industry in any country depends on the ability of farmers to produce beets at a low cost. In unusual times and when sugar is scarce and high priced, it may be manufactured at a profit even if the beets are not raised in an efficient manner and if the cost of production is high; but if conditions throughout the world become balanced, beet-sugar will not be able to compete with cane-sugar, even though the former may enjoy a limited protection. The life of the industry depends on the efficiency of the beet farmer, who should seek in every way to reduce costs rather than to increase them. The process of extracting sugar from beets has reached a high state of perfection. The farmer should try to make his methods equally perfect.

The constant friction between the farmer and the sugar company regarding the price of beets causes the farmer to make his costs seem as high as possible, whereas the manufacturer wants them to be low. This leads to considerable discrepancy in estimates of costs and makes it more difficult to determine actual costs. The profit-sharing plans for paying for beets, which are being discussed more each year, will necessitate definite cost figures being obtained, not only for the making of sugar, but also for the raising of beets. Farmer and manufacturer alike should be interested in keeping the cost of both phases of the industry as low as possible in order that each may obtain the greatest profit.

Practically the entire world's supply of sugar under normal conditions comes from countries such as Cuba, Java, Germany, Austria-Hungary, France, and Russia, where labor is much cheaper than in the United States. If we are to produce sugar in competition, it is essential that our labor be made as efficient as possible by the use of machinery and the application of scientific methods to the farm. It will also be necessary to raise sugar-beets in the parts of the country best adapted to their growth. It is on the farm that this greater efficiency must be sought, since the price paid for the beets is the chief item of expense involved in the cost of beet-sugar.

DIFFICULTY OF OBTAINING COSTS

It is often asserted that beet producers are receiving abnormal profits for their crops; and about equally often the beet-growers contend that there is no profit in raising beets, or that if all costs were considered the crop is ordinarily produced at a loss. Data to prove either contention can be gathered from both large and small farms. In some communities only a very few farmers can produce beets at a profit when the average for a number of years is taken. Naturally, in such places, beets become unpopular and conclusive results can be given to show that beets are unprofitable; in a more favored locality, the opposite can be shown as readily.

It is highly desirable to find unbiased results that will show the true condition for the sugar-beet producers of the country as a whole, for each locality, and for each individual farm. At present such data have not been determined satisfactorily. Much valuable material has been compiled to show the costs, but since many factors are unfortunately left out of most of these compilations, they do not represent the true cost. Results in this regard, as reported from experiments on a small scale, generally show high yields and a high labor cost, indicating that more care has been taken than could be reasonably expected in ordinary farm practice. Often such costs as land rent and depreciation of machinery are omitted entirely. Estimates from farmers are usually unsatisfactory because very few keep accurate accounts of the various small items. Reports from farmers, in order to be reliable, must be taken systematically and carefully, and the number of farmers interviewed must be large if error is to be reduced to a minimum.

Except for general study, it is imperative that all conditions be given in order that a true interpretation can be made, since cost of labor, nature of soil, efficiency in work, thoroughness of method, and numerous other factors vary so much that general estimates are of little value. Many of the figures available are for only one season, and it is well known that costs and yields vary greatly with the year.

COST OF GROWING IN VARIOUS SECTIONS

When averages of a large number of growers are taken, the cost of producing beets is nearly equal to the price received for them, all factors being considered. A slight profit would be expected if the true averages were available, because in general the farmers of the older beet-growing sections consider the crop worth while. The profitableness of a crop is usually indicated by the readiness with which the farmers grow it; and farmers are usually glad to raise beets.

The Federal Trade Commission in 1917 made a "Report on the Beet Sugar Industry in the United States."

This study covered practically every beet-producing section in the United States. Estimated costs were obtained from many farmers in each district. These are summarized by states in Fig. 28. Since the data were carefully collected and compiled, they may be considered

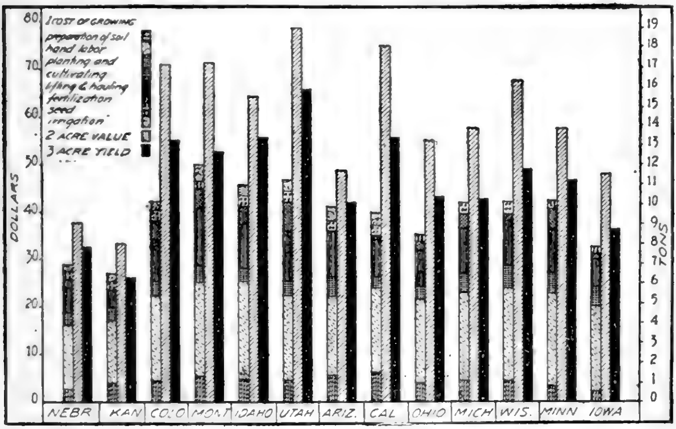

Fig. 28. — Diagram of costs involved in producing sugar-beets in various states. (Compiled from Report of the Federal Trade Commission, May 24, 1917.)

to be approximately correct for the districts and for the costs during that year (1913) at least. The figure shows the cost, including the following items: soil preparation, hand labor, planting and cultivating, lifting and hauling, fertilizing, seed, and irrigation; but it omits the rental value of the land and depreciation of machinery, ditches, fences, and the like. The item of land rent is important in considering cost of production, for it is ordinarily from one-sixth to one-fourth of the value of the crop. That the value of the farms studied in this survey were above the ordinary beet land is seen from the fact that the yields reported average in the neighborhood of one-third higher than the yields for states as reported from other sources.[1]

In addition to the rental cost, there should be added from 3 to 10 per cent of the costs mentioned for taxes, depreciation on machinery, and other incidentals. Then about 6 or 7 per cent of the cost as given should be added to account for crop failures or acreages not harvested, if the true cost is to be found. Keeping this in mind when studying the gross returns from the crop and the yield to the acre represented in columns two and three of the chart, it will be seen that beets on the better class of land in most of the states yield a profit under normal conditions. It is evident, however, that the true net returns are not so great as one is sometimes led to believe from incomplete costs. The cost data are not complete enough to draw satisfactory conclusions, because we do not know whether the land represented in the high-producing states — Utah, Idaho, California, and Colorado — was on the 200- to 300-dollar-an-acre land that rents for fifteen to twenty dollars an acre each year, or whether the low-producing states represented the 100- to 200-dollar-an-acre land drawing a rent of six to ten dollars an acre. But it appears that the profit to the acre from the crop increases rather strikingly as the yield increases above a minimum point. The larger yields in the West permit more care to be given economically to the crop as the yield increases; or rather, the high wages and other

[1] *U. S. Dept. of Agri. Yearbook* (1913), p. 447.

costs in the West can be paid because the yields are high enough to cover them, and still leave a profit.

The results are interesting in that they show the relation of yield to the various factors of production in the different localities, although it should be remembered that climatic and soil factors are much more important in determining the profitableness of beets than is labor. The cultural practices, except special operations such as irrigation, are thought, on an average, not to differ so widely in the different states as do wages. It will be noticed that the costs of hand labor and lifting and hauling the beets vary somewhat according to yield and that the greatest variations are in the cost of lifting and hauling. Since the cost of harvesting is known to constitute from one-fifth to one-third of the total cost of growing beets, this is to be expected. This increases somewhat with the yield.

RELATION OF NUMBER OF ACRES RAISED TO COST AND PROFIT

By arranging the data from the above survey in Table XIII, according to the number of acres of beets grown, it is found that the acreage of beets has but little influence on the cost of production, farms with only a few acres of beets producing them as economically as those with over a hundred acres. Farm surveys in general show that the larger farms up to a certain point are the more efficient; this is thought to hold good with beet farms as well as others. A survey in Utah indicated that the proportion of the land devoted to beets increased as the profitable-

TABLE XIII. — EFFECT OF NUMBER OF ACRES OF BEETS RAISED ON THE FARM ON THE COST OF PRODUCTION. (COMPILED FROM RECORDS TAKEN BY THE U. S. FEDERAL TRADE COMMISSION FROM 453 BEET FARMS IN DIFFERENT PARTS OF THE UNITED STATES)

LIMITS SIZE	AVERAGE ACRES OF BEETS	NO. OF FARMS REPRESENTED	COST IN DOLLARS PER ACRE							YIELD PER ACRE TONS
			Hand Labor	Planting and Cultivating	Lifting and Hauling	Irrigation	Fertilizer	Seed	Misc.	
0–2½ . . .	1.90	20	18.43	5.02	10.11	—	4.01	2.24	.38	11.66
2½–5 . . .	3.66	41	17.73	3.72	9.84	3.13	5.53	2.15	.41	11.77
5–10 . . .	6.92	81	17.90	3.65	9.82	2.58	5.34	2.11	.47	12.07
10–15 . . .	12.03	67	17.93	3.01	8.95	2.40	4.81	2.06	.74	11.56
15–20 . . .	16.82	39	17.12	3.19	8.90	2.93	4.91	2.03	.25	11.54
20–25 . . .	21.71	35	19.20	3.16	9.47	2.66	5.22	2.11	.30	12.47
25–30 . . .	26.71	22	19.47	3.04	9.75	2.56	3.01	1.99	.44	10.83
30–40 . . .	34.05	42	19.44	3.00	10.29	2.81	5.09	2.07	.40	14.36
40–50 . . .	43.20	27	18.11	2.83	7.82	2.52	2.27	2.22	.58	11.46
50–75 . . .	58.60	35	23.59	2.86	9.20	3.09	3.68	4.92	.49	13.01
75–100 . .	88.85	13	17.51	2.38	7.61	3.34	4.32	2.05	.88	11.94
Over 100 . .	232.73	30	16.31	2.25	8.10	4.00	2.26	2.33	.29	12.54

ness of the farm decreased, but the acres of beets grown increased as the profitableness of the farm increases. Therefore, the only conclusion that may be drawn from these data is that both good and poor farmers grow large and small acreages of beets. It is regretted that the rental value of the land was not taken in the survey, because this, it is thought, would modify considerably the results on this point, as the size of the farms varied considerably in the different districts and the rental value would have varied in the same way.

Moorhouse[1] and his associates in the Office of Farm Management, United States Department of Agriculture, have obtained some interesting figures on the relation of acreage and yield to costs. The results are given in Tables XIV and XV.

These figures show that in each of the areas under investigation the yield to the acre exerted a very important influence on the cost of producing a ton of beets.

TABLE XIV. — RELATION OF ACREAGE AND YIELD PER ACRE TO COST PER ACRE AND PER TON. UTAH AND IDAHO

	10 Tons or Less			11 to 15 Tons			16 Tons and Over		
	No. of Farms	Per Acre	Per Ton	No. of Farms	Per Acre	Per Ton	No. of Farms	Per Acre	Per Ton
10 acres or less	12	$62.59	$8.65	17	$72.47	$5.53	29	$75.70	$4.12
11 to 20 acres	14	59.04	6.69	24	66.87	5.01	32	71.81	3.93
21 acres and over	8	60.20	6.22	18	64.70	4.85	19	70.19	4.02

[1] Correspondence with the author. Also see *U. S. Dept. of Agr., Bul. No.* 693 for additional figures.

Table XV. — Relation of Acreage and Yield per Acre to Cost per Acre and per Ton. Colorado

	10 Tons or Less			11 to 15 Tons			16 Tons and Over		
	No. of Farms	Per Acre	Per Ton	No. of Farms	Per Acre	Per Ton	No. of Farms	Per Acre	Per Ton
10 acres or less	12	$72.31	$7.72	23	$71.90	$5.64	24	$83.22	$4.87
11 to 20 acres	10	62.38	7.92	46	66.77	4.99	40	78.25	4.42
21 to 40 acres	21	57.35	6.30	80	65.78	4.99	56	75.09	4.21
41 acres and over	1	49.85	4.92	33	63.86	4.68	21	75.82	4.43

The relation between size of farm, area of beets planted, and labor income on 276 Utah farms is shown in Table XVI. The table shows that the labor income of farmers raising sugar-beets is higher than that of farmers not raising them. This is probably due as much to secondary profits, discussed in Chapter XII, as to direct returns from beets. On the average the yield was slightly higher on the medium-sized farms than on the very large or the very small ones.

COST BASED ON TIME

Because the prices paid for labor vary so much in different regions, it is impossible to give money costs that apply to all conditions. The length of time required in performing the various operations should be approximately the same. This offers a means of securing definite figures which may be computed for each region by using the price of man and horse labor that prevails.

TABLE XVI. — RELATION OF SUGAR-BEETS TO LABOR INCOME ON 276 FARMS IN CACHE, SALT LAKE, AND SEVIER COUNTIES, UTAH. (COMPILED BY N. I. BUTT FROM FARM MANAGEMENT SURVEYS.)

Labor Income		Number Farms Reported	Acres of Land			% Farms Raising Beets	Acre Yield Beets	Farm Income from		Number Crops Raised
Limits	Average		Total Farm	In Beets	% Land Beets			Crops	Stock	
Farms Raising Beets										
Over $2000 . .	$12,438	13	539.7	16.88	3.13	86.7	13.12	$3083	$17,044	6.15
$1000 to $1999	1430	44	107.5	11.19	10.41	84.6	14.53	1384	1999	5.55
500 to 999 . .	691	42	70.1	8.96	12.78	67.7	14.15	1026	785	5.64
0 to 499 . .	270	60	60.8	6.59	10.84	63.2	12.44	633	514	5.18
Less than 0 .	– 199	28	42.1	5.95	14.13	53.8	12.37	606	322	5.57
Farms Not Raising Beets										
Over $2000 .	6025	2	2661.5					430	11,094	4.50
$1000 to $1999	1371	8	128.0					1328	643	4.50
500 to 999 . .	769	20	76.5					960	584	6.70
0 to 499 . .	216	35	70.1					414	780	5.49
Less than 0 .	– 459	24	155.6					671	481	6.33

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Peck,[1] in Minnesota, has made a rather careful study of the cost of producing beets in that state, which unfortunately does not represent an important beet-producing area. Figs. 29, 30. Table XVII, taken from his work, gives the total man hours to produce an acre of beets as 155.4 and the horse hours as 110.7. The time spent on the various operations is also shown:

TABLE XVII. — LABOR REQUIREMENTS FOR PRODUCING SUGAR-BEETS [2]

Operation	Total Acres	Hours per Acre	
		Man	Horse
Manuring	833.9	9.9	21.7
Plowing	1426.0	4.4	13.1
Disking	1134.0	2.3	8.2
Harrowing	1451.4	1.1	2.9
Planking	559.5	.9	2.1
Seeding	1458.4	1.3	2.6
Cultivating	1447.4	11.1	17.2
Bunching and thinning	462.1	44.2	—
Hoeing	—	21.0	—
Pulling and topping	—	37.8	—
Lifting	1458.4	3.5	6.7
Hauling	1458.4	17.9	36.2
Total		155.4	110.7

[1] Peck, F. W., "The Cost of Producing Sugar Beets," *Minn. Exp. Sta., Bul. No.* 154 (1916).

[2] Not contract labor. On an average the land was disked 2.4 times; harrowed, 2.3 times; cultivated, 5.2 times; and hoed, 1.4 times.

Mendelson[1] reports as follows results of a hearing before the United States Food Administration at Fort Morgan, Colorado, in 1918, on the work required in raising sugar-beets:

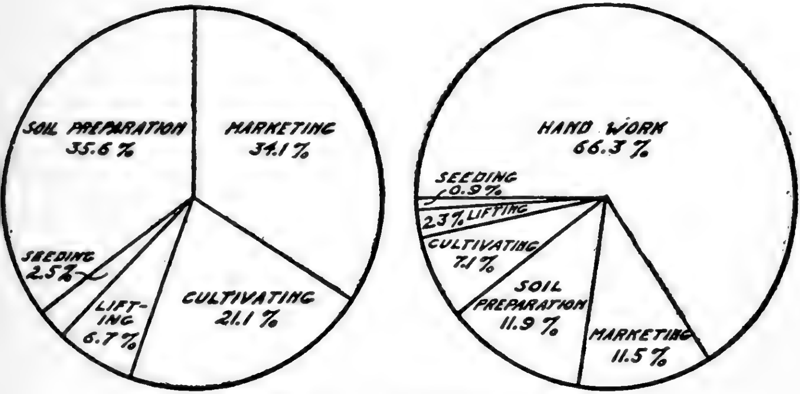


FIG. 29. — Man labor on sugar-beets. (F. W. Peck.)

"*Spreading manure.* Two men, four horses, and spreader will spread 20 beet boxes of manure on two acres in one day.

"*Crowning alfalfa* (once in 4 years). One man and five horses will crown three and one-half acres per day.

"*Harrowing the crowning twice* (once in 4 years). One man and three horses will harrow twenty acres per day.

"*Floating the crowning* (once in 4 years). One man and four horses will float 15 acres per day.

[1] Mendelson, H., "A Day's Work," *Sugar*, Vol. 20, p. 140 (April, 1918).

"*Plowing.* One man and five horses will plow two acres per day.

"*Harrowing.* One man and three horses will harrow sixteen acres per day.

"*Floating.* One man and four horses will float 10 acres per day.

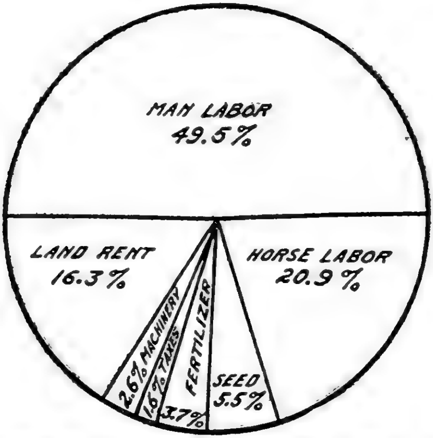


FIG. 30. — Distribution of cost of sugar-beet production. (F. W. Peck.)

"*Planting.* One man and two horses will plant nine acres per day.

"*Rolling.* One man and two horses will roll 14 acres per day.

"*Cultivating.* One man and two horses will cultivate eight acres per day.

"*Furrowing.* One man and two horses will furrow 15 acres per day.

"*Irrigating.* One man in twenty-four hours will irrigate eight acres.

"*Plowing out.* One man and four horses will plow out $2\frac{1}{4}$ acres per day.

"*Hauling.* One man and four horses will haul twelve tons per day.

"According to this schedule, the number of man and horse hours required per acre of beets for work done every year is as follows:

	Hours per Acre	
	Men	Horses
Spreading manure	10.0	20.0
Plowing	5.0	25.0
Harrowing three times	1.9	5.7
Floating two times	2.0	8.0
Planting	1.1	2.2
Rolling	0.7	1.4
Cultivating four times	5.0	10.0
Furrowing	0.7	1.4
Irrigating $2\frac{1}{2}$ times	7.5	—
Plowing out	4.4	17.6
Hauling (12 tons)	10.0	40.0
Total	48.3	131.3

"In addition to this in the above schedule, it is calculated that alfalfa is broken every fourth year, and that, therefore, one-fourth of the time required to break an acre of alfalfa should be charged against every year's beet crop.

"The total work required to break an acre of alfalfa, according to this schedule, is as follows:

	Men Hours	Horse Hours
Crowning	2.9	14.5
Harrowing twice	1.0	3.0
Floating once	0.7	2.8
Total	4.6	20.3

"One-fourth of this is, 1.2 men hours and 5.1 horse hours. This added to the regular work gives 49.5 men hours and 136.3 horse hours.

"This means that on a 25-acre patch of beets you will have to spend 1207.5 hours of work, or 120.75 working days of 10 hours, during a growing season for this work, and your horses will have performed 3410 hours, or 341 days of 10 hours each, or if you have 6 horses, each horse has averaged 57 days' work during the growing season on 25 acres of beets."

L. A. Moorhouse[1] found the following for man and horse labor in producing one acre of beets:

Table XVIII. — Information Pertaining to Practice and Cost of Production of Sugar-Beets. (1914–1915)

Item	Provo District, Utah	Garland District, Utah	Idaho Falls District, Idaho
No. of operators reporting	58	79	36
No. of acres grown	833	1461	735
Yield to the acre	14.9 tons	14.8 tons	13.6 tons
Hours of man labor	130.8	133.3	119.4
Hours of horse labor	117.1	98.5	79.3

[1] Correspondence with the author.

Commenting on this, Moorhouse says: "Labor was by far the most important item in this study. The total labor cost under the rates that prevailed in 1914–1915 varied from $35.25 an acre to $40.18. These sums constituted from 54.4 to 58.3 per cent of the total cost of production."

Although the different figures given above do not agree entirely, they are all suggestive and will be of assistance to any one who wishes to compute costs for his own neighborhood.

The beet farmers and sugar companies of Utah and Idaho agreed on the following schedule for contract hand labor for each acre during 1918: Thinning, $8; first hoeing, $3; second hoeing, $2, — or $26 for all hand labor based on a twelve-ton crop with one dollar extra for each additional ton and seventy-five cents less for each ton decrease in yield.

EXAMPLES OF ACRE-COST

Blakey[1] has made rather extensive investigations of the cost of producing sugar based on reports of farmers, actual field tests, and work of the experiment stations. His findings are summed up in Table XIX. In the table he does not include the cost of land, rent, taxes, and the like, which would probably be between $15 and $20, making the total cost about $75. The figures are fairly accurate for the dates represented, but they are doubtless too low for war-time prices of labor and materials.

[1] Blakey, R. G., "The United States Beet-Sugar Industry and the Tariff" (1912), pp. 113–140 and pp. 267–273.

TABLE XIX. — COSTS OF GROWING BEETS, ACTUAL AND ESTIMATED (BLAKEY)

	1905–1906 Actual Crops 3-year Average (Colorado)	Estimated Normal Average after This Experience
Labor costs		
Plowing and preparation for same	$ 4.06	$ 4.00
Harrowing, leveling, etc.	2.75	2.50
Seeding	.57	.45
Cultivating	3.64	3.25
Irrigating	2.42	2.25
Spraying	.22	—
Thinning	7.42	7.25
Hoeing	2.96	2.85
Topping	8.70	8.00
Pulling	2.16	2.00
Hauling	8.41	7.50
Siloing	1.15	1.00
Other costs		
Seed	1.87	1.85
Dump	.77	.75
Blacksmithing and repairs	1.15	1.00
Miscellaneous expenses	.39	.50
Implement depreciation (estimated)	2.56	2.00
Interest, crop investment (estimated)	1.33	1.30
Subtotals	(52.53)	(48.45)
Water rates	1.40	1.40
Management and supervision (estimated)	3.19	2.50
Totals [1]	$57.12	$52.35
Rent on land, taxes, etc.	——	——

[1] Does not include rent, interest on money invested in land, or taxes. However, this expenditure would produce more than the present normal yield for the country.

In many districts farmers maintain that the cost of producing an acre of beets is over $100. This is probably much more than the farmer ordinarily spends, and includes every expenditure that would be made in producing a maximum crop. The farmer does not of course commonly go to this amount of trouble and expense; he is usually satisfied to do a moderate amount of work and to secure an acre-yield somewhere near the average.

No accurate figures have been compiled for the cost of producing a ton of beets or for producing the beets necessary to make one hundred pounds of sugar. This phase of the cost of beet production deserves more attention on the part of students of beet-sugar economics.

CHAPTER XVII

BEET RAISING AND COMMUNITY WELFARE

In considering the value of the beet-sugar industry to the community, the indirect benefits of raising beets, as well as the direct value of the crop, should be considered. Those who have made a careful study of the subject are agreed that the introduction of sugar-beets into the agriculture of a region results in good in many ways. In the European countries where beet raising has seen its greatest development, agriculture has a stability not found in the newer countries where sugar-beets have not been introduced.

Palmer[1] says: "For fifteen years I have made a personal study of the sugar industry in the United States, Germany, Austria-Hungary, Russia, France, Belgium, Holland, Denmark, Sweden, and some portions of the tropics. In the above named countries of Europe, I have met or studied the writings of their leading agriculturists, economists, and other thinking men, and without exception they state that the culture of sugar-beets raises the standard of their agricultural methods as does no other crop, rids their fields of noxious growth, puts

[1] Palmer, Truman G., *Journal of the National Institute of Social Sciences*, July, 1916.

their soil in better condition, increases by 25 to 80 per cent the acreage yield of all other crops grown in rotation, and annually saves them from sending several hundred million dollars to the tropics to purchase a necessary food commodity. In no beet country visited was there found a disposition to regret its establishment or the money it cost to establish it. Germany alone spent over $351,000,000 in export bounties in order to encourage the industry."

STABILITY TO AGRICULTURE

Wherever the beet-sugar industry is permanently established, agriculture reaches a greater stability than it had previously. The fact that the farmer has a sure market for his crop at a price known in advance enables him to judge more accurately the value of the land. Experience shows the approximate yield of beets he may expect; and since he knows the costs of producing the crop and the returns he is likely to receive from it, he is able to calculate rather accurately how much he can afford to pay for beet land of known quality. This reduces the rapid fluctuation in the price of land that is often met in regions where profits are less certain.

In areas where crops have no regular cash market, it is difficult to obtain stability to the agriculture. Many fruit-producing sections boom during years of good market, and land prices become greatly inflated. This condition may be followed by a series of years when no market can be secured or when the crop is a failure due to frost or some other unfavorable condition. The result is that many farmers fail and have to sell the farm at a loss and seek employment elsewhere. Farming under these up-and-down conditions is not satisfactory. The introduction of beet raising into the farming system tends to overcome this variation. Fruit raising may yield higher profits during favorable years, but the uncertainty of its returns is not attractive to the conservative farmer and, therefore, not conducive to permanent agriculture.

PROMOTES GOOD FARMING

The raising of sugar-beets is not consistent with poor farming. Rye may be raised on land that is merely scratched; it needs but little attention in addition to the work of planting and harvesting. Sugar-beets, on the other hand, cannot be raised without careful attention being given to every operation, from plowing to the delivery of the crop at the factory. The expense of producing the crop is so great that the farmer cannot afford to neglect any phase of the work; carelessness in thinning may reduce the returns by several times the amount of the cost of thinning. The farmer cannot afford to allow weeds to grow, since these pests reduce the yield not only by using moisture and plant-food needed by the crop, but they cause a decrease in sugar formation by shading the beet leaves. In a cheaper crop, the cost of keeping weeds under complete control might not justify the expense; but in beet fields weeds cause greater injury than the expense of removing them. Thus, in every phase of sugar-beet farming, thoroughness is demanded. This is certain to reflect in the raising of other crops and to cause a general improvement in the agriculture of the section.

INCREASES CROP YIELDS

Statistics[1] show an increase in the yield of crops in every country where the raising of sugar-beets has been introduced. This is not due to any plant-food added to the soil by the beet plant, for it adds none, but is the result of the good tillage methods necessary to successful beet-culture. The fleshy tap-root of the beet penetrates deeply into the soil, which it loosens and allows to become thoroughly aërated. Any tendency to the formation of a "plow sole" is overcome, and there is a thorough mixing of the soil and the upper subsoil.

Beets require deep plowing in preparation for the crop; they are given constant cultivation during the growing period; and at harvest time the land is stirred deeply in removing the beets. This cultivation is paid for by the beet crop, but it also improves the condition of the soil for the crop that follows to such a marked degree that the yield is decidedly increased.

Pure sugar takes no fertility from the land; consequently, if all of the by-products of the beet-sugar industry are returned to the land, its fertility can be maintained readily. With most other crops, the marketable part contains large quantities of the mineral plant-foods. Of

[1] A great many figures on this subject have been compiled by Truman G. Palmer and published in his pamphlet entitled "Sugar at a Glance". — *U. S. Senate Document No.* 890, 62d Congress (1912).

course, it is not practical to return all by-products to the land, but with care the greater part may be conserved. The increased yield in crops brought about by beet raising is due in part to the better farming methods discussed in the previous section.

In order to realize the full value of sugar-beets in increasing crop yields, it is necessary to have well-planned rotations supplemented by an economical use of farm manure or other fertilizing materials. The high yields of European countries would not be possible without scientific rotations and the extensive use of manures.

EDUCATIONAL VALUE

The beet-sugar industry is based on technical skill. The breeding of strains of beets high in sugar calls for special training in the principles of breeding. Many chemists are needed to analyze the mother beets and special skill is required in the field work. In the making of sugar from beets, engineers, chemists, and other technically trained men are required. This means that any community having a beet-sugar factory must have trained men to carry on the industry. This necessity so promotes education that sugar-beet production has a direct educational value to any community.

Farmers take up better business methods, being encouraged to keep records by cost of labor, cash product, contract crop, and contract labor, also because of its being one of two or three general crops that can pay on high-priced land.

EMPLOYMENT FOR CHILDREN

In raising sugar-beets, considerable hand labor is required. Much of this work can be done well by children; in fact, children often can thin beets better and more rapidly than their parents. They can be used to advantage also in weeding and in topping. This means that in regions where sugar-beets are raised, children who go to school during the winter can earn good wages in vacation times.

In many irrigated districts of the West, where most of the sugar-beets of America are produced, persons live in towns and not on their farms. These towns provide many children who have no regular employment in the summer. These small communities lack the industries found in the large cities. Many of the inhabitants do not have land of their own; as a result, their children are idle when not in school. If the farms of the region produce only hay and grain, no work is available for children; but when sugar-beets are added, these young persons find healthful and paying employment instead of spending the summer on the streets. In this, as in other work for children, care must be taken to avoid the evils of child labor.

WINTER EMPLOYMENT

In all the farming communities work is more pressing in the summer than in the winter. In order to have sufficient help to care for crops during the busy season, there is an excess at other times. This means that ordinarily some of the hands are idle and that winter wages are low.

If there is a sugar factory in the community, it uses a great number of men in the winter and the congestion is relieved. Those who would otherwise be idle are given employment and the entire winter wage scale for the community is advanced.

CENTRALIZED POPULATION

Sugar-beet raising calls for intensive farming. A given area of land producing beets will give employment to several times as many men as the same area devoted to hay or grain. With sugar-beets as an important crop, the farmer does not require so large an acreage in order to make a living as would be necessary with many other crops. This means that sugar-beet farming promotes a denser population. This has many advantages. It makes possible better educational facilities and more desirable social opportunities, thereby reducing to a minimum some of the chief disadvantages of farm life.

INCREASES OTHER BUSINESS

The raising of sugar-beets and the manufacture of sugar from them bring increased business to many other industries not directly connected with the farmer or the sugar factory. Thus, every community in which the beet-sugar industry is established has the pulse of its entire business quickened thereby. Railroads receive much traffic in transporting beets, lime, sugar, machinery, and the many other commodities that are incidental to sugar-making. Bank clearings are increased by the money paid for beets and supplies and that received for sugar.

The live-stock business is advanced by the cheap feeds resulting as by-products of beet raising and sugar-making. Several secondary manufacturing industries also grow out of the use of sugar-house products. All business is enhanced by the presence of a sugar factory.

NATIONAL INDEPENDENCE

Perhaps the most important contribution of the beet-sugar industry to community welfare comes in the greater degree of national independence that it insures. In modern days, sugar has come to be a food necessity. Its high food value, its palatability, and the ease with which it fits into the human ration make it almost indispensable. The European war taught us much concerning the hardship that may result from a shortage of sugar.

Any nation that finds itself dependent on some other nation for so important a commodity as sugar cannot boast that it is really independent. In time of war when an old supply is likely to be shut off, the nation that does not produce its own sugar may find itself seriously handicapped. The beet-sugar industry owes its origin to just such a condition. Later international troubles have shown that preparation for an emergency of this kind must be made in times of peace; it is too late after fighting has begun.

It now seems evident that, aside from other considerations, the American beet-sugar industry should be enlarged as a matter of national preparedness. The American people cannot afford to place themselves at the mercy of a possible enemy by not having at home a source of sugar sufficient to meet their needs in times of war.

CHAPTER XVIII

SUGAR-MAKING

THE processes involved in the manufacture of beet-sugar have undergone a great change in a little more than a hundred years since the industry was first established. At first it was difficult to secure a good product and only a small percentage of the sugar in the beet could be recovered as refined sugar. Improvement in manufacturing processes has gone hand in hand with the breeding of a higher grade of beets in making possible the extension of the beet-sugar industry. The making of beet-sugar involves a number of rather complex problems in physics, chemistry, and engineering; and since it is beyond the scope of this book to go thoroughly into these technical questions, only a brief description of the process of sugar-making will be given. The following well-defined stages are involved in the process: (1) storing and cleaning of beets, (2) extraction of juice, (3) purification of juice, (4) formation of grain, (5) partial drying, (6) final drying, and (7) packing the sugar.

STORING THE BEETS

After the beets are received by the sugar company, it is often necessary to store them for some time before they are sliced. If this is done at the factory, bins are usually available. These are so arranged that the beets can be worked with the least amount of handling. Where cars are not available for immediate transportation, the beets must be stored in the districts where they are raised. This is usually done in large piles near the weighing station and dump.

The loss during storage is due to respiration, which is greatly increased as the temperature rises. This means that in sections where the temperature is high at harvest time, the beets must be sliced within a few days after they are dug. In sections where

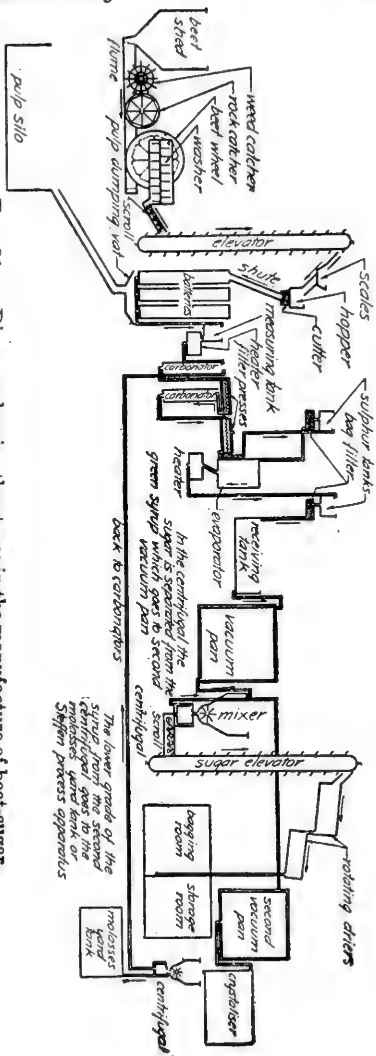


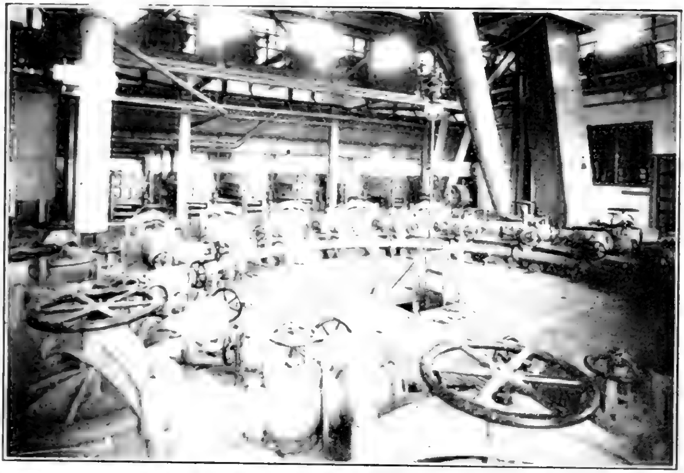
FIG. 31. — Diagram showing the stages in the manufacture of beet-sugar.

the temperature is cool at the time of harvest and where severe cold is not experienced, large uncovered heaps are to be preferred to all other methods of storage, since little expense is involved and the loss of sugar is slight. Beets are not injured by temperatures slightly below freezing when they thaw out slowly; consequently, only those lying on the very outside of the heap will be injured by frost. A light frost will result in no injury whatever. Care must be taken to see that these heaps do not begin to heat. If heating begins, the pile must be opened and the decaying beets removed.

Beets stored at the factory are placed in V-shaped bins, the bottom of which is a flume covered with removable boards. By taking out these boards one at a time, the beets drop into a swift stream of water and are carried to the factory.

WASHING AND WEIGHING

The first step in preparing the beets for the factory is to remove rocks, sand, weeds, and other foreign material that might interfere with slicing. This foreign material is removed by a set of special devices shown in Fig. 31, after which the beets are carried up to the washer. The mechanical washer consists of a tank in which arms keep up an agitation in such a way that all dirt not removed while the beets were being carried by the stream of water into the factory is washed off. The beets after being thoroughly cleaned are elevated to a scale which weighs and records automatically. They are now ready to be sliced.



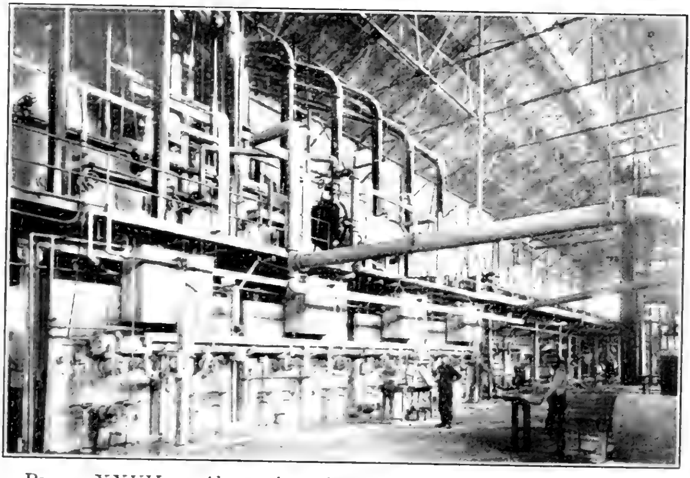


PLATE XXVII. — *Above*, view of top of diffusion battery; *below*, carbonation and sulfur tanks where the warm raw juice is purified. (Courtesy Truman G. Palmer.)

SLICING AND EXTRACTION

The chief object sought in slicing is to obtain as large a surface as possible and at the same time to leave the pieces of beet in such a condition that they will not pack into a mass through which water will not pass readily. Many kinds of slicing knives are used, but all cut the beets into long thin strips called "cossettes." These are so thin that the sugar contained in the cells of the root can readily diffuse out into the water with which the cossettes are treated in the diffusion batteries. The corrugated slicing knives revolve rapidly and are able to handle large quantities of beets.

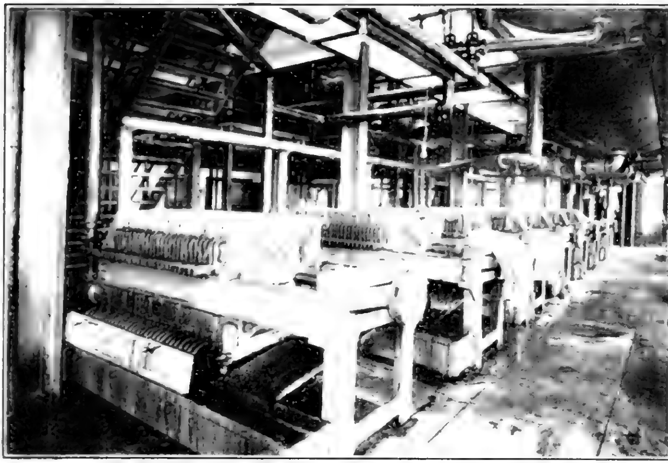
The cossettes pass from the knives to the cells of the diffusion battery, shown in Plate XXVII. These are large iron containers, cylindrical in shape, and terminating in truncated cones having covers; they are arranged in a circle or in a straight line. The series usually contains from ten to fourteen of these tanks. Each is so connected at the bottom by means of a pipe with the top of the next in the series that a continual flow of warm water passes through the cossettes as long as they remain in the battery. The batteries are so arranged that the container which has had its charge for the longest time receives the fresh water, which removes the last bit of sugar that can be extracted. The pulp from which the sugar has been removed is dumped out and the tank is again filled with fresh slices. This tank then becomes the last in the series and receives the water laden with juice after it has passed through all the other cells of the battery.

The pulp is carried off in a stream of water to a silo, where it is held till it is dried or hauled away to be fed to stock. Plate XIX. Methods of handling the pulp are discussed in detail in Chapter XII. The juice, containing the sugar, on coming from the batteries is dark in color, and, in addition to the sugar, contains many impurities which must be removed before the sugar can be made to crystallize out. Up to this point, the method of making beet-sugar differs completely from that used for cane-sugar; beet juice is obtained by diffusion, whereas the cane juice is removed by crushing.

PURIFICATION OF THE JUICE

After the juice is measured, it passes to the carbonation tanks (Plate XXVII) where purification begins. Here it is treated with 3 to 4 per cent of caustic lime in the form of thick milk. After thorough agitation, the excess lime is precipitated with carbon dioxid from the lime kiln. The addition of lime is considered the most important operation in the sugar mill, and unless properly done the final product is affected both in color and amount. The effect of lime on the juice is both chemical and mechanical. The lime unites chemically with a number of substances that later interfere with the manufacturing process, and it causes many of the solids held in suspension to settle to the bottom, leaving a clear liquid of light amber color.

When the proper condition in the juice is obtained, it is passed through filter presses, shown in Plate XXVIII, to remove the precipitated lime and other solid matter. These solid materials are retained in the frame of the



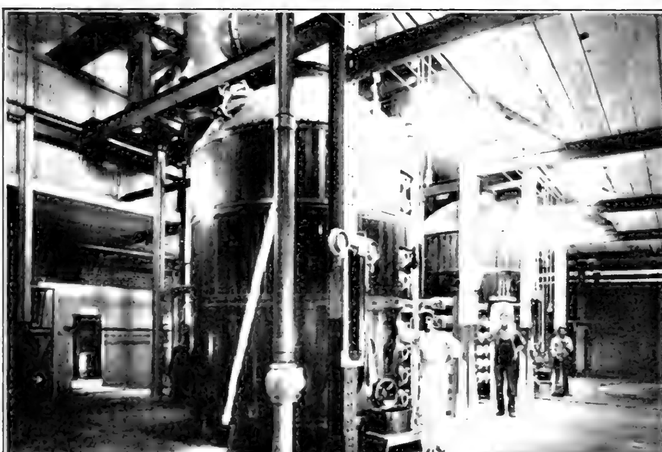


PLATE XXVIII. — *Above*, filter presses made of iron frames covered with cloth through which juice filters as a clear liquid; *below*, vacuum pans where the juice is concentrated and the grains formed. (Courtesy Truman G. Palmer.)

presses. As soon as the frame is full, the lime cake is washed by passing water through it till the sugar-content of the cake has been sufficiently reduced. The press is then opened and the cake removed and disposed of in the manner discussed in Chapter XII. A second filtration is usually practiced in order to remove any solids that may have gone through the first time. Later, the juice is again treated with a little lime and with carbon dioxid to reduce further the impurities, after which it receives the third filtering.

In most sugar houses, the juice is treated with sulfur fumes before it is concentrated, although sometimes concentration precedes this process. The object of treating with sulfur is to reduce the alkalinity caused by the lime, and to remove additional impurities. The sulfur also has a bleaching action, removing color from the liquid that might be carried on to the sugar. The sulfur fumes are obtained by passing air over burning sulfur which yields sulfurous acid. After being sulfured, the juice is passed through special filter presses after which it is ready for evaporation.

EVAPORATION

During the processes of purification the juice contains a large quantity of water which was used to extract the sugar in the diffusion battery. This must be evaporated before the sugar will crystallize. The first beet factories did this evaporating in open pans and as a result did not secure a good quality of sugar. The heat required to evaporate water rapidly at ordinary atmospheric pressure is so high that sugar is likely to be charred. For this reason, evaporation is carried on under reduced pressure which lowers the boiling point of the liquid. After the juice is reduced from about 82 per cent of water to about 40 per cent, it is again treated with sulfur and filtered in a manner similar to that used for the "thin juice." This is the final process of purifying the beet juice, which is then ready for graining.

In refining cane-sugar, there is no treatment with sulfur; impurities are removed with bone black. This is the chief difference in the method of making sugar from cane and from beets in the United States. In Europe, where raw beet-sugar is produced by many factories, this product also is refined by the aid of bone black. In early days blood was used extensively in sugar refining, but this practice has now been discontinued entirely.

GRAINING

The vacuum-pan serves not only for evaporating the sirup but also for crystallizing the sugar. This pan is a large cast-iron tank in which the air pressure can be kept low to reduce the danger of browning the sugar by high heat. If the juice has been purified properly, there is no trouble about producing good sugar in this pan; but if impurities remain, it is difficult to obtain good crystallization. This mixture of crystals and sirup is called "massecuite." It is run through a centrifugal machine, like that shown in Plate XXIX, revolving at a rate of 1200 revolutions a minute. The sirup is thrown out through fine perforations in the wall of the machine, and the crystals of sugar remain, dropping out through the bottom when enough sirup is thrown off to permit crumbling. From the centrifugal machine the sugar is sent to the driers, where any excess moisture is removed by a current of warm air. The sugar is then ready to be sacked and sent to the market.

The sirup thrown from the centrifugal machines goes to the second vacuum-pan, where it is further concentrated; a second yield of sugar smaller than the first is taken from it in the centrifugal machine. The molasses is sometimes carried to tanks, where it is used in a manner discussed in Chapter XII. If the factory is equipped with the Steffen process, a third yield of sugar is secured. This yield is small and represents only that part which would remain as molasses or be partly saved, if the ordinary processes are used instead of the Steffen.

THE STEFFEN PROCESS

Regarding this process Rolph[1] has the following to say: "In some of the beet factories the sugar left in the final molasses is extracted by what is known as the Steffen process. The final low-purity molasses is diluted with water and cooled to a very low temperature, after which finely powdered lime is constantly added to the solution at a uniform and slow rate. The sugar combines with the lime and a saccharage of lime is formed which is insoluble in the liquid. The suspended matter, or saccharate, is then separated and washed in filter presses.

"The cake from these filter presses, which is the sac-

[1] Rolph, G. M., "Something about Sugar" (1917), pp. 115–116.

charate of lime, is mixed with sweet water to a consistency of cream and takes the place of milk of lime in the carbonation process. When the Steffen process is employed, about ninety per cent of the sugar originally in the beet is extracted. The loss of sugar that does take place is accounted for in the exhausted cossettes or pulp, in the pulp water which surrounds them when they are dumped from the diffusion cells, in the cake and wash waters from the carbonation presses, and in the waste and wash waters from the Steffen process. As the water used in washing the saccharate press cake is rich in fertilizing qualities, it is used for irrigating the lands adjoining the factory.

"The 6,511,274 tons of beets harvested in the United States during the season of 1915 contained an average of 16.49 per cent of sucrose, of which 14.21 per cent found its way into the sacks as white sugar. The difference, 2.28 per cent, represented the loss in working up the beets. As only a few factories, however, were using Steffen process, a considerable amount of sugar was left in the waste molasses. For the same period, the beets produced in California contained 17.82 per cent of sugar, of which 15.64 per cent found its way into the sacks, showing a loss of only 2.18 per cent. This may be accounted for by the fact that probably more of the California factories were equipped with the Steffen process than the average for the United States, and that the purity of the juices of California beets was higher than the average for the United States.

"A factory equipped with the Steffen process and running on beets containing 17.82 per cent sugar, with a

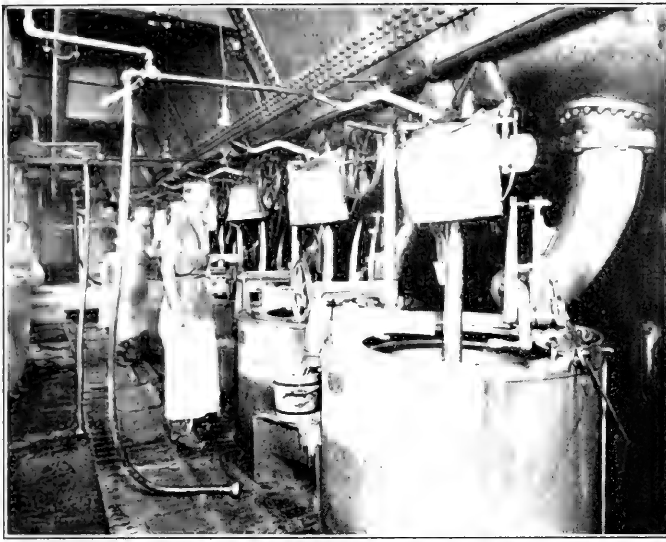


Plate XXIX. — *Above*, centrifugal machines where the molasses is thrown out of the sugar; *below*, sugar warehouse, Garden City, Kansas. (Courtesy Truman G. Palmer.)

purity of 82, should lose not over 1.9 per cent of the sugar in the beet. The same factory without the Steffen process would probably lose 5.04 per cent of the sugar." It would, however, have a considerable quantity of molasses.

CHAPTER XIX

SUGAR-CANE

No discussion of the sugar-beet would be complete without mention being made of its great rival, sugar-cane. The beet furnishes a comparatively new source of sugar, whereas cane has been a commercial source of sugar for centuries. If sugar-cane could be raised in temperate climates in as great profusion as it grows in the tropics, sugar would probably never be obtained commercially from the sugar-beet, since the yield of cane is much greater than that of beets, and the expense of handling the crop is very much less.

Sugar-cane, however, is confined to hot countries; this means that sugar made from it has to be transported great distances in order to reach the big markets, which are found in the centers of population. This gives beet-sugar a much better chance to compete. No one can predict exactly the relative production of cane- and beet-sugar in the future. It seems probable that both crops will continue to be raised, each one supplying the market that it can reach most easily.

The sugar-cane plant belongs to the grass family, and is usually classed in the genus Saccharum, although it was formerly known as *Arundo saccharifera.* Many varieties of cane are grown. These differ greatly in their various properties, and they have the following colors: green, yellow, red, brown, black, white, purple, and mixed. Some varieties may be attractive to the grower, while the manufacturer may prefer others. This is not unlike the conditions with varieties of other crops. The producer seeks yield and resistance; the manufacturer desires quality and ease in handling. No one variety is best suited to all conditions; a choice must be made on the basis of local needs.

The roots are fibrous and lateral and do not penetrate deeply. The root-stalk is an elongation of the stem, which is made up of numerous nodes and internodes varying in length from four to ten inches. The epidermis is polished and in some varieties is very thick. Leaves are alternate; they are large at the base and gradually taper to the point, being about three feet long and in some varieties bearing pricks. The older leaves drop off as the plant grows, leaving only those near the tip actively functioning.

A bud, called the eye, is borne under the base of each leaf at the node. These contain the germ from which new plants are produced. Each bud is capable of producing a complete plant which may tiller and produce many stalks. The seed is produced in panicles of silken spikes and is often infertile, but propagation is carried on vegetatively by planting stalks or pieces of stalks. Around each bud are found numerous little dots which produce roots when the bud is planted. In some climates cane bears flowers when twelve or thirteen months old; in other climates a longer period is required. Flowering takes place before the cane is entirely ripe.

In Hawaii, eighteen months are required for it to ripen; it tassels about a month before it is ready to cut. In Louisiana and Texas, the crop is harvested in nine or ten months after planting; in Cuba, it is cut in twelve months whether it is ripe or not. In the Philippines, it is harvested in about fourteen months, being planted in November and December and harvested a year from the next January and February.

ADAPTATION

Sugar-cane is strictly a hot-climate plant. In order to flourish, it must have abundant sunshine, plenty of moisture, and a fertile soil. It is usually confined to the tropics, included between twenty-two degrees north latitude and twenty-two degrees south latitude, although in a few places it reaches beyond these boundaries, having been grown as far north as thirty-two degrees in Spain and as far south as thirty-seven degrees in New Zealand. The most favorable growing conditions are found with an average annual temperature of about 75° F. and seven to nine months of growing season with warm days and nights.

It flourishes in the Hawaiian Islands, Cuba, Mexico, Central America, islands of the East and West Indies, Australia, China, India, along the shores of the China Sea and Indian Ocean, and in parts of Africa and South America. In the low altitudes of temperate zones it grows, but is only fairly successful.

The water requirement of the crop is exceedingly large and can only be met by an extremely heavy rainfall or

PLATE XXX. — *Above*, planting sugar-cane; *below*, unloading cane with a derrick, Cuba. (Courtesy N. Kopeloff.)

by irrigation. The distribution of moisture is highly important, most of it being required during the period of rapid growth. A comparatively dry season during ripening and harvest is desirable; and in the growing season, periods of clear skies and hot sunshine should alternate with the rainy periods.

SOILS AND MANURING

Because the cane plant is a vigorous feeder, it needs a fertile soil for its best growth. When so heavy a crop must be supported from the zone that is penetrated by the shallow roots of the cane, considerable available plant-food is required. If this is not present in the soil, it must be added as fertilizer if the highest yield is realized. No particular kind of soil is required; any good agricultural land that can be well aërated and that has sufficient plant-food will raise sugar-cane. Limestone soils are to be preferred for this as well as for many other crops. The saline condition often found along the coast causes trouble with cane, although high yields are sometimes obtained in the presence of some salt. A soil high in vegetable mold is likely to produce a vegetative growth at the expense of sugar formation.

In some cane-producing sections, fertilizer is added twice for one crop, the first about planting time and the second after growth is well under way. In Hawaii, about $25 an acre are spent each year for fertilizers.

Where irrigation is practiced, the land is laid out with furrows about five feet apart and eighteen inches deep, running on a contour with the land to prevent washing.

In these furrows the cane is planted, and they also serve as carriers for the irrigation water later. Water is applied soon after planting and at intervals of about a week throughout the growing period.

CULTURAL METHODS

The cane stalk is so cut in joints that there will be at least one bud on every joint; these are dropped in the furrow end to end, as shown in Plate XXX, with a slight lapping to insure a good stand. The upper part of the stalk, not suited for anything else, is usually planted. They are covered with one inch to an inch and a half of soil, and carefully watered in order to promote an early sprouting. Cultivation is also begun and continued as long as the plants permit. In some parts of the tropics, practically no care is given the cane after it is planted; it is allowed to yield from year to year whatever nature will produce unaided.

In some sections, fresh plantings are made for every crop, but a more common practice is to allow "ratooning," or a growing up from the roots. When this is done, a furrow is plowed along the row after cutting to help in aërating the soil, and a fresh growth begins at once. When but one year of growth from the roots is practiced, it is called a "short ratoon"; when the growth is continued two or three years or longer, it is called a "long ratoon." In Hawaii it used to be the practice to plant every crop, but now ratooning two or three crops is more common. In Cuba the crop is ratooned for long periods, sometimes twenty years or more.

PLATE XXXI. — *Above*, a vigorous growth of sugar-cane, Argentina; *below*, sugar-cane in Louisiana. (Courtesy N. Kopeloff.)

In Hawaii and other parts of the tropics, planting is done from March to September, the cane beginning to ripen a year from the next December. The period of harvest extends from January to the latter part of July or August. It is, therefore, necessary to have double the amount of land that is to be harvested each year, since practically two years are consumed in the planting, growing, and harvesting of a crop. .

The growth of a vigorous crop of sugar-cane resembles that of a jungle, Plate XXXI. After the stalks become heavy with sugar, they sag into all shapes. Stalks that are twenty-four feet long may become so prostrate that they seem to be only ten or twelve feet high. Some varieties retain their upright growth much better than others.

HARVESTING

The cane is cut near the ground with heavy knives and at the same time the top is cut off and the stalk cut into convenient lengths. In many sections, before cutting is begun, the field is set on fire in order to rid the plants of leaves; in other places the leaves are stripped off. The cane is taken to the mills either on railroads or wagons similar to those shown in Plate XXXII or carried by water through flumes. Where railroads are used, paths are cut through the fields about 150 feet apart, and rails laid through these. In loading the cane on the cars, a strap is bound around as large a load as a man wishes to carry, and the load is placed on his back and is carried up an inclined plank to the car. Since fire kills the buds, the plants that are to be used for seed are not burned.

In Hawaii a yield of twenty to eighty-five tons of cane to the acre is secured. This contains from two and a half to twelve tons of sugar, with an average of about five tons.

EXTRACTION OF SUGAR

The sugar is removed from beets by dissolving it from the cells with water in the diffusion battery; it is removed from cane by crushing the stalks and squeezing out the juice between heavy rollers. The cane on the car in which it comes from the field is weighed and samples are taken for analysis. It is then ready for the mill. It passes along conveyers to the crusher, which consists of two large corrugated rollers which break the stalks and squeeze out part of the juice. The cane mat is then passed on through the mill, where it passes between several sets of rollers which squeeze out all possible juice.

The bagasse, or woody part of the cane, which has been squeezed dry, is conveyed to the engine house to be used as fuel. The juice, after being screened to remove the coarser solids held in suspension, goes to the purification tanks, then to the multiple evaporators, and finally to the crystallizing vacuum-pan, where it is usually made into raw sugar. Most of the raw sugar is taken to large refineries in the coast cities, where it is made into the refined sugar of commerce.

The processes of making cane- and beet-sugar are very similar except in one or two stages. These processes are discussed in greater detail in the chapter on sugar-making.

PLATE XXXII. — *Above*, hand cutters harvesting sugar-cane; *below*, train of cane wagons drawn by tractor, Cuba. (Courtesy N. Kopeloff.)

CHAPTER XX

WORLD'S USE AND SUPPLY OF SUGAR

THAT each year sees an increase in the use of sugar in all civilized nations indicates its fundamental value as a desirable and economic food. Formerly there was much prejudice against the use of sugar. In ancient times it was thought to be useful only as medicine; later it was considered as a delicacy to be used sparingly; only recently has it taken a place as an economical food used for its energy value as much as for its agreeable flavor.

The increased use of sugar in practically all countries will necessitate a great extension of the present sugar-producing area, if the rate of increase in use is continued. The place where this increase in production will be made depends on several important factors. Transportation facilities and legislative enactments will have quite as much to do with the problem as will the adaptation of various sections to the growth of sugar-producing plants.

KINDS OF SUGAR AND PROPERTIES

Sugar is a general name applied to a large group of substances which, together with the starches, constitute the carbohydrates. The name "carbohydrate" was given because these compounds are made up of carbon combined with hydrogen and oxygen in the ratio in which these elements are found in water. This makes the carbohydrates in reality carbon-water compounds. The sugars are as a rule crystalline, soluble in water, less soluble or insoluble in alcohol, and insoluble in ether and other solvents that are immiscible with water. They all have a more or less sweet taste, but vary considerably in sweetness. Most sugars have the property of rotating the plane of polarized light. This property is of great aid to the chemist in making rapid determinations of the quantity of sugar present in any substance.

The commercial sugars are divided chemically into two classes: monosaccharids and disaccharids. The monosaccharids have the formula $C_6H_{12}O_6$ and include dextrose, or grape-sugar, and levulose, or fruit-sugar. The disaccharids have the formula $C_{12}H_{22}O_{11}$ and include sucrose, or cane-sugar, lactose, or milk-sugar, and maltose, or malt-sugar. They may be considered as condensation products of the monosaccharids and derived from two molecules by the elimination of water thus: $2\,C_6H_{12}O_6 - H_2O = C_{12}H_{22}O_{11}$. The sugars of the disaccharid group are hydrolyzed when heated in solution with dilute acid; in the case of sucrose a mixture of dextrose and levulose results, the change consisting of the addition of a molecule of water and a bisection of the sucrose molecule. This action is called "inversion."

Sucrose, or cane-sugar, is the most important of the sugars; it is the ordinary sugar of commerce. It is about two and one-half times as sweet as grape-sugar. The name cane-sugar was given because it was first obtained from cane; but it might just as well be called beet-sugar, since the sugar obtained from the beet is exactly the same chemically as that obtained from cane. This sugar is made up of monoclinic prisms — usually with hemihedral faces — and contains no water of crystallization. The crystals are colorless, transparent, and have a specific gravity of about 1.6 and a melting point of about 160° C. At this temperature there is no decomposition in the melted liquid, which solidifies on cooling to an amorphous glassy mass and will after a short time assume crystalline structure and become opaque. If heated to a higher temperature, decomposition takes place between 200° and 210° C., when considerable gas is given off and a dark brown substance with a bitter taste called caramel is left.

Sucrose is a strong reducing agent, which means that it is readily oxidized. It does not ferment until converted into invert sugar by the action of the yeast plant, or invertin from yeast, or by some acid.

SUGAR IN NATURE

The sugars are found very widely distributed throughout the plant kingdom. It is stated [1] that more than one-half of the foods have a sweetish taste as compared with one-third that taste salty and about one-tenth bitter or sour. Sucrose, in addition to being present in large quantities in sugar-cane and the sugar-beet, is found in sorghum, in corn-stalks, in the sap of many forest trees, in seeds, in most sweet fruits, — usually associated with invert sugar, — in many kinds of roots, and in the nectar

[1] Surface, G. M., "The Story of Sugar," p. 31.

of flowers. It exists in solution in the cells of plants. Dextrose and levulose, which usually occur together, are found in most fruits, in honey, and in many other products. Honey consists of a natural mixture of about 37 per cent each of dextrose and levulose, and may contain as high as 6 or 8 per cent of sucrose. Milk-sugar, or lactose, is contained in milk, from 4 to 5 per cent being present. Malt-sugar, or maltose, results from the action of diastase on starchy materials.

Newlands[1] quotes the following analyses from Payen to show the amount of sugar contained in a number of fruits:

TABLE XX. — PERCENTAGE OF SUGAR IN FRUITS

	CANE-SUGAR	TOTAL SUGARS
Pineapple (Montserrat)	11.33	13.30
Strawberry (Collina d'Erherdt)	6.33	11.31
Apricot	6.04	8.78
Apple, gray Reinette (fresh)	5.28	14.00
Apple, gray Reinette (preserved)	3.20	15.83
Apple, English	2.19	7.65
Calville (preserved)	0.43	6.25
Plum, Mirabelle	5.24	8.67
Plum, Reine Claude	1.23	5.55
Lemon	0.41	1.47
Orange	4.22	8.58
Raspberry	2.01	7.23
Peach	0.92	1.99
Pear	0.68	8.78
Pear, St. Germaine (preserved)	0.36	7.84

[1] Newlands, J. A. R., and B. E. R., "Sugar, A Handbook for Planter and Refiners," p. xvi.

The purity of sucrose in raw sugar from different sources is given by Abel[1] as follows:

TABLE XXI. — AVERAGE PERCENTAGE COMPOSITION OF RAW SUGAR FROM DIFFERENT SOURCES

SUGAR FROM	WATER	CANE-SUGAR	OTHER ORGANIC SUBSTANCES	ASH
	Per cent	*Per cent*	*Per cent*	*Per cent*
Sugar-cane	2.16	93.33	4.24	1.27
Sugar-beet	2.90	92.90	2.59	2.56
Maize	2.50	88.42	7.62	1.47
Palm	1.86	87.97	9.65	.50
Maple	7.50	82.80	8.79	.91

These figures would not be constant under different conditions, but they show average impurities in sugar from different sources before it is refined.

SUGAR AS A FOOD

The value of sugar as a food is discussed by Abel[2] as follows: "The main function of sugar as found in the blood, whether resulting from the digestion of sugar or of starch, is believed to be the production of energy for internal and external muscular work, and, as a necessary accompaniment, body heat. This has been amply demonstrated by experiment. By ingenious devices the blood going to and from a muscle of a living animal may be

[1] Abel, Mary Hinman, "Sugar and Its Value as Food," *U. S. Dept. of Agr., Farmers' Bul. No.* 535 (1917), p. 13.

[2] Ibid., pp. 16–18.

analyzed, and it is thus shown that more blood traverses an active or working muscle and more sugar disappears from it than is the case with a muscle at rest.

"To decide the question of the value of sugar as a source of energy for the working muscle, much careful laboratory work has been carried on. It has been found that an increase in the sugar content of the diet, when not too great and when the sugar is not too concentrated, lessens or delays fatigue and increases working power. Increased amounts of sugar were found to increase the ability to perform muscular work to such an extent that on a ration of 500 grams (17.5 ounces) of sugar alone a man was able to do 61 to 76 per cent more work than on a fasting diet, or almost as much as on a full ordinary diet. The addition of about half this quantity of sugar to an ordinary or to a meager diet also considerably increased the capacity for work, the effect of the sugar being felt about a half an hour after eating it, and its maximum effect showing itself about two hours after eating. The coming of fatigue was also found to be considerably delayed on this diet, and taking 3 or 4 ounces of sugar a short time before the usual time for the occurrence of fatigue prevented the appearance of it. Lemonade, or other similar refreshing drink, and chocolate have been suggested as mediums for supplying in small doses an extra amount of sugar to men called upon to perform extraordinary muscular labor. The application of these results to the food of soldiers who may be called upon for extraordinary exertion in marching or fighting is very evident. Practical tests of the value of sugar in preventing or delaying fatigue, made in both the German and

French armies, indicate the value of sugar in the ration when the men are subjected to great exertion.

". . . According to our present knowledge the value of sugar as a food for muscular work may be briefly summarized as follows:

"When the organism is adapted to the digestion of starch, and there is sufficient time for its utilization, sugar has no advantage over starch as a food for muscular work.

"In small quantities and in not too concentrated form sugar will take the place, practically weight for weight, of starch as a food for muscular work, barring the difference in energy and in time required to digest them, sugar having the advantage in these respects.

"It furnishes the needed carbohydrate material to organisms that have little or no power to digest starch. Thus, milk sugar is part of the natural food of the infant whose digestive organs are, as yet, unable to convert starch into an assimilable form.

"In times of great exertion or exhausting labor, the rapidity with which it is assimilated gives sugar certain advantages over starch and makes it prevent fatigue.

"This latter quality, which renders it more rapidly available for muscular power, may account for the fact that sugar is so relished by people who are doing muscular work, and by those of very active habits, such as children.

"The American farmer ranks high among agriculturists as a rapid and enduring worker, and his consumption of sweets is known to be very large. The same is true of lumbermen and others who work hard in the open air; sugar and seed cakes are favorite foods with them. Dietary studies carried on in the winter lumber camps of Maine showed that large quantities of cookies, cakes, molasses, and sugar were eaten, sugar of all sorts supplying on an average 10 per cent of the total energy of the diet.

"The value of sugar in cold climates, where foods containing starch are not available, is evident, and in the outfit of polar expeditions sugar is now given an important place.

"Oriental races are very fond of sweets, as often noted by travelers. Certain forms of confectionery are very popular in Turkey and other regions of the East, and in tropical lands the consumption of dates, figs, and other sweets is very large. In a discussion [1] of the food of the natives of India the great value set on sweetmeats or sugar by the Hindoo population of all classes is pointed out. Large quantities of brown or white sugar are used to sweeten the boiled milk, which is a common article of diet, and sugar is also used with sour milk, rice, cheese, and other foods. It has also been said that the employer who will not furnish the native laborers with the large amounts of sugar they desire, in their daily ration, must expect to lose his workmen.

"Certain rowing clubs in Holland have reported very beneficial results from the use of large amounts of sugar in training.

"Pflüger, who devoted so much attention to glycogen and other carbohydrates, says that undoubtedly sugar in the blood is heavily drawn on during violent exercise; hence the longing for it in a form that can be rapidly assimilated.

"Its use by mountain climbers is well known. The

[1] *U. S. Dept. of Agr., Off. Exp. Sta., Bul. No.* 175.

Swiss guide considers lump sugar and highly sweetened chocolate an indispensable part of his outfit."

INCREASE IN USE OF SUGAR

While man has probably always eaten considerable sugar, which he obtained in fruit and other foods, the use

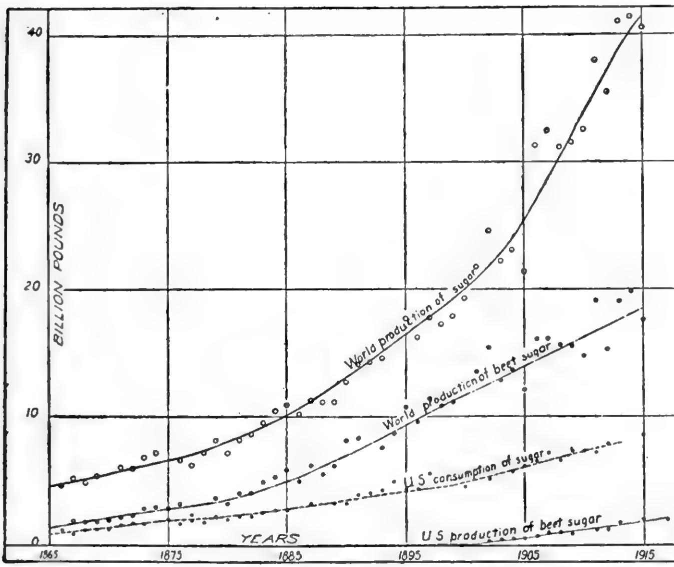


FIG. 32. — Production of total sugar and beet-sugar in the world and the United States' consumption of sugar and production of beet-sugar.

of refined sugar in large quantities is confined to modern times. As previously stated, sugar was anciently thought to be suitable for use only on special occasions; today

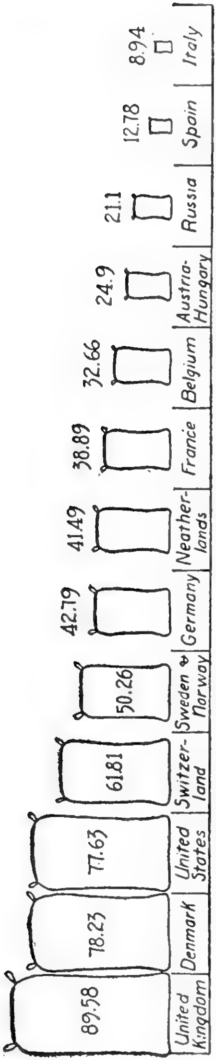


FIG. 33. — Number of pounds of sugar consumed by each individual in various countries.

it forms a part of every day's ration of civilized peoples. The increase in the use of sugar during the last generation is shown in Fig. 32, which gives the world's production over the period extending from 1865 to 1915. This curve shows that during a period of fifty years, the production and consequently the consumption of sugar increased from four and one-half billion pounds to over forty billion, or an increase of 900 per cent. Of course the population of the world increased during this period, but in no way did this compare with the increase in sugar consumption.

An examination of Fig. 33 shows that if all the countries come up to the per capita consumption of nations like Great Britain and the United States, the increase in the total sugar required in the world will continue. It is impossible to predict what the future consumption of sugar in the world will be, but it seems probable that more sugar will be required each year, especially if the price can be kept low. That it should find a greater

TABLE XXII. — CONSUMPTION OF SUGAR IN THE UNITED STATES AND THE PRINCIPAL SUGAR-PRODUCING COUNTRIES OF EUROPE. (Tons of 2000 lbs.)

Years	United States	Germany	Russia	Austria-Hungary	France	Belgium	Netherlands	Sweden	Denmark
1886–87	1,562,638	362,852	422,800	263,347	583,396	35,274	—	—	—
1887–88	1,508,180	444,509	377,924	368,961	520,544	34,171	—	—	—
1888–89	1,545,688	383,734	395,902	210,572	500,268	34,171	—	—	—
1889–90	1,596,368	549,429	415,229	316,365	551,540	48,501	—	—	—
1890–91	1,937,672	577,552	416,914	311,588	553,325	46,297	—	—	—
1891–92	1,959,836	586,755	437,567	335,737	576,561	40,785	—	—	—
1892–93	2,131,295	614,519	443,764	354,105	546,221	57,320	—	—	—
1893–94	2,468,191	633,278	444,443	345,430	520,698	70,547	50,706	72,046	—
1894–95	2,160,837	678,024	481,357	402,039	578,896	69,445	51,808	79,694	—
1895–96	2,247,341	820,516	557,720	417,600	505,578	63,933	52,359	79,546	—
1896–97	2,799,196	619,363	554,998	373,217	603,858	66,138	53,462	100,653	—
1897–98	1,734,368	780,690	592,395	411,034	559,459	58,422	54,564	94,849	—
1898–99	2,302,405	834,549	634,756	426,904	624,941	41,887	63,933	100,147	72,057
1899–1900	2,238,588	937,289	668,683	396,379	666,840	51,808	66,028	107,481	78,235
1900–01	2,792,504	854,631	724,891	420,335	597,166	61,729	68,784	111,332	89,113
1901–02	2,509,486	821,699	782,840	430,309	528,002	72,752	73,854	116,844	91,061
1902–03	3,190,083	895,016	808,669	420,939	895,509	55,115	77,933	118,696	85,725
1903–04	2,830,950	1,253,522	935,632	555,517	856,046	101,632	88,184	122,161	94,266
1904–05	3,012,886	1,064,837	1,038,587	493,500	664,246	87,853	99,207	119,633	78,284
1905–06	3,245,647	1,244,063	1,066,255	580,361	714,731	95,900	110,230	130,616	95,580
1906–07	3,544,834	1,280,046	1,074,302	590,833	704,039	104,498	114,639	140,296	113,173
1907–08	3,295,411	1,320,617	1,165,682	596,895	716,054	110,781	115,411	141,996	96,556
1908–09	3,641,682	1,378,124	1,220,246	635,145	740,194	116,293	121,694	140,604	117,500
1909–10	3,680,065	1,393,509	1,404,330	652,562	742,399	120,592	123,788	144,606	95,733
1910–11	3,617,986	1,525,501	1,429,817	732,699	843,039	132,607	132,056	154,322	—
1911–12	3,931,078	1,371,680	1,511,253	639,334	784,066	119,159	133,929	156,527	—
1912–13	4,117,239	1,574,788	1,648,049	744,053	861,117	135,362	147,378	—	—
1913–14[1]	4,396,897	1,618,176	1,786,167	782,633	870,817	143,299	150,684	162,148	—

[1] Preliminary figures.

use seems only reasonable, since it supplies a wholesome and nourishing food, which is relished by all classes of people.

USE IN DIFFERENT COUNTRIES

The annual per capita consumption of sugar in the United States and the leading countries of Europe is shown in Fig. 33. It varies from 89.59 pounds for each individual in the United Kingdom to 8.94 pounds in Italy. According to their use of sugar, the countries come in the following order: United Kingdom, Denmark, United States, Switzerland, Norway and Sweden, Germany, Netherlands, France, Belgium, Austria-Hungary, Russia, Spain, and Italy, — the people of the British Isles using ten times as much as the Italians. Figures compiled by Palmer[1] show the following percentage increase per capita in sugar consumption during the twenty-six-year period from 1889 to 1915 in the countries mentioned: Germany, 323; Netherlands, 198; Russia, 188; Austria-Hungary, 187; Switzerland, 150; Denmark, 144; Belgium, 102; United States, 71; France, 54; Spain, 46; United Kingdom, 22; and Italy, 16.

He also compiled Table XXII, which shows the total consumption of sugar in the United States and several European countries. This table shows that in less than thirty years the use of sugar has increased several hundred per cent in most countries. France is the only one in which it has not more than doubled in that time.

[1] Palmer, Truman H., "Concerning Sugar" (1916).

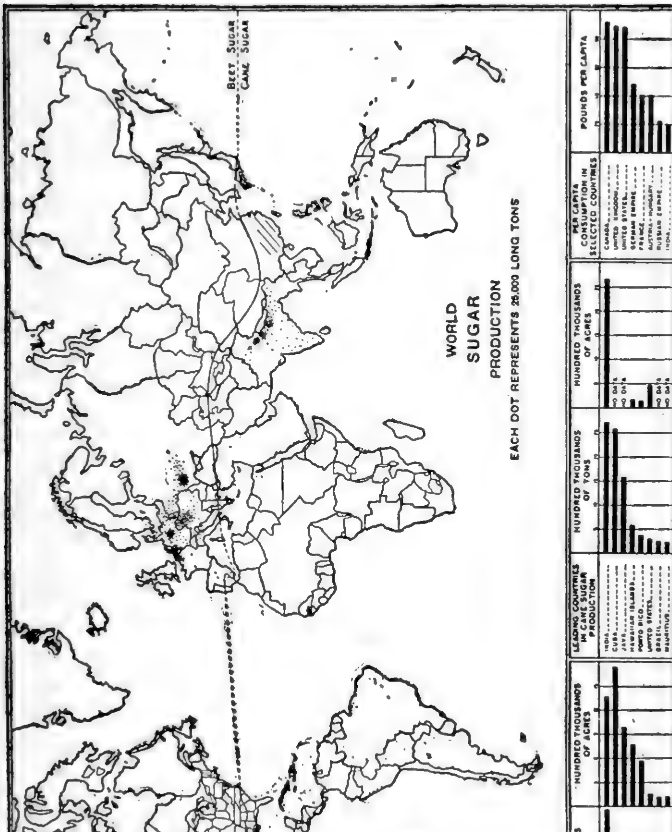


FIG. 34. — World production of sugar. (U. S. Dept. of Agr.)

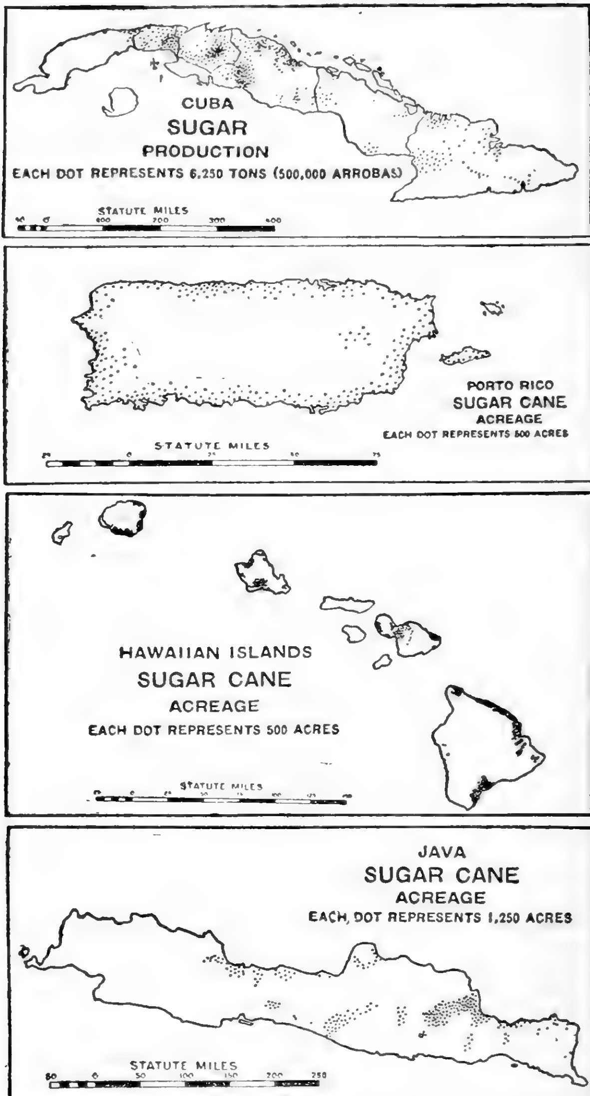


FIG. 35. — Sugar production in Cuba, Porto Rico, Hawaii, and Java. (U. S. Dept. of Agr.)

SOURCE OF SUPPLY

The supply of sugar for the world comes from comparatively few areas. One factor entering into this is

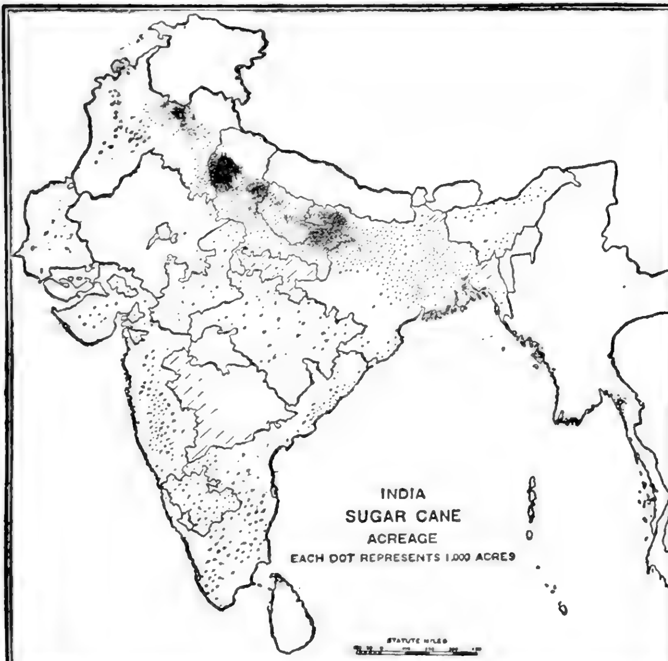


FIG. 36. — Production of sugar in India. (U. S. Dept. of Agr.)

that the individual farmer cannot make commercial sugar in regions where there are no sugar factories; and so much money is invested in a sugar factory that one is not likely to be built except in a region thought to be well adapted to the raising of either sugar-cane or sugar-beets. Sugar-cane is restricted to hot moist climates and sugar-beets are raised in comparatively few districts. The parts of the world that produce cane-sugar and beet-sugar are shown in Fig. 34. The sugar-producing area is seen to be very small in comparison to the total land area. The production of cane-sugar in Cuba, Porto Rico, Hawaii, Java, and India is shown in greater detail in Figs. 35 and 36. These represent the chief sources of cane-sugar.

The relative number of beet-sugar factories in Europe and the United States is given in Fig. 11, page 3. The maps are drawn to the same scale and give some idea of the expansion that would be necessary in beet raising in the United States if it were made equal to that of Europe.

At the opening of the European war, the world's sugar supply was about equally divided between beet-sugar and cane-sugar; but military operations in the beet-producing areas of northern France, Belgium, Poland, and Italy have greatly curtailed the making of beet-sugar in these sections, and cane-sugar has been given a decided lead.

The countries exporting and importing sugar are shown in Fig. 37. Cuba is the greatest exporter, followed by the Dutch East Indies, Germany, Austria-Hungary, and the smaller exporters. The United States is the leading importer, followed by the United Kingdom, British India, China, Canada, and the smaller importers.

The production of sugar in the United States and her possessions is shown in Fig. 38. These give about half of the sugar consumed in the country; most of the other half is imported from Cuba. An idea of the amount of sugar used in this country may be obtained when it is

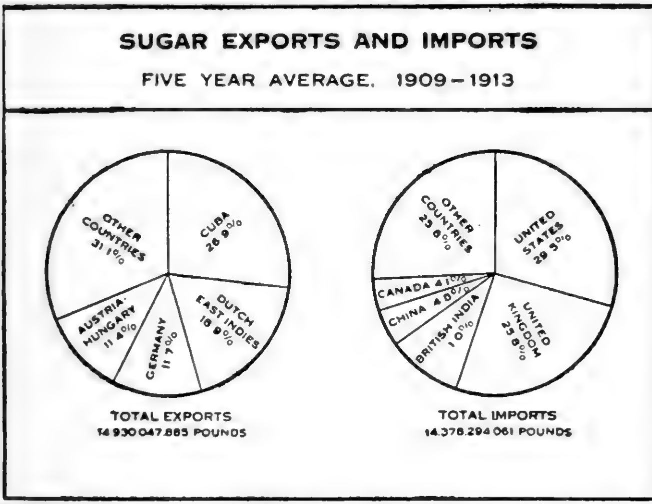


FIG. 37. — Sugar exports and imports in different countries. (U. S. Dept. of Agr.)

realized that a freight train extending from Boston to Denver would be required to haul one year's supply.

Detailed figures regarding the world's use and supply of sugar are given in Appendix C.

FUTURE USE AND SUPPLY

Figures have already been given to show that the use of sugar in the world is increasing very rapidly. There seems to be no good reason why this increase should not go on till the amount required to supply the world's needs will be several times what it is at present; nor is there any reason to believe that this demand cannot be met

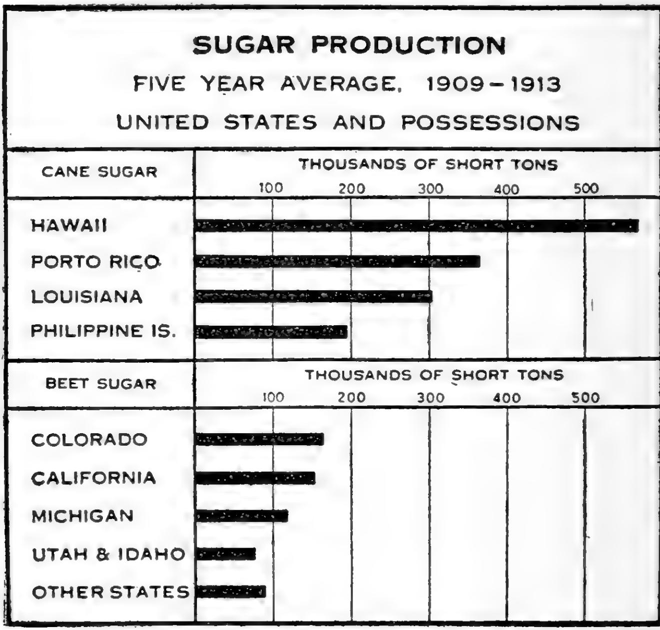


FIG. 38. — Production of sugar in the United States and possessions. (U. S. Dept. of Agr.)

easily. Under scientific methods, cane-sugar production in the tropics is capable of very great expansion; the world's entire sugar supply could be obtained from this source if there were no other.

The beet-sugar industry is only in its infancy in the

United States. It also could be extended to many other parts of the temperate zone. If necessary, the world's needs for sugar could be supplied from beets, so great is the area adapted to raising this crop. With these two sources of sugar, it seems reasonable to believe that there will be no permanent shortage in this product that is each year becoming a more important element in the diet of mankind.

APPENDIX A

BIBLIOGRAPHY [1]

Books

1840. CHILD, DAVID LEE. "Culture of the Beet, and Manufacture of Beet Sugar," pp. 156. (Boston.)
1880. WARE, LEWIS S. "The Sugar Beet," pp. 323. (Philadelphia.)
1897. SPENCER, G. L. "A Handbook for Beet-sugar Chemists," pp. 461. (New York.)
1898. WARE, L. S. "Sugar Beet Seed," pp. 264. (New York.)
1899. MYRICK, HERBERT. "The American Sugar Industry," pp. 220. (New York.)
1902. WARE, L. B. "Cattle Feeding with Sugar Beets, Sugar, Molasses, and Sugar Residuum," pp. 389. (Philadelphia.)
1905. WARE, L. B. "Beet Sugar Manufacture," 2 vol., pp. 543 and 647. (New York.)
1908. RODERNS, FRANK. "The American Beet Growers Annual," pp. 83. (Chicago.)
1909. NEWLANDS, J. A. R., and NEWLANDS, B. E. R. "Sugar, A Handbook for Planters and Refiners," pp. 876. (London and New York.)
1909. NIKAIDO, Y. "Beet-sugar Making and its Chemical Control," pp. 354. (Easton, Pa.)
1910. CLAASSEN, H. "Beet-Sugar Manufacture." Translated from third German Edition by W. T. Hall and G. W. Rolfe, pp. 343. (New York.)

[1] No attempt has been made to give a complete list of publications relating to the sugar-beet in America. Only the most available and most useful references have been included.

1910. Surface, G. T. "The Story of Sugar," pp. 238. (New York and London.)
1911. Jodidi, Samuel. "The Sugar Beet and Beet Sugar," pp. 76. (Chicago.)
1912. Browne, C. A. "A Handbook of Sugar Analysis," pp. 787. (New York.)
1912. Blakey, R. G. "The United States Beet Sugar Industry and the Tariff," pp. 286. (New York.)
1913. Adams, R. L. "Field Manual for Sugar-beet Growers," pp. 134. (Chicago.)
1914. Mackenzie, J. E. "The Sugars and their Simple Derivatives," pp. 236. (Philadelphia and London.)
1915. Palmer, T. G. "Concerning Sugar." (Washington.) A loose leaf service.
1917. Rolph, G. M. "Something About Sugar," pp. 341. (San Francisco.)
1918. Palmer, T. G. "Sugar-beet Seed," pp. 120. (New York.)

Periodicals

Facts About Sugar (New York).
Published weekly in the interest of American sugar production.

Sugar (Chicago).
Published weekly. An English-Spanish technical journal devoted to sugar production.

The Louisiana Planter and Sugar Manufacturer (New Orleans and Havana).
Published weekly. Chief interest is sugar-cane but devotes some space to sugar-beets. A Spanish edition is published monthly under the name of *El Mundo Azucarero.*

Through the Leaves (Longmont, Colorado).
Published monthly by the Great Western Sugar Company in the interest of sugar-beet production.

Willett and Gray's Statistical Sugar Trade Weekly Journal (New York).
Gives data on world market conditions and supply of sugar.

The International Sugar Journal (London, England).
A monthly technical and commercial periodical devoted to sugar problems in all parts of the world.

The Australian Sugar Journal (Brisbane, Queensland, Australia). Published monthly.

Bulletins, Reports, Etc.

1838. "Report on Mulberry and Sugar Beet." April 20, 1838. U. S. 25th Cong., 2d Sess., Reports of Committees, Vol. 3, No. 815.

1853. Wilson, John. "Manufacture of Sugar from Beet Root." Trans. N. Y. State Agr. Soc., Vol. 13, pp. 114–136.

1861. "Beet — Its Culture, Properties, and Qualities." Ohio State Board of Agr., 16th Ann. Rept., pp. 179–205.

1862. "Beet Sugar." Ohio State Board of Agr., 17th Ann. Rept., pp. 197–224.

1864. "On the Beet Root as a Source of Sugar." Maine Board of Agr., 9th Ann. Rpt., pp. 168–171.

1865. "Sugar Beets." Ohio State Board of Agr., 20th Ann. Rept., pp. 133–135.

"Analyses of Sugar Beets." U. S. Dept. of Agr., Ann. Rpt. 1865, pp. 46–48.

1868. Birbeck, John. "Manufacture of the Sugar Beet in the U. S." Jour. Franklin Inst., Phil., Vol. 85, p. 44.

1869. "Beet-root Sugar." Michigan Sta. Board of Agr., 8th Ann. Rpt., pp. 216–225.

Deby, Julien M. "American Beet-root Sugar." Scientific American, Vol. 20. A series of 11 articles scattered through the volume from pp. 57 to 354.

1871. Goessmann, C. A. "Report on the Production of Beet Sugar as an Agricultural Enterprise in Massachusetts." Mass. Agr. Coll., 8th Ann. Rpt. of Board of Trustees, pp. 43–80.

1872. Goessmann, C. A. "Report of Sugar Beets Raised on the College Farm." Mass. Agr. Coll., 9th Ann. Rpt., Board of Trustees, pp. 31–63.

1873. "Sugar-beet Machinery." Mass. Agr. Coll., 10th Ann. Rpt., Board of Trustees, pp. 87–93.

1874. Goessmann, C. A. "Report of Experiments with Sugar Beets." Mass. Agr. Coll., 11th Ann. Rpt., Board of Trustees, pp. 41–52.

1876. Goessmann, C. A. "Experiments in the Cultivation of Sugar-beet Roots in the State of N. Y." Trans. N. Y. State Agr. Soc., Vol. 32, pp. 163–169.

Brackett, G. E. "Beet Sugar." Maine State Board of Agr., 21st Ann. Rpt., pp. 80–84.

1876. Aubert, A. B. "Notes upon the Culture and Manipulation of Sugar Beets." Maine State Board of Agr., 21st Ann. Rpt., pp. 166–178.

1877. Humphrey, H. C. "Beet-sugar Interest." Penn. State Board of Agr., 1st Ann. Rpt., pp. 225–229.

1878. Demeritte, Albert. "Sugar-beet Culture." New Hampshire State Board of Agr., 8th Ann. Rpt., pp. 413–416.

Gennert, E. T. "Beet-sugar Industry in Maine." Maine State Board of Agr., 23d Ann. Rpt., pp. 174–181.

Humphrey, H. C. "Culture of Sugar Beets and Sugar Manufacture." Conn. Board of Agr., 11th Ann. Rpt., pp. 93–97.

1879. Goessmann, C. A. "On the Cultivation of Sugar Beets and the Manufacture of Sugar." Mass. State Board of Agr., 27th Rpt., pp. 378–402.

1880. McMurtrie, Wm. "Report of the Culture of the Sugar Beet and the Manufacture of Sugar Therefrom in France and the United States." U. S. Dept. of Agr., Special Report No. 28.

1882. Gennert, E. T. "Beet-sugar Industry in America." Trans. N. Y. State Agr. Soc., Vol. 33, pp. 75–83.

Ware, L. S., and Grinshaw, R. "Sugar-beet Industry." Jour. Franklin Inst., Vol. 113, pp. 292–298.

1884. Wiley, H. W. "Northern Sugar Industry." U. S. Dept. of Agr., Div. of Chem., Bul. No. 3, pp. 24–27.

1887. Hilgard, E. W. "Sugar Beets at Fresno." Cal. Sta. Bul. No. 72.

Spreckles, C. "Letter on Cultivation of Sugar Beets." Trans. Calif. State Agr. Soc., 1887, pp. 222–223.

1889. Cassidy, Jas., and O'Brine, D. "Potatoes and Sugar Beets." Colo. Sta. Bul. No. 7.

Almy, A. H. "Growth of the Beet-sugar Industry." Pop. Sci. Monthly, Vol. 35, pp. 85–92 and 199–211.

1890. Wiley, H. W. "The Sugar-beet Industry." U. S. Dept. of Agr., Div. of Chem., Bul. No. 27.

Wiley, H. W. "Experiments with Sugar Beets in 1890." U. S. Dept. of Agr., Div. of Chem., Bul. No. 30.

O'Brine, D. "Sugar Beets." Colo. Sta. Bul. No. 11.

Nicholson, H. H., and Lloyd, R. "Experiments in the Culture of Sugar Beets in Nebraska." Neb. Sta. Bul. No. 13.

1890. "Experiments with Sugar Beets." Kansas Sta. 3d Ann. Rpt., pp. 145–149.

PATRICK, G. E. "Sugar Beets." Iowa Sta. Bul. No. 8.

1891. PATRICK, G. E., and EATON, E. N. "Sugar Beets." Iowa Sta. Bul. No. 12.

WILSON, JAS. "Sugar Beet Growing." Iowa Sta. Bul. No. 15.

WILEY, H. W. "Culture of Sugar Beets." U. S. Dept. of Agr., Farmers' Bul. No. 3.

JAMES, C. C. "Pitting the Sugar Beet." Ontario Exp. Sta. Bul. 63.

HENRY, W. A. "Sugar Beet Culture in Wisconsin." Wis. Sta. Bul. No. 26.

McLAREN, DICE, and SLOSSON, E. E. "The Sugar Beet in Wyoming." Wyo. Sta. Bul. No. 3.

O'BRINE, D. "Progress Bulletin on Sugar Beets." Colo. Sta. Bul. No. 14.

HUSTON, H. A. "Sugar Beets." Ind. Sta. Bul. No. 34, pp. 57–65.

McDOWELL, R. H. "Sugar-beet Culture." Nev. Sta. Bul. No. 13.

NICHOLSON, H. H., and LLOYD, R. "Experiments in the Culture of Sugar Beets in Nebraska." Neb. Sta. Bul. No. 16.

HARPER, D. N., and HAYS, W. M. "Sugar Beets." Minn. Sta. Bul. No. 14.

KEDZIE, R. C. "Beet Sugar." Mich. Sta. Bul. No. 71.

KEDZIE, R. C. "Sugar Beets, Results for 1891." Mich. Sta. Bul. No. 82.

"Experiments with Sorghum and with Sugar Beets." Kansas Exp. Sta. Bul. No. 31.

1892. BRUNER, L. "Notes on Certain Caterpillars Attacking Sugar Beets." Neb. Sta. Bul. No. 24.

FOX, C. P. "Sugar Beets." Mo. Sta. Bul. No. 17.

HARPER, D. N. "Sugar Beets." Minn. Sta. Bul. No. 21.

FAILYER, G. H., and WILLARD, J. T. "Experiments with Sugar Beets." Kas. Sta. Bul. Nos. 31 and 36.

HUSTON, H. A. "Sugar Beets." Ind. Sta. Bul. No. 39.

WOLL, F. W. "Sugar Beet Experiments in Wisconsin in 1891." Wis. Sta. Bul. No. 30.

1892. Goss, A. "Experiments with Sugar Beets." New Mex. Sta. Bul. No. 8, pp. 33–34.

Shaw, G. W., and Lotz, Dumont. "Sugar Beets." Ore. Sta. Bul. No. 17.

Slosson, E. E. "Sugar Beets in 1892." Wyo. Sta. Bul. No. 9.

Wiley, H. W. "Experiments with Sugar Beets in 1891." U. S. Dept. of Agr., Bur. Chem., Bul. 33.

Watrous, F. L. "Sugar-beet Culture." Colo. Sta. Bul. No. 21.

Hickman, J. F. "Mangold Wurzels and Sugar Beets." Ohio Sta. Bul., ser. 2, b. 5, No. 2.

Ladd, E. F. "Sugar Beets; Experiments in North Dakota in 1891." N. D. Sta. Bul. No. 5.

McDowell, R. H., and Wilson, N. E. "Sugar Beets." Nev. Sta. Bul. No. 19.

Nicholson, H. H., and Lloyd, R. "Experiments in the Culture of Sugar Beets in Nebraska." Neb. Sta. Bul. No. 21.

1893. Wiley, H. W., and Maxwell, W. "Experiments with Sugar Beets in 1892." U. S. Dept. of Agr., Bur. Chem., Bul. No. 36.

Shaw, G. W. "Sugar Beets in Oregon." Ore. Sta. Bul. No. 23.

McDowell, R. H., and Wilson, N. E. "Sugar Beets." Nev. Sta. Bul. No. 23.

Nicholson, H. H., and Lyon, T. L. "Experiments in the Culture of Sugar Beets in Nebraska." Neb. Sta. Bul. No. 27.

Failyer, G. H., and Willard, J. T. "Experiments with Sugar Beets." Kas. Exp. Sta. Bul. No. 43.

Patrick, G. E., Heileman, W. H., and Eaton, E. N. "Sugar Beets in Iowa, 1892." Iowa Sta. Bul. No. 20.

Huston, H. A. "Sugar Beets." Ind. Sta. Bul. No. 43.

Gird, R. "Culture of Sugar Beets." Trans. Calif. State Agr. Soc. 1893, pp. 102–107.

1894. Wiley, H. W., and Maxwell, W. "Experiments with Sugar Beets in 1893." U. S. Dept. of Agr., Div. of Chem., Bul. No. 39.

Wilson, N. E. "Sugar Beets." Nev. Sta. Bul. No. 23.

1894. ROBERTS, I. P. "Coöperative Tests of Sugar Beets." Cornell Sta. Bul. No. 63.

NICHOLSON, H. H., and NICHOLSON, E. E. "Experiments in the Culture of Sugar Beets in Nebraska." Neb. Sta. Bul. No. 36.

NICHOLSON, H. H. "Nebraska and the Beet-sugar Industry." Neb. Sta. Bul. No. 38.

PATRICK, G. E., and PAGELSEN, O. H. "Sugar Beets in Iowa, 1893." Iowa Sta. Bul. No. 23.

FULMER, E. "Sugar Beets." Wash. Sta. Bul. No. 15.

SLOSSON, E. E. "Sugar Beets in 1893." Wyo. Sta. Bul. No. 17.

1895. HUSTON, H. A. "Experiments with Sugar Beets." Ind. Sta. Bul. No. 55.

1896. WILSON, W. E. "Sugar Beets." Nev. Sta. Bul. No. 32.

FULMER, ELTON. "Experiments in the Culture of Beets in Washington." Wash. Sta. Bul. No. 26.

NICHOLSON, H. H., and LYON, T. L. "Experiments in the Culture of Sugar Beets in Nebraska." Neb. Sta. Bul. No. 44.

SOWERS, E. "Sugar, An Industrial Opportunity for America." North Am. Rev., Vol. 163, pp. 316–325.

1897. WIDTSOE, J. A. "Utah Sugar Beets." Utah Sta. Bul. No. 53.

MCDOWELL, R. H., and WILSON, N. E. "Sugar Beets." Nev. Sta. Bul. No. 37.

WATERS, H. J. "The Sugar Beet." Mo. Sta. Bul. No. 40.

WATROUS, F. L. "Sugar Beets." Colo. Sta. Bul. No. 36.

DEVOL, W. S. "Sugar Beets." Ariz. Sta. Bul. No. 23.

HENRY, W. A. "Beet-sugar Production; Possibilities for a New Industry in Wisconsin." Wis. Sta. Bul. No. 55.

SHAW, G. W. "Review of Oregon Sugar Beets." Ore. Sta. Bul. No. 44.

VAN SLYKE, L. L., JORDAN, W. H., and CHURCHILL. "The Composition and Production of Sugar Beets." N. Y. Sta. Bul. No. 135.

MARROW, G. E., and BONE, J. H. "Experiments with Field Crops." Okla. Sta. Bul. No. 33.

1897. Armsby, W. P. "The Sugar Beet in Pennsylvania." Penn. Sta. Bul. No. 40.

Fulmer, E. "Irrigation Experiments in Sugar-beet Culture in North Yakima Valley." Wash. Sta. Bul. No. 31.

1898. McDowell, R. H., and Wilson, N. E. "Sugar Beets." Nev. Sta. Bul. No. 43.

Foster, Luther. "Sugar Beets in 1898." Utah Sta. Bul. No. 59.

Stone, J. L. "Sugar-beet Investigations." Cornell Sta. Bul. No. 143.

Headden, W. P. "A Soil Study." "The Crop Grown: Sugar Beets." Colo. Sta. Bul. No. 46.

Hall, F. H., and Van Slyke, L. L. "Sugar Beet Success for the Season." N. Y. Sta. Bul. No. 155.

Woll, F. W. "Sugar Beet Investigations in Wisconsin during 1898." Wis. Sta. Bul. No. 64.

Goss, A. "New Mexico Sugar Beets." New Mex. Sta. Bul. No. 26.

Selby, A. D., and Bloomfield, L. M. "Sugar Beet Investigations in 1897." Ohio Sta. Bul. No. 90.

Slosson, E. E. "Wyoming Sugar Beets." Wyo. Sta. Bul. No. 36.

Wiley, H. W. U. S. Dept. of Agr. "Special Report on the Beet-Sugar Industry in the United States."

Saylor, C. F. "Progress of the Beet-sugar Industry in the United States in 1898." Government Printing Office.

Goss, A., and Holt, A. M. "New Mexico Sugar Beets (1898)." New Mexico Sta. Bul. No. 29.

Holden, P. G., and Hopkins, C. G. "The Sugar Beet in Illinois." Ill. Sta. Bul. No. 49.

1898. Snyder, Harry. "Sugar Beets, Summary of Investigations from 1888 to 1898." Minn. Sta. Bul. No. 56.

Widtsoe, J. A. "Sugar Beets." Utah Sta. Bul. No. 53.

1899. McClatchie, A. J. "Sugar Beet Experiments during 1899." Ariz. Sta. Bul. No. 31.

Wilson, N. E., and McDowell, R. H. "Sugar Beets." Nev. Sta. Bul. No. 44.

Selby, A. D. "Sugar Beet Investigations in 1898." Ohio Sta. Bul. No. 99.

1899. Woll, F. W. "Sugar Beet Investigations in Wisconsin during 1898." Wis. Sta. Bul. No. 71.

Duggar, B. M. "Fungous Diseases of the Sugar Beet." Cornell Sta. Bul. No. 163.

Stone, J. L. "Sugar Beet Investigations for 1898." Cornell Sta. Bul. No. 166.

Wiley, H. W. "Experiments with Sugar Beets in 1897." U. S. Dept. of Agr., Div. of Chem., Bul. No. 52.

Cooke, W. W. "Sugar Beets in Colorado in 1898." Colo. Sta. Bul. No. 51.

Waters, H. J. "The Sugar Beet." Mo. Sta. Bul. No. 45.

Shaw, G. W. "Sugar-beet Experiments in 1898." Ore. Sta. Bul. No. 59.

Armsby, W. P., and Hess, E. H. "Tests of the Sugar Beet in Pennsylvania." Penn. Sta. Bul. No. 47.

Foster, L. "Sugar Beets in 1898." Utah Sta. Bul. No. 59.

Foster, L. "Sugar Beets in Sanpete and Sevier Counties." Utah Sta. Bul. No. 63.

Stewart, J. J., and Hite, B. H. "Sugar Beet Investigations in 1898." West Va. Sta. Bul. No. 55.

1900. Forbes, S. A., and Hart, C. A. "The Economic Entomology of the Sugar Beet." Ill. Sta. Bul. No. 60.

Headden, W. P. "A Soil Study. The Crop Grown: Sugar Beets." Colo. Sta. Bul. No. 58.

McDowell, R. H., and Wilson, N. E. "Sugar Beets." Nev. Sta. Bul. No. 50.

Selby, A. D. "Sugar Beet and Sorghum Investigations in 1899." Ohio Sta. Bul. No. 115.

Wing, H. H., and Anderson, L. "Sugar-beet Pulp as a Food for Cows." Cornell Sta. Bul. No. 183.

Towar, J. D. "Sugar Beet Investigations." Mich. Sta. Bul. No. 179.

Stone, J. L., and Clinton, L. A. "Sugar Beet Investigations for 1899." Cornell Sta. Bul. No. 182.

1901. Selby, A. D., and Ames, J. W. "Sugar-beet Investigations in Ohio in 1900." Ohio Sta. Bul. No. 126.

Wiley, H. W. "Influence of Environment upon the Composition of Sugar Beets, 1900." U. S. Dept. of Agr., Bur. of Chem., Bul. No. 64.

1901. HEADDEN, W. P. "Sugar Beets." Colo. Sta. Bul. No. 63.

WITHERS, W. A. "The Sugar Beet in North Carolina." N. C. Exp. Sta. Bul. No. 180.

1902. GRIFFIN, H. H. "Feeding Beet Pulp to Lambs." Colo. Sta. Bul. No. 76.

MCCLATCHIE, A. J. "Irrigation at Station Farm, 1898–1901." Ariz. Sta. Bul. No. 41.

TOWAR, J. D. "Sugar Beet Experiments." 1901. Mich. Sta. Bul. No. 197.

AMES, J. W. "Sugar Beet Investigations in 1901." Ohio Sta. Bul. No. 132.

FREAR, W., and CARTER, W. T. "Pennsylvania Sugar Beets in 1901." Penn. Sta. Bul. No. 59.

TRAPHAGEN, F. W. "Sugar Beets in Montana." Mont. Sta. Bul. No. 33.

LYON, T. L., and WIANCKO, A. T. "Experiments in the Culture of the Sugar Beet in Nebraska." Neb. Sta. Bul. No. 73.

WIDTSOE, J. A. "Irrigation Investigations." Utah Sta. Bul. No. 80.

1903. LYON, T. L., and WIANCKO, A. T. "Experiments on the Culture of Sugar Beets in Nebraska." Neb. Sta. Bul. No. 81.

CHITTENDEN, F. H. "The Principal Insect Enemies of the Sugar Beet." U. S. Dept. of Agr., Div. of Ent., Bul. No. 43.

WILEY, H. W. "The Influence of Soil and Climate upon the Composition of the Sugar Beet, 1901." U. S. Dept. of Agr., Bur. of Chem., Bul. No. 74.

SHAW, G. W. "The California Sugar Industry." Calif. Sta. Bul. No. 149.

WILEY, H. W. "The Influence of Environment upon the Composition of the Sugar Beet, 1902, Including a Study of the Irrigated Sections." U. S. Dept. of Agr., Bur. of Chem., Bul. No. 78.

TOWNSEND, C. O. "Relation of Sugar Beets to General Farming." U. S. Dept. of Agr. Yearbook, 1903, pp. 399–410.

SMITH, C. D. "Sugar-beet Experiments, 1902." Mich. Sta. Bul. No. 207.

1904. Rutter, F. R. "International Sugar Situation." U. S. Dept. of Agr., Bur. of Statistics, Bul. No. 30.

Saylor, C. T. "Methods and Benefits of Growing Sugar Beets." U. S. Dept. of Agr., Off. of Sec., Circ. No. 11.

Tracy, J. E. W. "Sugar-beet Seed Breeding." U. S. Dept. of Agr. Yearbook, 1904, pp. 341–352.

Traphagen, F. W. "Sugar Beets." Mont. Sta. Bul. No. 52.

Shaw, R. S. "Dried Beet Pulp and Dried Molasses-Beet-Pulp for Fattening Sheep." Mich. Sta. Bul. No. 220.

Smith, C. D. "Experiments with Sugar Beets in 1903." Mich. Sta. Bul. No. 215.

Merrill, L. A., and Clark, R. W. "Feeding Beet Molasses and Pulp to Sheep and Steers." Utah Sta. Bul. No. 90.

1905. Townsend, C. O., and Rittue. "The Development of Single-germ Beet Seed." U. S. Dept. of Agr., Bur. of Pl. Ind., Bul. No. 73.

Carlyle, W. L., and Griffith, C. J. "Feeding Steers on Sugar-beet Pulp, Alfalfa Hay, and Ground Corn." Colo. Sta. Bul. No. 102.

Billings, G. A. I. "Dried Beet Pulp as a Substitute for Corn Silage." II. "Dried Beet Pulp *vs.* Dried Molasses Beet Pulp." III. "Dried Molasses Beet Pulp *vs.* Hominy Meal." N. J. Sta. Bul. No. 189.

Woll, F. W., and Humphrey, G. C. "Dried Beet Pulp or Molasses Beet Pulp for Dairy Cows." Wis. Ann. Rpt., 1905, pp. 108–117.

Hills, J. L. "Feeding Value of Dried Molasses Beet-Pulp." Vt. 17th Ann. Rpt. (1904), p. 484.

Shaw, G. W. "Tolerance of the Sugar Beet for Alkali." Cal. Sta. Bul. No. 169.

Woll, F. W. "The Beet-sugar Industry of Wisconsin." Wis. Sta. Bul. No. 123.

Wiley, H. W. "The Influence of Environment Upon the Composition of the Sugar Beet, 1903." U. S. Dept. of Agr., Bur. of Chem., Bul. No. 95.

Wiley, H. W. "The Influence of Environment on the Composition of the Sugar Beet, 1904, Together with a Summary of the Five-year Investigation." U. S. Dept. of Agr., Bur. of Chem., Bul. No. 96.

1906. Ball, E. D. "The Beet Leafhopper." Utah Sta. 16th Ann. Rpt., p. 16.

Shaw, G. W. "Sugar Beets in the San Joaquin Valley." Calif. Sta. Bul. No. 176.

Harrison, G. B. "The Beet-sugar Industry in Kansas." Rpt. Kas. State Board of Agr., Vol. 25, No. 99, pp. 3–32 (Sept. 1906).

Townsend, C. O. "Methods of Reducing the Cost of Producing Sugar Beets." U. S. Dept. of Agr. Yearbook, 1906, pp. 265–278.

Danielson, A. H. "Fertilizer Experiments with Sugar Beets." Colo. Sta. Bul. No. 115.

Clark, R. W. "Feeding Experiments with Cattle, Sheep, Swine, and Horses." Utah Sta. Bul. No. 101.

1907. Fraser, S., Gilmore, J. W., and Clark, C. F. "Culture and Varieties of Roots for Stock-Feeding." Cornell Sta. Bul. No. 244.

Saylor, C. F. "Progress of the Beet-sugar Industry in the United States in 1906." U. S. Dept. of Agr., Report No. 84.

Shaw, R. S., and Norton, H. W., Jr. "Dried Beet Pulp for Fattening Steers." Mich. Sta. Bul. No. 247.

Woll, F. W., and Stoddart, C. W. "Sugar-beet Experiments During 1906." Wis. Sta. Bul. No. 150.

1908. Townsend, C. O. "By-products of the Sugar Beet and their Use." U. S. Dept. of Agr. Yearbook, 1908, pp. 443–452.

Saylor, C. F. "Progress of the Beet-sugar Industry in the United States in 1907." U. S. Dept. of Agr., Report No. 86.

Shepard, J. H. "Sugar Beets in South Dakota." S. D. Sta. Bul. No. 106.

1909. Townsend, C. O. "Conditions Influencing the Production of Sugar-beet Seed in the United States." U. S. Dept. of Agr. Yearbook, 1909, pp. 173–184.

Carlyle, W. L., and Morton, G. E. "Carrying Range Steers Through Winter and Sugar Beets for Fattening Steers." Colo. Sta. Bul. No. 149.

Ball, E. D. "The Leafhoppers of the Sugar Beet and their Relation to the Curly-leaf Condition." U. S. Dept. of Agr., Bur. of Ent., Bul. No. 66, Pt. 4.

1909. Shepard, J. H. "Sugar Beets in South Dakota." South Dakota Sta. Bul. No. 117.

Saylor, C. F. "Progress of the Beet-sugar Industry in the United States in 1908." U. S. Dept. Agr., Report No.90.

Townsend, C. O. "The Sugar Beet." Cyc. Am. Agr., Vol. II, pp. 588–595.

Chamberlain, G. M., Jr. "The Manufacture of Beet Sugar." Cyc. Am. Agr., Vol. II, pp. 595–599.

1910. Saylor, C. F. "Progress of the Beet-sugar Industry in the United States in 1909." U. S. Dept. of Agr., Report No. 92.

Wiley, H. W. "The Sugar Beet." U. S. Dept. of Agr., Farmers' Bul. No. 52 (Revised).

Shepard, J. H. "Growing Sugar-beet Seed in South Dakota." S. D. Sta. Bul. No. 121.

Shaw, H. B. "The Curly Top of Beets." U. S. Dept. of Agr., Bur. Plant Ind., Bul. No. 181.

Roeding, F. W. "Irrigation of Sugar Beets." U. S. Dept. of Agr., Farmers' Bul. No. 392.

1911. Knight, C. S. "The Sugar-beet Industry in Nevada." Nev. Sta. Bul. No. 75.

Shepard, J. H. "Growing Pedigreed Sugar-beet Seed in South Dakota." S. D. Sta. Bul. No. 129.

1912. Widtsoe, J. A., *et al.* "Irrigation Studies." Utah Sta. Buls. Nos. 116, 117, 118, 119, and 120. (1912.)

Underwood, O. W., *et al.* "Placing Sugar on the Free List." Report of Committee on Ways and Means, U. S. House of Rep., 62d Congress, 2d Session, Report No. 391, Mar. 5, 1912.

Fordney, J. W., *et al.* "Placing Sugar on the Free List." Minority Report, Committee on Ways and Means, U. S. House of Rep., 62d Congress, 2d Session, Report No. 391, Part 2, Mar. 7, 1912.

Orton, W. A., *et al.* "The American Beet-sugar Industry in 1910 and 1911." U. S. Dept. of Agr., Bur. of Pl. Ind., Bul. No. 260.

Palmer, T. G. "Sugar at a Glance." Senate Doc. No. 890, 62d Congress, 2d Session.

Headden, W. P. "Deterioration in the Quality of Sugar Beets Due to Nitrates Formed in the Soil." Colo. Sta. Bul. No. 183.

1912. Lodge, H. C. "The Sugar Schedule." Speech before U. S. Senate, July 27, 1912.

1913. Crittenden, F. H. "Principal Enemies of the Sugar Beet." U. S. Dept. Agr., Bur. of Ent., Bul. No. 43, pp. 71.

Palmer, T. G. "The Sugar Beet Industry of the United States." Published by the Author, Washington, D. C.

Palmer, T. G. "Reply to Criticism of Sugar at a Glance." Published by the Author, Washington, D. C.

Benzel, H. H. "A Biochemical Study of the Curly-top of Sugar Beets." U. S. Dept. of Agr., Bur. of Pl. Ind., Bul. No. 277.

Shepard, J. H. "Sugar-beet Culture in South Dakota." S. D. Sta. Bul. No. 142.

Abel, M. H. "Sugar and Its Value as a Food." U. S. Dept. of Agr., Farmers' Bul. No. 535.

Edson. "Damping-off and Root Rot Parasites of Sugar Beets." Phytopathology, Vol. 3, No. 1, p. 76.

Smoot, Reed. "The Wilson-Underwood Tariff Bill and the American Sugar Industry." Speech, U. S. Senate, Aug. 19, 1913.

1914. Townsend, C. O. "Leaf-spot, a Disease of the Sugar Beet." U. S. Dept. of Agr., Farmers' Bul. No. 618.

Townsend, C. O. "Sugar-beet Growing under Humid Conditions." U. S. Dept. of Agr., Farmers' Bul. No. 568.

Townsend, C. O. "Sugar-beet Growing under Irrigation." U. S. Dept. of Agr., Farmers' Bul. No. 567.

Andrews, Frank. "Statistics of Sugar in the United States and Its Insular Possessions, 1881–1912." U. S. Dept. of Agr., Bul. No. 66.

Shaw, H. B. "Thrips as Pollinators of Beet Flowers." U. S. Dept. of Agr., Bul. No. 104.

Knorr, F. "Irrigated Field Crops in Western Nebraska." Neb. Sta. Bul. No. 141, pp. 18–21.

1915. Harris, F. S. "The Commercial Production of Sugar Beet Seed in Utah." Utah Sta. Bul. No. 136.

Edson, H. A. "Seedling Diseases of Sugar Beets and their Relation to the Root-rot and Crown Rot." Jour. Agr. Res., Vol. 4, pp. 135–168 (May 15, 1915).

1915. Bessey, E. A., and Byars, L. P. "The Control of Root-knot." U. S. Dept. of Agr., Farmers' Bul. No. 648.

Harris, F. S. "Effect of Alkali Salts in the Soil on the Germination and Growth of Crops." Jour. Agr. Res., Vol. 5, pp. 1–53 (Oct. 4, 1915).

Townsend, C. O. "Field Studies of the Crown-gall of Sugar Beets." U. S. Dept. of Agr., Bul. No. 203.

Milliken, F. B. "Grasshoppers and their Control on Sugar Beet and Truck Crops." U. S. Dept. of Agr., Farmers' Bul. No. 691.

Shaw, H. B. "Sugar Beets: Preventable Losses in Culture." U. S. Dept. of Agr., Bul. No. 238.

Ince, J. W. "Progress Report of Sugar Beet Trials." N. D. Sta. Bul. No. 113.

Shaw, H. B. "Loss in Tonnage of Sugar Beets by Drying." U. S. Dept. of Agr., Bul. No. 199.

Hartung, W. J., and Severin, H. H. P. "Natural Enemies of the Sugar-beet Leafhoppers in California." Monthly Bul., Cal. Com. Hort., IV, pp. 277–280.

Edson, H. A. "Histological Relations of Sugar-beet Seedlings and Phoma betae." Jour. Agr. Res., Vol. 5, pp. 55–58 (Oct. 4, 1915).

Pool, V. W., and McKay, M. B. "Phoma betae on the Leaves of the Sugar Beet." Jour. Agr. Res., Vol. 4, pp. 169–177 (May 14, 1915).

1916. Pritchard, F. J. "Some Recent Investigations in Sugar Beet Breeding." Bot. Gaz., Vol. 41, No. 6, pp. 425–465 (Dec., 1916).

Pritchard, F. J., and Longly, L. E. "Experiments in Transplanting Sugar Beets." Jour. Am. Soc. Agron., Vol. 8, No. 2, pp. 106–110.

Shaw, H. B. "Control of the Sugar-beet Nematode." U. S. Dept. of Agr., Farmers' Bul. No. 772.

Pool, V. W., and McKay, M. B. "Relation of Stomatal Movement to Infection by Cercospora beticola." Jour. Agr. Res., Vol. 5, pp. 1011–1038 (Feb. 28, 1916).

Pool, V. W., and McKay, M. B. "Climatic Conditions as Related to Cercospora beticola." Jour. Agr. Res., Vol. 6, pp. 21–60 (Apr. 3, 1916).

1916. Pritchard, F. J. "Correlations between Morphological Characters and the Saccharine Content of Sugar Beets." Am. Jour. Botany, Vol. 3, pp. 361–376 (July, 1916).

Harris, F. S., and Hogenson, J. C. "Some Correlations in Sugar Beets." Genetics, Vol. I, pp. 334–347 (July, 1916).

Pritchard, F. J. "Some Recent Investigations in Sugar-beet Breeding." Science, N. S., 43, p. 219.

Peck, F. W. "The Cost of Producing Sugar Beets." Minn. Sta. Bul. No. 154.

Townsend, C. O. "The Present Status of the Sugar-beet Seed Industry in the United States." U. S. Dept. of Agr. Yearbook, 1916, pp. 399–410.

White, Wm. H. "The Sugar-beet Thrips." U. S. Dept. of Agr., Bul. No. 421.

1917. Federal Trade Commission, "Report on the Beet-sugar Industry in the United States." Govt. Printing Office.

Harris, F. S. "The Irrigation of Sugar Beets." Utah Sta. Bul. No. 146.

Ball, E. D. "The Beet Leafhopper and the Curly-leaf Disease That It Transmits." Utah Sta. Bul. No. 155.

Townsend, C. O., and Gore, H. C. "Sugar-beet Syrup." U. S. Dept. of Agr., Farmers' Bul. No. 823.

Elliott, Perry. "Production of Sugar in the United States and Foreign Countries." U. S. Dept. of Agr., Bul. No. 473.

Shepard, J. H., and Sherwood, R. C. "Sugar Beets in South Dakota." S. D. Bul. No. 173.

Adams, R. L. "Fundamentals of Sugar-beet Culture under California Conditions." Calif. Sta. Cir. 165.

Petriking, W. L. "The Beet Sugar Industry and Live Stock Production." Great Western Sugar Co., Agr. Dept., Bul. No. 2 (Jan., 1917).

Palmer, T. G. "Questions and Answers Concerning Sugar." Published by the Author, Washington, D. C.

The World's Sugar Supply. Published by the National Bank of Commerce in N. Y. (Dec., 1917).

Andrew, Frank. "Sugar Supply of the United States." U. S. Dept. of Agr. Yearbook, 1917, pp. 447–460.

1918. Wojta, J. F., and Wright, A. H. "How to Succeed with Sugar Beets." Wis. Ext. Serv. Circular No. 103.

Javitz, C. A., and Mason, A. W. "Sugar Beets." Ontario Agr. College Bul. No. 262.

Moorhouse, L. A., *et al.* "Farm Practice in Growing Sugar Beets for Three Districts in Utah and Idaho, 1914–1915." U. S. Dept. of Agr., Bul. No. 693.

APPENDIX B

AMERICAN BEET-SUGAR COMPANIES AND FACTORIES, JANUARY, 1918

Compiled by Truman G. Palmer

Alameda Sugar Company. Executive Office, 310 Sansome Street, San Francisco, California, Capital $1,500,000.

Factory	*Erected*	*Capacity*
Alvarado, Calif.	1870	800 tons
	Rebuilt, 1879; 1887	

Amalgamated Sugar Company. Executive Office, Ogden, Utah. Capital, $5,824,000.

Factories	*Erected*	*Capacity*
Ogden, Utah	1898	1,000 tons
Logan, Utah	1901	600 tons
Lewiston, Utah	1905	800 tons
Burley, Idaho	1912	600 tons
Twin Falls, Idaho	1916	600 tons
Brigham City, Utah	1916	500 tons
Paul, Idaho	1917	500 tons
Smithfield, Utah	1917	500 tons

American Beet Sugar Company. Executive Office, 32 Nassau Street, New York City. Capital, $20,000,000.

Factories	*Erected*	*Capacity*
Grand Island, Neb.	1890	500 tons
Chino, Calif.	1891	1,100 tons
Oxnard, Calif.	1898	3,000 tons
Rocky Ford, Colo.	1900	1,800 tons
Lamar, Colo.	1905	500 tons
Las Animas, Colo.	1907	1,000 tons

Anaheim Sugar Company. Executive Office, Merchants National Bank Building, Los Angeles, Calif. Capital, $547,800

Factory	*Erected*	*Capacity*
Anaheim, Calif.	1911	1,200 tons

Chippewa Sugar Refining Company. Executive Office, 428 Grand Avenue, Milwaukee, Wis. Capital, $500,000.

Factory	*Erected*	*Capacity*
Chippewa Falls, Wis.	1904	600 tons

Columbia Sugar Company. Executive Office, Bay City, Mich. Capital, $3,000,000.

Factories	*Erected*	*Capacity*
Bay City, Mich.	1901	1,500 tons
Paulding, Ohio	1910	900 tons

Continental Sugar Company. Executive Office, 520 Lafayette Boulevard, Detroit, Michigan. Capital, $1,732,400.

Factories	*Erected*	*Capacity*
Fremont, Ohio	1900	468 tons
Blissfield, Mich.	1905	868 tons
Findlay, Ohio	1911	871 tons

Delta Beet Sugar Corporation. Executive Office, Delta, Utah. Temporary Corporation.

Factory	*Erected*	*Capacity*
Delta, Utah	1917	1,000 tons

Garden City Sugar and Land Company. Executive Office, Mining Exchange Building, Colorado Springs, Colo. Capital, $2,677,200.

Factory	*Erected*	*Capacity*
Garden City, Kansas	1906	1,000 tons

Great Western Sugar Company. Executive Office, Sugar Building, Denver, Colo. Capital, $30,000,000.

Factories	*Erected*	*Capacity*
Loveland, Colo.	1901	1,950 tons
Greeley, Ohio	1902	1,050 tons
Eaton, Colo.	1902	1,200 rons
Ft. Collins, Colo.	1903	2,150 tons
Windsor, Colo.	1903	1,150 tons
Longmont, Colo.	1903	2,350 tons
Sterling, Colo.	1905	1,050 tons
Brush, Colo.	1906	1,100 tons
Ft. Morgan, Colo.	1906	1,200 tons
Billings, Mont.	1906	2,000 tons
Scottsbluff, Neb.	1910	2,000 tons
Lovell, Wyoming	1916	600 tons
Gering, Neb.	1916	1,100 tons
Bayard, Neb.	1917	1,000 tons
Missoula, Mont.	1917	1,000 tons
Brighton, Colo.	1917	1,000 tons

Holland-St. Louis Sugar Company. Executive Office, Holland, Mich. Capital, $1,695,340.

Factories	*Erected*	*Capacity*
Holland, Mich.	1899	500 tons
St. Louis, Mich.	1903	600 tons
Decatur, Ind.	1912	800 tons

Holly Sugar Corporation. Executive Office, Boston Building, Denver, Colo. Capital, $4,781,700 outstanding.

Factories	*Erected*	*Capacity*
Grand Junction, Colo.[1]	1899	700 tons
Swink, Colo.	1906	1,200 tons
Huntington Beach, Calif.	1911	1,200 tons

Independent Sugar Company. Executive Office, Bay City, Michigan.

Factory	*Erected*	*Capacity*
Marine City, Mich.	1900	600 tons

[1] Leased by Holly Sugar Corporation.

Iowa Sugar Company. Executive Office, Waverly, Iowa. Capital, $550,000.

Factory	*Erected*	*Capacity*
Waverly, Iowa	1907	500 tons

Layton Sugar Company. Executive Office, Layton, Utah. Capital, $500,000.

Factory	*Erected*	*Capacity*
Layton, Utah	1915	700 tons

Los Alamitos Sugar Company. Executive Office, Pacific Electric Building, Los Angeles, Calif. Capital, $500,000.

Factory	*Erected*	*Capacity*
Los Alamitos, Calif.	1897	800 tons

Menominee River Sugar Company. Executive Office, Menominee, Mich. Capital, $825,000.

Factory	*Erected*	*Capacity*
Menominee, Mich.	1903	1,200 tons

Michigan Sugar Company. Executive Office, Union Trust Building, Detroit, Mich. Capital, $11,174,600.

Factories	*Erected*	*Capacity*
Bay City, Mich.	1899	1,400 tons
Alma, Mich.	1899	1,400 tons
Caro, Mich.	1899	1,200 tons
Carrollton, Mich.	1902	900 tons
Croswell, Mich.	1902	750 tons
Sebewaing, Mich.	1902	850 tons

Minnesota Sugar Company. Executive Office, Chaska, Minn. Capital, $1,200,000.

Factory	*Erected*	*Capacity*
Chaska, Minn.	1906	800 tons

Mt. Clemens Sugar Company. Executive Office, Bay City, Mich. Capital, $600,000.

Factory	*Erected*	*Capacity*
Mt. Clemens, Mich.	1902	600 tons

National Sugar Manufacturing Company. Executive Office, Sugar City, Colo. Capital, $750,000.

Factory	*Erected*	*Capacity*
Sugar City, Colo.	1900	500 tons

Nevada-Utah Sugar Company. Executive Office, Salt Lake City, Utah. Capital, $500,000.

Factory	*Erected*	*Capacity*
Fallon, Nevada	1911	500 tons

(Control acquired by Utah-Idaho Sugar Company, 1916)

Northern Sugar Corporation. Executive Office, Union Trust Building, Detroit, Mich. Capital, $1,250,000.

Factory	*Erected*	*Capacity*
Mason City, Iowa	1917	1,200 tons

Ohio Sugar Company. Executive Office, Ottawa, Ohio. Capital, $400,000.

Factory	*Erected*	*Capacity*
Ottawa, Ohio	1912 Remodeled 1917	600 tons

Owosso Sugar Company. Executive Office, Bay City, Mich. Capital, $1,875,000.

Factories	*Erected*	*Capacity*
Lansing, Mich.	1901	600 tons
Owosso, Mich.	1903	1,200 tons

Pacific Sugar Corporation. Executive Office, 74 New Montgomery Street, San Francisco, Calif. Capital, $2,000,000.

Factory	*Erected*	*Capacity*
Tracy, Calif.	1917	600 tons

People's Sugar Company. Executive Office, 712 McIntyre Building, Salt Lake City, Utah. Capital, $765,000.

Factory	*Erected*	*Capacity*
Moroni, Utah	1917	400 tons

Pingree Sugar Company. Executive Office, 311 California Street, San Francisco, Calif. Capital, $1,000,000.

Factory	*Erected*	*Capacity*
Corcoran, Calif.	1908	600 tons

Charles Pope. Executive Office, 332 South Michigan Avenue, Chicago, Ill.

Factory	*Erected*	*Capacity*
Riverdale, Ill.	1905	500 tons

Rock County Sugar Company. Executive Office, Bay City, Mich. Capital, $800,000.

Factory	*Erected*	*Capacity*
Janesville, Wis.	1904	700 tons

Sacramento Valley Sugar Company. Executive Office, 602 I. W. Hellman Building, Los Angeles, Calif. Capital, $2,210,000.

Factory	*Erected*	*Capacity*
Hamilton City, Calif.	1906	700 tons

San Joaquin Valley Sugar Company. Executive Office, 311 California Street, San Francisco, Calif. Capital, $1,000,000.

Factory	*Erected*	*Capacity*
Visalia, Calif.	1906	400 tons

Santa Ana Sugar Company. Executive Office, Boston Building, Denver, Colo. Capital, $596,200.

Factory	*Erected*	*Capacity*
Dyer, Calif. . . . . (P. O. address, Santa Ana, Calif.)	1912	1,200 tons

Sheridan Sugar Company. Executive Office, Boston Building, Denver, Colo. Capital, $730,000.

Factory	*Erected*	*Capacity*
Sheridan, Wyo.	1915	900 tons

Southern California Sugar Company. Executive Office, Boston Building, Denver, Colorado. Capital, $500,000 outstanding.

Factory	*Erected*	*Capacity*
New Delhi, Calif. . . . . . . (P. O. address, Santa Ana, Calif.)	1908	600 tons

(Acquired by Holly Sugar Corporation, 1916.)

Spreckels Sugar Company. Executive Office, 60 California St., San Francisco, Calif. Capital, $5,000,000.

Factories	*Erected*	*Capacity*
Spreckels, Calif.	1899	4,500 tons
Manteca, Calif.	1917	1,200 tons

Toledo Sugar Company. Executive Office, Union Trust Building, Detroit, Mich. Capital, $485,900.

Factory	*Erected*	*Capacity*
Toledo, Ohio	1912	1,100 tons

Union Sugar Company. Executive Office, 310 Sansome Street, San Francisco, Calif. Capital, $3,000,000.

Factory	*Erected*	*Capacity*
Betteravia, Calif.	1899	1,000 tons

United States Sugar Company. Executive Office, 428 Grand Avenue, Milwaukee, Wis. Capital, $700,000.

Factory	*Erected*	*Capacity*
Madison, Wis.	1905	600 tons

Utah-Idaho Sugar Company. Executive Office, Salt Lake City, Utah. Capital, $23,626,350 issued.

Factories	*Erected*	*Capacity*
Lehi, Utah	1891	1,200 tons
Garland, Utah	1903	900 tons
Idaho Falls, Idaho	1903	900 tons
Blackfoot, Idaho	1904	800 tons
Sugar, Idaho	1904	900 tons
Elsinore, Utah	1911	750 tons
Payson, Utah	1913	750 tons
Spanish Fork, Utah	1916	1,000 tons
West Jordan, Utah	1916	750 tons
Grant's Pass, Ore.	1916	750 tons
Shelley, Idaho	1917	750 tons
North Yakima, Wash.	1917	750 tons

West Bay City Sugar Company. Executive Office, Bay City, W. S., Mich. Capital, $200,000.

Factory	*Erected*	*Capacity*
West Bay City, Mich.	1899	900 tons

West Cache Sugar Company. Executive Office, 39 Main Street, Logan, Utah. Capital, $800,000.

Factory	*Erected*	*Capacity*
Cornish, Utah	1917	600 tons

Wisconsin Sugar Company. Executive Office, 428 Grand Avenue, Milwaukee, Wis. Capital, $800,000.

Factory	*Erected*	*Capacity*
Menomonee Falls, Wis.	1897 Rebuilt 1901	600 tons

Wyoming Sugar Company. Executive Office, 618 David Eccles Building, Ogden, Utah. Capital, $1,000,000

Factory	*Erected*	*Capacity*
Worland, Wyo.	1917	600 tons

APPENDIX C

SUGAR STATISTICS[1]

TABLE I. — SUGAR PRODUCTION IN THE UNITED STATES AND ITS POSSESSIONS, 1856–57 TO 1917–18. (U. S. DEPARTMENT OF AGRICULTURE, YEARBOOK, 1917, P. 691)

Year	Beet-Sugar (chiefly refined)	Cane-Sugar (chiefly raw)					
		Louisiana	Other States	Porto Rico	Hawaii	Philippine Islands	Total
	Short tons	Short tons	Short tons	Short tons	Short tons	Short tons	Short tons
Average:							
1856–7 to 1860–1 . .	—	132,402	5,978	75,364	—	46,446	200,190
1861–2 to 1865–6 . .	269	74,036	1,945	71,765	—	54,488	202,503
1866–7 to 1870–1 . .	448	44,768	3,818	96,114	—	81,485	226,633
1871–2 to 1875–6 . .	403	67,341	4,113	87,606	—	119,557	279,020
1876–7 to 1880–1 . .	470	104,920	5,327	76,579	27,040	169,067	383,403
1881–2 to 1885–6 . .	692	124,868	7,280	87,441	76,075	189,277	485,633
1886–7 to 1890–1 . .	1,922	163,049	8,439	70,112	125,440	186,129	555,091
1891–2 to 1895–6 . .	19,406	268,655	6,634	63,280	162,538	286,629	807,142
1896–7 to 1900–1 . .	58,287	282,399	4,405	61,202	282,585	134,722	823,690
1901–2 to 1905–6 . .	239,730	352,053	12,126	141,478	403,308	108,978	1,257,673
1906–7 to 1910–11 . .	479,153	348,544	13,664	282,136	516,041	145,832	1,785,370

1901–2	184,606	360,277	4,048	103,152	355,611	75,011	1,082,705
1902–3	218,406	368,734	4,169	100,576	437,991	123,108	1,252,984
1903–4	240,604	255,894	22,176	138,096	367,475	82,855	1,107,100
1904–5	242,113	398,195	16,800	151,088	426,248	125,271	1,359,715
1905–6	312,921	377,162	13,440	214,480	429,213	138,645	1,485,861
1906–7	483,612	257,600	14,560	206,864	440,017	132,602	1,535,255
1907–8	463,628	380,800	13,440	230,095	521,123	167,242	1,776,328
1908–9	425,884	397,600	16,800	277,093	535,156	123,876	1,776,409
1909–10	512,469	364,000	11,200	346,786	517,090	140,783	1,892,328
1910–11	510,172	342,720	12,320	349,840	566,821	164,658	1,946,531
1911–12	599,500	352,874	8,000	371,076	595,038	205,046	2,131,534
1912–13	692,556	153,573	9,000	398,004	546,524	345,077	2,144,734
1913–14	733,401	292,698	7,800	351,666	612,000	408,339	2,405,904
1914–15	722,054	242,700	3,920	346,490	646,000	421,192	2,382,356
1915–16	874,220	137,500	1,120	483,590	592,763	412,274	2,501,467
1916–17	820,657	303,900	7,000	503,081	644,663	262,425	—
1917–18 . . . . (Preliminary)	765,207	233,000	2,240	546,000	—	—	—

[1] The European war has so thoroughly upset industrial conditions that figures for Europe since 1914 have but little meaning.

TABLE II. — SUGAR-BEETS AND BEET-SUGAR PRODUCTION IN THE UNITED STATES, 1911–1917. (U. S. DEPARTMENT OF AGRICULTURE, YEARBOOK, 1917, P. 692)

STATE AND YEAR	NUMBER OF FACTORIES	AVERAGE LENGTH OF CAMPAIGN	SUGAR MADE (chiefly refined)	SUGAR-BEETS USED				ANALYSIS OF BEETS		RECOVERY OF SUCROSE		LOSS
				Area harvested	Average yield per acre	Quantity worked	Average price per ton	Percentage of sucrose	Purity coefficient	Percentage of weight of beets	Percentage of total sucrose in beets	
		Days	*Short tons*	*Acres*	*Short tons*	*Short tons*	*Dollars*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
California:												
1917 . . .	14	92	209,325	161,909	8.16	1,321,716	7.60	18.48	82.09	15.84	85.71	2.64
1916 . . .	11	108	236,322	141,097	10.37	1,462,805	6.30	18.35	84.13	16.15	88.01	2.28
1915 . . .	11	97	195,343	122,737	10.2	1,249,111	5.86	17.82	82.65	15.64	87.77	2.10
1914 . . .	10	97	169,004	104,000	10.4	1,082,000	5.68	18.46	82.70	15.62	84.62	2.84
Colorado:												
1917 . . .	15	91	234,303	161,476	10.84	1,749,875	7.28	15.40	85.16	13.39	86.95	2.01
1916 . . .	14	102	252,147	188,568	10.25	1,933,591	6.06	15.00	85.79	13.04	86.93	1.96
1915 . . .	14	104	273,780	171,222	11.0	1,888,860	5.88	16.53	84.84	14.49	87.66	2.04
1914 . . .	13	96	220,799	135,400	12.6	1,706,300	5.68	15.35	84.22	12.94	84.30	2.41
Idaho:												
1917 . . .	7	70	38,376	37,745	7.59	286,446	7.06	16.74	84.84	13.40	80.05	3.34
1916 . . .	5	86	45,874	42,135	7.87	331,478	6.16	16.95	86.39	13.84	81.65	3.11
1915 . . .	4	100	51,225	35,068	9.7	339,859	5.08	17.85	87.14	15.07	84.43	2.78
1914 . . .	4	78	39,613	25,300	10.5	264,400	4.96	17.78	87.74	14.98	84.25	2.80

Michigan:												
1917 . . .	14	53	64,247	82,151	5.62	461,721	8.04	16.28	86.57	13.91	85.44	2.37
1916 . . .	15	49	69,341	99,619	5.05	502,705	6.14	16.37	85.22	13.79	84.24	2.58
1915 . . .	15	78	129,997	122,000	8.2	997,972	5.91	15.45	84.08	13.03	84.34	2.42
1914 . . .	15	68	110,630	101,300	8.5	857,100	5.23	15.78	82.85	12.91	81.81	2.87
Ohio:												
1917 . . .	5	70	24,467	24,234	8.36	202,624	7.18	16.24	86.25	12.08	74.38	4.16
1916 . . .	4	45	18,234	24,767	5.56	137,696	6.83	15.89	83.36	13.24	83.32	2.65
1915 . . .	4	80	33,472	25,684	10.9	279,427	5.29	14.19	81.99	11.98	84.43	2.21
1914 . . .	3	56	21,425	17,800	10.4	184,700	5.04	14.50	83.82	11.60	80.00	2.90
Utah:												
1917 . . .	15	82	83,662	80,289	8.68	696,522	7.04	15.61	82.27	12.01	76.94	3.60
1916 . . .	11	95	90,277	68,211	10.38	708,237	5.73	16.05	84.79	12.75	79.44	3.30
1915 . . .	8	96	85,014	56,226	11.2	629,204	4.91	16.43	85.06	13.51	82.23	2.92
1914 . . .	7	100	78,619	41,300	13.7	564,600	4.79	17.03	85.60	13.92	81.74	3.11
Other States:												
1917 . . .	21	60	110,827	116,993	7.75	906,641	7.37	15.17	81.87	12.22	80.55	2.95
1916 . . .	14	66	108,462	100,911	8.35	843,071	6.18	15.69	82.67	12.87	82.03	2.82
1915 . . .	11	84	105,389	78,364	9.8	765,860	5.67	16.38	84.24	13.76	84.00	2.62
1914 . . .	8	76	81,964	58,300	10.8	629,500	5.67	15.80	83.35	13.02	82.40	2.78
United States:												
1917 . . .	91	74	765,207	664,797	8.46	5,625,545	7.39	16.28	83.89	13.60	83.54	2.68
1916 . . .	74	80	820,657	665,308	8.90	5,919,673	6.12	16.30	84.74	13.86	85.03	2.44
1915 . . .	67	92	874,220	611,301	10.1	6,150,293	5.67	16.49	84.38	14.21	86.17	2.28
1914 . . .	60	85	722,054	483,400	10.9	5,288,500	5.45	16.38	83.89	13.65	83.33	2.73
1913 . . .	71	85	733,401	580,006	8.76	5,659,462	5.69	15.78	83.22	12.96	82.13	2.82
1912 . . .	73	86	692,556	555,300	9.41	5,224,377	5.82	16.31	84.49	13.26	81.12	3.05
1911 . . .	66	94	599,500	473,877	10.68	5,062,333	5.50	15.89	82.21	11.84	74.51	4.05

TABLE III. — WHOLESALE PRICE OF SUGAR PER POUND, ON NEW YORK MARKET, 1912–1917. (U. S. DEPARTMENT OF AGRICULTURE, YEARBOOK, 1917, p. 694)

DATE	RAW				REFINED									
	Molasses, 89° Polarization		Centrifugal, 96° Polarization		Cut Loaf		Powdered		Granulated, Fine or Standard		Soft Sugar, No. 1		Soft Sugar	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
	Cents	*Cents*	*Cents*	*Cents*	*Cents*	*Cents*	*Cents*	*Cents*	*Cents*	*Cents*	*Cents*	*Cents*	*Cents*	*Cents*
1912														
Jan.–June	3.33	4.30	3.83	4.80	5.80	6.65	5.10	5.90	5.00	5.85	4.85	5.65	4.25	5.05
July–Dec.	3.23	3.86	3.73	4.36	5.70	5.90	5.00	5.20	4.90	5.15	4.65	4.95	4.05	4.35
1913														
Jan.–June	2.75	3.23	3.25	3.73	5.05	5.70	4.35	5.00	4.25	4.95	4.00	4.65	3.40	4.05
July–Dec.	2.62	3.30	3.12	3.80	5.05	5.60	4.25	4.90	4.15	4.85	4.05	4.55	3.45	3.95
1914														
Jan.–June	2.27	2.98	2.92	3.48	5.05	5.25	3.95	4.40	3.85	4.35	3.60	4.10	3.00	3.50
July–Dec.	2.61	5.87	3.26	6.52	5.25	8.40	4.40	7.60	3.85	7.55	4.10	7.30	3.50	6.70
1915														
Jan.–June	3.20	4.27	3.95	5.02	5.85	7.00	5.05	6.20	4.95	6.15	4.70	5.85	4.10	5.25
July–Dec.	2.73	4.43	3.50	5.20	5.80	7.05	5.00	6.25	4.90	6.20	4.65	5.90	4.05	5.30
1916														
January	3.56	4.00	4.33	4.77	6.65	6.85	5.85	6.05	5.75	6.00	5.50	5.70	4.90	5.10
February	3.93	4.31	4.70	5.08	6.90	7.40	6.10	6.35	6.00	6.30	5.75	6.10	5.15	5.50
March	4.12	5.25	4.83	6.02	7.40	8.15	6.35	7.10	6.25	7.05	6.10	6.85	5.50	6.25
April	5.06	5.69	5.83	6.46	8.15	8.55	7.10	7.50	7.00	7.45	6.85	7.25	6.25	6.65
May	5.25	5.75	6.02	6.52	8.55	8.80	7.50	7.75	7.40	7.70	7.25	7.50	6.65	6.90
June	5.25	5.63	6.02	6.40	8.80	8.80	7.75	7.75	7.65	7.70	7.50	7.50	6.90	6.90
Jan.–June	3.56	5.75	4.33	6.52	6.65	8.80	5.85	7.75	5.75	7.70	5.50	7.50	4.90	6.90

July	5.31	5.63	6.08	6.40	8.80	8.80	7.75	7.75	7.65	7.70	7.50	7.50	6.90	6.90
August	4.09	5.50	4.89	6.27	8.15	8.80	7.10	7.75	7.00	7.70	6.85	7.50	6.25	6.90
September	4.09	5.25	4.89	6.02	7.40	8.15	6.35	7.10	6.25	7.05	6.10	6.85	5.50	6.25
October	5.00	5.88	5.77	6.65	7.90	8.65	6.85	7.60	6.75	7.55	6.60	7.35	6.00	6.75
November	4.87	5.75	5.64	6.52	8.65	8.65	7.60	7.60	7.50	7.55	7.35	7.35	6.75	6.75
December	4.25	4.87	5.02	5.64	8.00	8.65	6.95	7.60	6.85	7.55	6.70	7.35	6.10	6.75
July–Dec.	4.09	5.88	4.89	6.65	7.40	8.80	6.35	7.75	6.25	7.70	6.10	7.50	5.50	6.90
1917														
January	3.98	4.62	4.75	5.39	7.90	8.00	6.85	6.95	6.75	6.90	6.60	6.70	6.00	6.10
February	3.87	4.63	4.64	5.52	7.90	8.40	6.85	7.35	6.75	7.30	6.60	7.10	6.00	6.50
March	4.25	5.19	5.02	5.96	8.15	8.40	7.10	7.35	7.00	7.30	6.85	7.10	6.25	6.50
April	5.00	5.69	5.77	6.46	8.40	9.00	7.35	7.65	7.25	7.55	7.10	7.35	6.50	6.75
May	5.20	5.52	5.95	6.27	—	9.00	—	7.65	7.50	7.55	—	7.35	—	6.75
June	5.06	5.77	5.83	6.52	—	9.00	—	7.65	7.50	7.55	—	7.35	—	6.75
Jan.–June	3.87	5.77	4.64	6.52	7.90	9.00	6.85	7.65	6.75	7.55	6.60	7.35	6.00	6.75
July	5.23	6.02	6.23	7.02	9.00	9.40	7.65	8.05	7.50	7.95	7.35	7.60	6.75	7.15
August	6.02	6.89	7.02	7.77	9.65	9.90	8.30	8.55	8.15	8.45	8.00	8.25	7.40	7.65
September	6.02	6.05	6.90	7.02	9.90	9.90	8.55	8.55	8.40	8.45	8.25	8.25	7.55	7.65
October	6.02	6.02	6.90	6.90	9.85	9.90	8.50	8.55	8.35	8.45	8.20	8.25	7.60	7.65
November	6.02	6.02	6.90	6.90	9.85	9.85	8.50	8.50	8.35	8.40	8.20	8.20	7.60	7.60
December	5.90	6.02	5.92	6.90	9.65	9.85	8.30	8.50	8.15	8.40	8.00	8.20	7.40	7.60
July–Dec.	5.23	6.89	5.92	7.77	9.00	9.90	7.65	8.55	7.50	8.45	7.35	8.25	6.75	7.65

TABLE IV. — BEET AND SUGAR PRODUCTION OF VARIOUS COUNTRIES. (U. S. DEPARTMENT OF AGRICULTURE, YEARBOOK, 1917, pp. 697–698)

COUNTRY AND YEAR	FACTORIES IN OPERATION	SUGAR MADE, RAW	BEETS USED FOR SUGAR			AVERAGE EXTRACTION OF SUGAR	
			Area harvested	Average yield per acre	Quantity worked	Percentage of weight of beets used	Per short ton of beets used
	Number	*Short tons*	*Acres*	*Short tons*	*Short tons*	*Per cent*	*Pounds*
Austria-Hungary							
1910–11 . . .	214	1,549,102	918,201	11.95	11,038,503	17.5	281
1911–12 . . .	210	1,180,605	968,771	8.18	8,623,578	16.6	274
1912–13 . . .	218	2,093,439	1,088,088	13.00	13,911,305	14.8	301
			Area cultivated		Produced	Percentage of weight of beets produced	Per ton of beets produced
Belgium							
1910–11 . . .	92	299,035	148,858	13.41	1,996,977	14.97	299
1911–12 . . .	89	258,780	145,119	11.45	1,660,872	15.58	312
1912–13 . . .	88	309,308	152,913	12.47	1,907,358	16.22	324
1913–14 . . .	84	249,395	129,527	11.85	1,534,311	16.25	325
Denmark							
1910–11 . . .	8	110,792	—	—	817,381	13.56	271
1911–12 . . .	8	128,032	—	—	809,616	15.81	316
1912–13 . . .	9	148,447	79,986	14.49	1,159,369	12.80	256
1913–14 . . .	9	179,002	—	—	1,025,140	17.46	349

Country and Year	Factories in Operation	Sugar Made, Refined	Beets Used for Sugar			Average Extraction of Sugar	
			Area harvested	Average yield per acre	Quantity worked	Percentage of weight of beets used	Per ton of beets used
	Number	*Short tons*	*Acres*	*Short tons*	*Short tons*	*Per cent*	*Pounds*
France							
1910–11 . . .	239	717,033	549,969	10.76	6,426,226	11.80	236
1911–12 . . .	220	512,986	555,575	8.09	4,669,083	11.41	228
1912–13 . . .	213	967,440	566,539	12.99	7,960,926	13.15	263
1913–14 . . .	206	790,790	534,230	12.24	6,539,725	12.09	242
1914–15 . . .	69	333,953	242,781	11.92	2,892,878	11.54	231
1915–16 . . .	64	149,801	146,305	8.65	1,265,518	11.84	237
Germany		Raw					
1910–11 . . .	354	2,770,001	1,180,913	14.72	17,360,003	15.96	319
1911–12 . . .	342	1,551,797	1,247,213	8.03	9,987,473	15.54	311
1912–13 . . .	342	2,901,564	1,353,181	13.56	18,344,738	15.82	316
1913–14 . . .	341	2,885,572	1,316,655	14.19	18,672,939	15.45	309
Italy			Area cultivated				
1910–11 . . .	35	190,901	124,044	14.92	1,698,551	11.24	225
1911–12 . . .	37	174,894	131,260	13.30	1,621,760	10.78	216
1912–13 . . .	37	218,628	133,434	14.40	1,879,328	11.63	233
1913–14 . . .	37	336,823	152,700	19.70	2,994,816	11.25	225

TABLE IV. — BEET AND SUGAR PRODUCTION OF VARIOUS COUNTRIES. — (*Continued*)

Country and Year	Factories in Operation	Sugar Made, Refined	Beets Used for Sugar			Average Extraction of Sugar	
			Area cultivated	Average yield per acre	Quantity worked	Percentage of weight of beets used	Per short ton of beets used
	Number	*Short tons*	*Acres*	*Short tons*	*Short tons*	*Per cent*	*Pounds*
Netherlands							
1910–11 . . .	27	219,947	138,554	12.94	1,678,803	13.10	262
1911–12 . . .	27	265,401	137,388	16.06	1,896,187	14.00	280
1912–13 . . .	27	315,775	160,180	14.99	2,228,851	14.17	283
1913–14 . . .	27	231,073	149,001	12.27	1,705,878	13.55	271
1914–15 . . .	27	316,346	156,251	14.06	2,193,577	14.42	288
1915–16 (prelim.)	23	240,828	139,644	13.52	1,755,964	13.71	274
Russia		Raw					
1910–11 . . .	276	2,074,410	1,631,188	8.9	14,437,305	14.61	292
1911–12 . . .	281	2,036,990	1,923,539	7.8	14,754,312	13.84	277
1912–13 . . .	287	1,361,842	1,847,313	6.4	11,538,078	11.73	235
1913–14 . . .	293	1,680,893	1,756,160	7.7	13,436,058	14.51	250
1914–15 . . .	265	1,958,975	1,941,122	7.4	13,979,662	14.01	280
1915–16 . . .	235	1,697,356	1,748,466	7.0	12,324,612	13.77	275

Country and Year	Factories in Operation	Sugar Made, Raw	Beets Used for Sugar			Average Extraction of Sugar	
			Area cultivated	Average yield per acre	Quantity worked	Percentage of weight of beets used	Per short ton of beets used
	Number	Short tons	Acres	Short tons	Short tons	Per cent	Pounds
Spain							
1910–11 . . .	33	68,743	[1]	[1]	532,882	12.90	258
1911–12 . . .	32	102,859	90,787	[1]	872,834	11.78	236
1912–13 . . .	33	171,839	105,213	[1]	1,302,871	11.33	264
1913–14 . . .	31	186,680	146,745	[1]	1,478,114	12.62	252
1914–15 . . .		112,231	78,642	[1]	813,790	—	—
1915–16 . . .	31	117,334	[1]	[1]	921,013	—	—
Sweden							
1910–11 . . .	24	191,713	86,816	13.56	1,218,166	15.53	315
1911–12 . . .	24	140,409	71,790	14.83	908,372	15.27	309
1912–13 . . .	24	145,462	66,900	13.95	922,083	15.59	316
United States		Refined	Area harvested				
1910–11 . . .	61	510,172	398,029	10.17	4,047,292	12.61	252
1911–12 . . .	66	599,500	473,877	10.68	5,062,333	11.84	237
1912–13 . . .	73	692,556	555,300	9.41	5,224,377	13.26	265
1913–14 . . .	71	733,401	580,006	9.76	5,659,462	12.96	259
1914–15 . . .	60	722,054	483,400	10.90	5,288,500	13.65	273
1915–16 . . .	67	874,220	611,301	10.10	6,150,298	14.21	267
1916–17 . . .	74	820,657	665,308	8.90	5,919,673	13.86	277

[1] No data.

TABLE V. — CANE AND SUGAR PRODUCTION IN VARIOUS COUNTRIES. (U. S. DEPARTMENT OF AGRICULTURE, YEARBOOK, 1917, P. 699)

Country and Year	Factories in Operation	Sugar Made	Cane Used for Sugar			Average Extraction of Sugar per Ton of Cane Used
			Area cultivated	Average per acre	Quantity worked	
	Number	Short tons	Acres	Short tons	Short tons	Pounds
Argentina						
1910–11	[1]	163,701	178,060	[1]	[1]	[1]
1911–12	[1]	198,515	230,866	[1]	[1]	[1]
1912–13	39	162,313	232,830	[1]	2,338,594	139
1913–14	38	304,389	263,656	[1]	3,451,321	176
1914–15	37	370,324	269,833	[1]	4,027,067	184
Australia			Harvested		Produced	
1910–11	53	253,131	100,237	22.36	2,240,849	226
1911–12	53	210,292	101,010	18.65	1,884,120	223
1912–13	50	144,776	84,279	15.09	1,271,358	228
Cuba			Cultivated			
1910–11	171	1,670,151	—	—	14,736,981	227
1911–12	172	2,142,420	—	—	20,679,593	207
1912–13	171	2,737,264	1,340,139	—	25,137,684	218
1913–14	170	2,891,281	1,334,070	—	25,644,949	226
Hawaii			Harvested			
1911–12	[1]	595,038	113,000	42.0	4,774,000	249
1912–13	[1]	546,524	114,600	39.0	4,476,000	244
1913–14	46	612,000	112,700	45.0	5,094,000	240
1914–15	45	646,000	113,200	46.0	5,185,000	249
1915–16	[1]	592,763	115,419	42.0	4,859,424	244

[1] No data.

Japan			Cultivated			
1910–11	13	72,454	49,166	18.49	892,662	162
1911–12	14	75,797	52,153	18.16	941,550	161
1912–13	17	68,867	51,293	17.15	879,624	157
1913–14	16	72,613	53,300	17.91	954,758	152
Java (factory plantations)			Harvested			
1910–11	189	1,583,178	321,720	46.43	14,936,035	212
1911–12	193	1,424,657	336,021	40.71	13,679,962	208
1912–13	191	1,527,584	340,739	45.11	15,370,765	199
Spain			Cultivated			
1910–11	27	22,371	11,666	21.9	258,138	173
1911–12	23	17,831	9,983	16.5	167,092	213
1912–13	21	14,585	9,844	15.6	153,707	190
1913–14	22	8,131	4,581	17.4	79,719	204
1914–15	[1]	6,168	[1]	[1]	—	[1]
1915–16	16	4,700	2,950	16.59	48,937	194
United States (Louisiana)			Harvested for sugar			
1911–12	188	352,874	310,000	19.0	5,887,292	120
1912–13	126	153,573	197,000	11.0	2,162,574	142
1913–14	153	292,698	248,000	17.0	4,214,000	139
1914–15	149	242,700	213,000	15.0	3,199,000	152
1915–16	136	137,500	183,000	11.0	2,018,000	135
1916–17	150	303,900	221,000	18.0	4,072,000	149

[1] No data.

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