4-1935

The Sugar Beet Industry of Nebraska

Esther S. Anderson

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The University of Nebraska

BULLETIN 9
CONSERVATION DEPARTMENT
OF THE
CONSERVATION AND SURVEY DIVISION
UNIVERSITY OF NEBRASKA

Contribution from the Department of Geography

By Authority of the State of Nebraska
Lincoln, Nebraska
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As defined by law, the Conservation and Survey Division of the University includes the following state departments and surveys: Soil, Geological, Water, Biological, Industrial, Conservation and Information Service. Its major purpose is to study and describe the state's resources and industries for use in development. Reports are published in three series, i.e., Nebraska Soil Survey, Nebraska Geological Survey, and the Conservation Department.

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INTRODUCTION

The Conservation and Survey Division, by statutory enactment, is required to study and describe the leading industries of the state. Thus far, two general and three special bulletins have been published in compliance with this requirement. These publications, however, were rapidly exhausted by constant demand for them by the schools and the general public.

Brief reviews of the resources and industries of the state, prepared by the writer, have been published in various volumes of the Nebraska Blue Book, which are available in most public libraries of the state. Aside from these reviews and the publications issued by the Division, the College of Agriculture has published some material on Nebraska industries. There remains, however, a great dearth of literature on the industries of this state. At present the Conservation and Survey Division is making detailed studies of irrigation, dairying, and other industries of the state, which are to be published in bulletin form as soon as they are completed.

Doctor Esther S. Anderson has studied the sugar beet industry both extensively and intensively for a number of years. She has become acquainted with the processes involved from field to factory and has investigated economic relations of the industry. She has taught the subject at the University, has lectured on it before state, national, and international meetings, and has become a recognized authority on this subject.

This bulletin was prepared by Doctor Anderson through her own initiative and at her expense. It is a valuable contribution, intended primarily as a reference for use in the schools of the state, and secondarily, for the general reader.

G. E. Condra,
Dean and Director

The Sugar Beet Industry of Nebraska

During the last fifty years sugar has become one of the staple articles of food in nearly all civilized countries. In the United States the per capita consumption of sugar increased from 79 pounds in 1909 to 103 pounds in 1932, and the present annual consumption is approximately 6,000,000 tons, 20 per cent of which is supplied by the domestic sugar beet crop.

USES OF SUGAR

Ordinary sugar (sucrose) is a highly nutritious carbohydrate that is easily digested and that produces much energy. It is used in various forms of food, such as candy, ice cream, pastries, beverages, preserves, jellies, and canned fruits. Sugar supplies about 13 per cent of the energy obtained from food by the people in the United States; grains furnish approximately 35 per cent; beef, pork, mutton, 22 per cent; milk and dairy products, 15 per cent; and all other foods, 15 per cent.[1] It is one of the most economical sources of body fuels. One pound of sugar yields about 1,800 calories of heat, and at five or six cents a pound, it is cheaper than almost any other heat producing food.

Sweets have formed a part of the human diet since time immemorial. Honey, mentioned in the Bible and in other early writings, was the only concentrated sweet used as food prior to the separation of sugar from sugar producing plants.

Sugar is supposed to have been known by the inhabitants of India and China at a very early period. The ancient Hebrews also were acquainted with it. In several places in the Old Testament, reference is made to the "sweet cane", apparently an article of merchandise coming from a distant country.

Sugar was first used as medicine.[2] In the first century of the Christian Era, Pliny, the noted historian, described it as "honey collected from canes" and added that it was used as medicine.[3] Diphylos of Siphnos, a doctor in the fourth century before Christ, used sugar for curing diseases.[4] Investigations as to the value of sugar for medicinal purposes were started about 500 A.D. by eminent Arabian physicians near Jondisapur in the Tigris-Euphrates valley.[5] Paul Egineta, a doctor, 625 A.D., described sugar

[1] *Yearbook, United States Department of Agriculture,* 1923.
[2] Lippmann, E. O., *Geschichte des Zuckers,* Leipzig, 1890, p. 400.
[3] Reed, William, *History of Sugar and Sugar Yielding Plants,* London, 1866, p. 1.
[4] Lippmann, E. O., *op. cit.*
[5] Andree, Karl, *Geographie des Welthandels,* Stuttgart, Erster Band, 1867, p. 600.

as "Indian Salt" and recommended that a "piece" be kept in the mouth during fevers. It was also designated as "Indian Salt" by the Greeks and Romans, who obtained it in India in small quantities at an enormous cost.[6] The sugars mentioned were obtained either from bamboo or from sugar cane and were highly prized as medicine. This fact seems to have been the origin of the ancient proverb: "Like an apothecary without sugar".[7]

Sugar continues to hold a high place in the field of medicine. Many of the medicines of today are made either partially of sugar or are coated with it so that they have a pleasant taste and are more readily taken by the patient.

Sugar as Food. The nourishing value of sugar was recognized early but due to its high price, it was used for centuries only for medicinal purposes and as a luxury. Later, it became an essential part of the diet of civilized people.

The Crusaders found extensive areas of sugar cane in Tripoli, Mesopotamia, Palestine, Syria, and Antioch. About 1108 A.D., a monk, Albertus Agnesis, wrote that "sweet honeyed reeds", called "zucra" were found in Tripoli. The Crusaders sucked these reeds and "found much nourishment in them". Agnesis also mentions the use of sugar by the natives who crushed the cane in mortars and let the juice stand until it "concentrated in the form of snow, or of white salt". This they mixed with bread and water to make a pottage.[8] During the tenth century enough sugar was manufactured in the far eastern countries to attract the attention of European and Asiatic traders. The material then began to be used as a delicious food luxury for special feasts.

In 1482 sugar sold for $275 per hundred pounds on the London market. By the end of the fifteenth century, the sugar cane industry had expanded widely, and the price of sugar on the London market was $53 per hundred pounds. It is said that in England sugar was made an article of the household diet by Queen Elizabeth during whose reign its price became much lower, and hence more people used it. Since the beginning of the nineteenth century, the expansion of the cane sugar industry, the introduction of beet sugar, improved methods of transportation, and better factory equipment have caused sugar to become so cheap that it is now a household necessity.

Per Capita Consumption. The average annual per capita consumption of sugar in the United States increased from 24 pounds in 1866 to 76.6

[6] Reed, William, *op. cit.*, p. 2.
[7] Surface, G. T., *The Story of Sugar*, New York, 1910, p. 16.
[8] Reed, William, *op. cit.*, pp. 2-3.

pounds in 1905 and to 108 pounds in 1930. In 1930 only three countries consumed more sugar per capita than did the United States (Table 1).[9]

TABLE 1.—*Average Per Capita Consumption of Sugar in 1930 (Raw Value)*

	Pounds
Denmark	123.6
Australia	117.7
Hawaii	117.5
United States	108.1
Cuba	103.3
United Kingdom	101.1
Canada	100.5
Switzerland	95.0
Sweden	89.9
Argentina	71.8
Belgium	61.5
Germany	57.7
Netherlands	68.3
France	54.2
Mexico	29.5
Spain	28.2
Japan and Formosa	21.8
Italy	21.4
Java	20.0
Haiti and San Domingo	18.9
China	5.5

DEVELOPMENT OF THE SUGAR BEET INDUSTRY

Origin of the Sugar Beet. The origin of the sugar beet is uncertain, yet it is believed that the sugar cane and the sugar beet were indigenous in approximately the same regions. The original beet seems to have been an annual plant having a slender, tough root and a top with small leaves, but following its introduction into the countries of higher latitudes, it became a biennial plant which now produces seed only after two years of growth.

According to De Condolle,[10] beets with slender roots grew wild in sandy soils in the Canary Islands, along the coasts of the Mediterranean Sea, and as far east as Persia and Babylon. They may have grown even as far east as western India.

Early Use of Beets. Herodotus mentions the beet as one of the plants which served as nourishment for the builders of the pyramids.[11] Hippokrates,[12] the noted physician, was among the first to use beet sap in-

[9] Statistics by Doctor Gustav Mikusch, secured from H. A. Austin, United States Beet Sugar Association, Washington, D. C.
[10] De Condolle, A. T., *Origin of Cultivated Plants*, New York, 1885, p. 58.
[11] Lippmann, E. O., *op. cit.*, p. 399.
[12] *Ibid.*, p. 400.

stead of honey for medicine. The beet was well known in ancient Greece five centuries before the Christian Era. It was an important source of food and was considered as one of the most common market articles in Athens, where not only the root but also the leaves were eaten.[13]

The sugar beet was known in ancient Italy. It is said that Hannibal retreated from Casilium because the astute inhabitants grew beets within the walled city, and he believed that they would be well supplied with provisions if they could hold out until the beets were ripe. Cato spoke of beets in his work on agriculture, Plautus named them as a universal food of the poor people, and Cornelius Celsus (about 30 A.D.) and Columella (60 A.D.) recommended their cultivation.[14] The distribution of the beet and its importance as food at the time of the Roman emperors are most clearly shown in the detailed account of Pliny who says:[15]

> "Next to cereals and beans no plant is more useful than the white beet of which the root serves as food and as forage, the sprouts as a vegetable and the leaves as fodder; also if the beets are stored in the earth they will keep until the new crop is again ready."

Dioskorides declared that the white beet "was good for the stomach" and used both raw and cooked sap for various healing purposes. He used the beet with alum or caraway and also the leaves either alone or with wine in the treatment of certain diseases. The beet was known in the Orient in ancient times. Arabian doctors often used and prescribed beet juice.[16]

Early Cultivation of Beets in Europe. The beet was cultivated in the Rhine district, southern France, and in northern Italy in the twelfth and thirteenth centuries. Its cultivation was extended in Germany and spread into the Netherlands in the fourteenth and fifteenth centuries. It was taken to Spain in 1525 and to western and southwestern Germany in 1700. In 1780 it had reached central, eastern, and northeastern Germany, Bohemia, and northern France.[17] The sugar beet had been used for fodder since the middle of the eighteenth century in the region of Magdeburg and Halberstad.

The Discovery of Sugar in Beets. Olivier de Serres (1539-1619), the French agronomist, author of "Theatre d' Agriculture", was among the first to suggest that beets contained sugar. In 1600 he said:

> "The beet has come to us recently from Italy and is large, red, many-leaved, and of agreeable taste . . . . it needs well tilled soil

[13] *Ibid.*, p. 699.
[14] *Ibid.*, p. 400.
[15] *Idem.*
[16] *Ibid.*, pp. 400-401.
[17] Lippmann, E. O., *Geschichte des Zuckers,* Zweite Auflage, 1929, p. 700.

so that the root can penetrate deeply; the root has tender flesh and gives by cooking a juice which really tastes like sugar syrup and is splendid red to look at." [18]

In 1605 Olivier de Serres discovered that alcohol could be obtained from the fermentation of beet juice, from which he concluded that beets contained sugar.[19]

Early Attempts in Sugar Extraction. Even though Olivier de Serres was the first to realize that sugar occurred in beets, Andreas Marggraf, a Prussian chemist in Berlin, proved in 1747 that the sweet taste in beets was due to sugar. He was one of the first chemists to use a microscope in his investigations.[20]

It was not until about 1785 that Marggraf's discovery was studied again. At that time Franz Karl Achard, son of a French refugee in Prussia and a pupil of Marggraf, continued the research work. He was encouraged through financial assistance by Frederick the Great (1712-1786), King of Prussia.[21] Achard planted large areas of beets on his estate near Berlin, in order to attempt to raise beets high in sugar content and low in impurities.[22] Due to lack of finances, he was compelled to abandon his experiments for a time after the death of Frederick the Great. Frederick Wilhelm III then became interested in the industry and made additional grants to Achard to continue the work.[23]

After ascertaining which kind of beets produced most sugar, Achard turned his attention to sugar manufacture. Finally, in 1799, he announced the results of his experiments and presented them together with samples of beet sugar to King Frederick Wilhelm III. In 1800 the King presented Achard with a gold medal in honor of his work.[24]

The First Beet Sugar Factory. Convinced that Achard's experiments were successful, the King assisted him in establshing a factory in 1802 on the Cunern estate near Steinau, Germany. This was the first beet sugar factory in the world. Its capacity was only a few hundred pounds of sugar per day.

King Frederick Wilhelm III was so pleased with the returns from the factory that he contributed to the erection of other sugar factories near

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[18] *Ibid.*, pp. 403-404.

[19] Lippmann, E. O., *Chemie der Zuckerarten*, Vol. II, Braunschweig, 1904, p. 1046.

[20] Lippmann, E. O., *Geschichte des Zuckers*, Zweite Auflage, 1929, p. 700.
Achard, *Traite Complet sur le Sucre Européen de Betteraves*, Traduction abrégéé de M. Achard, par M. D. Angar, Paris 1812, p. a.

[21] Ware, L. S., *The Sugar Beet*, Philadelphia, 1880, p. 26.
Palmer, T. G., *The Beet Sugar Industry of the United States*, 1913, p. 19.

[22] Lippmann, E. O., *op. cit.*, pp. 405-406.

[23] Palmer, T. G., *op. cit.*, p. 119.

[24] Lippmann, E. O., *op. cit.*, pp. 701-702.

Berlin, in Pomerania, and in Silesia. He also offered premiums to any farmer or manufacturer who would work more than twenty tons of beet roots per year.[25]

Development of the Beet Sugar Industry in Europe. Vilmorin brought the beet to France in 1775. Abbe Rozier first started regular cultivation of beets in 1782.[26] In 1786 Abbe Commerel published a book calling the farmers' attention to the advantages of beet roots for feed.[27]

As a result of Napoleon's "Berlin Decree," which prohibited imports to the continent, the price of sugar increased rapidly and gave an impetus to the French and the Germans in their experiments with the sugar beet.

On March 23, 1811, Napoleon issued a decree appropriating 1,000,000 francs ($200,000) for the establishment of six technical beet sugar schools and compelled the peasants to plant 32,000 hectares (79,000 acres) of sugar beets the following season. On January 15, 1812, he issued another decree which provided (1) that 100 students should be selected from the schools of medicine, pharmacy, and chemistry and transferred to the technical beet sugar schools; (2) that 150,000 acres of sugar beets should be grown; (3) that financial inducements be extended to scientists to perfect the process of extraction and to capitalists to engage in sugar manufacture; and (4) for the immediate establishment of four imperial beet sugar factories.[28]

As a result of the vigorous action of Napoleon, 334 factories were erected in France within the next two years. The first factory was built near Lille in 1811.[29]

After the overthrow of Napoleon and the raising of the continental blockade, the young industry could not meet the competition of foreign sugar. The result was that only one factory survived. In 1815 high duties in various countries again stimulated the industry so much that by 1838, there were more than 575 beet sugar factories in Europe. Through the assistance of Napoleon III the output of French sugar was doubled by 1853.[30]

The success of the industry in Germany and France led to its extension into Austria-Hungary, Russia, Belgium, and later into Sweden, Spain,

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[25] Geerligs, H. C. P., *The World's Cane Sugar Industry, Past and Present,* London, 1912, p. 14.

[26] Lippmann, E. O., *op. cit.,* pp. 405-406.

[27] Ware, L. S., *op. cit.,* p. 26.

[28] Palmer, T. G., *Questions and Answers,* Washington, 1917, p. 8.

[29] Lippmann, E. O., *op. cit.,* p. 417.
Palmer, T. G., *The Beet Sugar Industry of the United States,* 1913, p. 120.

[30] Palmer, T. G., *The Beet Sugar Industry of the United States,* 1913, p. 121.
Blakey, Roy G., *The United States Sugar Industry and the Tariff,* New York, 1912, Vol. XLVII, p. 18.

England, and Italy. The present centers of sugar beet production in Europe are in Germany, Russia, Czechoslovakia, France, and Poland.

In 1786 Perkins brought the beet to England, and in 1830 John Vaughan and James Donaldson brought the sugar beet to America.[31]

GROWTH OF THE SUGAR BEET INDUSTRY IN THE UNITED STATES

The earliest attempts at beet sugar manufacture in the United States were made in Philadelphia in 1830 by a company organized by John Vaughan and James Donaldson. These attempts resulted in failure. Practical information was lacking and therefore little was accomplished in raising sugar beets and in the manufacture of sugar.

Massachusetts. The Northampton Beet Sugar Company manufactured at Northampton, Massachusetts, the first beet sugar in the United States in 1839. This company, organized by David Lee Child,[32] made 1,300 pounds of sugar during the first year of operation. In recognition of this accomplishment, a medal with the following inscription was awarded to David Lee Child:

> "The Massachusetts Charitable Mechanic Association. Award to David Lee Child, for the first beet sugar made in America. Exhibition 1839." [33]

Due to the lack of knowledge in both field and factory operations, the industry was not a paying proposition, and hence the factory at Northampton ceased operation after 1840. However, the manufacture of sugar in Massachusetts opened a new phase of agriculture in the United States which was destined to become of considerable importance within seventy-five years.

One of the immediate results of the Massachusetts experiment was the early interest shown by the United States Government in the development of the sugar beet industry. Some states offered bounties on sugar produced within their boundaries. In Massachusetts the bounty was three cents a pound for a period of five years. Some of the attempts in establishing the sugar beet industry in the United States are presented in the following discussion.

Utah. Endeavors at raising sugar beets were made by the Mormon pioneers soon after their settlement in Utah in 1847. The difficulty and expense encountered in hauling supplies by wagon from the Missouri

[31] Ware, L. S., *op. cit.*, p. 26.
Lippmann, E. O., *op. cit.*, pp. 405-406.

[32] Harris, F. S., *The Sugar Beet in America*, 1919, p. 16.

[33] Palmer, T. G., *Beet Sugar Industry in the United States, op. cit.*, p. 6.

River to Salt Lake City by team caused the cost of sugar to range from forty cents to one dollar a pound.

Two years after settlement, John Taylor and other Mormon missionaries were sent to France to preach the new religion and to translate the "Book of Mormon" into French. They secured Philip de La Mare to assist in the translation. In the spring of 1851 Taylor and de La Mare visited the noted sugar beet district in northern France, which then produced from 2,000,000 to 3,000,000 pounds of sugar annually. After investigating the industry, the soils, and the growing plant, they were convinced that the sugar beet could be grown in Utah. They secured plans for the manufacture of beet sugar and left for England where approximately $60,000 was raised to incorporate the Deseret Manufacturing Company. In the fall of 1851 Taylor and de La Mare purchased the necessary machinery for the manufacture of beet sugar. This machinery was shipped from Europe by way of New Orleans and St. Louis, arriving at Provo, Utah, in November, 1852.[34]

On account of unexpected expenses, the Deseret Manufacturing Company was not able to finish the factory at Provo. The machinery of the unfinished factory was purchased by the Mormon Church and moved to Salt Lake City, where it was installed in an adobe building. On account of the difficulty experienced in making the sugar crystallize, only syrup was made, and the project was abandoned in 1855. Although the beet sugar industry was not successful until years later, Philip de La Mare is credited as being one of those who laid the foundation of the beet sugar enterprise in the United States.

Illinois. In 1864 the Gennert Brothers, Germans living in New York, purchased 2,300 acres at Chatsworth, Illinois, and organized the German Beet Sugar Company with a capital of $200,000. A mill with a capacity of fifty tons per day was erected, but it could extract only a small per cent of the sugar from the beets. In 1866 approximately 4000 tons of beets were produced on 400 acres. Poor selection of land and poor seed resulted in a series of unfavorable years for the factory, and the company moved the plant first to Freeport, Illinois, and later to Black Hawk, Wisconsin.[35] It was never a success.

Wisconsin, California. About 1866, two Germans, Bonesteel and Otto, established a factory at Fond du Lac, Wisconsin.[36] The enterprise was abandoned after two years of partial success. Otto went to Alvarado,

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[34] "History of the Western Sugar Beet Industry". *The Business Farmer*, Scottsbluff, Nebraska, Volume 5, No. 2, February 13, 1930; and Vol. 5, No. 15, August 28, 1930. Based partially upon *Utah Geneological and Historical Magazine*.

[35] Harris, F. S., *op. cit.*, p. 18.

[36] Ware, L. S., *op. cit.*, p. 42.

California, and became associated with E. H. Dyer in 1870, who had raised 150 acres of beets as an experiment during the previous year. The factory which they erected produced 250 tons of sugar in 1870 and 750 tons in 1873. The average cost of production of sugar was about ten cents per pound. The plant was not a success and was later moved to Santa Cruz County. In 1871 the Sacramento Beet Sugar Company began operating a small plant which made sugar and molasses for several years and was finally sold to E. H. Dyer. This was the first factory to use the diffusion battery system of extracting the juice from beets.

The first successful* beet sugar factory in the United States was erected at Alvarado, California, in 1879 by E. H. Dyer (known as the "father of the American beet sugar industry").[37] Because of favorable tariff and bounty conditions Claus Spreckles constructed a factory at Watsonville, California, in 1888, which produced 1,000 tons of sugar during the first year. It was the largest beet sugar factory in the United States and operated until 1898.[38] Since then more than ninety factories have been established in the United States.

DEVELOPMENT OF THE SUGAR BEET INDUSTRY IN NEBRASKA

The Oxnard Brothers early became interested in the establishment of the sugar beet industry in America. After making extensive studies of the soil and climatic requirements of the beet, both in America and in Europe, they established the second successful factory in the United States at Grand Island, Nebraska, in 1890.

Grand Island Factory. Previous to the erection of this plant a number of Hall County citizens, who contended that the sugar beet industry was feasible in Nebraska, had some soil samples from the county analyzed. In 1888 beets produced in Hall County from French and German seed were tested at the University of Nebraska and in Washington, D. C., and were found to contain a satisfactory sugar content. Beet raising was continued on a more extensive scale in 1889, at which time an expert chemist and fieldman was brought from Germany to supervise the production of the crop. Tests of the beets grown here showed a sucrose content of 18 per cent. The results were so satisfactory that the plan for locating a beet sugar factory at Grand Island was proposed in November, 1889. It was decided to raise $100,000 for this purpose, of which sum the citizens subscribed $60,000 before the matter was submitted formally to the public.

* By "successful" is meant that the factory has operated every year since its construction.

37 Harris, F. S., *op. cit.*, p. 19.

38 Surface, *op. cit.*, p. 19.

University Experiments. In the late eighties and early nineties, Professor H. H. Nicholson, of the University of Nebraska, was given an appropriation by the legislature to conduct experiments with sugar beets grown in Nebraska. He was one of the first to bring beet seed into the state and to start experiments in sugar beet culture. He also directed a school for the training of young men in methods of beet production and improved and extended the experimental work in Hall County. Dr. Samuel Avery, now Chancellor Emeritus, University of Nebraska, assisted Professor Nicholson by making chemical analyses of the beets grown in different parts of Nebraska. It was found that these beets generally contained from 12 to 16 per cent of sugar and had a purity coefficient of 80 to 85.*

Difficulties Encountered. Like many other new enterprises, the beet sugar industry had much difficulty in its early development in Nebraska. The farmers did not know what land was suited to beet culture, nor did they know the proper practices in raising the crop. In addition, the dry season of 1890 produced a low yield. The following year was too wet, and again there was a low production. These conditions caused the farmers to become discouraged.

The effects of weather conditions upon early beet culture and some of the early problems of the industry are summarized as follows: The farmers were unacquainted with this kind of work and made many mistakes; in some cases the ground was not properly prepared; some planted on too high and too dry soils, and others on too wet grounds; some seasons were too dry, and others were too wet; and as a result, the yields were low. Because of these conditions the sugar manufacturers received such scanty supplies of good beets during the first years that they were forced to raise their own sugar beets by leasing a large tract of land and hiring experienced German workmen.

Gradually the farmers of Hall County gained sufficient experience and were willing to increase their sugar beet acreage in spite of attempts to create a hostile sentiment among them. Credit is due those farmers, mostly Germans, who persisted in growing beets, and their results eventually induced many others to follow their example. Soon large fields of beets, sometimes covering a hundred acres, provided work for laborers and profit to beet raisers and to the factory.

The difficulty of introducing this industry was increased in Hall County because it was one of the first places in the country to introduce the sugar beet. There were no examples or experiments from which

* Purity coefficient refers to the percentage of sugar in the sugar beet juice.

the beet farmer could learn, nevertheless the energy of the company and of the farmers conquered many difficulties.[39]

About 1890 the Grand Island factory, through Heyward G. Leavitt, engaged Lewis Hoche, a French expert in beet culture, to supervise the growing of sugar beets at Grand Island. All the handwork was done by day laborers who drove from the city to the beet fields and received a daily wage of $1.50 for 14 or 15 hours work. At first much of the seed was planted with a hand seeder, one row at a time, and later four-row drills were used. All beet cultivation was done with a hoe until the hand cultivator was introduced. Another handicap was the damage done to crops by animal pests and plant diseases, as no methods of combating them were known.

At the time the Grand Island factory was established, the state, in order to encourage the industry, offered a bounty of one cent per pound on sugar produced in Nebraska. This bounty yielded the factory $7,364 on the output in 1890.

Norfolk Factory. Encouraged by the bounty afforded by the state, the Oxnard Brothers erected a factory at Norfolk, Nebraska, in 1891.

The temperature, rainfall, humidity, and soil conditions in the Norfolk district proved unfavorable for the growth of sugar beets of good yields and high sugar content. Farmers of this area found that they received better returns with less labor by raising corn and livestock than by producing beets. The result was an insufficient supply of beets for the Norfolk factory; consequently it was abandoned in 1905, and the equipment was moved to Lamar, Colorado.

Ames Factory. Mr. Leavitt continued his interest in sugar beet culture and induced the Standard Land and Cattle Company to raise sugar beets on its land in the vicinity of Ames, Nebraska. He engaged a German expert, Henry Huxman, under whose tutelage the company's beet prospects brightened. The yields and the sugar content were favorable. In 1899 a factory was constructed at Ames, Nebraska, by the Standard Beet Company, Mr. Leavitt being its president. Its period of operation ceased in 1906, due to an inadequate supply of beets resulting from adverse weather conditions. The factory was moved to Scottsbluff in 1910.

Reasons for Slow Development. The early sugar beet industry in the state developed slowly, because (1) the farmers were slow to introduce the sugar beet; (2) the state bounty was repealed; and (3) the result of the national election of 1892 forecasted the repeal of the McKinley tariff, all of which resulted in lower prices for beets.

[39] "The Independent Souvenir" published by *The Independent*, Grand Island, Nebraska, Vol. XV, No. 1, Sat., Jan. 1, 1898.
Myrick, *The American Sugar Industry*, 1899, pp. 52-54.

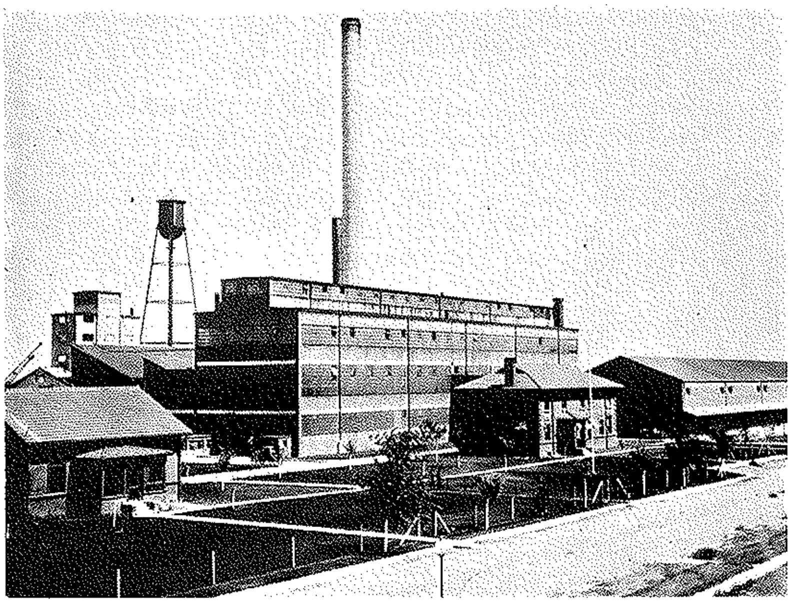
Since the factories had been obliged to reduce the price of beets from \$5.00 to \$4.00 per ton, not enough beets had been planted to run the factories a reasonable length of time. In addition, the drouth of 1894 reduced the yield. The state came to the rescue and passed an act on March 25, 1895, offering a bounty of ⅝ of a cent per pound on all sugar manufactured, provided the price of beets was raised from \$4.00 to \$5.00 per ton. Thus encouraged, the farmers in 1895 contracted to plant 5,000 acres for the Norfolk factory and 4,000 for the Grand Island factory.

Weather conditions reduced the crop of 1895. There was an unfavorable spring and an early dry summer. Later, excellent growing weather seemed favorable for a good crop, but September opened with a general rain, followed by a period of high temperature. As a consequence of the excess moisture and warmth, the early ripened beets began a second period of growth, drawing sustenance from the sugar stored in the roots. Before they could begin elaborating sugar again, cold and cloudy weather checked the growth, leaving the beets in such an immature condition that many of them were rejected by the factory, because, being below 12 per cent in sugar content and under 80 per cent purity, it did not pay to mill them. Much dissatisfaction resulted among the growers, who at first did not believe that the factory tests were reliable. They employed a chemist to test the beets and also sent samples to the state experiment station for analysis. The results of these analyses corroborated those reported by the factory chemists, and the farmers were convinced "that the fault was in the weather and not in the factory."

Since the bounty was supposed to continue another year, every effort was made in 1896 to test the industry thoroughly. The weather conditions were excellent, and a good crop resulted. The farmers made a profit and felt that they had mastered the culture of the sugar beet and offered to grow more beets in 1897 than the factories could use.

Sugar Beets in the North Platte Valley. In 1900-1901 the Burlington Railroad was extended into the North Platte Valley, and Mr. Leavitt, constantly on the lookout for new opportunities, became interested in the sugar beet potentialities of the newly opened territory. He was convinced that the valley was suited to sugar beet production under irrigation. Realizing that more land could be brought under irrigation, he and his associates purchased a large acreage and promoted the building of the Tri-State Canal, now known as the Farmers Canal. At the same time some land irrigated by the older canals was purchased, and definite plans were laid for beet culture.

In the spring of 1908 the Great Western Sugar Company began raising sugar beets in the North Platte Valley. By that time a considerable



Photograph, L. H. Andrews

FIG. 1.—Beet sugar factory at Mitchell, Nebraska.

acreage was under cultivation. The company introduced standardized farm practices in the growing of sugar beets. By 1910 sufficient beets were grown to warrant the building of a factory and, as noted before, the Ames factory was moved to Scottsbluff and enlarged. It has operated annually since that date, and now it has a slicing capacity of 2,000 tons of beets per day.

Five additional factories were erected in the North Platte Valley in Nebraska as follows:

Gering, Scotts Bluff County, 1916, capacity, 1200 tons.
Bayard, Morrill County, 1917, capacity, 1300 tons
Mitchell, Scotts Bluff County, (Figure 1) 1920, capacity, 1300 tons.
Minatare, Scotts Bluff County, 1926, capacity, 1300 tons
Lyman, Scotts Bluff County, 1927, capacity, 1300 tons

Most of these factories have increased their capacity since they were established.

In 1905 about 250 acres of sugar beets were grown in the North Platte Valley with an average yield of 7 tons per acre, while in 1933, 88,000 acres were grown with an average of 12.12 tons per acre.

Acreage and Yield. The average annual acreage of beets in Nebraska from 1928 to 1932 was 78,000 and the average annual yield was 1,006,200 tons. More than 90 per cent of the entire crop was grown in the North Platte and Platte valleys (Figure 2). Scotts Bluff and Morrill counties produced 76 per cent of the acreage and 79 per cent of the tonnage. Scotts Bluff County alone contributed 48,000 acres or 61 per cent of the acreage and 646,500 tons or 64 per cent of the tonnage, while Morrill County raised 12,000 acres or 15 per cent of the acreage and 148,000 tons of beets or 15 per cent of the entire crop in the state (Table 2 and Figure 2). From 2,000 to 3,000 acres and 21,000 to 31,000 tons of beets were produced

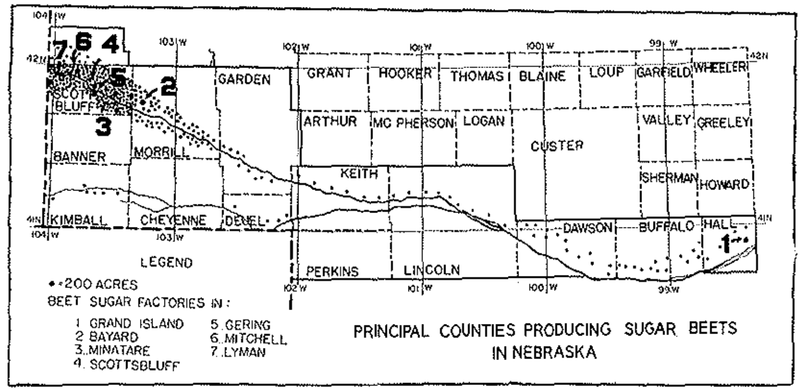


FIG. 2.—Principal counties producing sugar beets in Nebraska.

annually in each of Dawson, Buffalo, Sioux, and Garden counties. During the last two or three years the production of beets in the Republican Valley of Dundy and Red Willow counties has practically ceased. The beets produced in these counties were shipped to the sugar factories in Colorado.

During the period from 1929 to 1932, Sioux County (southwestern part) led in the average annual yield of beets per acre with 14.2 tons, and Scotts Bluff County followed with 13.6 tons per acre. The yield in other counties ranged from 9 to 13 or more tons per acre (Table 2).[40]

A large acreage is well suited to beet production in the irrigated regions of western Nebraska, but the expansion of the industry is dependent on good prices for the beets as well as upon the geographical conditions of the region.

Inasmuch as the Nebraska sugar beet industry is a part of a carefully managed agricultural enterprise of the United States and since much

[40] *Nebraska Agricultural Statistics*, issued co-operatively by the United States Department of Agriculture and Nebraska Department of Agriculture, Lincoln, Neb.

TABLE 2.—*Average Annual Acreage, Tonnage, and Yield per Acre of Sugar Beets in the Principal Beet Producing Counties of Nebraska, 1928-1932*

County	Acres	Tonnage	Yield per Acre Tons
Scotts Bluff	48,149	646,477	13.6
Morrill	12,118	147,968	12.4
Dawson	2,981	30,448	10.2
Buffalo	2,853	30,316	10.5
Sioux	2,027	28,045	14.2
Garden	1,023	21,445	11.2
Lincoln	1,828	19,630	10.9
Keith	1,267	13,462	11.1
Kimball	1,170	12,919	12.4
Dawes	986	8,140	10.5
Deuel	931	10,188	11.0
Hall	894	8,957	10.0
Hitchcock	848	10,612	12.5
Red Willow	399	5,218	13.0
Dundy	238	2,979	12.6
Kearney	218	2,083	9.2
Phelps	162	1,665	10.0

of it is in the semiarid region of the Middlewest, a review of the production and distribution of sugar beets in the United States is included in this bulletin.

SUGAR BEETS, REGIONS AND PRODUCTION IN THE UNITED STATES

Sugar beet production in the United States increased from 376,000 acres and 4,236,000 tons in 1906 to 768,000 acres and 8,991,000 tons in 1932. The three years of maximum production were 1920 (872,000 acres; 8,538,000 tons), 1930 (775,000 acres; 9,199,000 tons), and 1932 (768,000 acres; 8,991,000 tons)[41] (Figure 3).

Regions. For convenience, the sugar beet areas in the United States are here divided into four major regions, and the percentage of the total crop grown in the United States is given for each region: (1) the Great Lakes Region, mostly in Michigan, 11%; (2) the Great Plains Region, 64%; (3) the Intermontane Region, 12%; and (4) the California Region, 10% (Figure 4).

The Great Plains Region is the most important sugar beet producing region in North America. Its principal subdivisions or areas are: (1) the Arkansas Valley in western Kansas and southeastern Colorado; (2) the

[41] *Yearbook of Agriculture,* (1906-1932), United States Department of Agriculture, Washington, D. C.

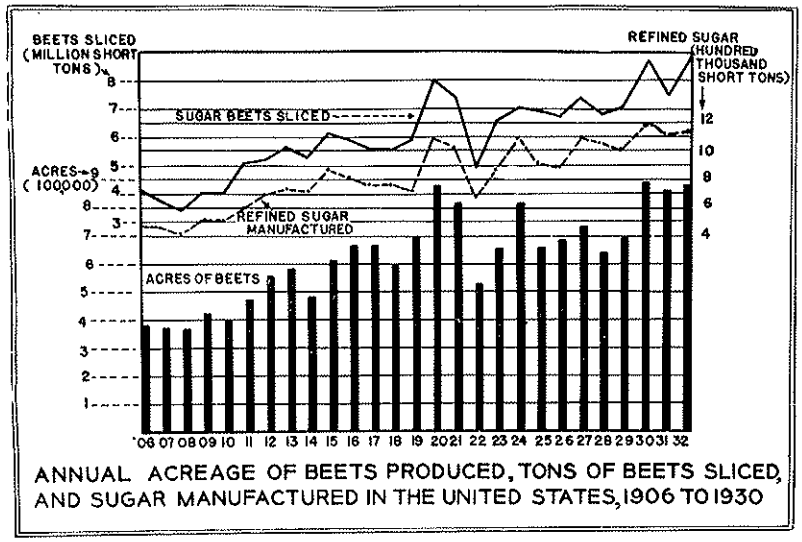


FIG. 3.—Annual acreage of beets produced, tons of beets sliced, and sugar manufactured in the United States, 1906-1930.

South Platte Valley in northeastern Colorado; (3) the North Platte Valley in Wyoming and western Nebraska; (4) the Northern Great Plains District in eastern Wyoming and Montana; and (5) the Northern Montana areas in Milk and Lower Yellowstone valleys.

The Intermontane Region extends from central Idaho through Utah and to southwestern Colorado. The Great Lakes Region includes Michigan,

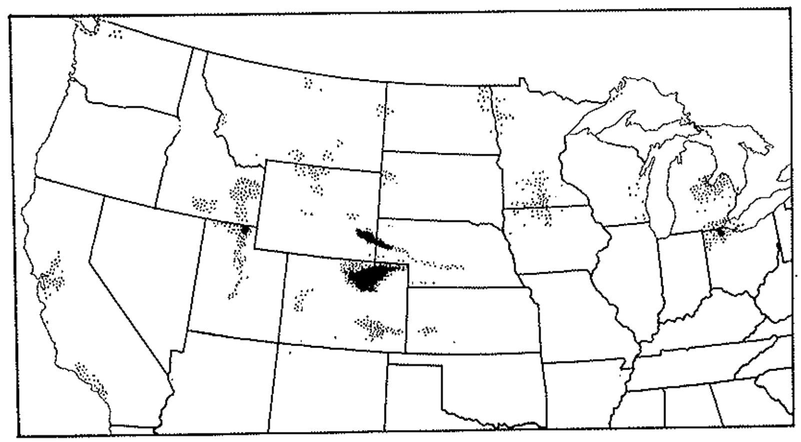


FIG. 4.—Distribution of sugar beet acreage in the United States. Each dot represents 250 to 500 acres.

Wisconsin, and portions of northern Ohio, Indiana, and Illinois. Michigan produces the largest amount of beets in this region.

The California Region includes the Great Valley and the coastal district centering about Oxnard, Santa Ana, Spreckles, and Anaheim. Even though the acreage in California is only about 8 per cent of the total acreage in the United States, this region manufactures approximately 11 per cent of the total output of beet sugar.

State Rank in Production of Sugar Beets. The six leading sugar beet producing states from 1923 to 1932 were Colorado, Nebraska, Michigan, California, Utah, and Idaho. Colorado ranked first in average annual sugar beet acreage (198,000), first in tonnage (2,365,000), and second in yield per acre (12.3 tons); Nebraska ranked first in yield per acre (12.7 tons); second in tonnage (932,000), and third in acreage (74,000); Michigan was third in tonnage (732,000), second in acreage (81,000), and sixth in yield per acre (9.8 tons); California held fourth place in acreage (69,000) and tonnage (699,000), and was fifth in yield per acre (10.2 tons; Utah was fifth in acreage (51,000) and tonnage (687,000) and third in yield per acre (11.8 tons); Idaho was sixth in acreage (38,000) and tonnage (395,000), and fourth in yield per acre (10.4 tons) (Figure 5, Table 3).[42]

TABLE 3.—*Average Annual Acreage, Tonnage, and Yield of Beets Per Acre in the Six Principal Sugar Beet Producing States, and in the United States, 1923-1932*

State	Acreage	Production	Yield per acre
Colorado	198,000	2,365,000	12.3
Nebraska	74,000	932,000	12.7
Michigan	81,000	732,000	9.8
California	69,000	699,000	10.2
Utah	51,000	687,000	11.8
Idaho	38,000	395,000	10.4
United States	718,000	7,736,000	10.9

During the decade 1923-1932 Colorado and Nebraska produced an average of 272,000 acres of beets or 38 per cent of the acreage in the United States—Colorado producing 28 per cent and Nebraska 10 per cent. The average annual yield of beets in the two states was 3,297,000 tons or 43 per cent of the total production of the United States of which Colorado produced 31 per cent and Nebraska 12 per cent.

[42] *Idem.*

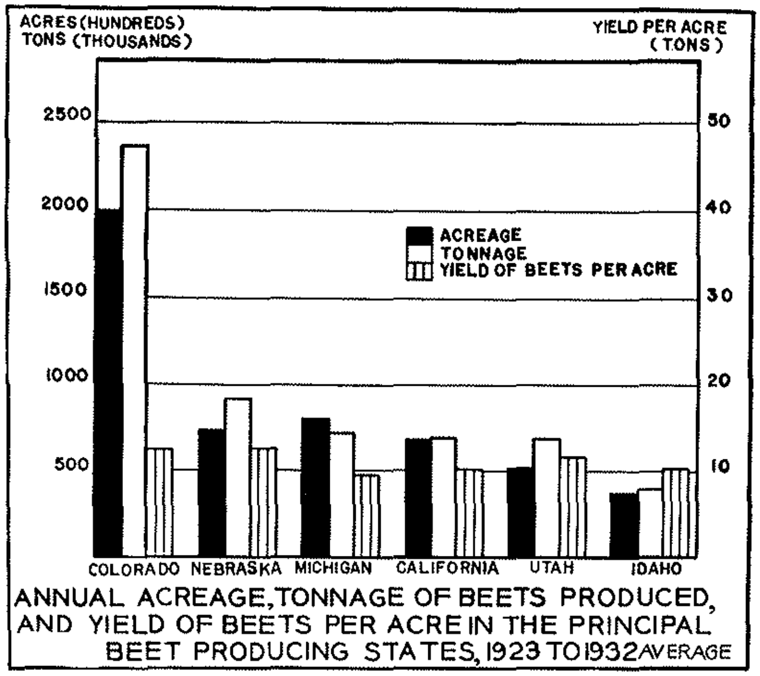


FIG. 5.—Annual acreage, tonnage of beets produced and yield of beets per acre in the principal beet producing states, 1923-1932 acreage.

Production of Beet Sugar. Beet sugar production in the United States since 1921 has ranged from 650,000 to 1,308,000 tons, the highest being in 1932-33. In 1929 there were manufactured 1,068,285 tons of granulated sugar valued at $100,249,000 and 17,700 tons of unfinished sugar valued at $517,800.[43] The major portion of this granulated sugar was produced in the Intermontane and Great Plains regions in Colorado, Nebraska, Idaho, Montana, Utah, and Wyoming, while 103,990 tons were manufactured in California. The greater part of the unfinished sugar was made in Ohio, Indiana, Wisconsin, Iowa, Kansas, Minnesota, and Nebraska. The molasses discarded from the desugarization processes (exclusive of that used for beet pulp) totaled 53,000 tons, valued at $790,000. The dried beet pulp totaled 87,500 tons and was valued at $2,127,000. Colorado, Nebraska, and Utah produced 32,297 tons of dried beet pulp. The largest amount of dried pulp produced was 134,000 tons in 1925. Approximately 1,297,000 tons of moist pulp, valued at $1,124,000, and about 76,000

[43] Bureau of Census, *The Sugar Industries and Corn Syrup, Corn Oil, and Starch*, Washington, D. C.

tons of molasses pulp, worth $1,979,000, were made. California produced 39,745 tons of molasses pulp or about 52 per cent of the total output. The moist pulp output in the United States in 1929 was 1,297,368 tons, valued at $1,124,038. In 1925 the total production, 1,362,000 tons, was larger, but the value, $823,000, was lower than that of 1929. The total value of the products from the beet sugar industry in 1929 was $108,552,581. The highest total value (1921) was $138,109,665. Since the statistics given by the United States Census are arranged according to groups of states rather than as individual states, it is difficult to give the percentage of value in the various sugar beet regions. Approximately 75 per cent of the total value of the products is produced in the Intermontane and Great Plains regions.

The beet crop of the United States for 1929 was harvested from 650,000 acres. The quantity of beets received by the factories was 7,186,443 tons, of which approximately 6,934,000 tons were grown under contract by independent growers. The total quantity of beets treated (milled) was 6,999,000 tons, and the average yield of sugar per ton was 311 pounds. In 1927 the total tonnage was approximately the same as for 1929. Since 1921 the largest acreage planted to beets was 840,030 in 1929.[44]

Number of Factories. During the sugar campaign * of 1929, 82 factories were in operation in the United States. Colorado operated 17, Michigan 12, Utah 10, Nebraska 7, Idaho 7, California and Ohio 5 each, Wyoming 4, Wisconsin, Minnesota, and Iowa 2 each, and Washington, Indiana, Kansas, and South Dakota one each. The number of factories in operation in the United States from 1906 to 1933 varied from 60 to 97 (Table 4).[45]

Materials, Labor, and Values. In 1929 the cost of materials and power used in the manufacture of beet sugar in the United States aggregated $70,923,000. The wages paid in connection with manufacture was $10,-021,000. The value added by manufacture was $37,630,000. Although the value of the products from the beet sugar industry was more than $108,000,000, an average of only 7,496 wage earners were employed. In 1921 the cost of materials and power was $121,869,000, and the cost of labor was $22,658,000, the highest since 1919. About 13,600 persons were employed in 92 factories in 1921.

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[44] *Idem.*

* The various activities connected with the harvesting, transporting, and milling of the beets are collectively known as the "sugar campaign".

[45] Palmer, Truman G., *Beet Sugar Industry of the United States,* Washington, D. C., 1913, p. 5., and *Yearbook of Agriculture,* U. S. Department of Agriculture, Washington, D. C.

TABLE 4.—*Number of Beet Sugar Factories in Operation in the United States from 1906 to 1930*

Year	No.	Year	No.
1906	63	1920	97
1907	63	1921	92
1908	62	1922	81
1909	65	1923	89
1910	61	1924	90
1911	66	1925	88
1912	73	1926	78
1913	71	1927	83
1914	60	1928	82
1915	67	1929	79
1916	74	1930	77
1917	91	1931	66
1918	89	1932	75
1919	89	1933	84

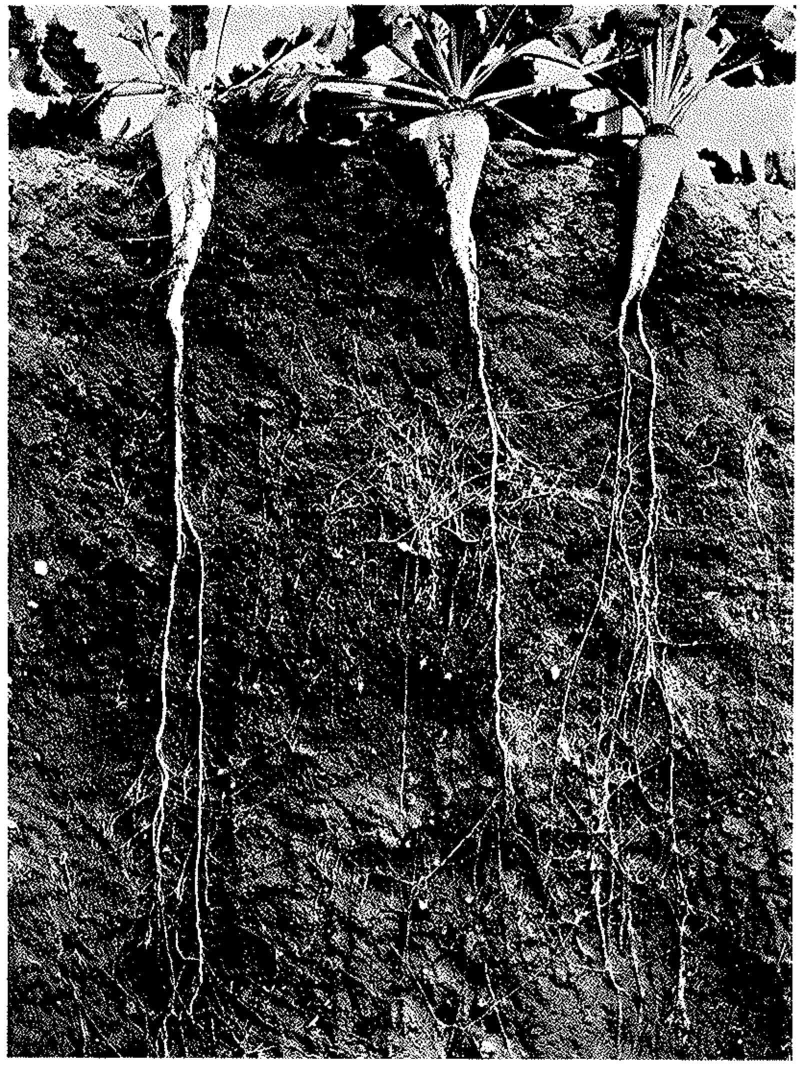
THE SUGAR BEET PLANT

Botanical Relations. The sugar beet belongs to the goosefoot family, Chenopodiaceae. Among the wild species of this family are the pigweed and lambs quarter. Linnaeus classified the beets into two groups, *Beta vulgaris* and *Beta maritima.*[46] The species *Beta vulgaris* includes the sugar beet, mangel wurzel, the common table beet, and the leaf-beet. A slender rooted wild form of the same genus, *Beta maritima,* grows along the coast of southern Europe and eastward to the Caspian Sea and Persia. Some botanists, who maintain that the domesticated forms and the wild forms are the same, use the term *Beta vulgaris* for the entire group. Those who prefer to separate botanically the cultivated and wild forms use the term *Beta vulgaris* for the cultivated group and *Beta maritima* for the wild species.

Parts of the Plant. The domestic sugar beet consists of a taproot, many fibrous roots, a crown, and leaves. The upper part of the beet contains the crown and the medium green, succulent leaves arranged in a modified rosette position (Figure 6). The leaves vary from 8 to 12 or more inches in length and from 3 to 6 inches in width. Their stems and veins are generally white.

The beet proper, the part from which sugar is extracted, is the cream colored fleshy part of the taproot. It varies from 6 to 10 inches in length and weighs from one to two or more pounds. The network of roots extends 4 to 6 feet into the ground and spreads in every direction, thus

[46] De Condolle, Alphonse, *op. cit.,* pp. 58-59.
Harris, F. S., *op. cit.,* pp. 22-23.



Photograph, L. H. Andrews

FIG. 6.—Sugar beets showing taproots and fibrous root systems. Roots penetrate to depths varying from 4 to 6 or more feet.

nearly filling the soil with large and small roots. A more complete description of the root system is given under the discussion of "Soils".

Seed Producing Plants. Since the sugar beet is a biennial plant, the beets raised the first year must be stored through the winter and then planted during the next year in order to develop a plant for seed production. In seed producing plants the leaves are smaller and more numerous and extend to the top of the stem, which becomes the seed stalk. The seed is produced in a group of clusters at the top of this stalk.

SUGAR BEET SEED

Imported Seed. The sugar beet industry in the United States requires from 15,000,000 to 20,000,000 pounds of beet seed annually. Prior to the World War, America was dependent almost entirely upon foreign countries for its supply of beet seed. Most of it came from Germany. The disturbed agricultural and trade conditions from August 1914 to the close of the World War reduced the quantity of available European seed. In 1915 our Federal Government cooperated with the beet sugar companies in securing sufficient seed for planting requirements, but these agencies failed to obtain sufficient seed for 1916, and many farmers were unable to plant as large acreages as they had planned.

During 1914, 1915, and 1916 the World War reduced the available seed supply in Germany to such proportions that it became necessary for the beet growers in America to look to other European countries for seed. From 1916 to 1918 an average annual supply of 9,759,000 pounds of seed was imported from Russia. The heaviest importation of seed from Russia was 14,381,000 pounds in 1917. During the period 1916 to 1929 the four principal countries supplying most seed for the United States were Germany 2,000,000 to 12,000,000 pounds, annual average 7,825,000; Russia 39,000 to 14,381,000 pounds, average 3,687,000; Netherlands 75,000 to 8,821,000 pounds, average 2,106,000; and Denmark 300,000 to 4,588,000 pounds, average 1,001,000.[47] The largest amount of sugar beet seed imported during any year was 23,446,000 pounds in 1920. Since the World War the United States is again obtaining its seed from Russia and other European countries.

Domestic Seed. The United States produced very little sugar beet seed during the pre-war period, when it was generally considered that seed produced in America was inferior to that of Europe. The American sugar beet industry expanded rapidly during the war, because seed was no longer available from Europe. The American beet growers were thus forced to produce it on a commercial scale. A three-fold purpose prompted the undertaking of raising sugar beet seed in America. These were (1) to produce a quantity of sugar beet seed immediately; (2) to develop a permanent beet seed industry; and (3) to improve strains of American

[47] *Foreign Commerce and Navigation of the United States*, Department of Commerce, Washington, D. C.

grown beets. The most important sugar beet seed producing districts in the United States were in Utah, Idaho, Montana, Colorado, and western Nebraska. Although the quality of beets grown from the domestic seed was generally superior to that of beets grown from foreign seed, the high cost of production did not warrant the continuance of the local beet seed industry after the war.

The United States Beet Seed Company was incorporated at Salt Lake City, Utah, October 7, 1915.[48] This company and several others produced much seed during the war period. Now the Great Western Sugar Company and others are trying to develop a beet resistant to curly-top.

RELATION OF PHYSICAL ENVIRONMENT TO THE GROWTH OF SUGAR BEETS

TOPOGRAPHY AND SOILS

Sugar beet production requires relatively level to gently rolling land with deep, fertile soil. The beet roots penetrate deeply and require a fairly porous soil. As moisture is a major controlling factor in raising beets, the soil must be able to absorb water, to hold it, and to release it to the crop.

The well-drained bottomlands and terraces of the major river valleys in central and western Nebraska are admirably suited to sugar beet production. The soils contain sufficient lime, potash, and usually enough of other mineral nutrients for the successful growth of the crop. However, some of the soils in the beet regions are becoming depleted in phosphates.

The sugar beets in Nebraska and adjacent states are grown largely under irrigation, which supplements the rainfall. Unfortunately the excessive use of irrigation in some places has developed "alkali" in the soils to the extent that it has become a problem in the growth of beets. The term "alkali" as used in this connection refers to the accumulation of sodium chloride, sodium sulphate, sodium carbonate, and magnesium sulphate in the soil to the extent that they are toxic to the growth of crops.

Sugar beets are more tolerant of alkali than most crops and produce good yields on moderately alkaline soils. Since the root system develops rapidly, and much of its absorption of moisture takes place in the deeper soils, beets thrive even though the alkali content in the surface soil is moderately high. One of the most serious environmental problems, which has arisen in the irrigated areas, is that of seepage water from the irrigation canals and ditches lying at higher levels than some of the beet fields.

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48 "Raising Sugar Beet Seed in Idaho," *Sugar*, October 1916, pp. 512-515.

The average yield of beets per acre varies somewhat with the kinds of soil (Figure 7). For example, the production of beets per acre on soils in the North Platte Valley is about as follows: Tripp fine sandy loam and the Tripp very fine sandy loam, 16 to 20 tons; Mitchell silt loam and the Mitchell very fine sandy loam, 12 to 13 tons; Epping silt loam, 10 to 16 tons; Tripp loamy fine sand and Tripp loam 10 to 12 tons.* The Minatare silt loam was formerly a leading beet producing soil, but it is now quite alkaline because of poor drainage. The water from the High Line Irrigation Canal has produced a high water table near the river which has caused extensive seepage and the withdrawal of many acres of this soil from cultivation. However, in areas where drainage is adequate, good crops are produced on the low-lying soils.

Relation of Roots to Soil. Even though the taproot of the beet is the storage house for sugar, many feet of smaller roots and rootlets are included in the root system (Figure 6). The ordinary observer does not realize the extent of the sugar beet root system. The fibrous roots contained in an acre of beets when decayed, are said to add about one ton of organic matter to the soil. In addition, they leave minute channels in the soil that become filled with moisture, or they make small passageways that become filled with air and thus provide aeration in the soil.

The root system responds readily to environment, especially to differences in water content, aeration, mineral content, structure, and texture of the soil. Beets grown in a medium textured, fairly porous soil underlain by a relatively loose subsoil are usually large and well shaped. If the surface soil is mellow and a compact layer of earth underlies it, the fibrous roots spread horizontally. If another zone of more porous material underlies the compact layer, the root again penetrates downward.

Most of the fine, fibrous lateral roots occur in the upper 8 to 14 inches of soil. The fibrous feeder roots originate in two spiral or straight rows on opposite sides of the fleshy beet root and radiate laterally for an average distance of two or more feet in all directions. These roots often extend beyond the adjoining beets in the same row and those in opposite rows. The extensive root system causes a large amount of root competition for moisture and nutrients.

Root Study. The relations of the root habits of Kleinwanslebener, the most widely grown beet in Colorado, to environment at various periods during growth at Greeley, Colorado, are illustrated in experiments con-

* The detailed description of the soils mentioned is found in the "Soil Survey of Scotts Bluff County, Nebraska", Field Operations of the Bureau of Soils, 1913, Washington, D. C. The soils of the beet districts of Nebraska have been surveyed and described by the State Soil Survey in cooperation with the United States Bureau of Chemistry and Soils.

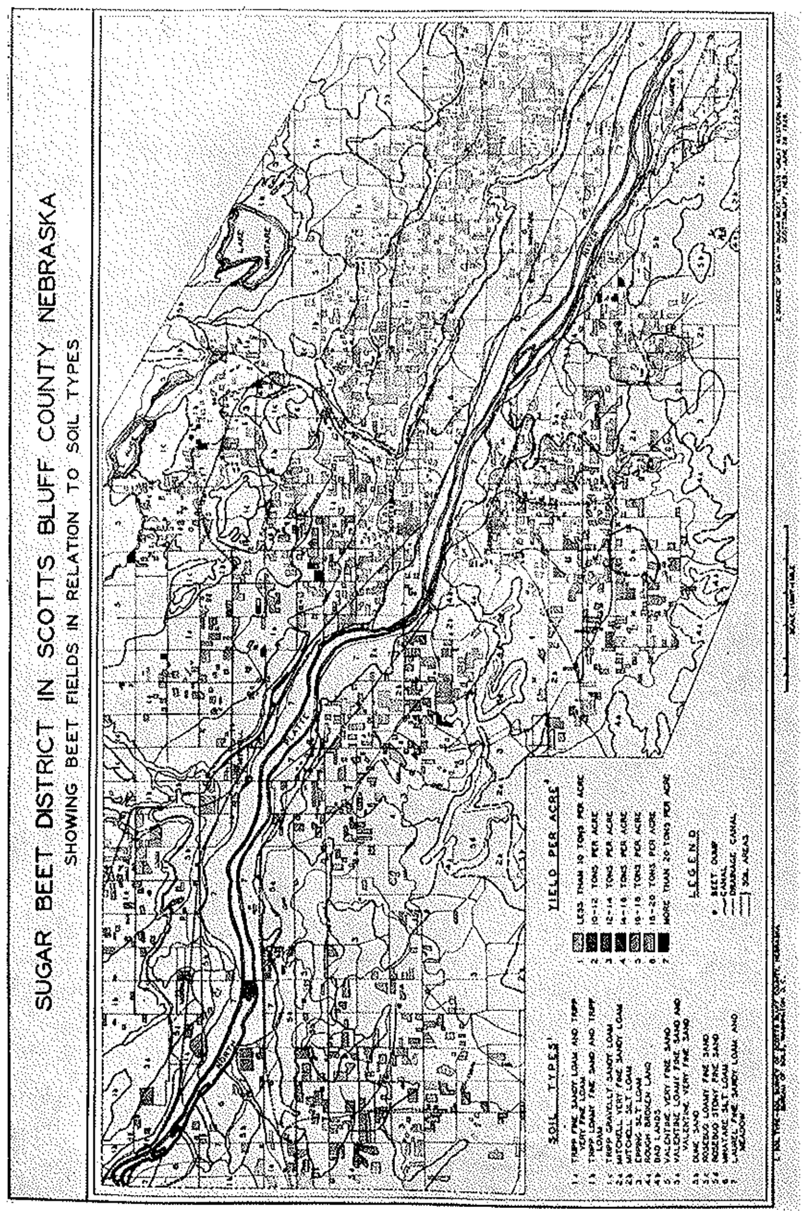

Fig. 7.—Sugar beet district in Scotts Bluff county showing beet fields in relation to soil types.

ducted by Professors John E. Weaver of the University of Nebraska and F. E. Jean of the State Teachers College at Greeley, Colorado.[1] The purpose of their experiments was to compare the effect of irrigated and dry land upon the root development of sugar beets.

Weaver and Jean selected a non-irrigated plot on a level tract of land within the western edge of Greeley and an irrigated plot, approximately a mile west of the city limits, for their experiment. The annual precipitation averages about 12.7 inches, three-fourths of which occurs during the growing season but is usually so poorly distributed that even dry farming becomes hazardous. The temperature during the growing season increases from 48° F. in April to 70° F. in August. The first of May marks the average date of the latest killing frost in spring and October first the average date of the earliest killing frost in autumn. The sky is usually clear, and the percentage of possible sunshine averages about 66 per cent from April to September. A fairly large diurnal change in temperature prevails, and a higher relative humidity usually characterizes the night.

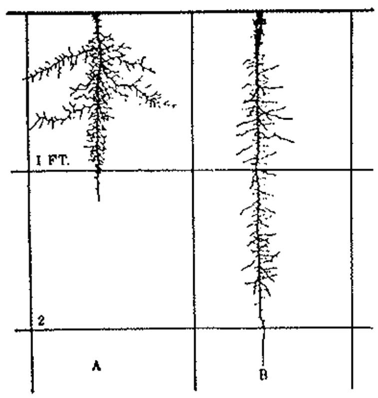

FIG. 8.—Sugar beets about two months old: A, dry land, practically no water available for plant use in the second foot; B, irrigated soil. (Weaver and Jean.)

The soil of both areas consisted of a fine sandy loam of alluvial origin. In the dry land plot the subsoil at a depth of 18 to 24 inches contained a claypan layer, usually 10 to 12 inches thick. Looser soil occurred above, and under it was a layer of intermixed gravel and sand at depths of 5 to 6 feet.

Results of the Experimental Study. The experiments show that the taproots of the irrigated beets were longer, more fully developed and larger at all periods than those of the non-irrigated beets (Figure 8). When two months old, the plants in both fields were from 4 to 5 inches in height, and each had 8 to 10 leaves. The plants had good taproots, but those of the beets grown in dry land soils, though not so long, were more branched than those grown

[1] Jean, Frank C., and Weaver, John E., *Root Behavior and Crop Yield Under Irrigation,* Carnegie Institution of Washington, September, 1924.

Weaver, John E., *Root Development of Field Crops,* McGraw-Hill Book Company, New York, 1926, pp. 85, 206-214.

Andrews, Lyman H., "The Relation of the Sugar Beet Root System to Increased Yields," *Through the Leaves,* January 1927, pp. 17-26. Photograph from Lyman Andrews, Great Western Sugar Company, Lyman, Nebraska.

under irrigation. In the moist soils the taproots averaged ¼ inch in thickness, but tapered rapidly and lost half of their width in descending 3 to 4 inches. The more profusely branched dry land taproots measured only half the length of those grown under irrigation (Figure 8).

In all of the half grown plants the number of leaves varied from 15 to 18, the leaves of those produced in the irrigated soils being much larger. A height of 14 inches and a spread of 18 inches at the top characterized the leaves of the large plants in the irrigated field, while the leaves of the beets raised on dry land measured only 5 inches in height and had a spread of 11 inches at the top.

The roots of all plants extended into the third to fifth foot of soil and were profusely branched. The outstanding features of the root systems in the irrigated plot were the marked growth of the shallow system of roots and the development of long, deeply penetrating branches in the subsoil. The dry land plants had developed a large number of horizontally spreading major lateral roots, 12 to 18 inches long, near the surface where the moisture had been more abundant. The taproots in the irrigated plot measured about 2.5 inches in diameter as compared with slightly less than 2 inches of the dry land plants.

The taproots tapered so rapidly that even the larger ones were hardly more than an inch in diameter at a distance of 6 inches below the surface. They zigzagged downward to depths of 30 to 46 inches in the hard soil of the dry land, but they had a more vertical course reaching a depth of 50 to 54 inches in the irrigated soil.

In the surface soil, the beets in the dry land showed a limited number of branches consisting of tiny rootlets less than an inch in length with no root hairs. In contrast, the irrigated beets had developed 60 to 75 roots per linear inch in zones 4 to 5 inches on two sides of the taproot. They spread horizontally for distances of 3 to 5 inches with secondary laterals at the rate of 8 to 12 per inch. The smaller dry land plants contained many strong laterals in the surface foot of soil, which grew shorter downward, and they usually averaged from 4 to 7 per inch.

In September each plant possessed from 20 to 30 leaves; those in the irrigated areas were about 18 inches long, or twice the length of the leaves of non-irrigated beets. The larger beets of the irrigated plot had a photosynthetic area about 3 or 4 times that of the non-irrigated plants. Root development was similar in extent to that of the tops. In the irrigated soils, the taproots ranged from 3 to 6 inches in diameter in contrast to approximately 2.7 inches in the dry land soil. The roots in the dry land extended to depths of 3.5 feet (maximum 4.5 feet), and the roots in the irrigated soils reached depths of 5 or 6 feet (Figure 9). The roots grown

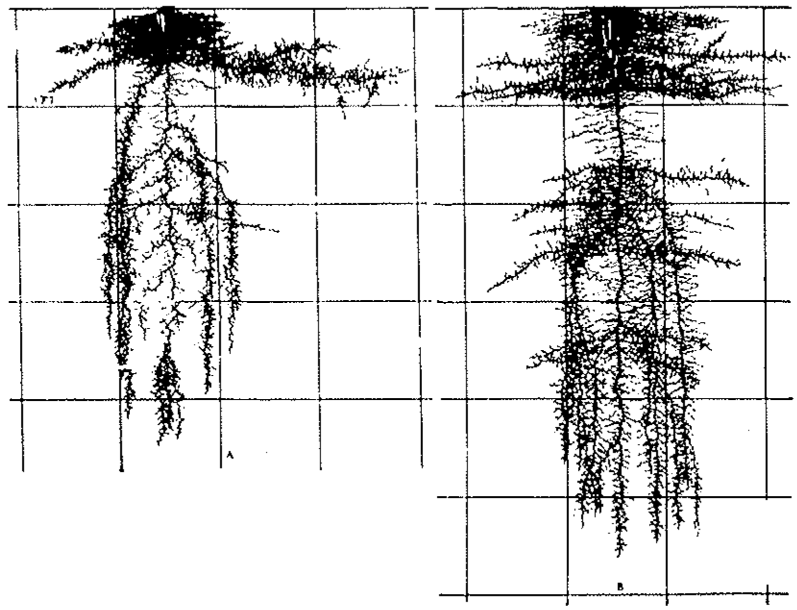

FIG. 9.—Sugar beets on September 12: A, dry land; B, fully irrigated soil. Note difference in size of taproots and the more extensive root system in the irrigated soil. The place where fibrous roots are smaller was due to a hard layer of soil. (Diagram J. E. Weaver.)

on dry land were profusely branched in the upper surface and quite generally branched at depths of 1.5 to 3 feet. The final root systems of the beets in the irrigated area had widely spreading horizontal roots and somewhat vertically descending and deeply penetrating major branches which contained many rootlets (Figure 9).

Another response to the growth of beet roots to environment shown in the experiments of Weaver and Jean was the lack of branching in the roots when they penetrated a harder stratum of soil. After they reached the looser soils, they again branched more profusely in both the dry and moist areas (Figure 9).

Each beet root sends laterals into the soil occupied by the roots of other plants, consequently there is much competition for moisture and mineral foods. Ordinarily each beet actually has at least 10 times the number of roots indicated in Figure 6 because the roots in only one plane are shown. The branching of the roots is well represented. The main root of one of these plants descended to a depth of 7 feet 3 inches until it encountered water-bearing gravel. The root system was so extensive that it filled a column of soil more than 6 feet in diameter and 7 feet deep.

CLIMATIC FACTORS

Temperature, precipitation, sunshine, and wind are climatic factors that influence the growth of sugar beets. All of these, with the exception of precipitation, are almost ideal for beet growth in western Nebraska and in eastern Colorado and Wyoming.

Temperature. Experiments in European countries and in the United States indicate that sugar beets attain their greatest perfection in a zone where the summer temperature averages about 70° F., where day temperatures rarely exceed 95° F., and where the nights are cool. Sugar beets require a long day with abundant sunshine during the period of growth, which should total more than 130 days. To insure roots of desired size and form, adequate rainfall is needed in the early growth of the plant, to be followed by a period of less rainfall, more sunshine, and cool nights for the manufacture of sugar in the leaves and the storage of it in the root.

The principal beet growing region of the Great Plains has a mean daily temperature of over 45° F. from April 1 to May 1, which affords a relatively early planting season, especially in the southern part of the district. The mean daily temperature does not fall below 45° F. until October 16 in the northern part of the area and not until November 16 in the southern part. The harvesting season, therefore, can extend fairly late into autumn.

In the United States most of the sugar beets are produced in areas where the mean daily temperature rises above 35° F. between February 16 and April 1, and where it rises above 45° F. from March 16 to May 1. The mean daily temperature falls below 45° F. between October 16 and November 16, and it falls below 35° F. from November 16 to December 1.[2]

High and low temperatures both affect the growth of sugar beets. Low temperatures are most injurious when the plants are just coming through the ground, as they are then very tender and susceptible to injury by frosts. After the roots are established, the beet plants become hardy and more resistant to frost.

A killing frost coming when the plants are in early growth often necessitates the expense and labor of replanting, therefore, planting is usually delayed until there is no danger from frost. After maturity low temperatures will not harm beets because they can stand freezing without materially reducing the sugar content. The great danger from cold temperatures at the end of the growing season is that the beets may be frozen in the ground so tightly that they are difficult to harvest. After harvesting

[2] *Atlas of American Agriculture, Part III, Climate, Section I, Frost and Growing Season,* United States Department of Agriculture, Washington, D. C.

freezing does not cause any considerable loss in sugar content providing the beets remain frozen until they are put through the mill, but alternate freezing and thawing causes discoloration, decay, and fermentation, thus reducing the sugar content. In order to avoid this danger, piles of beets are covered with leaves, straw, or dirt.

Length of Growing Season. Sugar beets require a growing season with an average of 130 or more days, a condition that prevails in the North Platte Valley of Nebraska. In the sugar beet regions of the Great Plains, the growing season varies from about 120 days in the northern to 150 days in the southern part. In the higher latitudes the smaller number of days is compensated by more hours of daylight during the summer.

Moisture. As previously stated, abundant moisture is needed during the early growth of the plants in order to insure good sized roots. Too much moisture during the ripening period causes a dilution of the beet sap, resulting in a lower per cent of sugar.

The mean annual precipitation in the beet region of western Nebraska varies from 16 to 20 inches, of which 40 to more than 80 per cent occurs during the growing period from April to September. Rainfall is an asset in irrigated regions because it decreases the need and cost of irrigation. In addition, the winter rains and snows help to condition the soil. In many parts of the sugar beet areas the moisture received from rainfall is enough to assure germination and early plant growth.

In regions with limited rainfall, as in western Nebraska, it is essential that the soil be kept in the best possible condition in order to receive and retain moisture, as this is one of the factors which enables soil organisms to make plant food available.

Dashing rains cause much run-off; they pack the soil; they sometimes wash out the young plants or cover them with soil; or they wash the soil from the roots and cause them to dry.

The rainfall in western Nebraska is not sufficient to produce good sugar beets, hence irrigation is necessary. The dry autumns aid in harvesting the beets. They are also conducive to the production of beets with a high sugar content. Furthermore, losses from plant diseases and animal pests are not so great in dry climates as they are in some of the more humid and warmer sugar beet regions.

Hail. This sometimes damages the sugar beet crop, but losses from this source are small. Even though the leaves may be partially or almost completely destroyed by hail in July and August, a good crop may result, because the beets send up new growths from dormant buds.

Humidity. High relative humidity, high temperature, and excessive moisture in the soil form ideal conditions for the development of root-rot and leaf-spot. Curly-top, on the other hand, develops best in regions of low relative humidity.

Sunshine. Much sunshine is required to produce sugar beets with a high sugar content. Inasmuch as the rainfall in western Nebraska is moderately low, the number of clear days is high, and sunshine conditions are excellent for beet growth. The percentage of possible sunshine ranges from 60 to 80 in summer and from 50 to 80 in autumn, thus affording abundant light which is so essential in the elaboration of sugar in the plant.

Winds. The irrigated beet districts in Nebraska lie in the westerly wind belt. The general wind direction is from the west, northwest, and north during the colder season and from the south, southeast, and southwest during most of the warmer season of the year. The wind velocity averages from 9 to 12 miles per hour but sometimes reaches 25 miles or more during a storm.

Winds influence the sugar beet crop in various ways. They may (1) blow the seed out of the ground; (2) they may cover the planted seed with soil so deeply that the young sprouts cannot reach the surface; (3) they may cover the plants with soil and smother them; (4) they may remove the soil from the roots and expose them to the sun and drouth; and (5) they may drive sand particles against the leaves and stems cutting them from the roots. The destructive effects of the wind are partly prevented by planting the seed in rows at right angles to the prevailing winds and by slightly ridging the ground between the rows. In some regions the destructive effect of the winds has been reduced by planting windbreaks.

Winds also influence the sugar beet crop indirectly through their effect upon the soil moisture Where hot, dry winds prevail, there is more evaporation from the soil than in localities with no such winds, and thus at times it becomes necessary to irrigate "up" the beets. Transpiration is more effective during winds than during calms, other conditions being equal. This deprives the soil of moisture, and it becomes necessary to prevent this loss by proper cultivation or to counteract it by irrigation.

Relation of Temperature and Rainfall to Sugar Content. The climatic conditions in western Nebraska, except the rainfall, are near the optima for growing sugar beets. These are (1) an average temperature of 65° to 70° F. (65° to 68° F. best) during the growing season; (2) relatively few days with temperatures above 95° F.; (3) a growing season of 120 to 160 days; (4) fairly wide daily temperature range and cool nights which are favorable to the development of sugar and its storage in the plant; (5) adequate moisture, in part supplied by irrigation, during the early period of growth, followed by scant precipitation during the harvest season, especially during October and November; and (6) abundant but not too intense sunshine.[3]

Studies made by the investigator show that the sugar content in beets grown in semiarid regions generally varies inversely with the average temperature of the growing season and inversely with the total autumn rainfall, especially that in October and November. A closer relationship between these factors was noted at individual stations, but since the beet sugar companies and the Bureau of Agricultural Economics, Washington, D. C., gave the data only for confidential use, averages had to be made in order not to reveal the identity or source of the figures.

Inasmuch as the soil and topographic conditions in the North Platte Valley of Nebraska are similar to those of the South Platte Valley of Colorado, and because more data relative to the sugar content in beets were available, the South Platte Valley of Colorado was used as a type region for a study to show the relationship between the climate and sugar content in the beets grown in the Great Plains Region.

The sugar content of the beets in the South Platte Valley of Colorado ranged from 14 to 17 per cent during the period from 1915 to 1930. In 1915, 1917, 1918, 1920, 1924, and 1928, the percentage of sugar was high or more than 16 per cent each year. During these years the optima average daily summer temperature of 65° to 68° F. prevailed through June, July, and August. The average total rainfall for September, October, and November ranged from 1.33 inches to 4.4 inches, the major number of the years mentioned showing less than 3.00 inches (Figure 10). Although the total rainfall during the harvest season in 1915, the year in which the per cent of sugar was highest, was 4.37 inches, most of it came in September and early October.

Sugar contents of approximately 14 per cent were recorded in 1919, 1922, 1925, and 1929. In these years the growing season temperatures averaged 68.9° F., and the average total rainfall, during September, October, and November was 3.51 inches. In 1919 the average sugar content was 13.9 per cent. This year had the highest growing season temperature, 69.7° F., and the second highest autumn rainfall, 4.16 inches, during the period from 1915 to 1930 (Figure 10). The July temperature averaged 75° F. which is too high for best beet growth.

A more detailed study of the responses of the sugar content to climatic influences shows that the highest sugar content was 16.9 per cent in 1915 when the temperature averaged 67.7° F. during the growing season, and

[3] Data obtained from *Climatological Data for the United States by Sections* (U. S. Weather Bureau, Washington, D. C.) and from confidential reports of beet sugar manufacturing companies at various points in western Nebraska, in Colorado, and in Wyoming are used in this bulletin.

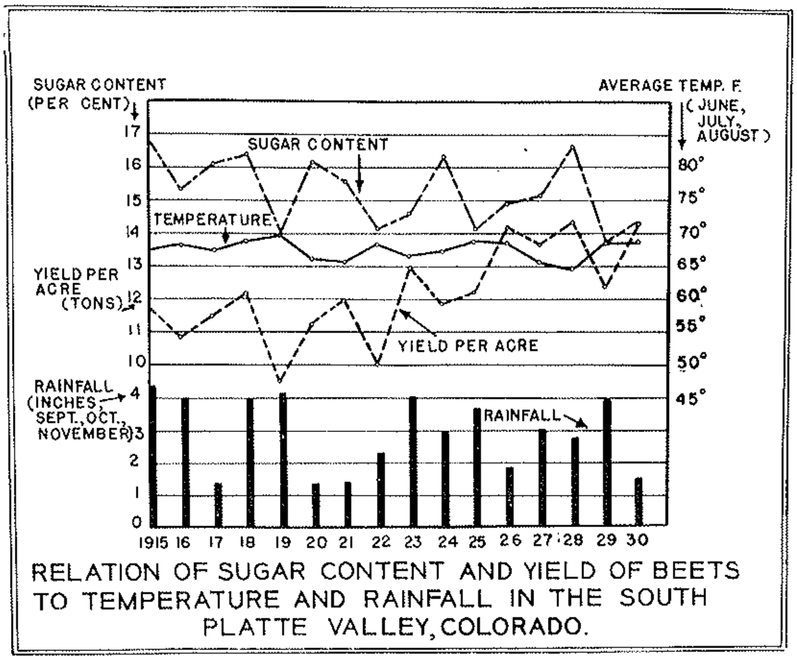

Fig. 10.—Relation of sugar content and yield of beets to temperature and rainfall in the South Platte Valley, Colorado.

although the rainfall in September, October, and November was 4.37 inches, little of it fell in November. In 1916 the sugar content was lower, the temperature higher, and the total rainfall less than in 1915, though more of it fell in November. In 1917 the temperature and rainfall were lower than in 1916, and the sugar content was higher. The sugar content of beets in 1918 was slightly higher than in 1917, a cool temperature prevailed during the growing season, and the rainfall was moderate during the harvest, especially in October and November. The sugar content dropped to 13.9 per cent in 1919. The summer temperature averaged 70° F. and the autumn rainfall was relatively high. The temperature in July averaged about 75° F. at some of the stations, too high for the best growth of beets. In contrast, the sugar content in 1920 was more than 16 per cent. The average growing season temperature then was 66° F. and uniformly distributed, and the rainfall during the harvest months was low. In 1921 the sugar content was slightly lower than in 1920, the temperature higher, especially in August, and the rainfall was low during the harvest months.

Although the temperature was lower in 1922 than in 1921, and the autumn rainfall was moderate, the sugar content decreased, probably due to a high average August temperature of 71° F. Some of the maximum temperatures in July were near 98° F. In 1923 the sugar content was higher, the temperature lower than in 1922, and the precipitation was heavier but most of it occurred in September. The temperature in 1924 was slightly higher but uniformly distributed during the three months, July, August, and September, but the rainfall was less than in 1923, and the per cent of sugar was higher. Much rainfall in October and a higher summer temperature resulted in a lower sugar content in 1925. This was followed by a lower temperature, less rainfall, and more sugar in 1926. In 1927 the temperature averaged 65.7° F., rainfall was moderate, and most of it fell in September, and the sugar content was 15.19 per cent. During the interval 1915-1929 the lowest average seasonal temperature, 64.9° F., occurred in 1928, which together with a moderate rainfall, mostly in September and October, resulted in a high sugar content of 16.66 per cent. In contrast, the highest average seasonal temperature, a high harvest season rainfall, and the lowest sugar content occurred in 1929. In 1930 the sucrose content was higher, and the autumn rainfall was less.

The relationships between the sugar content and climatic conditions may also be shown by comparing groups of years arranged according to the percentages of sucrose in the beets (Figure 11). A classification prepared on this basis shows (1) that the years in which the sugar content

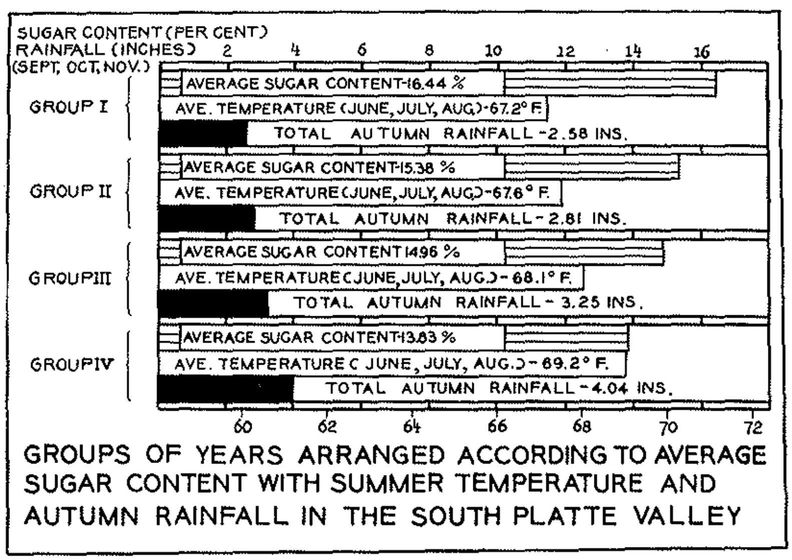

FIG. 11.—Groups of years arranged according to average sugar content with summer temperatures and autumn rainfall in the South Platte Valley, Colorado.

of the beet averaged more than 16 per cent had an average growing season temperature of 67.2° F. and a total rainfall of 2.58 inches during September, October, and November; (2) that the years showing an average of 15 to 16 per cent sugar content had a temperature average of 67.6° F. and a total autumn rainfall of 2.81 inches; (3) that the years when the sugar content was below 15 per cent showed a summer average temperature of 68.1° F. and an average autumn rainfall of 3.25 inches; and (4) that the years when the sugar content was below 14 per cent showed a summer average temperature of 69.2° F. and an average autumn precipitation of 4.04 inches.

Briefly stated the highest percentage of sucrose in beets occurred in the years which had the lowest summer temperature and the lowest total autumn rainfall, while the beets which were raised in the years having the warmest growing season and the highest total autumn rainfall had the lowest sugar content. From these conclusions, therefore, a general principle may be formulated that the sugar content in beets grown in the semiarid Great Plains usually varies inversely with the summer temperature and the total rainfall in autumn, especially in October and November.

Length of Day and Sugar Content. Experiments made in Europe seem to prove that a cool climate with long summer days is a more important factor in beet growth than is the soil. Recently Ing. J. Urban, Research Manager of the J. Zapotil Breeding Station, and Mr. J. Zapotil, the well known breeder of sugar beet seed, of Vetrusice, near Prague, conducted investigations to compare the qualities of beets produced in Italian and in Czechoslovakian soils. Experiments were made at Vetrusice and at Rigo in the Po Valley of Italy.[3] Czechoslovakian and Italian seeds were planted at each place during the same year. The results were as follows:

Seed	In Italy		In Czechoslovakia		Difference in Sugar Content of Same Variety in the Two Countries Per cent
	Sugar Content Per cent	Yield of Sugar, lbs. Per Acre	Sugar Content Per cent	Yield of Sugar, lbs. Per Acre	
Czechoslovakian	15.69	5896	19.09	5535	3.40
Italian	15.18	5553	18.59	5368	3.41
	0.51		0.50		

The sugar content of either variety was 3.4 per cent greater in Czechoslovakia than in Italy. The difference in sugar content between the two varieties in the same country was only .5 per cent. The experiment

[3] Urban, Ing. J., Research Manager of J. Zapotil Breeding Station, Prague, Czechoslovakia, Correspondence, March 28, 1931.

shows that climate exerts greater influence upon the sugar content and the quality of the beet than does the variety, as is indicated by the differerence in sugar content between beets grown in the warmer and those grown in the cooler climates. The yield of sugar per acre was higher in Italy than in Czechoslovakia because the tonnage of beets was larger.

Not being satisfied with the results of the experiment described, Mr. Urban undertook to obtain additional proof that the temperature and the length of day are important in beet growth. In 1922 he shipped a carload of Czechoslovakian soil to Italy and a carload of Italian soil to Vetrusice, near Prague, Czechoslovakia. Mr. Urban planted the same kind of seed and gave the crops identical care in each locality. The results showed a sugar content of 19.9 per cent in the beets grown in the Italian soils, and 19.1 per cent in those produced in the Czechoslovakian soil at Vetrusice, Czechoslovakia. He did not give the results of the beets produced in Italy. The sucrose content was a little higher in Italian than in Czechloslovakian soils, showing that under favorable climatic conditions, the Italian soils had no difficulty in producing excellent beets. Mr. Urban says:

> "We can make a conclusion that the low sugar content of beets in Italy is caused by the climate favoring a very quick vegetation."[4]

It appears that the length of daylight (photoperiodism) influences the growth of plants more than is generally realized. Although considerable experimental research has been done to determine the effect of the length of daylight upon plant growth, data showing the effect upon sugar beet culture are meager. Sugar beets grown in the higher middle latitudes in northern United States, southern Canada, and northern Europe where the summer days provide many hours of daylight have a higher sugar content than those produced farther south.

In general, sugar beets thrive best as far north as climate will permit the growth and harvest of the crop before freezes occur. The mild climate and long summer days in northern Europe are excellent for the growth of beets high in sugar content. The European crop is grown almost entirely north of 48° North Latitude. In contrast, the climate in the higher latitudes of North America is more severe and less favorable for beets than in Europe, therefore, most of the crop is raised in areas south of 45° North latitude.

The following discussion on photoperiodism is presented because an interesting correlation between the length of day and the sugar content of beets is apparent when comparisons made in various latitudes are considered.

[4] *Idem.*

In the United States during the period from 1915 to 1930 the average sugar content was 14.5 per cent in the Arkansas Valley (about 38° N.). It was 15.4 per cent in the North and South Platte valleys (about 42° N.), 16.5 per cent [5] (Table 5) in Montana and Wyoming (about 44° N.), and about 17.5 per cent at Raymond, Canada (about 50° N.). In Europe the leading sugar beet districts lie in latitudes from 48° to 55° N. and the sugar content usually ranges from 17 to 18 per cent. Beets containing highest sucrose content, 18-21 per cent and 90 purity, are grown in Sweden (55° to 60° N.), about the same latitude as Hudson Bay (Table 5).

TABLE 5.—*Average Sugar Content at Various Latitudes*

Latitude	Place	Sugar Content (Per cent)
30° N.	Arkansas valley	14.55
42° N.	North and South Platte valleys	15.47
44° N.	Montana and Wyoming	16.51
48° to 55° N.	Czechoslovakia; Germany; England; Raymond, Canada	17-18
55° to 60° N.	Sweden	17-21

Mr. Dahlberg, Research Manager, Great Western Sugar Company, says:

> "The real answer to this question of northern latitudes is the fact that while the growing season is shorter in number of days, the number of working hours per day is greater—By this I don't mean that they have that much more sunshine, but it is becoming more and more evident that diffused light such as we have before sunrise and after sunset is a very desirable form of light for developing sugar content.
>
> "The fact of having more working hours of daylight points to another thing; under these conditions the beet has time to really ripen by using up the available nitrogen, and this time is characterized by the yellowing of the leaves. As a general rule, the leaves of the beets turn yellow earlier in Lovell and Billings than they do in other territories, and this is confirmed by the higher purities we have there." [6]

Evidence from reports of experiments carried out at two Russian experiment stations, situated respectively on the parallels 59° 44′ and 67° 44′ North Latitude, indicate that beets grown in high latitudes may produce

[5] Sugar content based on average for 15 years where factories have operated that long. Data obtained from various beet sugar companies.

[6] Dahlberg, Henry W., "Soil Composition as Related to the Composition of Sugar Beets", *Through the Leaves*, Vol. 18, No. 4, April, 1930, p. 174.

seed during the first year. Sugar beets which were left exposed to the sun during the long summer days in the high latitudes produced seed during the first year, the roots being small. When beets in the same field were artificially shaded so that they received direct sunlight only 12 hours daily, they produced larger roots but did not form seed the first year.[7]

Finally it may be said that even though temperature, moisture, soils, topography, and methods of cultivation are the most important influences in the growth of sugar beets, photoperiodism plays a noticeable part in affecting the sugar content. The percentage of sugar in beets apparently increases with the number of hours of daylight during summer. The yield of beets is generally lower in the areas of many hours of daylight but this is offset by a higher sucrose content.

ADJUSTMENTS WHICH INCREASE THE EFFECTIVENESS OF THE BEET GROWING SEASON IN SEMIARID REGIONS OF THE UNITED STATES

Even though the growing season in some of the sugar beet districts of the semiarid regions is relatively short, its effectiveness may be increased by earlier planting and by delaying harvest.

In 1923 reports from farmers in the entire northeastern beet district of Colorado showed an average difference of nearly 3½ tons per acre in favor of the beets planted before April 15 as compared with those planted after May 15. Beets planted after May 15 yielded about 24 per cent less tonnage than those planted by April 15, while those planted from April 30 to May 15 showed a decrease of 1½ to almost 2 tons per acre or 10.5 to 13.5 per cent from those planted by April 15 (Table 6).[8]

TABLE 6.—*Average Yield of Beets per Acre and Dates of Planting in Colorado in 1923*

Date of Planting	Tons Per Acre	Tons Decrease	Per cent Decrease
April 15	14.32	...	....
April 30	12.82	1.50	10.54
May 15	12.39	1.93	13.48
After May 15	10.86	3.46	24.16

Irrigating "up" beets is a method the farmer can use to help the plant emerge from the soil. The seeds sprout rapidly when plenty of water is available in the soil, and thus the young plants are soon through the ground and ready to manufacture food for their growth.

[7] Saillard, E., in Supp. Circ. Hebd. No. 2091, April 21, 1929, *Facts about Sugar*, Vol. XXIV, No. 21, May 25, 1929.

[8] Ward, E. Jr., "Early Planted Beets Generally Produce the Highest Yields", *Through the Leaves*, April, 1926, p. 157.

A reasonable delay in the date of harvest usually increases the sugar content and the yield of beets per acre in Colorado and Nebraska, especially (1) where beets follow alfalfa or sweet clover, (2) where beet land has been manured, and (3) where the first irrigation was not applied sufficiently early to produce a good growth of the plants during the early part of the growing season. Delayed harvest thus gives them a longer time to develop sugar after the beets are grown than they would have if the beets are harvested earlier. An increased average yield of more than a ton of beets per acre, a two per cent increase in sugar content, and 1,155 additional pounds of sugar per acre resulted from beets that were 175 days old as compared with those 140 days old at harvest during the period 1923-1927 (Table 7).[9]

TABLE 7.—*Effect of Delayed Harvest on Tonnage, Sugar Content, and Sugar per Acre in Colorado, 1923-1927*

Age at Harvest, Days	Tons Per Acre	Per cent Sugar	Pounds Sugar Per Acre
175	22.59	16.22	7,346
140	21.55	14.22	6,191
	1.04	2.00	1,155

Ordinarily, lengthening the growing period by early planting increases the yield of beets per acre proportionately more than the sugar content, whereas maximum yield and an increased per cent of sugar result from reasonably early planting and reasonably delayed harvest.

Effect of Early Thinning and Spacing. Data taken from fieldmen's records in the Colorado district served by the Great Western Sugar Company from 1923 to 1926 and covering thousands of acres of sugar beets show that the best yields result where the thinning has been completed before June 15. The yields of beets from 1923 to 1926 varied from 2 to almost 9 tons more per acre in the fields which were thinned from May 15 to June 1 than those which were thinned after July 1 (Table 8).[10]

Effect of Spacing upon Yield. Correct spacing of the plants is one of the most important adjustments to increase the production of beets. The yield is determined by the number of uniform, medium-sized beets grown per acre. The quantity of beets that land can support depends upon the soil volume in which the plants absorb water and plant nutrients. However, no definite rule can be made as to the number of beets which

[9] Maxson, Asa, Personal Notes, Research Agriculturalist, Great Western Experiment Farm, Longmont, Colorado, 1928.

[10] *Through the Leaves*, June 1928, p. 244.

TABLE 8.—*Relation of Dates of Thinning to Yields of Beets in Tons Per Acre in Colorado, 1923-1926*

Tons per Acre

Thinning Completed	1923	1924	1925	1926
May 15	15.05	12.90	14.81	19.25
June 1	13.05	13.26	15.45	17.35
June 15	13.37	13.31	14.32	15.52
July 1	12.48	12.38	13.38	13.15
After July 1	10.94	10.41	11.88	10.45

should be grown per acre. Experience and experimentation indicate that on an average on most soils 216 square inches to each beet gives maximum yields, an equivalent of a 12-inch spacing in rows 18 inches apart, or 10.8-inch spacing in rows 20 inches apart.

In Nebraska most of the beets are planted in rows from 18 to 22 inches apart, with spacing from 8 to 12 inches in the row. From observations made in many fields and experiments in Nebraska and Colorado, it is evident that high yields are determined by many moderate sized beets rather than by fewer large ones or by many small beets per acre (Table 9).[11]

TABLE 9.—*Effect of Spacing on Yield, Nebraska, 1925*

Average Spacing in Inches in Row	Weight of Beets in Ounces	Tons of Beets Per Acre	Number of Contracts
51.5	35.2	6.70	16
33.9	34.7	10.05	47
26.5	34.9	12.95	194
21.7	33.9	15.35	511
18.7	32.9	17.28	569
16.3	31.0	18.60	212
14.6	29.1	19.58	29
11.5	23.4	19.96	9
Average 20.0	33.7	16.47	...

Experiments conducted in Nebraska in 1928 show that a rate of spacing 10 to 13 inches between beets in rows 18 inches apart produces highest yields. When the rows are 20 to 22 inches apart, the beets may be closer, because the roots have more available soil space between the rows.

In fields with poor stands, special care in thinning should be exercised. A careful beet thinner is the grower's best servant. No matter how carefully the seed bed may be prepared or how favorable the germination con-

[11] Robbins, W. W., *Principles of Plant Growth*, p. 177.

ditions are, unfavorable conditions such as hail, wind, drouth, cutworms, or perhaps poor seed may produce a poor stand of unthinned beets. It is in such fields that the workman must try to obtain best results by selective thinning.

YIELD OF BEETS PER ACRE IN THE CENTRAL GREAT PLAINS

The average annual yield of beets per acre in the Great Plains of western Nebraska and northeastern Colorado ranged from 9.5 to 14.5 tons from 1915 to 1930. Even if favorable physical environment promotes rapid growth of high quality beets, superior agricultural practices, both hand and machine, and careful seed selection are almost as essential for large yields. A study of the yields per acre in the South Platte Valley shows that methods of cultivation definitely affect the yields. Data showing the yields per acre and sugar contents indicate that the changes in the yield and sucrose content of the beets from year to year were somewhat similar (Figure 10). The production of beets per acre from 1915 to 1923 averaged 11.17 tons while that from 1923 to 1929 averaged 13.27 tons, a difference of 2.1 tons or about 20 per cent. Although the percentage of sugar in the beets fluctuated annually with variations in weather conditions, the average of the sugar contents 15.59 per cent from 1915 to 1922, remained about the same as the average from 1923 to 1930 which was 15.10 per cent. Even though the yield of beets per acre varied from year to year, a general increase especially since 1923 occurred (Figure 12).

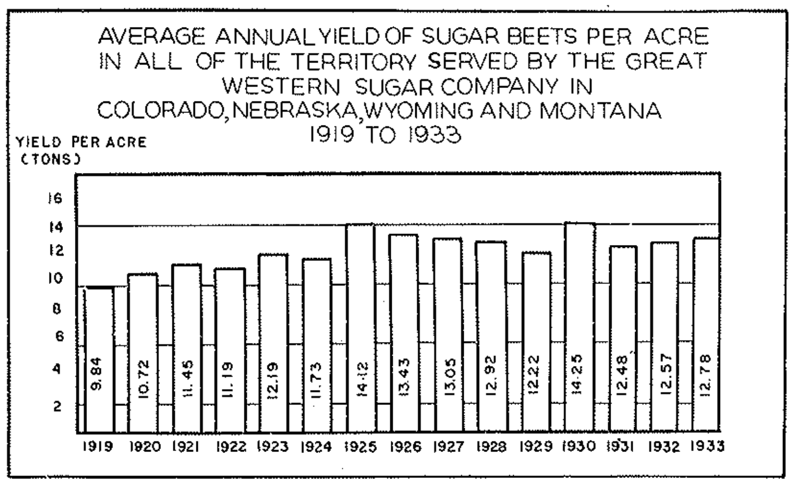

FIG. 12.—Average annual yield of sugar beets per acre in all of the territory served by the Great Western Sugar Company in Colorado, Nebraska, Wyoming, and Montana, 1919-1933.

At no time since 1925 has the average annual yield of beets per acre been so low in all of the territory served by the Great Western Sugar Company in Colorado, Nebraska, Wyoming, and Montana as it was in any year from 1919 to 1924 (Figure 12). The highest yield per acre from 1919 to 1924 was 12.19 tons and the minimum yield was 9.84 tons. In contrast, the maximum yield per acre from 1925 to 1933 was 14.12 tons, while the lowest yield was 12.22 tons, which was more than the highest yield per acre in any year from 1919 to 1924 (Figure 12). Apparently the increased yields were due largely to improved methods of cultivation, better seed selection, better management, and more adequate irrigation practices which the beet growers developed during the last fifteen years.

THE GROWTH AND CULTIVATION OF SUGAR BEETS

Sugar beets require a fine-textured, firm seed bed, the preparation of which involves a number of processes, such as plowing, disking, harrowing, and rolling.

Preparation of Seed Bed. Deep plowing, usually to a depth of 8 to 12 inches, is essential in developing a good seed bed. Where the fields contain considerable vegetal matter from preceding crops or weeds, it is necessary to remove this before plowing or the material must be deeply incorporated in the soil in order to insure a compact seed bed.

Alfalfa land that is to be planted to sugar beets requires special treatment. It is first plowed to a depth of about three inches to cut the alfalfa crowns from the taproots. This process is known as "crowning the alfalfa" or "scalping the land". After the crowns are dried, the land is plowed to a depth of six to nine inches in order to bury the crowns deeply so that they are not likely to sprout and cause difficulties in the cultivation of the beets and thus necessitate additional hand labor.

Fall-plowed land has several advantages. It catches the winter snows and rains better than land not plowed and thereby increases the moisture of the soil. Its alternate freezing and thawing improves the tilth of the soil which can be quickly prepared for planting in spring when work accumulates. On the other hand, fall-plowed land is apt to suffer more from wind erosion than the land left in stubble or with other plant cover. Then, too, fall is the time when the farmers are busy with the beet harvest and have little time to plow.

Disking may either precede or follow plowing in the preparation of the seed bed. If done before plowing, it breaks up the vegetal cover and stirs the soil to some extent. Following plowing it breaks the larger clods of soil which are further reduced by harrowing.

The fields are often rolled to crush the coarser particles and to compact the seed bed. Sometimes they are alternately rolled and harrowed.

It is essential that the seed bed be uniform in texture, compactness, and moisture content to insure uniform depth of planting and germination. After the land has been prepared as stated above, it is ready for seeding.

Planting. Drills are used in planting the seed in rows 18 or more inches apart. This spacing allows the use of horse or tractor-drawn machinery in cultivating and harvesting.

In Nebraska the seeding is done during April and early May, as soon as the soil temperature is favorable for germination. From 15 to 20 pounds of seed per acre are planted. Moderately late planting is best, as the danger from late frosts is thus decreased, and, in addition, a cold moist soil causes the seed to decay.

The depth of planting should vary with the amount of moisture in the soil. A depth of one-half to three-fourths inch is advisable, provided there is sufficient moisture to allow germination. If the soil is dry, the seed should be planted from one to one and one-half inches deep. The problem is to get the sprouting plant to the surface in a strong condition, consequently shallow planting is preferable. The press wheel on the drill compacts the soil and favors capillarity which brings moisture to the seed, thus promoting rapid germination.

Blocking and Thinning. The plants must be thinned to give the right spacing in rows (Figure 13). This is done by a combined process known as blocking and thinning, so called because (1) superfluous plants are cut

FIG. 13.—Mexicans blocking sugar beets. Note short-handled hoe which they use.

out usually with a hoe, leaving bunches or blocks of them at intervals of about 10 inches (blocking), and (2) the blocks are then thinned by hand to a single healthy plant for each block, hence thinning is also referred to as "singling". Blocking and thinning involve much hand labor. These processes take place usually between June 10th and July 4th. Much thinning is done by women and children.

It is essential that blocking and thinning be done as soon as possible after the plants are up, because there is only a limited amount of available plant food and moisture in the soil for the plants that are to make the crop.

Mechanical devices have been used to reduce the cost of blocking. The common cultivator with ordinary shovels or with special attachments is drawn across the field at right angles to the rows of sugar beets. This process, known as mechanical blocking, cuts open spaces between clusters or blocks of sugar beets in the rows, similar to that done by hand blocking. It adds an additional cultviation and it decreases the amount of hand labor necessary in blocking, thinning, and hoeing. In addition, the workers find that they can top more beets per day on the mechanically blocked fields than they can in fields blocked by hand. These fields usually produce about two tons more per acre than the others because the soil is thoroughly loosened and cultivated between the plants within the rows as well as between the rows.

Cultivation. Cultivation begins almost as soon as the beets are up. Its purpose is to aerate the soil, to destroy weeds, and to keep the soil in a condition that will conserve its moisture. The fields are cultivated from two to four times, depending upon the condition of the soil and the amount of weeds.

Specially constructed cultivators, varying from the walking cultivator to the four-row riding cultivator with foot guides, are used (Figure 14). Various attachments, such as teeth and shovels, are used, depending on the condition and size of the plants and the purpose to be served. These conditions also govern the depth of cultivation.

The cultivation with machinery does not destroy the weeds close to the rows and between the beet plants in a row, therefore, hoeing is necessary. Fields that have been blocked by the mechanical method are cross-cultivated. This reduces the amount of hoeing that is required.

IRRIGATION AND DRAINAGE

An essential factor in the growth of sugar beets is favorable soil moisture. The beet requires an intermediate amount of water, as it is neither a drouth resistant nor a water-loving plant. Since the amount of labor

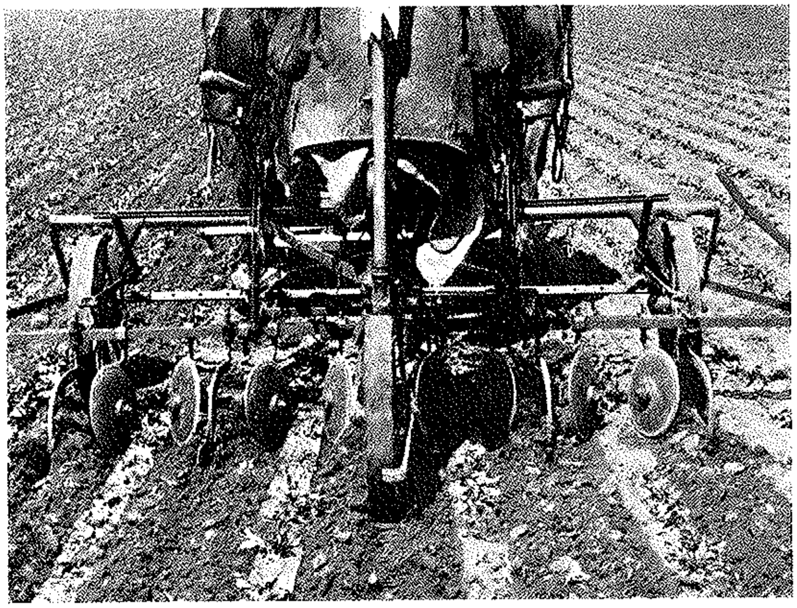

Fig. 14.—Cultivating sugar beets.

expended on a crop of sugar beets is great, every effort must be made to maintain the most favorable moisture content in the soil in order that the yield may justify the expense necessary to produce it.

The methods of making the soil moisture satisfactory are irrigation in regions where the rainfall is inadequate, and drainage where it is necessary to remove excess water.

Irrigation. Irrigation has opened much land for sugar beet production. At present between two-thirds and three-fourths of the sugar beet crop in the United States is grown under irrigation. The soils on which the irrigated beets are raised were originally rich in plant foods, because they had not been leached by heavy rains, nor had the native vegetation been sufficiently abundant to remove too much of the plant nutrients.

Prior to 1891 it was thought that irrigated beets would be low in sugar content. In that year the management of a newly erected factory in California, learning that some of its contracting farmers were irrigating beets, notified them that irrigated beets would not be received under their contracts. Nevertheless some of the growers continued to irrigate their crop, which yielded a high tonnage of beets as well as a high percentage of sugar in the beets. As a result of this discovery sugar beets became an important factor in the development of some semiarid regions where irrigation was possible.[12]

The proper use of water, that is, the time and method of application and the quantity of water used, is an important consideration in growing beets. In all the irrigated sections there is some precipitation in the form of rain or snow, although this moisture is uncertain both as to time and amount. However, it should always be conserved and utilized to full extent, and the irrigating water should be used to carry the crop through periods of insufficient rainfall.

Irrigation in the North Platte Valley of Nebraska began about 1895. At first, private corporations and individuals used the water diverted from the North Platte River. The Federal North Platte Irrigation Project, initiated in the early part of 1900, now supplies the major part of the water for irrigation in the North Platte Valley of western Nebraska and eastern Wyoming. The irrigable land lies principally in Goshen County, Wyoming, and in Scotts Bluff, Sioux, and Morrill counties, Nebraska. It covers a territory about 100 miles long and 25 miles wide at the widest part. Settlement in the valley started in the eighties and has developed rapidly since the advent of private and government irrigation enterprises. Much of the irrigation water of this district is obtained by the storage of flood water of the North Platte River in the Pathfinder and Guernsey reservoirs. The Pathfinder Reservoir has an area of 27,700 acres and a capacity of 1,070,000 acre feet at spillway level. The Pathfinder Dam rises 218 feet above its rock foundation and is one of the largest masonry dams in the world. Water is released from this reservoir as needed and flows down the North Platte River for a distance of 165 miles to the Guernsey Reservoir,[13] which has a storage capacity of 71,060 acre feet and serves for regulating purposes. The latter reservoir is located ten miles above the Whalen Dam where water is diverted into canals which carry it to the farming districts both north and south of the river. The Interstate Canal, lying north of the North Platte River, is 95 miles long and has a capacity of 2,200 second-feet (Figures 7, 15). The Fort Laramie Canal, located south of the river, is 130 miles long and has an initial capacity of 1,550 second-feet. A recent extension of this canal by tunnel through a spur of Wildcat Ridge, west of Gering, has opened many hundreds of additional acres to sugar beet production. There are 810 miles of canals and laterals on the Interstate Division and 700 on the Fort Laramie Divi-

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[12] Palmer, T. G., *Questions and Answers*, United States Sugar Manufacturers Association, Washington, D. C., 1917, p. 43.

[13] Federal Irrigation Projects. United States Bureau of Reclamation, Washington, D. C., 1930, pp. 51-54.

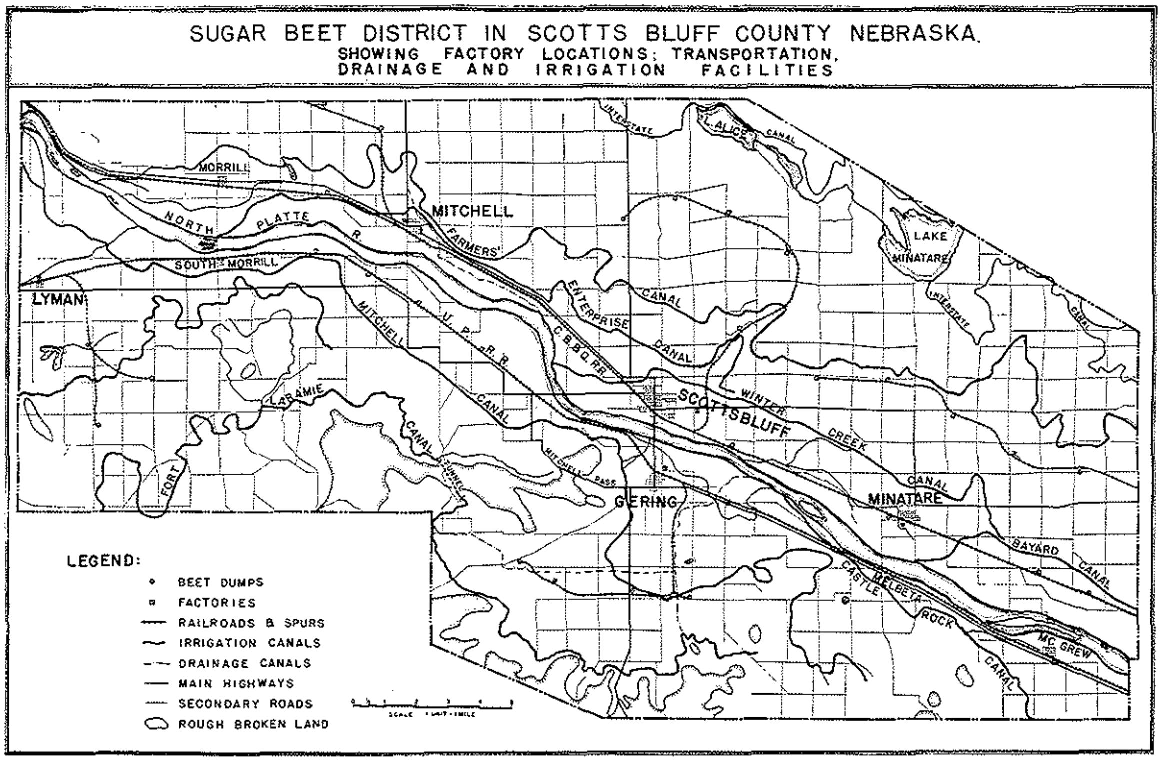


FIG. 15.—Maps showing locations of railroads, railroad spurs, beet dumps, irrigation canals, and highways.

sion. Approximately 114,000 acres of irrigable land are under the Interstate Canal and 107,000 acres under the Fort Laramie Canal. The total irrigable area on the project is 237,000 acres. Various stock company canals and those of private irrigation projects supply water for an additional 45,000 acres in this area.

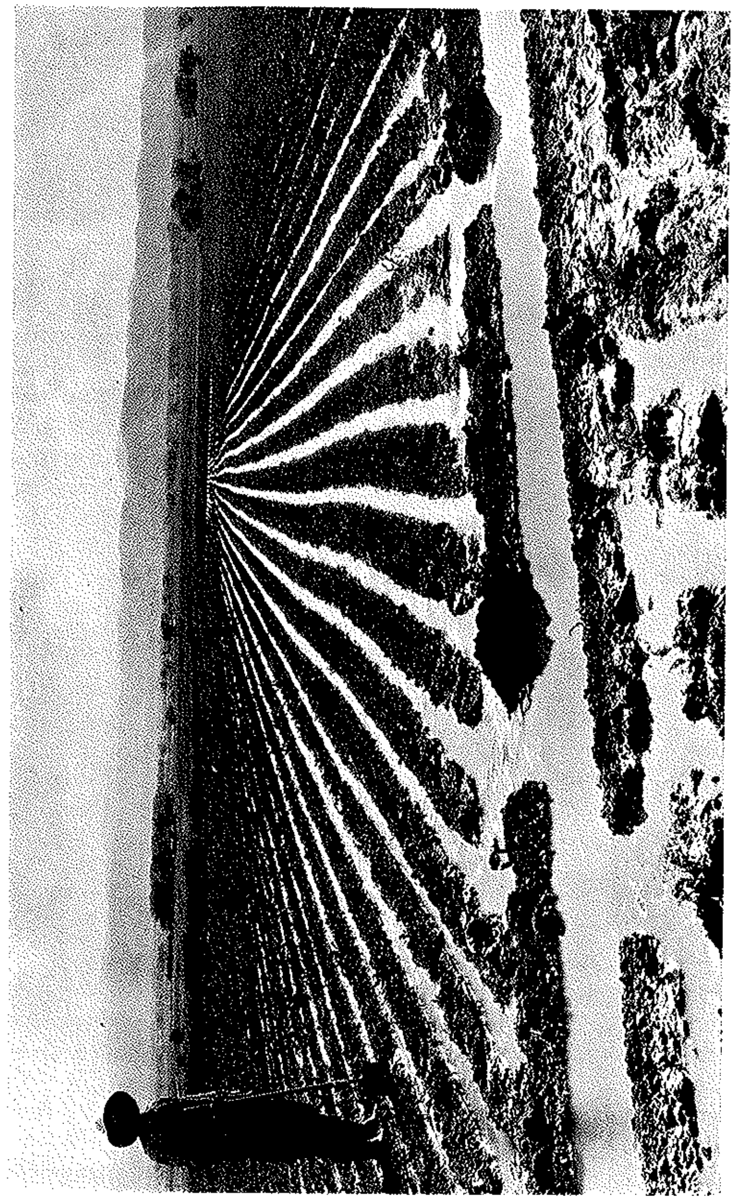
Preparation of Land for Irrigation. The yield of any crop in the irrigated areas depends largely upon proper leveling of the land to be irrigated. If the ground has not been properly leveled, the water is distributed unevenly causing drowning or scalding of the plants in the depressions. The area to be devoted to the growth of sugar beets should, therefore, have a fairly level surface and a uniform slope. A large expenditure of money is often necessary in order to make a uniform slope and to smooth a surface that is uneven. One leveling suffices for years.

In some localities where winter precipitation is light, irrigation at that season is highly beneficial and ought to be practiced whenever possible. A common practice in some areas is to irrigate "up" beets, that is, the seed is planted in dry ground, then the field is flooded in order to facilitate germination of the seed.[14] The flooding method of irrigating "up" beets should be avoided, especially in fields where the soils have a tendency to form a crust.

Where water is applied before planting, furrows, five or six inches deep and about 20 inches apart, are prepared. Water is run into these small furrows until the ground is thoroughly wet, and as soon as the surface is sufficiently dry to be worked, the land is harrowed, and the seed is planted. If the ground has been carefully prepared so that the soil does not form a crust around the plants, a good stand of beets is produced by this method. Enough moisture should then be applied to carry the plants beyond the thinning period.

Methods of Irrigation. Topographic conditions determine the methods of irrigation used in various localities. With the exception of California and to some extent the Kansas and Idaho fields, the furrow method has been generally adopted (Figure 16). It is the most satisfactory method and can be applied to nearly any kind of surface whether it be level or sloping because the quantity of water applied to each furrow can be regulated, and the depth and length of the furrow can be arranged according to the topography. Some of the advantages of this system are (1) the relatively low cost of preparing the fields, (2) the ease of retaining them in good condition, and (3) the greater facility of keeping the applied water from touching the plants and thus forming a crust of earth around them. Beets should not be watered by flooding but by applying the water to the furrows between the rows. This is especially true when the plants are

[14] *Ibid.*



Photograph, T. H. Ferril

FIG. 16.—Furrow method of irrigation. This is the common method used in western Nebraska and eastern Colorado.

young, since flooding at that time may cause scalding of stems and produce a surface crust around the beets which cuts off the air supply from the soil, thus retarding growth. The ideal condition is developed by maintaining a continuous good mulch close to the beet itself to aerate the soil and to prevent evaporation from its surface. In addition, the furrow system leaves the surface in good condition for subsequent crops which may be used in rotation.

Important factors to be considered in irrigating beets are (1) the time to apply water, (2) the number of applications, and (3) the amount of water applied at each irrigation. The smaller the beets, the lighter should be the application of water, as nothing is gained by filling the soil with water below the beet roots. On the contrary, a loss may occur as the soluble plant food will be leached below the roots, temporarily retarding the growth of the plants. Since beets use more water and exhaust the soil moisture faster as they grow larger, the heaviest irrigations should generally be applied in July and August. Maximum yields are ordinarily obtained if 15 to 25 inches of water are applied during the growing season.

Experiments performed at Windsor, Littleton, and Ovid, Colorado, show the effect of time and frequqency of irrigation on the yield and sugar content of beets (Tables 10 and 11).[15]

TABLE 10.—*Frequency of Irrigation, Yield, and Sugar Content*

Frequency of Irrigation	Tons Per Acre	Per cent Sugar	Pounds Sugar
Windsor Experiment			
Three heavy irrigations	13.82	10.60	2932
Four medium irrigations	14.77	11.19	3307
Five light irrigations	15.07	11.33	3416
Littleton Experiment			
Three heavy irrigations	10.63	13.84	2943
Five medium irrigations	10.69	14.94	3196
Six light irrigations	13.34	15.36	4099

The same amount of water for the season was applied to each plot, but the amount used at each application differed. The results showed that the highest yields were produced when five to six medium or light applications of water were made.

In the test at Ovid, no attention was given to the amount of water applied, but the time and the number of irrigations were the factors in the results produced. This experiment showed that when water was

[15] McCreery, N. R., "Water-Tonnage-Sugar Content", *Through the Leaves,* Vol 19, No. 5, July 1931, p. 138.

TABLE 11.—*Time and Frequency of Irrigation Ovid Experiment*

Time and Number of Irrigations	Tons of Beets	Per cent of Sugar	Pounds of Sugar	Purity
Four early	14.30	11.6	3330	76.8
Three intermediate	13.77	11.1	3046	74.6
Two late	12.98	11.1	2881	75.5
One very late	10.83	10.9	2374	71.6

applied early and when four irrigations were made, the yield per acre, the sugar content, and the purity of the beets were higher than was the case with beets grown under later and less frequent applications of water.

From other experimental data and from observations in the beet districts, it is evident that only a comparatively small proportion of beets throughout the territory are watered early enough. A large percentage of the growers do not water their beets until after July 4, and by the time all the beets are irrigated, it is much later. Often the fields do not suffer for water during the last 10 days in June and early July and perhaps do not show serious wilting or suffering, but when they do begin to wilt, it is apparent that there has been insufficient water for some time to carry them through a critical time in their growth. The lack of early stimulation affects the sugar content, because the beets will usually make up the delayed growth in the autumn when they should be manufacturing sugar.

Drainage. Inasmuch as the topography in the beet areas of Nebraska varies from a gently rolling to a moderately sloping surface, natural drainage is generally good.

Well drained soils are absolutely necessary for successful beet growth. They enable the plant roots not only to grow deep and to secure nutrients from the subsoil, but they provide optima conditions for the growth of microorganisms essential in preparing food for the plants; hence good drainage is important in both humid and irrigated regions.

Drainage might seem unnecessary in an irrigated area, but experience has shown that under certain conditions, continuous application of water makes water-logged soils. This is especially true where the surface soil is underlain with a dense subsoil that is nearly level and impervious or nearly impervious to water. Natural drainage in most of the irrigated areas is generally sufficient. It is due to the porosity of the soil, or to the slope of the soil or subsoil. If the water passes too rapidly from the soil as a result of rapid runoff or percolation, the humus content and fertility decrease to such an extent that the soil lacks the required amount of moisture and fertility for crop production.

If soils are water-logged, either from continuous application of water in irrigated areas or from incomplete natural drainage in the more humid regions, artificial drainage should be provided. Excess water in the soil reduces aeration and brings alkali to the surface. Some alkalies, when present in large quantities, are so injurious to plant growth that some fields which were formerly productive have become non-productive. Such non-productive fields may be reclaimed by leaching the alkali through flooding with irrigation water and by maintaining proper drainage. Some lands may be reclaimed by the application of proper mineral fertilizers. Wet soils are too cold for optimum plant growth and they retard the decomposition of organic matter. This results in an unfavorable physical condition of the soil.

Beets produced in poorly drained areas become deformed and develop many small roots and poor taproots; thus the quality of the beet is lowered, and the tonnage of beets per acre is decreased.

Two general systems of artificial drainage are used in removing excess water or too much alkali from the soil, namely, (1) the open ditch, and (2) the blind ditch in which tile is used to aid the movement of water through the ground. In the major part of the beet growing sections the land is too valuable to admit the use of the open ditch to any considerable extent except as outlets for the blind ditches. The blind ditch is generally used, and even though the initial cost is somewhat greater than that of the open ditch type, it is more economical. It permits the use of all the land, and if properly constructed, it does not require as much expenditure of time and labor to keep it in order as the open ditch does. The depth at which tile should be laid varies according to the topography and the types of soil and subsoil. The tile should be laid so deep that the water table will be several inches below the lower end of the beet roots; that is, 18 or more inches below the soil surface. They should be laid with a gentle slope, and the lines of tile should be so spaced that the whole area may be properly drained.

THE SUGAR BEET HARVEST

Harvest is a busy season for the beet grower and requires much hand labor. During the latter part of August and in September the beets are tested for sugar content. If this reaches approximately 12 to 13 per cent, harvest is started in order to avoid the danger of freezing, although the beets are not always fully matured. They are not completely ripe until the lower leaves turn brown, and the others have a yellow color.

Lifting, Pulling, and Topping. The beet is deep-rooted and is not easily removed from the soil. The first process in harvesting is known as "lifting". This is done by means of a special plow drawn by horses or by tractor. The purpose of lifting is to loosen the beets from the soil. The next process, known as "pulling", is done by hand, often by women and children. After the beets are pulled they are usually thrown into windrows or piles ready for "topping".

Topping is the process by which the crown and leaves are separated from the sugar producing part of the root. This work must be carefully done (Figure 17). The crown should be cut from the root at the "soil line". If the beet is topped below the soil line, considerable sugar remains in the crown. If the beet is topped above the soil line, mineral salts and fibers in the crown of the beet add to the difficulty of refining, as they interfere with the purification and crystallization processes. The crown is low in sugar content, but has considerable salts, which are valuable plant foods. Since the sugar manufacturer is interested only in the sugar and the farmer needs the salts in order to help in maintaining soil fertility, proper topping is emphasized.

Topping is done by means of a long, heavy knife with a hook on the end of the blade. The operator lifts the beet by the hook and severs the top from the root by one heavy stroke of the blade. After topping, the roots are thrown into piles ready for haulage. The tops are usually placed in rows and are used for covering the beets or for stock feed.

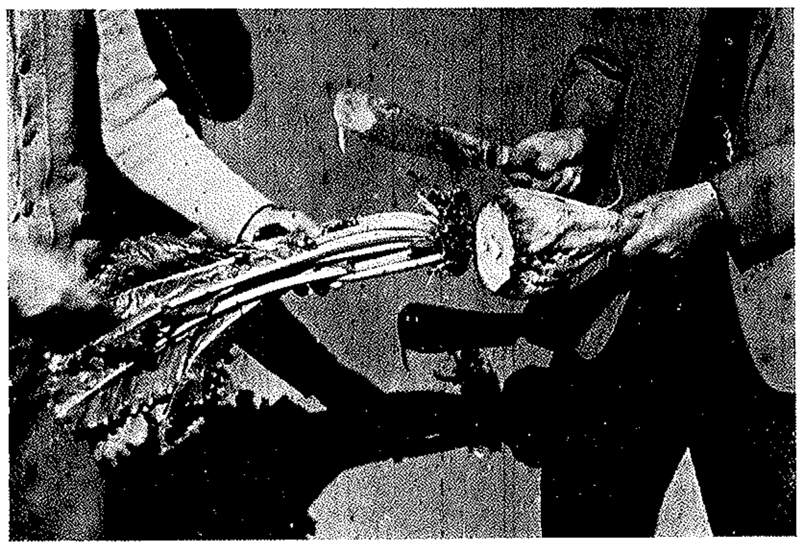


FIG. 17.—Topping sugar beets. Note the long knife used. Beets must be topped just below the crown. Only one person does the topping.

Harvesting Machinery. The use of labor-saving machinery in harvesting beets is slowly increasing. More than fifty kinds of machines designed to perform mechanically the work of pulling and topping sugar beets have been invented and tested during recent years. Some machines have been perfected which are fairly successful in pulling and topping the beets. Roots vary in size and in distance below the soil surface, consequently it is difficult to make a machine which can be adjusted to roots not uniform in size and in depth.

In 1930 the Great Western Sugar Company made experiments at Longmont, Colorado, with harvesting machines which dug and topped beets at the rate of 100 tons per day. The harvesting was done in two operations and by two machines. The first machine topped the beets while they were in the ground, and the second machine lifted the beets. These machines harvested two rows at a time. This system requires considerable hand labor to follow the machines in throwing the beets into piles. The experiments proved to be quite satisfactory.

The level topography of the sugar beet area of western Nebraska and its deep soil favor the introduction of labor-saving machinery in preparation of the soil, in blocking, cultivation, harvesting, and in the delivery of the beets.

When the soil is too soft to bear the weight of wagons or trucks, sleds with boxes of various dimensions are used to haul the beets from the fields. In this case the beets, as they are topped, are thrown into the boxes, and when these are full, they are hauled to the roads and unloaded into wagons or trucks. If the roads are in bad condition or the fields muddy, so that the beets cannot be hauled from the fields, they are placed in piles and protected with a layer of straw or beet leaves covered with soil. This process is known as "siloing" and requires extra labor for which the farmer receives from 50 to 75 cents per ton.

Haulage of Beets. Wagons or trucks with capacities ranging from 2 to 5 or more tons are used to haul the beets from the fields. They have racks with hinged sideboards which permit easy and rapid unloading (Figure 18).

Beets are loaded from the fields into wagons or trucks by means of fork-like shovels made especially for this purpose. These shovels have short handles and long, heavy tines with protected points so as not to injure the beets. When beets are bruised or otherwise injured, fermentation may develop which causes a decrease in sugar content.

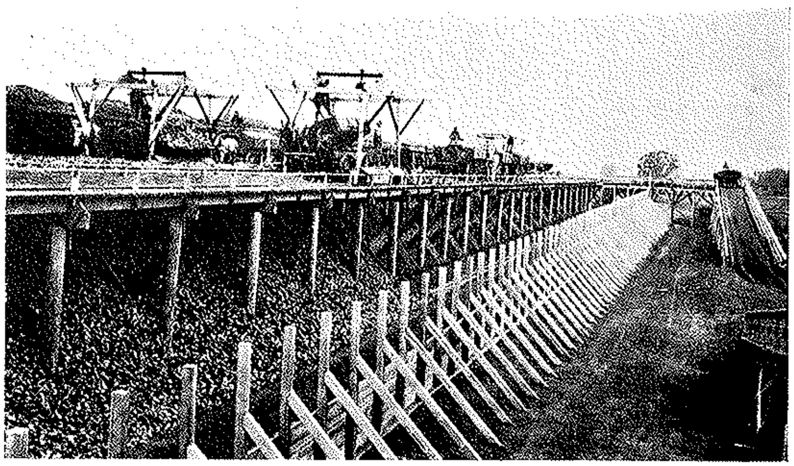
When distance is not too great, beets are hauled directly to the factory, otherwise they are transported to dumps located at convenient points along a railroad (Figure 15). At the dumps the beets are mechanically unloaded. One side of the truck or wagon is tilted to the chute by a cable

Photograph, L. H. Andrews

FIG. 18.—Loaded wagons and truck ready for delivery to the factory or beet dump. These hold from one to three or more tons each.

operated by machinery; the hinged sideboard is let down, and the beets fall directly into railroad cars.

Weighing Beets. Wagons and trucks bringing beets to the dumps or factories bear the farmer's contract number which serves as a means



Photograph, L. H. Andrews

FIG. 19.—Unloading wagons at factory. Side board is lowered and wagon box is lifted on one side causing the beets to slide over a chute into the bin or railroad car.

of keeping account of deliveries. When the wagon or truck arrives at the dump or factory, it is weighed, driven onto the platform, and dumped (Figure 19). The chutes are so constructed that when the beets are unloaded, the soil and waste materials pass through a lattice work and fall into a container which is automatically emptied into the wagon or truck as it leaves the dump.

The Tare. After unloading, the wagon or truck is weighed again in order to ascertain the tare. Samples of beets from each load are taken to the factory to be tested for the tare that adheres to the beets and for sugar content. These beets are weighed, then cleaned with a brush, the green tops remaining from improper topping are removed, and the cleaned sample of beets is again weighed to discover further tare. This results in a further deduction ranging from 2 to 10 per cent or more according to the care used in topping and the quantity of soil clinging to the beets. It is essential, therefore, that the beets be clean and carefully topped in order to make the final tare as low as possible.

Dumping and Piling. The cost of dumping and piling beets at the factory or at the railroad dumps is an important item in the marketing of sugar beets (Figure 20). The old "high line" type of dumps (Figure 21) which have been in use in western Nebraska for many years are being

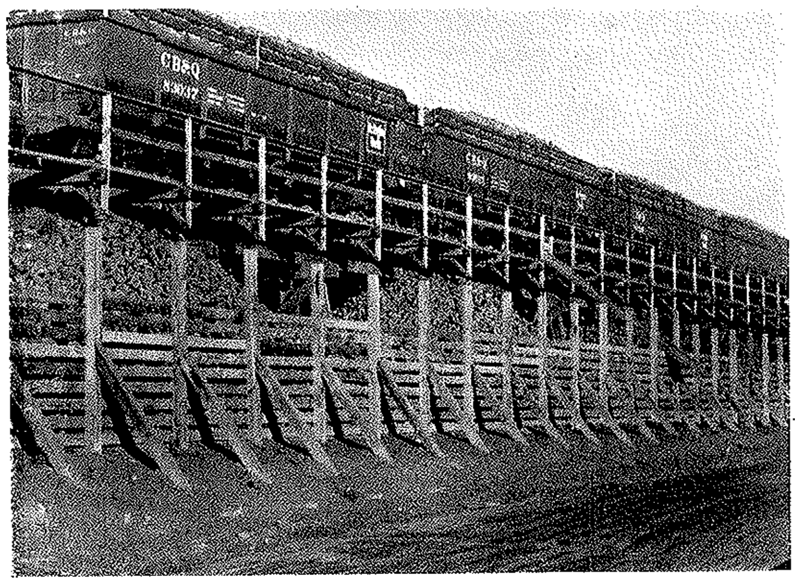
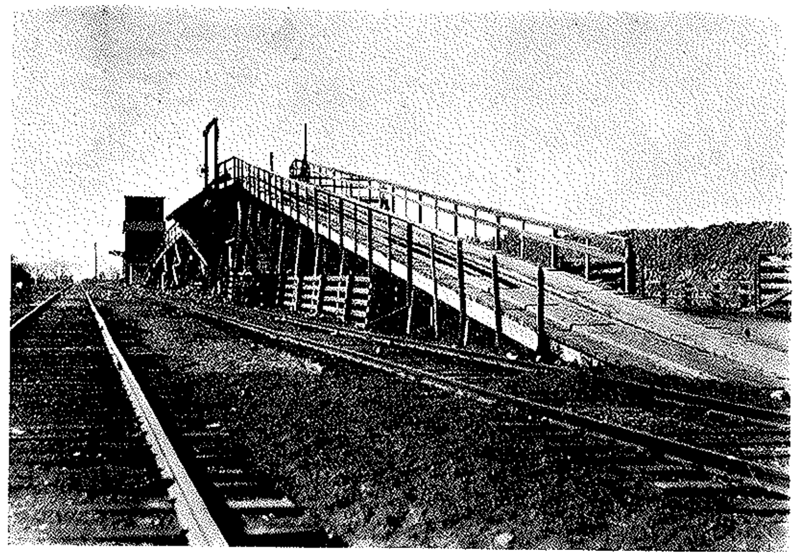


FIG. 20.—Unloading railroad cars at factory. Cars are opened at the bottom to permit beets to drop into bins at factory.

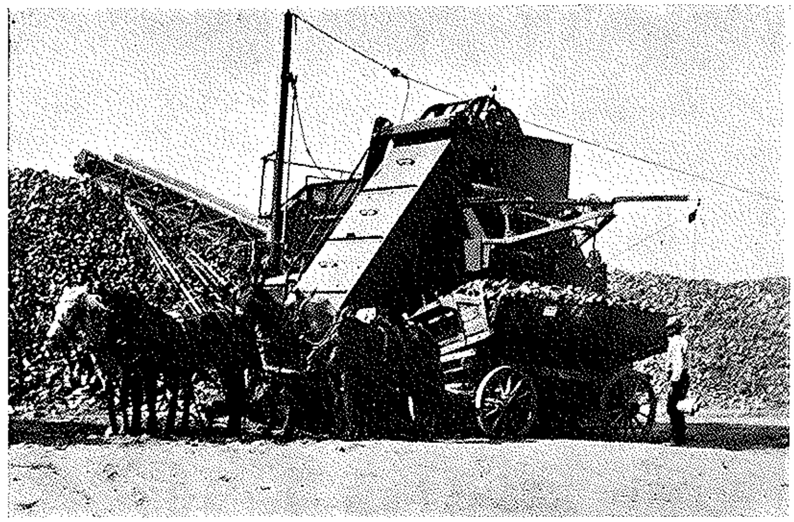


Photograph, H. L. Hartburg

FIG. 21.—Old type "high line" dump, formerly very common.

Photograph, T. H. Ferril

FIG. 22.—New Hartburg portable dump which is replacing the older kind. These can be moved and can unload beets from wagons quickly. They are used also in loading beets from piles into raliroad cars or trucks for shipment to factory.



Photograph, H. L. Hartburg

FIG. 23.—Close view of unloading a wagon by the Hartburg dump.

replaced by a new portable piler (Figure 22). Mr. H. L. Hartburg, District Engineer for the Great Western Sugar Company, has invented a portable piler which is being successfully used in the northeastern districts of Colorado and western Nebraska. It can be moved from place to place to empty the beets from the wagon or from the railroad cars and to place them in piles or to remove the beets from the piles into railroad cars. The Hartburg machines weigh approximately 52,000 pounds each and crawl over the ground like wartime tanks (Figure 23). The wagon or truck is often unloaded in 90 seconds; the old method often required 20 to 30 minutes. The machine handles 35 to 40 loads of 3 tons per hour, requiring two or three men to operate the machine and two men to take samples and to test the beets for tare.

The Great Western Sugar Company has a dozen or more machines in operation. One of these machines replaces about two or three of the old type "high line" dumps and can be operated at a lower cost. Formerly when beets were shoveled by hand, the piles could be only about 8 feet high, but the Hartburg pilers allow the height to be about 18 feet. A large amount of labor is eliminated by this method in unloading wagons as against the old method of unloading by fork, to say nothing of the time saved.

Railroad Shipment. When it is impossible to ship fast enough, beets are piled along or near the railroad dumps for future delivery. Piles, 8 to 15 feet high, containing from 2,000 to 50,000 tons of beets dot the landscape in the sugar beet areas of Nebraska during the harvest season. From the piles at the dumps the beets are later loaded into cars and shipped to the factory, where the cars are placed on elevated tracks. Unloading is done by opening the bottoms of the cars, thereby dropping the beets into storage bins having a capacity of hundreds of tons (Figure 19). While the beets are dropping into these bins, samples are taken to be tested for tare and sugar content.

ANIMAL PESTS AND PLANT DISEASES OF THE SUGAR BEET

As the sugar beet industry expanded the animal pests and plant diseases became troublesome. Many thousands of dollars are lost annually in beet regions of the United States as a result of damage to beets from animal pests and plant diseases. Profitable sugar beet production in some sections has practically ceased because the seriousness of this danger was not recognized in time.

ANIMAL PESTS

Among the most important animal pests are the sugar beet webworm, beet army worm, blister beetle, beet wireworm, leaf beetle, leaf hopper, root louse, aphid, false chinch bug, cutworm, grubworm, grasshopper, and the nematode.

Webworm. The sugar beet webworm causes much damage. It feeds on the beet foliage thereby reducing the sugar manufacturing surface of the plants. It also subsists on weeds, such as lambs quarters, pigweed, and Russian thistles. Estimated losses as high as $2,000,000 per annum to beets have been caused by this worm in the United States.

The webworm can be controlled by spraying the sugar beet leaves with chemicals such as arsenates and Paris green.

Army Worm. The army worm, another destructive pest, can also be controlled by chemical sprays. It may be checked by plowing three or four furrows facing the direction from which the horde of army worms is approaching and dragging a log through the furrows to make a loose dust mulch. Many worms suffocate when they fall into the soft dust. A kerosene emulsion sprayed on the surface of the ground, or a heavy dose of lead arsenate to the crop around the edge of the field is one of the most successful methods of combating them. Early planting and thinning also help to solve the eradication problem, as army moths seem to lay eggs where the foliage is heaviest, consequently the unthinned beets offer excellent feeding ground for the worms. If the field is thinned early, the moths will probably lay their eggs in the weeds around the edge of the field and spraying can be done without much damage to the beet plants.

Wireworm. The wireworms are most destructive along the Pacific coast, though they do not affect sugar beets as much as they do some other crops. They are difficult to eradicate. The best way to exterminate them is by summer fallowing or by growing crops on which they do not feed, thereby starving them.

Beet Leaf Beetles. These pests, sometimes called "alkali bugs", are most harmful in alkali regions. They attack beets after the removal of the pest's natural food plants, such as pigweed and lambs quarters. The most severe injury occurs to young beets when they have from 2 to 8 leaves. The injury is done in skeletonizing the leaves by eating out the pulp between the veins. The beet leaf beetles do not ordinarily destroy large acreages. Arsenate of lead is an excellent spray to use in eradicating the insects.

Leaf Hopper. The sugar beet leaf hoppers, or "white flies", are the transmitters of curly-top and curly-leaf and exist in many fields during the growing season. The disease carried by the hoppers causes the beet leaf to bunch or form a rosette.

The insect is single-brooded, hibernates as an adult, flies to the beet field in late spring and lays a few eggs at a time in beet stems until midsummer. The larvae mature in summer. They are also found on shadscale, greasewood, Russian thistles, and annual fine-leaved salt bushes. The insects appear suddenly in swarms in the beet fields previously uninfested. Evidence points to the conclusion that the swarms fly from their breeding places on wild plants to far distant beet fields.

During some years the disease transmitted by this insect causes losses in the United States of $1,000,000 to $2,000,000.

Much research work has been done, and large sums of money have been spent in trying to eradicate the leaf hopper. The most promising control seems to be in developing strains of beets resistant to curly-top.

Nematode. The sugar beet nematode is one of the most destructive of animal pests but luckily it is not so widespread in Nebraska as it is in some other states.

Sugar beet root knot ("bearded roots", or "hairy roots") is caused by the beet nematode, a minute worm-like organism which lives in the soil and feeds upon the sugar beet. It appears as a small milky white lemon shaped body clinging to the beet root.

The female nematode lays 100 or more eggs from which small slender worms hatch. Strong spire-like organs in the mouths of the worms enable them to enter the beet root to feed upon the juices, after which they soon molt. The female becomes dark brown as the season advances and in this form, the body surface has a protecting sack for the eggs which remain dormant. This condition may exist for 5 or 6 years, and thus prolong the infestation of a beet region.

Fields become infected by farm implements, especially cultivators, harrows, and levellers which drag particles of soil containing the nematodes from infested areas to uninfested areas. Irrigation waters running over the infested soil may pick up nematodes and carry them into other fields. Often the infested area in a field may be only three or four rods wide and several times as long following the course of irrigation and cultivation. Animals and man trampling in the mud may carry the worms to other sections of the field. The dirt from infested areas which is returned after beets have been dumped should be placed where it will not reach the beet field.

The best control of nematodes is by crop rotation. Several years must be left between periods of sugar beet growth, as the eggs lie dormant for a long period. Early planting is also valuable because the young beets then make a better start and are more able to withstand attacks of nematodes.

Chemicals do not always kill nematodes. Many chemicals are fatal to them, but it is impossible to obtain deep enough penetration of the chemicals into the soil to kill all the nematodes. A considerable number escape, and when beets are planted on the same field, year after year, serious infestations develop. One crop is generally benefited by spraying, but the returns from it are not sufficient to pay the expense of treatment.

The control of nematodes is difficult but necessary in the production of good yields of sugar beets. A brief summary of crop rotation as related to the nematode control is presented herewith, because it, crop rotation, is the only efficient way of eradicating and checking the spread of the nematode. It is very important that farmers in Nebraska should give this problem careful consideration, because it is not yet as serious in this state as in other areas; consequently, every effort should be made to keep the infestation low.

The nematode is becoming the most detrimental of the sugar beet pests. Much investigational work has been done to determine the best method of its control. In 1927 and 1928 sugar companies in the Intermontane and Great Plains regions made an extensive series of investigations in order to determine the fields which were most generally infested by nematodes. Examinations for infestations were made in 21,246 beet fields in Colorado and Nebraska, and it was found that 6 per cent of the fields contained the worm. In 1,276 fields where beets had been grown only one year, there was an infestation of 1.57 per cent, whereas 1,568 fields on which beets had been raised six years in succession had 22.26 per cent infestation. In contrast, 1,571 fields which had not been planted to beets

TABLE 12.—*Relation of Continuous Cropping and Rotation to Nematode Infestation*

Years	Continuous Cropping		Rotation	
	No. of Fields	Per cent Infested	No. of Fields	Per cent Infested
1	1,276	1.57	1,571	5.28
2	4,667	4.05	814	3.44
3	2,265	5.92	530	0.90
4	1,269	8.04	1,462	1.71
5	710	15.21	3,476	1.09
6	1,568	22.26	26	0.00

for one year had an infestation of 5.28 per cent, and 26 fields without beets in rotation showed zero infestation (Table 12). It is evident, therefore, that the increase in nematode infestations is proportional to the number of years that a field has continuously produced sugar beets (Table 12).

Studies and observations show that nematodes are also tolerant of other crops. If the preference of nematodes for sugar beets is 100, their tolerance for oats, rape, and wild mustard is equal to about 65 to 75; for barley and wheat, 12 to 20; for potatoes, alfalfa, clover, corn, and rye, practically nothing.[1] In order to destroy nematodes, it is necessary not only to rotate crops but to use in the rotation such crops as will not furnish feed for the nematodes. An excellent rotation which will both reduce nematode infestation and build up the fertility of the soil is to follow sugar beets with three or four years of alfalfa, one year in corn or potatoes, and then one year in sugar beets, or follow sugar beets with two years in clover, one year in potatoes, one in corn, and then beets again.[2]

Sugar beet root knot causes serious losses because the beets become small, deformed, and contain lower sugar contents than well shaped, well developed roots. Another injury to the plant caused by the nematode is the curtailed supply of moisture through the roots causing the plant to wilt more rapidly.

Other Animal Pests. The beet root lice or aphids have spread throughout the entire sugar beet area of the United States. Crop rotation, irrigation, and destruction of cottonwoods which house the winged form of the pest are methods used in controlling these insects.[3]

1 Willcox, O. W., "Nematodes and Sugar Beets", *Through the Leaves*, Feb. 1929, p. 76.

2 *Ibid*, p. 77.

3 Harris, F. S., *Sugar Beet in America*, pp. 184-204; also "Sugar", *Agricultural Yearbook 1923*, pp. 191-193.

The grasshopper and false chinch bugs attack sugar beets and other crops and are only periodically destructive.

PLANT DISEASES

The losses caused by plant diseases of the sugar beet have not been wide spread in America. The sugar beet industry is relatively young and a few new disease free areas of beet production have been developed each year. Diseases are appearing in the older areas, and effort is being made in their control and eradication. Among the most serious sugar beet diseases are curly-top, root-rot, leaf-spot, "damping-off" of seedlings, and root knot.

The Federal Government, state experiment stations, private sugar companies, and individuals are investing much money and time in research for the control of sugar beet diseases.

Curly-top. This is found in the semiarid areas of the United States. It is distributed from plant to plant and from field to field by means of the leaf hopper which thrives in warm, dry climates. This is, probably, the most serious plant disease in the western beet growing areas and is caused by punctures made in the leaf by the leaf hopper.

Leaf hoppers do not transmit the disease until they have fed on infected beets. Warm, dry weather is favorable for the spread of leaf hoppers. The only real control of curly-top now known is in developing curly-top resistant beets. The disease causes a dwarfing of the plant, curling the leaves irregularly, and swelling the veins on the under side of the affected leaves. It causes more losses than most sugar beet diseases in the United States.

Leaf-spot. One of the most widely distributed diseases of sugar beets in the United States is the leaf-spot. It is caused by a fungus, which infects the tissues of the leaf and leaf stem.

The disease first appears as small spots which later become larger and cause a curling of the leaves. The older leaves of the plant are attacked first. As the number and size of the leaf spots increase, the leaves gradually die. The disease develops best when temperatures and humidity are high.

Leaf-spot disease propogates by spores which are small, needle-shaped bodies. The spores are usually light in color and are easily brushed from the surface of the leaves and scattered by wind, water, insects, and animals.

The most satisfactory methods known for controlling leaf-spot are deep, fall plowing and crop rotation. The principle of disease control by crop rotation is that certain fungi can thrive only on certain kinds of plants, therefore, if crops which are not suited as hosts for the spores are planted, the fungi will die. Another method of controlling leaf-spot is by spraying with Bordeau mixture.

A uniform moisture supply in the soil is beneficial in retarding outbreaks of leaf-spot, because moisture reduces the temperature of the soil and of the atmosphere surrounding the beets and prevents the leaves from wilting. A long, dry, hot spell is a favorable condition for outbreaks of leaf-spot as it causes wilting of the leaves.[4]

Root-rot. Root-rot is distributed over the entire sugar beet areas of North America. Two groups of fungi appear to cause root-rot. According to Harris, the group of fungi, called Rhizoctonia by De Condolle, appeared to be responsible for injury to beets. The disease works principally through the seedling stage of the beet, at which time the disease shuts off the supply of food to the roots. This causes "damping-off" of seedlings. Another fungus, Phoma, is also thought to be the cause of root-rot.

The most rapid development of the disease follows periods of excessive moisture and high temperature. The control of the disease is difficult; no effective control measures are known. Crop rotation, proper drainage, and good aeration of the soil help in restraining its growth. To delay planting until the soil is sufficiently warm to cause the seed to germinate rapidly helps in the control of root-rot, as it develops healthy seedlings.

Several other diseases, such as heart-rot, scab, soft-rot, beet-rust, sugar beet mosaic, and "damping-off" affect the yield of sugar beets. Root knot has been described under nematode.

THE MANUFACTURE OF BEET SUGAR

The raising of beets and the manufacture of sugar are so closely related that they really constitute a single industrial unit, even though they may not be carried on by the same persons or organizations. Since the beets are bulky and perishable, they cannot be transported economically for great distances, consequently they are produced in as close proximity to the beet sugar factory as possible.

Sugar Campaign. The various activities connected with the harvesting, transporting, and milling of the beets are collectively known as the "sugar campaign". The length of the campaign varies from 80 to 130 days, depending upon the quantity of beets available. The manufacture of beet sugar does not require a large number of employees, and since the campaign extends into the winter months some of the beet workers are employed in the factory after they have finished the harvest.

Materials needed. The factory processes require the use of consider-

[4] Townsend, C. O., "*Leaf-Spot, A Disease of the Sugar Beet,*" United States Department of Agriculture, *Farmers' Bulletin No. 618*, Washington, D. C., p. 19.

able quantities of limestone, coal, coke, sulphur, and water. A limekiln is a necessary part of a beet sugar factory. Limestone equivalent to 4 per cent of the weight of beets is used in refining beet sugar or 80 pounds of limestone per ton of beets. A factory which slices 2,000 tons of beets per day uses 80 tons of limestone every 24 hours. Coke from the eastern states is the fuel used in the kilns to reduce the limestone to burnt lime, commonly known as quicklime. Quicklime is added to water to form "milk of lime" which is used in clarifying beet juices.

Coal equal to 12 or 13 per cent of the weight of beets, or 240 to 260 pounds per ton is necessary in the operation of a factory. About 6.6 pounds of sulphur are used per ton of beets. Approximately 2,500 gallons of good water are needed for every ton of beets used in the factory. A factory having a slicing capacity of 2,000 tons of beets per day, therefore, uses about 5,000,000 gallons of water every 24 hours. Most of the water used in the factories in Nebraska is secured from wells on or near the factory grounds.

The manufacture of beet sugar is complicated. Until a few years ago, the methods used were not highly developed and, as a result, impurities remained in the sugar, making it less pure than cane sugar. During the last 25 or 30 years, however, new inventions and improved processes have made the refining of beet sugar so perfect that it is now impossible to distinguish it from cane sugar. Of course, many people claim that beet sugar is inferior to cane sugar. This opinion is not well founded because cane sugar and beet sugar are the same chemically, and, therefore, the same in food value.

Since economic success in the manufacture of beet sugar is dependent upon abundant supplies of good beets, and profits in raising them are dependent upon a ready market at the factory, a brief summary of the processes involved in converting the beets into their finished products is given in this bulletin.

Preparation of Beets for Sugar Manufacture. The beets, having been weighed, tested for tare, and placed in large bins near the factory, are then sluiced in flumes to the mill (Figure 24). The water used in conveying them to the factory also washes the beets for the first time. At the entrance of the factory is a trash collector, a revolving wheel, which collects some of the sticks, stones, brush, and other detrimental materials. The beets are further cleaned in a mechanical washer in the form of a long rectangular tank containing a horizontal shaft provided with short paddle-like arms. The rotation of the shaft and arms agitates the beets, thereby washing them (Figure 25).

Following the washing, the beets are carried by an endless belt bucket conveyor to a sorting table on the upper floor of the factory. Here men

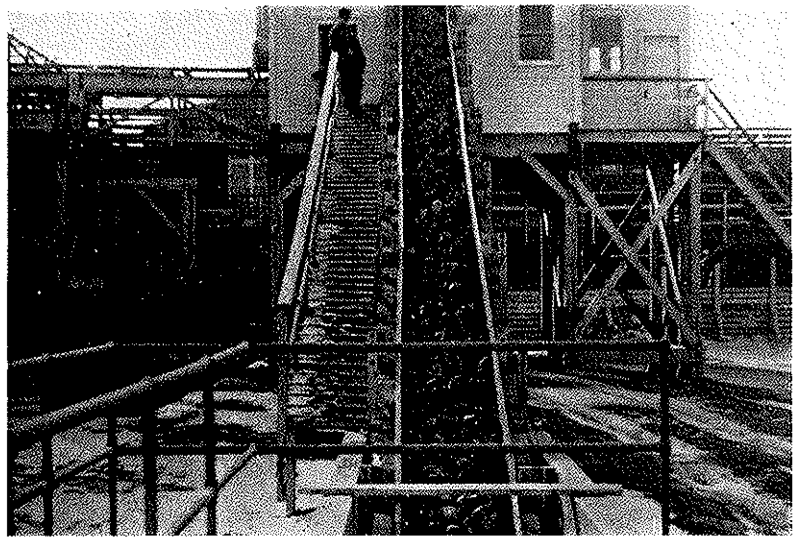


FIG. 24.—Conveying beets to the factory

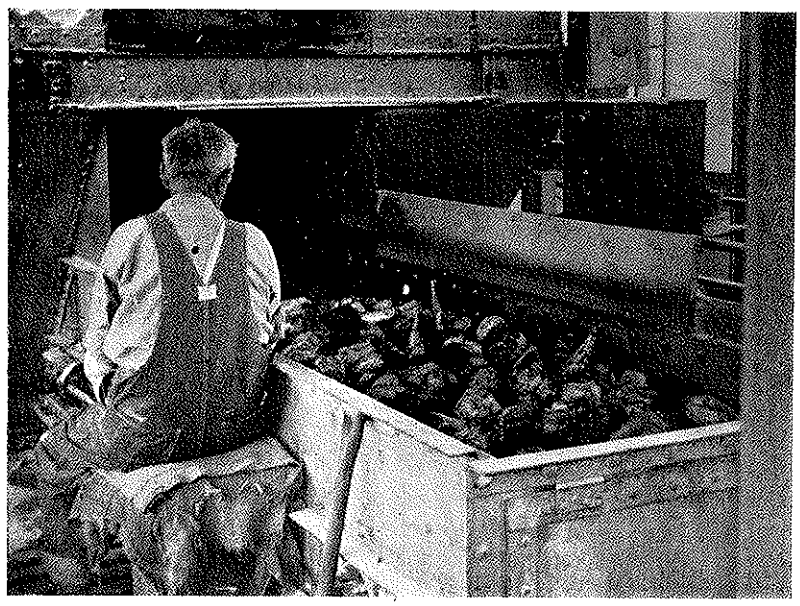


FIG. 25.—Washing sugar beets in the factory. Rotating arms in the washer agitates the beets thereby cleaning them.

pick out the remaining foreign materials that would injure the slicing equipment.

Weighing and Slicing. The cleaned beets are automatically weighed. Then, by means of special designed knives set in a revolving disk, they are cut into slender, pencil-shaped shreds called **cossettes,** which look somewhat like "shoe-string" potatoes.

Removing the Sugar. The cossettes are conveyed to the "diffusion battery" consisting of a series of cylindrical tanks, each with a capacity of 3 to 5 tons of sliced beets. When filled, the tanks are closed and charged with currents of hot water (not boiling) to remove the sugar from the cossettes. The principle involved in the extraction of the sugar is called **diffusion,** hence the name "diffusion battery".

The diffusion battery consists of 14 to 16 units arranged either in a circle or in a straight line. The water, after passing through the first tank or unit of the battery, continues through a heating apparatus where its temperature is raised before entering the second cell or tank in the series. This process continues until the water passes through all of the cells in the battery, gradually receiving more and more sugar. Fresh water is started in the second cell and passes through the same process that the first water did. Similarly fresh water is added to each succeeding cell, and it follows the same course as the first water did in the first cell. The process is continued until the cells have been washed by as many waters as there are cells or tanks in the battery. The juice, carrying the sugar extracted from the cossettes, is then drawn, measured, and placed in tanks awaiting treatment (Figure 26), and the pulp, which remains in the

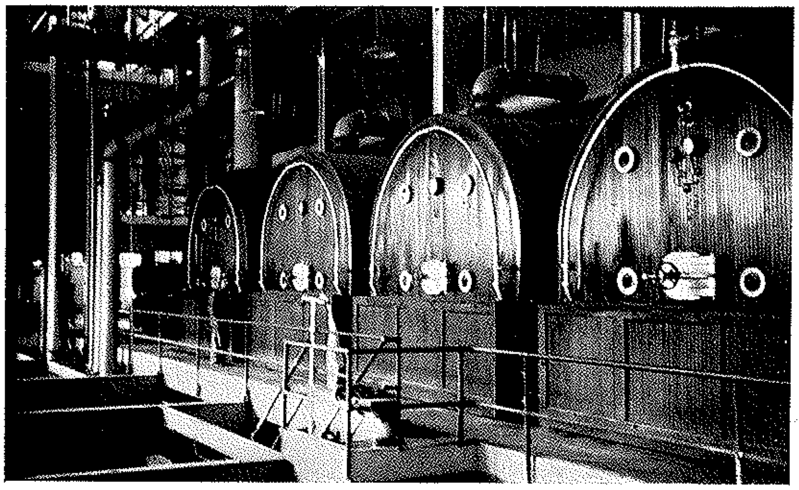


FIG. 26.—Sugar beet juice in tanks awaiting treatment.

cells, is dumped into conveyers which carry it to storage from which it is either taken to the dryers or is hauled and fed to livestock.

Treating the Juice. The juice from the diffusion batteries contains considerable quantities of impurities which must be removed. Carbonation, the process by which impurities are removed from the juices, includes treatment with milk of lime, carbon dioxide gas, and sulphur. The main purposes of this treatment are (1) to change the impurities in the juice into a condition whereby they can be separated from the sugar and (2) to whiten the sugar.

The raw juice is heated to a temperature of 85° to 90° Centigrade. Next it is treated with a milk of lime solution, about like ordinary white wash. The lime effects the juice both chemically and mechanically. Chemically, the lime unites with a number of substances that later interfere in the manufacturing processes, and it causes many of the solids held in suspension to settle at the bottom, thus leaving a clear liquid of light, amber color. Carbon dioxide or carbonic acid gas from the lime-kiln is forced through the treated juice, thus throwing out the excess of lime, converting it into a carbonate of lime. In the last carbonation process, usually the third or fourth, a small amount of sulphur dioxide gas is forced through the juice to reduce the alkalinity caused by the lime, and to remove additional impurities. The sulphur fumes also have a bleaching effect because they remove color from the liquid that might be carried on to the sugar.

Filtration. From the carbonation tanks the juice is pumped or forced through filter presses consisting of a battery of iron frames which support screens made of cloth. The juice is forced through the cloth partitions of the presses, coming out as a clarified liquid, leaving the lime and impurities in the press as a form of lime cake. Some sugar remains in the lime cake. Part of this is recovered by leaching with water, leaving the rest in the lime cake. This is one of the major losses of sugar in the factory.

Following filtration and bleaching, the presses are opened, and the lime cake is removed from the frames and hauled or sluiced from the factory. The cloths are now cleaned and again reassembled in the presses for another run of juice. Much of the lime cake is wasted but some is used for liming soils.

Evaporation. The purpose of this process is to evaporate the water and thus make a concentrated solution of the sugar. The sugar-bearing juice from the filter presses is known as "thin juice". It is passed through multiple-effect evaporators, consisting usually of four or five large boiling chambers which are heated by the vapor from the one preceding. This heating is made possible by maintaining a higher degree of vacuum in each successive chamber, causing the juice in them to boil at a lower temperature in order to prevent discoloration and, to a large extent, the damage to sugar which may occur under high temperature. The juice becomes thicker as it passes through the series of chambers. In the first vessel or chamber it contains 10 to 12 per cent sugar, and in the last it becomes a syrup containing 50 to 60 per cent and is called "thick juice". This concentrated juice is again treated with sulphur dioxide gas and is filtered to remove impurities.

Crystallization of Sugar. The filtered thick juice is run into large cylindrical, air tight "vacuum pans" (Figure 27), which are heated by steam coils to reduce the boiling point. The vacuum pans have diameters of 10 to 15 feet and heights of 10 to 25 feet. They are among the most noticeable features of a factory.

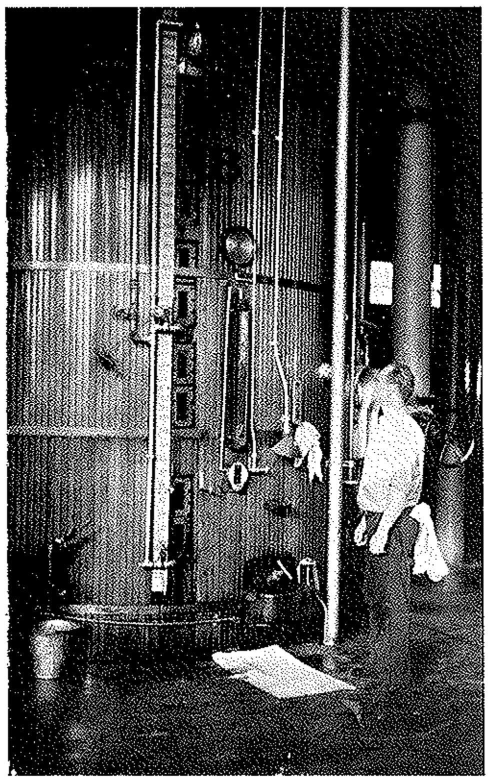


FIG. 27.—Vaccum pans wherein evaporation of beet juice takes place.

The process of crystallization in the vacuum pans is conducted under expert supervision by the "sugar boiler" who regulates the size and evenness of the grain of the resulting sugar. A large quantity of juice is admitted first, and as it boils to form crystals, fresh juice is added gradually to the pan wherein crystals are built to the desired size. The "sugar boiler" examines the size of the crystals at times and when the desired size has been attained, crystallization is stopped. The product, known as "white massacuite" or "white fillmass", is a brownish and comparatively viscous fluid filled with crystals of sugar. It is placed in "mixer" tanks in which it is agitated to facilitate further crystallization and keep the mass viscous.

Separation of Sugar from Syrup. The separation of sugar from the syrup in the massacuite is brought about in centrifugal machines, which operate on the same principle as cream separators (Figure 28). Each

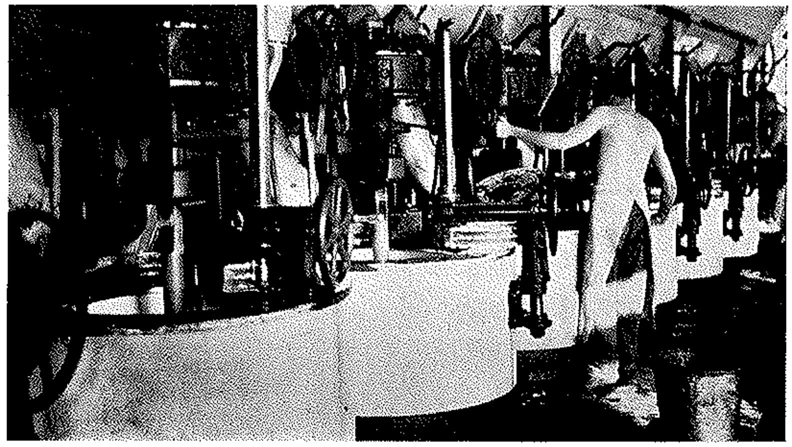


FIG. 28.—Centrifugal machine. Syrup is removed by centrifugal force.

machine consists of a cylindrical brass drum inset with a screened metal basket having a removable bottom sometimes called the bell. This basket is attached to a driving shaft which is operated electrically and makes from 1,200 to 1,500 revolutions per minute.

The operator runs the massacuite into the basket of the centrifugal machine and starts the rotation of the container. Then the centrifugal force so developed throws the syrup out through the screen to the space between it and the drum, leaving light colored sugar on the inside of the basket. Some syrup remains with the sugar at the close of this operation. It is removed by spraying warm water on the sugar in the rotating basket.

The syrup drained from the machine during centrifugation is carried to storage tanks. When rotation has stopped, the operator removes the bottom or bell of the container, adjusts a knife-like blade in the basket, and by slow rotation of the latter, scrapes the sugar from the walls of the screen. The sugar drops to a conveyer which carries it to the dryer.

Drying the Sugar. This is done in the "granulator", or dryer, which is a nearly horizontal, rotating, cylindrical drum, 5 or 6 feet in diameter and about 25 feet in length. The granulator is lined with narrow inclined shelves on which the sugar is lifted and dropped through hot air during its rotation. The air is forced through the drum and dries the sugar which is then stored and sacked.

Sacking Sugar. The sugar is automatically sacked in bags, each of which holds 10, 25, 50, or 100 pounds, and placed in storage (Figures 29 and 30). The sugar in the smaller bags is for the retail trade, especially for the chain stores. In a few factories the sugar is held in bulk storage until the time of sacking and shipment.

Disposal of Syrup. The fluid which has been removed by the centrifugal machine is known as "high green syrup". That thrown off by washing is called "high wash syrup". The syrups are boiled again and treated by the same methods used in the manufacture of sugar from the clear juice. The result from this process is brown sugar. The brown sugar or raw sugar is reboiled with thick juices in the "white pan" to produce pure granulated sugar. The "low green" and "low wash" syrups resulting from the last process may be used in making a third grade sugar.

Molasses. The molasses, which remains after the treatment of the syrup, is further treated by the Steffen process, a chemical technique which removes some of the sugar contained in the molasses. The final discarded molasses in most beet sugar factories in Nebraska and other states is used for cattle and sheep feed. In some countries it is used in the production of yeast and in the manufacture of alcohol. The Great Western Sugar Company is treating some of this molasses for sugar extraction by another process in a specially built plant at Johnstown, Colorado, where excellent confectioners sugar is manufactured. The process of refining at the

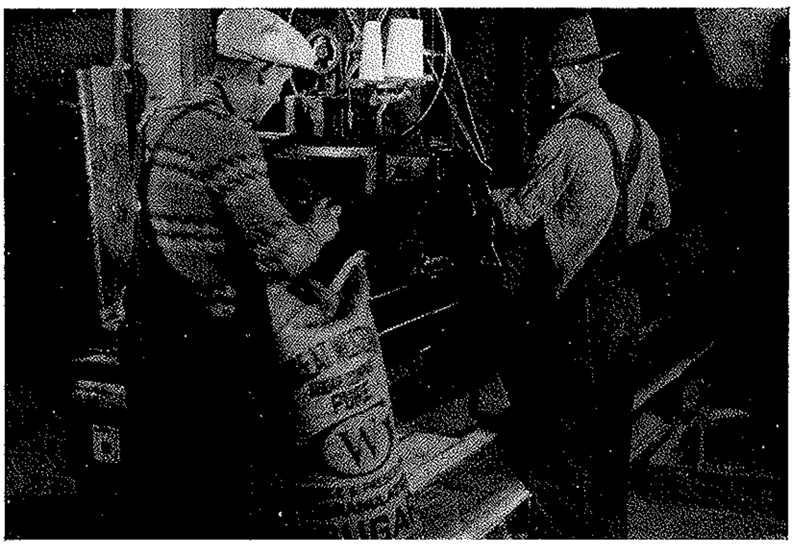


FIG. 29.—Sacking sugar. Sacks are automatically filled, weighed and sewed.

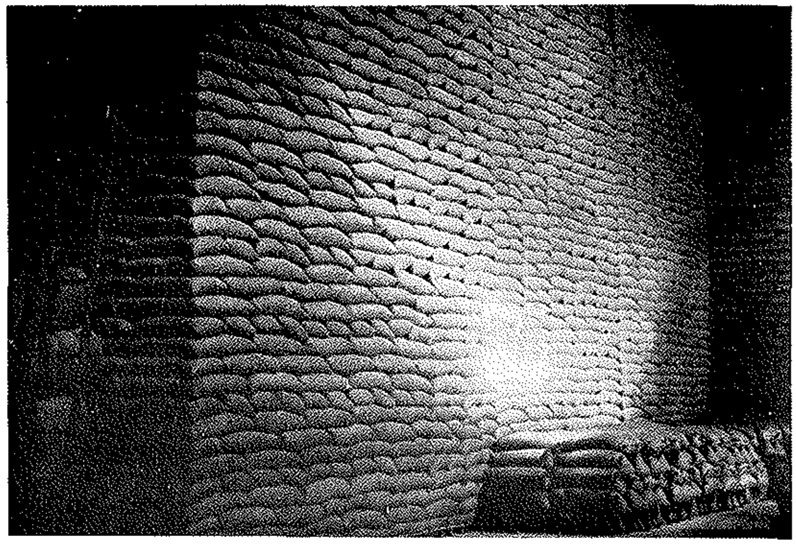


FIG. 30.—Storage of sugar in sacks. In some factories, part of the sugar is stored in bulk and later placed in sacks.

Johnstown plant is a secret operation whereby the molasses is treated with barium sulphate from California or England. The plant has a capacity of 110 tons of sugar per day. The recovery of sugar from molasses in this factory is 80 to 85 per cent whereas in the Steffen House process only 40 to 45 per cent of the sugar is recovered.

MARKET FOR NEBRASKA-MADE SUGAR

Most of the sugar made in Nebraska is marketed at home or in nearby states. Some is shipped to Pennsylvania, New York, New Jersey, and other states.

The sugar companies are the major distributors of the production to the wholesale and jobbing trade from which the retailing agencies supply the ultimate, small consumers. The retail price of sugar is comparatively uniform regardless of the nearness of factories or the distance the sugar is shipped.

Notwithstanding the fact that beet sugar is chemically the same as cane sugar, there is some prejudice among people for the latter. This causes the market value of beet sugar to be slightly lower than that of cane sugar.

Formerly it was claimed by some that beet sugar was not suited for jelly making but this claim has been found to be groundless, and this sugar now is used generally like cane sugar.

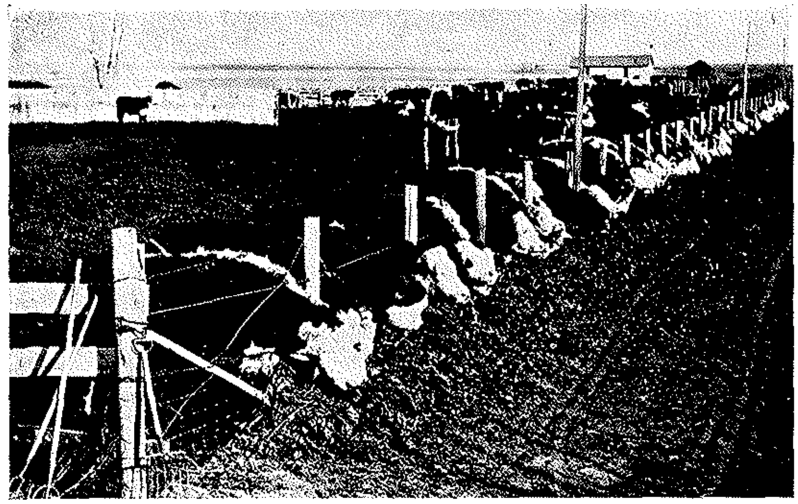
BY-PRODUCTS FROM THE BEET INDUSTRY

The so-called by-products of the sugar beet industry, consisting of beet tops, beet crowns, beet pulp, and molasses, are very important because they supply large quantities of stock feeds. Thousands of cattle and sheep in the beet regions are fattened annually on these products mixed with other feeds. It is estimated that an acre yielding a good crop of beets, furnishes almost as much feed in the form of beet tops and crowns as an acre of ordinary forage crops.

The by-products from the sugar beet industry have made stock feeding an important part of the agricultural scheme in the beet growing regions. The fattening of many animals not only adds to the financial profits of the beet farmer but also adds greatly to the fertility of the soils by the manures formed. The manufacture of dried pulp and briquets makes it possible for the cattle and dairy producers who are not near the factory to derive benefits from the beet industry.

Beet Tops and Crowns. The weight of leaves and crowns per acre varies greatly in different parts of the country according to soil and climatic conditions. An annual yield of 3 to 4 tons of tops and crowns per acre is generally produced (Figure 31). About one-third of the weight consists of crowns which contain mineral salts. These salts are troublesome in sugar refining but have value in restoring soil fertility. They must be removed from the root by proper topping. Approximately three-fourths of the tops consist of leaves which are excellent feed for cattle and sheep (Figures 32 and 33).

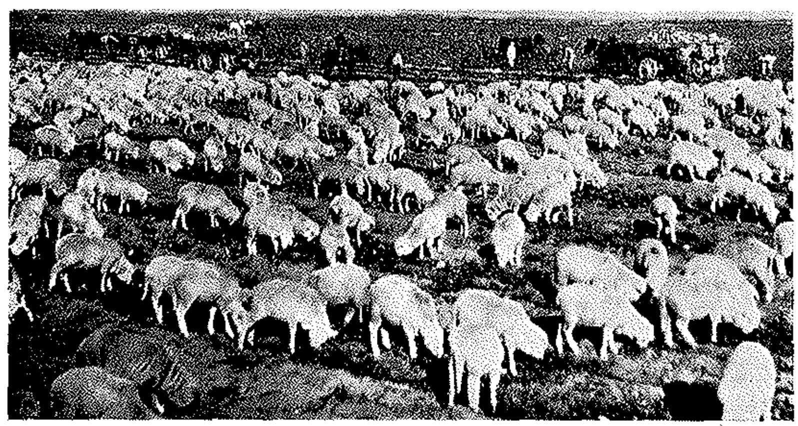
FIG. 31.—Piles of beet tops ready to be fed or to be stored for winter use.



Photograph, L. H. Andrews

FIG. 32.—Beet tops as a feed for White Faced Herefords in the North Platte Valley.

Beet tops may be utilized by turning the stock into the field where they do their own foraging, or by feeding the cured product to animals in the farmyard, or by placing it in a silo and later feeding it as silage. The first method, quite commonly used, is the most wasteful, because the stock trample many of the tops under foot. The best method is to feed the cured tops or the ensilage with other feeds such as chopped corn stalks



Photograph, L. H. Andrews

FIG. 33.—Sheep feeding on beet tops in the field.

or straw mixed with them. At present, many of the tops are stacked and used for feed during the winter.

Beet Pulp. Thousands of tons of pulp, the residue remaining after sugar has been extracted from the beet slices, are made annually (Figure 34).

Pulp is fed in either a wet or dried form. Because of its bulk, the wet pulp is generally used near the factories. It is fed with or without molasses. Experiments show that pulp has 78 per cent or more of the feeding value of corn, depending upon the amount of molasses fed with it.

Because of the high prices of concentrated feeds and the favor with which wet pulp was received by stockmen, many sugar companies have equipped their factories with machinery for drying pulp so that it contains only 8 to 12 per cent moisture. After drying it is placed in 100 pound bags for shipment. The dried form is an excellent feed and is being shipped to dairymen who are far from the factories, thus affording them the advantage of using this material.

Both wet and dried pulp are fed to cattle and sheep as forage or as a part of a grain ration together with alfalfa or other hays.

Molasses. An important product from the refining of beet sugar, as stated before, is molasses. Some of it is placed in the Steffen House from which a third grade sugar is manufactured, and some of it is taken to

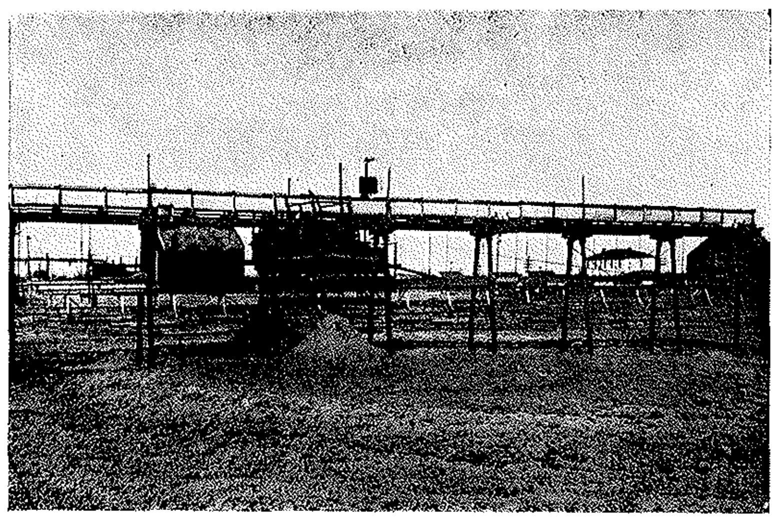


FIG. 34.—Beet pulp in a silo. Thousands of tons of beet pulp are stored until the pulp is fed or taken to the drying plant in a factory. The odor usually informs visitors when they are approaching a beet pulp silo.

the desugarization plant at Johnstown, Colorado, where confectioners sugar is made.

The feeding molasses contains considerable sugar, hence it is valuable either as a feed by itself or when mixed with pulp or other feeds. Molasses is generally added to wet beet pulp for feed.

Dried pulp mixed with molasses is estimated to contain about 92 per cent of the feeding value of corn.

Dried Molasses-Cottonseed Meal Briquets.[1] The latest use of products from the sugar factory is in making dried molasses-cottonseed meal briquets, a new form of feed being made by the Great Western Sugar Company. The material is especially valuable to range producers of sheep and cattle who have long needed an easily handled, health producing winter feed. This feed consists of dried molasses beet pulp, 80 per cent, and cottonseed meal, 20 per cent, or it may contain dried molasses pulp without cottonseed cake, and is molded into the form of briquets. Each is cylindrical in shape, approximately five-eighths of an inch in diameter, and about one-half inch or more in length. This compressed and concentrated combination gives adequate protein constituents, together with all the beneficial properties of dried molasses.

The briquets are heavier than dried pulp, consequently they will not blow away so rapidly as dried pulp. Because of their dark color they can easily be seen on the snow and because they are heavier than dried pulp, they are used for sheep even when snow lies on the ground. Inasmuch as the feed is nutritious, compact, and easily handled and shipped, it fills a need for the stock producer at remote distances from the factories.

Lime Cake. Another product from the factory is lime cake, formed in the sugar refining processes. Many tons of lime cake are made annually. The product may be used for fertilizers, but since most of the soil in western Nebraska contains much calcium carbonate, little lime is needed, hence much of the lime becomes waste. The problem confronting the sugar companies is how to dispose of this waste product.

FACTORY EMPLOYEES

The factory employment is divided into four general classes, administrative, technical service, clerical work, and ordinary labor. The work aside from the management is departmental. The administrative and technical services are largely permanent, clerical service is permanent or temporary, and most of the common labor is temporary and is employed only during the sugar campaign.

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[1] "Dried Molasses Pulp and Cottonseed Meal Combined as Briquets", *Through the Leaves,* January 1932, p. 11.

The division of labor in a factory is made principally on a basis of processes involved in the manufacture and marketing of sugar. Several departmental foremen, assistants, and a moderate number of laborers are necessary.

The sugar companies are equipped for experimental investigation in the raising, marketing, and milling of the beets, and with laboratories in which chemical investigations are made on the sugar content and other qualities of beets. This research and chemical work requires technically trained men.

BEET FIELD LABOR

The sugar beet industry is managed more scientifically than most agricultural enterprises. Its intensive method of production requires much labor and care to make the crop profitable.

Contracts. The growers and the sugar companies enter into contracts in which the farmers agree to raise a definite acreage of beets and to deliver the production at the dumps or at the factory and are paid on a sliding scale, the price depending upon the quality and sugar content of the beets and the general market price of sugar. Because of these contracts the factory management can estimate about how many tons of beets will be available during a campaign, because the yield of beets per acre averages about the same from year to year. The agreements made between the growers and the factories also serve as a basis for adjustments by the Federal Government in which the amount of sugar production is regulated locally and nationally. Other contracts serve as the basis for the wage scale to be paid the field laborers.

There is usually more or less disagreement between the growers and the sugar companies regarding contractual matters. The growers are organized to further their interests in arriving at an equitable agreement with the companies concerning the acreage to be grown, the delivery of beets, and the price to be received per ton.

Fieldmen. The "intermediary" between the farmer and the beet sugar factory is the fieldman who makes the final contracts between the beet growers and manufacturers, assists growers in obtaining seed, advises regarding methods of cultivation, and helps in securing field labor. Thus, the fieldman is one of the principal helpers to both the grower and the factory management. He is the one to whom the farmers turn for advice in the formulation of crop policies, and is the manufacturer's representative whom farmers see most frequently. Through him the company likewise keeps in touch with the growers as to their progress. He is also the man who often gives assistance in settling difficulties between the farmer and the beet laborer. In the irrigated districts where much foreign labor is employed, it often becomes his duty to be the interpreter for the foreign laborer, the grower, and the factory management.

To be successful, a fieldman must know the problems of the farmer, the contract laborer, and the factory manager. He must be versed in the methods and problems of beet raising. A sympathetic attitude on the part of the fieldman often averts trouble among the growers, laborers, and manufacturers. The best fieldman is one who grew up in the beet district and who worked in the field and in the factory. This training also prepares him to become a good factory manager.

Labor. The labor requirements in beet production are heavy. Both skilled and unskilled labor are necessary. Skilled labor includes the work of plowing, planting, cultivating, lifting, and hauling. These operations call for experience and involve the use of machinery. The farmer himself or his laborers perform these operations.

The unskilled labor is mostly hand work, included under four operations: namely, (1) bunching (or blocking) and thinning (sometimes called singling); (2) hoeing; (3) weeding, and (4) pulling, topping, and piling. The laborers are hired by contract. They know what wages they are to receive and what they are required to do. Their work is monotonous and tedious. Thinning forces the worker to crawl along the ground and topping requires him to work in a slightly bent position. The German-Russians usually block beets with long-handled hoes, while the Mexicans and Japanese use short-handled ones, blocking with one hand and thinning with the other. Americans do not like this type of work, hence foreign laborers or those recently naturalized are employed. However, because of economic conditions, the trend now is for the growers and their families to do all or nearly all of the work in beet raising, thereby reducing the requiriments for foreign labor. This has greatly reduced the number of Mexicans employed in the beet districts of Nebraska.

Seasonal Distribution of Labor. Labor in the sugar beet industry is highly seasonal. The work must be done at definite periods, with intervals when there is little or no work. Blocking and thinning must be done rapidly before the beets become too large, so that the young plants, which are to remain, may develop into strong plants as early as possible. At this season of the year, the beet workers average 12 hours a day in the field. The women and children work fewer hours than the men. This is particularly true among the Mexican women and children, who usually do not work so hard as the German-Russian women and children. The working efficiency of German-Russian and Mexican labor is about the same.

The harvesting period requires intensive work on account of the danger of beets freezing in the ground. The average number of hours per day at this season is approximately 10.5. The working day is longer at the opening of the season and becomes shorter as the season advances and the length of daylight decreases.

The wage rate for hand labor varies with the price of beets. When the price of beets was high, $20 or more was paid per acre for the hand labor. Now the rate is considerably less. A small bonus per ton is paid the field workers for large acre yields.

At present, approximately 90 per cent of the beet work in the Great Plains Region is done by families. In Nebraska, the average number of acres worked per family varies from 35 to 40; in Colorado, from 30 to 80. In 1925 Professor Coen, Rural Sociologist of Colorado Agricultural College, found that among 296 labor contract families observed, 16 per cent tended 20 acres or less; 25 per cent tended 21 to 30 acres; 25 per cent tended 21 to 40 acres; 16 per cent tended 40 to 50 acres; and 18 per cent cared for 51 to 80 acres. The average was about 35 acres per family. Another survey, in which 271 families were observed, made in northern Colorado by Sara A. Brown for the National Child Labor Committee, showed an average of 43½ acres per family.

Housing Conditions. The contract laborers live in cottages and "shacks" on the farms where they are employed. The tenant homes vary from neat, well-kept modern cottages of several rooms to small shacks. Most of the beet workers have a garden. Much unfavorable publicity has been issued about the living conditions of the beet workers. Generally the most unfavorable of these are brought to the attention of welfare agencies, whereas the more pleasant features are not necessarily considered.

The German-Russians and Americanized laborers usually maintain better home conditions than do the Mexican and other Spanish-speaking people. They are proud of their gardens and flowers. The Spanish-speaking people usually have patches of potatoes and onions, but they ordinarily do not raise many other vegetables. Some of the Mexican women have lovely flower gardens. On the other hand, numerous beet laborers, both American and foreign, have neither gardens nor flowers, nor do they care how their premises appear. Their main object is to do no more work than that for which they are paid.

The writer visited a number of homes in the beet districts and found that the home equipment was often meager but sufficient. Most of the homes of the laborers visited were clean and quite well kept. It was interesting to note that neatness and cleanliness were common in most of the Mexican homes, a condition contrary to some reports.

Cost of Obtaining Labor. The cost of obtaining labor is high. The system of recruiting and shipping labor is expensive and involved. In 1926 the Great Western Sugar Company provided transportation for 14,500 persons who came by train or auto from eighteen states. To obtain these laborers, fifty-five labor agents were employed, twenty of them worked full time for three months, and thirty-five worked part time. Advertising materials consisting of 8,000 booklets, printed in Spanish were distributed; 1,000 large cardboard posters were displayed; 2,000 hand bills and 5,000 calendars were circulated and advertisements appeared in 15 newspapers. The cost of obtaining a worker in 1920 averaged $28, about 15 per cent of which was spent for soliciting and 85 per cent was used for railroad fares and food enroute.

The extent of the annual shipments of labor into the sugar beet area of the Great Western Sugar Company is shown in Table 13.[1]

TABLE 13.—*Number of Laborers Shipped Annually by the Great Western Sugar Company into its Colorado, Wyoming, Nebraska, and Montana Sugar Beet Territory* [2]

Year	Acres Planted	Laborers Shipped
1915	185,584	500
1916	218,240	1,500
1917	202,880	2,500
1918	159,457	1,500
1919	261,583	9,000
1920	276,550	13,041
1921	246,106	6,703
1922	189,000	4,619
1923	216,408	8,632
1924	270,690	12,043
1925	206,544	2,254
1926	291,797	14,538
1927	296,797	10,576
1928	256,484	4,230
1929	311,345	12,218
1930	294,531	7,560
1931	288,875	7,500

[1] Taylor, Paul S., *Mexican Labor in the United States, Valley of South Platte, Colorado*, University of California Publication in Economics, Vol. 6, No. 2, page 133; Maddux, C. V., (data for 1929, 1930, and 1931) Great Western Sugar Company, Denver, Colorado, Correspondence, July 29, 1931.

[2] Number of equivalent full fares paid; two half-fares paid for children are counted as one fare, or one laborer. Due to variations in methods of keeping records, some discrepancies may exist, but this method of statistical record was generally followed, and the figures given in this table are the best available. Figures for Nebraska alone were not available. Acres planted, instead of acres harvested, are shown in this table because the former determine the demand for labor in the spring when nearly all beet labor is shipped.

If interest in the beet work could be instilled into the minds and feelings of the American people, many unemployed industrial workers could find employment in the beet areas of the United States. However, the American people do not like the tedious work required in the beet districts, but they seem to be satisfied to work day after day in factories. In the past few years many of the Mexican laborers have left the beet districts, fewer German-Russians have been brought in, and some of the Japanese laborers have engaged in other activities. Now the farmers themselves are doing much of the field work, because the low prices which they receive for the beets make the employment of expensive labor prohibitive. As noted before, if this trend continues we may see the growers and their families doing most of the field work in the future.

Child Labor. Attempts have been made repeatedly to create the impression that the beet sugar companies engage in the exploitation of child labor in the beet fields. It is true, that the children do work in the beet fields but they are not employed by the companies.

When the laboring people go to a sugar beet district, they take their families with them and in many cases the families are large. Children of workable age often assist their parents in the beet fields as they do elsewhere in other farm work, where they perform certain tasks in connection with the harvesting and growing of crops on their parents' farm. This experience is more beneficial to the development of the child than is idleness. However, no one who realizes the fitness of things can condone the employment of children in sweat shops, mines, and factories. There is a difference between this character of child labor and that performed by children living on farms and helping their parents in tasks which they are able to perform without injury to themselves. No comparison can be made between the child working in a sweat shop, factory or mine, deprived of sufficient air and sunlight, and the child who helps his parents by working in the fields in the sunshine and fresh air. As a whole, therefore, it seems that the work done in the beet fields by young people is helpful rather than detrimental to their development, that is if it is not too much nor too strenuous.

ECONOMIC RELATIONS OF THE SUGAR BEET INDUSTRY TO OTHER AGRICULTURAL ENTERPRISES

It is interesting to note that even though the prices of sugar and sugar beets have been low at times, and that both the beet farmer and the manufacturer of sugar have had difficulty in maintaining a favorable balance in the cost of production and returns, the acreages and value of the beet crop have not shown the fluctuations that the wheat and corn crops have experienced. One of the influences in maintaining the stability of the sugar beet industry has been the guaranteed minimum price for sugar beets which the sugar beet grower receives by contract from the manufacturers. Since the farmers had a guaranteed price for beets, they could secure financial and labor assistance from the factories and were certain of a market, and could make more intelligent plans than could the grain producers. The farmers producing wheat and corn must depend upon the current market prices for their crops; hence, the variations from year to year in prices and production of these crops, except in cases of subsidization by the government, are greater than in the sugar beet industry.

The economic relations of sugar beets to wheat and alfalfa are quite definitely illustrated by data showing (1) the price of sugar beets per ton and their acreage and (2) the acreage of wheat and alfalfa for the period of 1916-1930 (Table 14). These relations are well shown in Scotts Bluff and Morrill counties in which are large acreages of beets, wheat, and alfalfa.

The three major crops consisting of wheat, sugar beets, and alfalfa are generally grown in rotation in Scotts Bluff and Morrill counties. Wheat and sugar beets are the two principal money or cash crops. Alfalfa provides hay which is fed with beet pulp in fattening sheep and cattle, and it improves the fertility and structure of the soil.

The sugar beet acreage of Scotts Bluff and Morrill counties declined in 1918, although the price of beets reached its maximum, $11.96 per ton. This decline was, no doubt, due to (1) lack of labor supply caused by the war and (2) the increase in wheat acreage. The guaranteed price of wheat in 1917, 1918, and 1919 was approximately $2.00 per bushel. The farmers found that at this price it was more profitable to raise wheat than to raise sugar beets. In 1920, the price and acreage of beets increased while the price and acreage of wheat decreased slightly from 1919, indicating that the high price paid for beets made it more profitable to raise beets than wheat. The unstable financial conditions following the war in the latter part of 1920 and during 1921 caused a drop in the price of sugar beets from $11.96 per ton in 1920 to $6.59 per ton in 1921, equivalent to a reduction of almost 50% from the peak price.

Prior to 1921, the sugar companies had paid the farmers on the basis of sugar content, but in 1921 they changed to a plan whereby the price for beets was determined by the price which the factories received for the finished sugar. Ordinarily the change in production of a farm product follows a year later than the change in price, but that is not so true in the sugar industry where the acreage of beets to be produced is determined in winter by contracts between the sugar companies and growers, and the farmers know just about what price they will receive. This is illustrated by both the decrease in acreage and the lower price coming in the same year, e.g., in 1921 (Table 14).[1]

TABLE 14.—*Data Showing Comparative Acreages and Prices of Principal Crops in the North Platte Valley of Western Nebraska, 1916-1930*

Year	Sugar Beets			Wheat		Alfalfa
	Acreage	Tonnage	Price per Ton	Acreage Scotts Bluff and Morrill Counties	Price per Bushel	Acreage, Scotts Bluff and Morrill Counties
1916....	44,800	404,000	$6.17	26,314	$1.60	41,944
1917....	55,520	444,000	7.22	23,369	1.95	65,075
1918....	36,100	450,000	9.96	51,037	1.97	53,056
1919....	65,000	601,000	10.90	54,697	2.02	50,597
1920....	79,000	718,000	11.96	51,998	1.31	47,432
1921....	72,000	773,000	6.59	60,370	.83	43,776
1922....	55,000	703,000	7.79	72,901	.96	41,636
1923....	60,000	640,000	7.45	43,319	.83	34,782
1924....	64,000	754,000	7.53	41,253	1.22	38,228
1925....	60,000	933,000	5.97	44,386	1.41	49,829
1926....	79,000	923,000	7.88	46,909	1.17	47,109
1927....	82,000	1,036,000	7.96	57,495	1.09	51,038
1928....	86,000	1,021,000	6.98	58,617	.94	45,915
1929....	92,000	1,054,000	7.00	72,991	.99	44,191
1930 .	81,000	1,132,000	7.00	60,500	.53	46,985

Even though there was a decrease in the price of wheat in 1921 and 1922, the per cent of decrease was not so great as in the beet industry; as a result, the farmers planted more wheat. After 1921, the price of beets in general was higher, and with that came an increase in acreage from 1922 until 1925 when the price of beets dropped to $5.97 per ton and the acreage decreased to 60,000. In 1925, the tonnage of beets was 933,000 with an average yield per acre of 15.6 tons, the highest recorded in Nebraska from 1915 to 1930. The price for sugar beets increased to $7.88 per ton in 1926 and was accompanied by an increased acreage to 79,000. The effect of relatively stable prices for beets from 1926 to 1929, when the prices of other farm products were declining, is indicated by the gradual increase in beet acreage until 1929, when a record acreage in Nebraska was harvested. Even though the price of beets was $7.00 in 1930, the problem of adjusting the price by contract in the spring was difficult, because the farmers wanted a higher price than the sugar companies felt they could give, consequently much time was lost in reaching an agree-

[1] Compiled from Yearbooks, United States Department of Agriculture; Annual Reports of the Nebraska Board of Agriculture; Nebraska Agricultural Statistics of the United States Bureau of Crop Estimates at Lincoln; Yearbooks; and reports from sugar companies.

ment. The matter was adjusted so late that the farmers could not plant so large an acreage as they would have done had an agreement been reached sooner.

The surplus of wheat on the market and the low prices of 1921 and 1922 caused the wheat acreage again to decrease in 1923 and 1924. In 1924, the price of wheat rose to $1.22 per bushel, and the acreage in 1925 increased to 44,386 in Scotts Bluff and Morrill counties. The better prices of wheat during the years from 1925 to 1929 were accompanied by increased acreage.

The alfalfa acreage declined steadily from 65,075 in 1917 to 34,782 in 1923, indicating that the farmers were realizing more profits from beets, wheat, and other crops. The acreage of alfalfa increased from 1924 until 1927 when it reached 51,038. With increased acreages of wheat and sugar beets in 1928 and 1929 alfalfa acreages decreased. In 1930, both the wheat and sugar beet acreage decreased, but the alfalfa area was extended.

It is evident, therefore, that sugar beets form an important factor in the stability of agriculture in normal times in the intensive, mixed agricultural scheme in the largest irrigated region in Nebraska. Sugar beets are valuable for the direct cash returns and for the feeding value of their by-products,—beet tops, pulp, and molasses; wheat is one of the principal cash crops and alfalfa is the leading roughage crop.

Cost in Production of Beets. The sugar beet industry is managed in a more business-like manner than most agricultural activities. The cultivation of sugar beets requires a large amount of hand labor, consequently the cost of production is relatively high.

The machinery needed in the industry, as a rule, is quite expensive and is another important item of expenditure. The third large expense is the cost of irrigation. Thus labor, expensive machinery, materials used in manufacture of sugar, and irrigation make the cost of beet sugar production high. Therefore, intensive methods of cultivation must be practiced, and good yields and fair prices must be obtained for the crop in order to make the industry profitable.

Distribution and Costs of Labor. The amount of labor required to grow an acre of beets is approximately ten times greater than that required for the production of an acre of wheat or corn. The cereal crops can be raised largely by the aid of machinery, whereas the growth of sugar beets requires much hand labor.

The man and horse labor per acre in sugar beet production varies according to the location and the methods of production. In Montana, approximately 70.8 horse hours per acre and 31.2 man hours per acre are required. The distribution of man and horse labor as determined by experiments at the Montana experiment station is shown in Table 15.[2] In addition to the processes listed in the table, some farmers disk the land, some roll it before seeding, and some use spring-tooth harrows.

TABLE 15.—*Labor Requirements for Beets, 1924, as Shown by Farm Management Survey*

Man and Horse Labor for Operations Listed

	Times over	Usual Man Hours per Acre for All Times Over	Horse Hours per Acre for All Times Over
Manuring	½ to 1	8.4	24.1
Plowing	1	3.8	16.0
Harrowing	3 to 5	2.4	9.3
Leveling	2 to 3	1.7	6.8
Planting	1	1.1	2.2
Cultivating	4 to 5	5.1	10.2
Spraying	1	1.3	..
Furrowing	1	1.1	2.2
Irrigating	3	6.3	..
Total labor * to raise crop per acre		31.2	70.8

* Lifting and hauling require about 1½ man hours and 4 horse hours per ton of beets.

Aside from the processes of blocking, thinning, weeding, pulling, and topping, the number of man hours per acre is less than one-half the horse hours per acre. Blocking, thinning, hoeing and weeding, and pulling and topping require from 85 to 100 or more man hours per acre.

The price paid for contract hand labor is one of the largest single items of expense in the production of sugar beets. The two highest priced items of hand labor are bunching and thinning, and pulling and topping.

In 1930, the following prices were paid:[3]

For bunching and thinning	$9.00 per acre
For hoeing	2.00 per acre
For weeding or weedings	1.00 per acre
For pulling and topping	11.00 per acre

In 1931 the laborers received $7.00 per acre for blocking and thinning and $9.00 per acre for pulling and topping. According to the 1932 contract, $6.00 per acre was paid for bunching and thinning and 50 cents per ton (net) of beets harvested, with the understanding that no less than $6.00 per acre be paid for pulling and topping.

[2] Bell, E. J., Jr., *Successful Farming and Practices in the Billings Beet Region*, Bozeman, Montana, September 1930, Bulletin No. 232, p. 14.

[3] Data from E. J. Bell.

The annual contract price for hand labor from 1916 to 1932 ranged from $15.00 and bonus per acre in 1932 to $30.00 in 1920 (Table 16).[4]

TABLE 16.—*Annual Contract Price Paid for Hand Labor from 1916 to 1932*

Year	Amount Received per Acre for Hand Labor
1916	$19
1917	22
1918	25
1919	25
1920	30
1921	22
1922	18
1923	22
1924	* 25 and $20.00
1925	** 24 and bonus
1926	** 26 and bonus
1927	** 24 and bonus
1928	** 23 and bonus
1929	** 23 and bonus
1930	** 23 and bonus
1931	*** 19 and bonus
1932	** 15 and bonus

* In 1924 the laborers were given an option. They either worked for $25 per acre and paid their own transportation to the place they obtained employment or they worked for $20 and the sugar company paid for their transportation. In either case the cost to the farm operator was $25 per acre.
** A bonus of 50 cents per ton above 12 tons per acre.
***A bonus of 50 cents per ton above 13 tons per acre.

One of the most authentic and carefully prepared reports on the costs of producing beets in the United States is "Costs of Producing Sugar Beets", United States Tariff Commission, 1928, Washington, D. C. Part III summarizes the work which was done in Nebraska. Nine states were considered in this report.

The following report is based on the summary in part X of the above series.[5]

According to the Yearbook issued by the United States Department of Agriculture, the farmers in Nebraska received the following prices per ton during the interim from 1921 to 1923; 1921, $6.59; 1922, $7.79; and 1923, $7.45. The cost per acre of producing sugar beets varied from $77.88 to $116.95. The farmers received a loss of $5.06 from the beets in 1921, a profit of $38.32 in 1922, and a profit of $17.43 in 1923.

[4] Paid by the Great Western Sugar Company, Headquarters, Denver, Colorado.
[5] *Costs of Producing Sugar Beets,* United States Tariff Commission, 1928, Washington, D. C.

TABLE 17.—*Analysis of the Weighted Average Costs of Producing Sugar Beets in Nebraska Three-year Average—1921-1923 (Per Acre)*

	Average	1921	1922	1923
Labor (machine, cintract, horse, and tractor)	$50.89	$51.30	$48.71	$52.46
Seed	3.34	3.62	3.62	2.72
Equipment	4.45	4.45	4.45	4.45
Irrigation	2.31	2.31	2.31	2.31
Manure	4.62	4.62	4.62	4.62
Total	$65.61	$66.30	$63.71	$66.56
Other items—Direct cost, general cost and taxes	4.52	4.52	4.52	4.52
Gross costs excluding capital charges	$70.13	$70.82	$68.23	$71.08
Net Cost including capital charges	80.98	82.94	78.63	80.77
Average returns to farmers from sale of sugar beets	95.87	77.88	116.95	98.20
Amount by which the average returns to growers exceed the average costs of production of sugar beets:				
(1) No allowance made for land rental and interest on other capital employed in sugar beet production	29.43	10.75	52.41	30.81
(2) After allowance was made for the above	14.89	–5.06	38.32	17.43

Statistics in the same table, in summary, Part X, Tariff Commission Report showed that during the year when the loss of money per acre in Nebraska was $5.06, it was $23.10 in Michigan; $32.77 in Utah; $27.28 in Idaho; $15.88 in Wyoming; $4.25 in Montana; $26.11 in California; but there was a profit of $6.90 in Colorado.

TABLE 18.—*The Amount by Which the Average Returns to Growers Exceeds the Average Costs of Production of Sugar Beets in Nine States Based on the Average per Acre from 1921-1923* [6]

State	No Allowance Made for Land Rental and Interest on other Capital Employed	After Allowance Was Made for Land Rental, etc.
United States	$17.09	$1.90
Michigan	2.98	–8.02*
Ohio	14.74	3.31
Nebraska	29.43	14.89
Colorado	18.75	2.75
Utah	15.37	–2.42
Idaho	24.27	8.10
Wyoming	11.02	.91
Montana	32.55	20.91
California	21.76	2.09

[6] *Idem.*
* – Represents loss.

The data show quite conclusively that there are usually profits, but also that losses and small profits may be expected.

Burdick, R. T., and Pingrey, H. B., of the Colorado Agricultural College, Fort Collins, have prepared an excellent report entitled "Cost of Producing Crops on Irrigated Farms", Bulletin 353, Colorado Experiment Station, 1929.

Another item that must be considered is that of tariff on sugar. Beet sugar cannot be produced so cheaply as cane sugar, because cane does not require so much expensive labor, nor such high priced land, nor so much care in its growth as does the beet. The sugar beet industry, therefore, in order to be profitable must be protected by a tariff. One of the main economic factors in the success of the industry is the maintenance of a protective tariff. Whether or not that is justice to the American people is a matter of opinion, but it is certain that the extension of the American beet industry is dependent on the tariff on sugar or by some kind of subsidization.

Besides the direct cash income from the sale of sugar beets, the farmer profits by feeding beet tops and beet pulp to cattle and sheep. Higher yields of wheat, alfalfa, and other crops result when beets are used in crop rotation.

VALUE OF SUGAR BEETS IN CROP ROTATION

The value of sugar beets in crop rotation in the United States was not known until recently. While it was generally known that American farmers were not securing maximum yields from various crops, the total yields were more than sufficient to supply the American people, and that condition seemed to be entirely satisfactory. The World War brought a change; a serious problem confronted the American people at this time, because the supply of grains and other agricultural products was exceedingly low, consequently the prices of all food commodities were excessively high. Government officials were pleading with the farmers to use every effort to increase the yields on their lands in order to prevent a further shortage of food supplies. Among other things the government recommended increased production through the rotation of crops. In contrast to this policy the farmers are now paid temporarily not to plant certain areas in order to restrict agricultural production.

The United States Department of Agriculture pointed out many advantages of sugar beet culture and urged farmers to engage in it. In contrast, various agricultural weeklies advised their readers that whatever might be the tonnage per acre and the price of beets per ton, they could not afford to raise them because the yields of other crops following beets would decrease.

Although the work of Cato, Pliny, and other ancient writers state that root crop rotation was practiced two thousand years ago, Great Britain was the first country in modern times to introduce a root crop, the turnip, in rotation with cereal crops as a means of increasing the yield of the latter. Since then, the introduction of sugar beets in crop rotation shows that they are valuable in three particular ways; (1) the soil after sugar beets is in good tilth for other crops, because the beets require deep plowing and careful preparation of the seed bed followed by cultivation and hoeing; (2) passages for air and water are increased when roots decay thus providing excellent aeration and increasing the water-holding capacity of the soils; and (3) the decomposition of numerous fibrous roots adds humus to the soil.

Inasmuch as the value of crop rotation is so well known, it is sufficient for this study to present a brief summary of the effects of rotation upon the yield of sugar beets and other crops grown in rotation with them.

Mr. James A. Holden, in charge of the Scottsbluff Agricultural Field Station, north of Scottsbluff, Nebraska, conducted many experiments from 1912 to 1925 to determine the yields of different crops grown in rotation under irrigation. His experiments show that sugar beets grown continuously on the same land or in short rotations with oats or wheat produced the lowest yields. The lowest acreage yield of sugar beets was 9.26 tons per acre where beets were grown continuously. Rotation with

TABLE 19.—*Yields of Sugar Beets in Irrigated Rotations at the Scottsbluff Field Station, Mean 1912-1925*

Rotation	Acre Yields (tons) Mean, 14 years
Sugar beets grown continuously	9.26
Two-year rotations	
Spring wheat, sugar beets	11.61
Sugar beets, potatoes	11.88
Sugar beets, potatoes (manured)	16.42
Oats, sugar beets	11.30
Oats, sugar beets (manured)	18.19
Three-year rotations	
Potatoes, oats, sugar beets	11.66
Potatoes, oats, sugar beets (manured)	17.85
Corn, oats, sugar beets	11.34
Four-year rotations	
Alfalfa (2 years), potatoes, sugar beets	18.01
Alfalfa (2 years), oats, sugar beets	15.87
Six-year rotations	
Alfalfa (3 years), potatoes, oats, sugar beets	15.08
Alfalfa (3 years), potatoes, oats, sugar beets (manured)	19.86
Alfalfa (3 years), corn, oats, sugar beets	14.68

cereals produced yields of 11.3 to 11.6 tons of beets per acre. Fields which included manure in rotation showed yields of 16.4 to 19.86 tons per acre (Table 19).[1]

The sugar content in beets grown after a fairly heavy application of manure is generally lower than when manure is not used. From 1912 to 1920 inclusive, six plots in the rotation field at Longmont, Colorado, were devoted to beets. Manure was added to three of the plots each year, while the other three were not fertilized. The per cent of sugar was higher each year in the non-manured fields, but the yields of beets and the production of sugar were higher in the manured fields (Table 20).[2]

TABLE 20.—*Sugar Content, Yield of Beets and Sugar Per Acre on Land Treated and Not Treated with Manure at Longmont, Colorado, 1912-1920 Average*

	Per cent Sugar			Yield per Acre (tons)			Sugar per Acre (lbs.)		
	I [1]	II [2]	Diff.[3]	I	II	Diff.	I	II	Diff.
1912	15.10	12.76	-2.34	13.21	16.50	3.29	3.989	4,211	222
1913	15.23	11.34	-2.89	12.90	15.56	2.66	3.671	3.529	-42
1914	16.24	14.51	-1.73	16.69	23.62	6.93	5.421	6.855	1434
1915	17.74	16.27	-1.47	14.47	18.45	3.98	5.134	6.004	860
1916	15.07	14.66	- .41	14.79	18.50	3.71	4.430	5.422	992
1917	17.08	15.06	-2.02	12.36	15.98	3.62	4.214	4.804	790
1918	16.96	14.91	-2.05	12.33	17.00	4.67	4.181	5.074	893
1919	14.34	12.53	-1.81	11.93	12.21	.28	3.421	3.060	-361
1920	17.40	15.70	-1.70	11.90	17.40	5.50	4.126	5.456	1330
Aver.	16.01	14.19	-1.82	13.40	17.25	3.85	4.287	4.935	648

[1] Land not treated with manure.
[2] Land treated with manure.
[3] A minus sign indicates that the beets produced in the manure treated ground contain less per cent sugar than the ones grown in non-manured soil.

Though the average per cent of sugar was 1.82 more in the beets grown in the non-manured fields, the increased average of 3.85 tons of beets per acre on the manured fields produced 648 pounds of sugar more per acre. When the farmer receives a stipulated price per ton of beets the higher yield is an advantage to him. The sugar companies, however, prefer beets with higher sugar content, because from them more sugar can be obtained with less expense.

Excellent yields were obtained from most crops when grown in rotations following sugar beets at the Scottsbluff Experiment Station.

[1] Scofield, Carl S., and Holden, James A., *Irrigated Crop Rotations in Western Nebraska*, Technical Bulletin, No. 2, United States Department of Agriculture, July 1927, p. 8.
[2] Maxson, Asa, Research Agriculturist, Great Western Sugar Company, *Personal Notes*, 1928.

Oats. Sugar beets, potatoes, and manure are essential to high yields of oats according to experiments made at the Scottsbluff station (Table 21).[3] The lowest average yield 44.3 bushels of oats per acre was in fields where oats had been grown continuously, or where they followed cereal crops. The yield per acre increased with the variety of crops in the rotation. That manure, sugar beets, potatoes, and alfalfa influence the yield of oats is shown by the gradual increase in yields as they were added to the rotations. The highest average yield of oats during the period, 1912-1925, was 75.9 bushels per acre in the rotation which included alfalfa (3 years), potatoes, sugar beets, and manure. The yield in rotations containing potatoes or sugar beets but no manure averaged 61.5 bushels, while the yield of oats in rotations containing neither alfalfa nor manure averaged 51.2 bushels. All rotations including manure averaged 69.3 bushels per acre.[4]

TABLE 21.—*Yields of Oats in Irrigated Rotations at the Scottsbluff Field Station, Mean 1912-1925*

Rotation	Acre Yields (bushels) Mean, 14 years
Oats grown continuously	46.6
Two year rotations	
Corn, Oats	48.6
Oats, sugar beets	54.1
Oats, sugar beets (manured)	65.1
Oats, potatoes	55.3
Oats, potatoes (manured)	62.7
Oats, (followed by rye plowed under), potatoes	62.3
Spring wheat, oats	44.3
Three-year rotations	
Potatoes, oats, sugar beets	59.0
Potatoes, oats, sugar beets (manured)	73.4
Corn, oats, sugar beets	46.9
Four-year rotations	
Alfalfa (2 years), oats, sugar beets	69.7
Alfalfa (2 years), potatoes, oats	72.2
Alfalfa (2 years), spring wheat, oats	67.5
Six-year rotations	
Alfalfa (3 years), potatoes, oats, sugar beets	71.5
Alfalfa (3 years), potatoes, oats, sugar beets (manured)	75.9
Alfalfa (3 years), corn, oats, sugar beets	63.7

Alfalfa. This crop generally produced the highest yields when potatoes, sugar beets, and manure were used in the rotations. Alfalfa grown in one rotation at the Scottsbluff Experiment Station which consisted of only spring wheat, oats, and alfalfa, yielded 3.88 tons per acre (Table 22).[5]

[3] Data compiled from statistics in Table 20.
[4] Scofield, Carl S., and Holden, James A., *op. cit.*, p. 7.
[5] Scofield Carl S., and Holden, James A., *op. cit.*, p. 11.

In contrast, the fields on which rotations containing potatoes, sugar beets, and some fields with manure yielded from 4.47 tons to 5.25 tons of alfalfa per acre (Table 22).

TABLE 22.—*Yields of Alfalfa in Irrigated Rotations at the Scottsbluff Field Station, Mean 1912-1925*

Rotation	Acre Yields (tons) Mean, 14 years
Alfalfa grown continuously	4.98
Four-year rotations	
Alfalfa (2 years), potatoes, sugar beets	4.53
Alfalfa (2 years), potatoes, oats	4.43
Alfalfa (2 years), spring wheat, oats	3.88
Six-year rotations	
Alfalfa (3 years), potatoes, oats, sugar beets	4.47
Alfalfa (3 years), potatoes, oats, sugar beets, (manured)	5.47
Alfalfa (3 years), corn, oats, sugar beets	4.50
Alfalfa (3 years), corn, oats, sugar beets, (manured)	9.58

Although alfalfa yields are not influenced so much by crop rotation as some crops are, it is a factor in improving the yields of alfalfa.

Beets following Alfalfa. Tests in various experiments and on numerous farms invariably show that beets grown after alfalfa or sweet clover are usually high in nitrogenous compounds, low in the per cent of sugar, and are immature at harvest. These conditions tend to increase the cost of storage, and to cause losses in refining. It is, therefore, advisable to raise some other crop, preferably an intertilled crop, such as corn or potatoes, following alfalfa before planting beets.

Potatoes. Potatoes do not show the increase in yield following sugar beets that some crops do because they are a root crop. Potatoes grown continuously produced only 100 bushels per acre (Table 23).[6] The highest yields of potatoes per acre ranged from 233 to 392 bushels. These yields were grown in rotation which contained alfalfa or manure or both. Yields of potatoes may, therefore, be increased by proper fertilizing and crop rotation.

Fertilizers. Manure is the principal fertilizer used in the beet areas. In recent years, the farmers have started the practice of using commercial fertilizers, especially those containing phosphates. Tests show that more than 50 per cent of the beet soils are deficient in phosphorus. The fields on which phosphate fertilizer is used usually yield from 2 to 10 or more tons per acre than the ones that have not been treated with this fertilizer. As a result of the increased yield of beets on the treated fields, the farmers are extending the use of phosphates in the beet areas.

[6] Scofield, Carl S., and Holden, James, *op. cit.*, p. 9.

TABLE 23.—*Average Yields of Potatoes in Irrigated Rotations at the Scottsbluff Field Station, Mean 1912-1925*

Rotation	Acre Yields (bushels) Mean, 14 years
Potatoes grown continuously	100.2
Two-year rotations	
Sugar beets, potatoes	150.0
Sugar beets, potatoes, with manure fertilizers	209.7
Oats, potatoes	160.4
Oats, potatoes, with manure fertilizer	228.7
Potatoes, corn	145.8
Oats, (followed by rye plowed under), potatoes	186.2
Three-year rotations	
Potatoes, oats, sugar beets	183.9
Potatoes, oats, sugar beets, with manure fertilizer	233.2
Four-year rotations	
Alfalfa (2 years), potatoes, sugar beets	276.4
Alfalfa (2 years), potatoes, oats	275.0
Six-year rotations	
Alfalfa (3 years), potatoes, oats, sugar beets	283.8
Alfalfa (3 years), potatoes, oats, sugar beets, with manure fertilizer	392.6

The other mineral nutrients and elements such as potassium, calcium, and nitrogen, are generally sufficient in the soil. They are usually quite easily maintained if the farmers add barnyard manure, or plow under growing crops to form green manure, and if they add a legume crop such as clover or alfalfa in the rotation of crops.

The effects of the work which has been done by experiment stations under the direction of the Bureau of Plant Industry and the sugar manufacturing companies are indicated by the general increase in the yield of beets per acre. Results of the experiments have been used by the sugar companies and their fieldmen to convince the farmers that suitable preparation of seed beds, careful cultivation, proper rotation of crops, and the use of essential fertilizers are necessary to obtain increased yields of beets.

Per acre Yield of Beets, 1919-1930. That soil control and proper methods of cultivation and rotation have increased the yield of beets per acre is evident from the yields in all of the territory served by the Great Western Sugar Company in Colorado, Nebraska, Wyoming, and Montana since the World War (Figure 23).[7] The yield per acre averaged 9.84 tons in 1919 and 14.25 tons in 1930. The average yield for the first six years, 1919 to 1924, was 11.2 tons per acre, whereas the average yield from 1925 to 1930 was 13.3 or 2.1 tons more per acre. The average yield from 1925 to 1933 was 13.1 tons per acre or 13 per cent higher than that from 1919 to 1924. The lowest yield, 12.22 tons, during the last nine years was

[7] *Through the Leaves*, March 1931, pp. 80-81.

higher than the highest yield, 12.19 tons, during the first six years. Inasmuch as the yield of beets per acre has increased since most of the experimental work was done at Longmont and Scottsbluff, it is evident that the advice given by the sugar companies has been accepted by the farmers, and that the farmers by cooperating with the sugar companies have aided materially in increasing the yield of beets per acre in the Great Plains.

THE TARIFF IN RELATION TO THE SUGAR BEET INDUSTRY IN THE UNITED STATES

Although geographic conditions in many regions in the United States are favorable for extended acreages of sugar beets, the financial success of the beet sugar industry is affected greatly by protective tariff on sugar imported from foreign countries where labor is cheap and abundant.

Tariff Acts. Refined sugar in the United States has always been subject to a higher duty than raw sugar, thus affording it a net protection. The first governmental act imposing tariff on sugar was passed July 4, 1789, which placed a duty of one cent per pound on raw sugars and three cents on refined.[1] In 1790, the first protective tariff was levied when the duty on refined sugar was increased from three to five cents per pound while the increase on raw sugar was only one-half cent. In the early duty acts various terms were used to designate different grades of sugars, such as white, clayed or powdered, refined, loaf, lump, and crushed or pulverized. The rate of duty was determined by these forms and their trade names.

Standard Tests. In the act of August 5, 1861, the so-called Dutch Standard of Color Test, a more scientific method of sugar classification, was inaugurated. In accordance with this act, the different grades of sugar were judged by color; the darker the color, the lower the grade of sugar. The term "Dutch Standard" originated from the use of graded samples for making comparisons. The samples were prepared by two Dutch firms and were generally accepted as standard by merchants and customhouse officials throughout the world.

On March 3, 1883, the polariscope test in combination with the Dutch Standard of Color test was adopted in the Morrill Bill. The last tariff act to use the Dutch Standard of Color test was the Payne-Aldrich Bill which was passed on August 5, 1909. The first bill to place duty on sugar by the polariscope method entirely was the Underwood-Simmons Bill passed October 31, 1912.

In order to make a comprehensive study of the effects of the tariff upon the industry in the United States, it would be necessary not only to study the influences of import duty on prices and importation of sugar, both raw and refined, but also how the duties upon sugar-syrup and molasses affect the industry.

The relation of the tariff to the growth of the sugar industry in the United States is a complicated problem and is almost purely one of economics; therefore a detailed study of it will not be made here.

[1] Vogt, Paul L., *The Sugar Refining Industry in the United States*, University of Pennsylvania, Philadelphia, Pennsylvania, 1908, p. 19.

From the time the first duty acts on sugar were passed to the present, the tariff on sugar has been an issue in nearly all national campaigns.

Tariff Evasion. Instances are recorded where water was added to raw sugar in order to bring the sugar into the country as a syrup without the payment of duty. This treatment was practical for the refiner, inasmuch as water must be added in the first step of refining. The government stopped this practice by placing a high duty on cane syrup. The next method used to evade the payment of duty on sugar by some refiners was to boil the cane juices until they became a thick molasses which was imported. The result was a higher duty on molasses.

Tariff Rates. Because the United States is usually alluded to as a country having a high tariff, an impression prevails among many people that the rates of duty on sugar are above the rates prevailing in other countries. A glance at the following table demonstrates the contrary (Table 24).

TABLE 24.—*Cents Per Pound at Exchange Rates on September 1, 1928*

	Import Duty on 100° Raw Sugar or Equivalent Cost per lb.		Import Duty on 96° Raw Sugar or Equivalent Cost per lb.
Brazil	17.610	Brazil	17.610
Salvador	15.876	Salvador	15.876
Peru	9.428	Guatemala	9.803
Greece	5.723	Peru	9.428
Belgium	5.047	Turkey	7.562
Guatemala	4.902	Costa Rica	7.074
Spain	4.822	Venezuela	6.566
Poland	4.572	Greece	5.723
Czechoslovakia	4.538	Poland	5.080
Turkey	4.478	Belgium	5.047
Costa Rica	3.773	Spain	4.822
Norway	3.703	Czechoslovaki	4.538
Honduras	3.587	Newfoundland	4.500
Rumania	2.914	Rumania	4.432
Finland	2.892	Russia	4.194
Uruguay	2.722	Norway	3.703
Paraguay	2.608	Honduras	3.587
Argentina	2.462	Argentina	3.427
Russia	2.330	Paraguay	3.260
Germany	2.270	Dominica	3.219
Irish Free State	2.270	Finland	3.204
Venezuela	2.189	Australia	3.016
Australia	2.022	Uruguay	2.786
Newfoundland	2.000	Germany	2.700
Bulgaria	1.962	Colombia	2.592
Hungary	1.816	Irish Free State	2.535
United Kingdom (plus bounty)	1.811	United Kingdom (plus bounty)	2.527
Canada	1.770	Bulgaria	2.403
United States (Cuban rate)	1.765	Italy	2.167
		Austria	2.002
		United States (Cuban rate)	1.912

Late Efforts to Stabilize the Price and Production of Sugar. During the World War, the European beet sugar supply was curtailed, consequently some countries which had not produced much cane or beet sugar developed a successful sugar industry. Among these were the United States, Brazil, and Peru. Cuba, Java, Hawaii, and Porto Rico increased their acreages of cane and the production of sugar. The result was a tremendous increase in sugar supply. After the World War, the German and Czechoslovakian beet industries again became important. The countries that had increased or developed the sugar industries during the war continued to produce large quantities of sugar. The result was an oversupply of sugar on the world market. The world production of cane and beet sugar in 1930-31 was 31,858,000 tons. This was 3.9 per cent more than the previous record crop of 30,655,000 tons in 1928-29. Approximately one and a half million tons of sugar were on hand in 15 countries at the beginning of 1930-31. The rate of consumption of sugar did not increase rapidly enough to use the additional supply of sugar consequently a general decline in prices occurred. The problem of equalizing the supply and demand thus confronted the sugar growers and manufacturers. The large yield of sugar in 1930-31, the record world surplus sugar stocks, a check in the upward trend in the world sugar consumption, and the unusually low prices for raw sugar were important factors in the establishment of an international sugar agreement known as the Chadbourne Sugar Stabilization Plan.

The Chadbourne Stabilization Plan.[1] This plan was officially inaugurated in May, 1931, when the main points of its program were decided and a full agreement was reached between the countries involved; namely, Cuba, Java, Germany, Czechoslovakia, Poland, Belgium, and Hungary, the world's most important sugar producers and exporters.

The plan, which is to be in force for five years beginning with the 1930-31 sugar year, is an effort to bring about an equilibrium between the supply and demand for sugar, by restricting the annual exports in each of the leading sugar producing countries and by segregating surplus sugar stocks from the market for gradual release in equal installments over a period of five years. In addition Java and Cuba are to restrict sugar production during these years. While nothing definite was said in regard to restrictive measures in countries outside of the Chadbourne Plan, each country will need to place some limitation on production in order to avoid the accumulation of surplus stocks. The sugar to be segregated has been definitely determined for Cuba and Java, Cuba to segregate

[1] *Foreign Crops and Markets,* Bureau of Agricultural Economics, United States Department of Agriculture, Washington, D. C., Vol. 22, No. 20, May 18, 1931; pp. 682-684.

1,456,000 short tons and Java, 551,000 short tons. It was estimated that the European countries would have to segregate about 861,000 short tons.

Export quotas will be permitted to increase provided the price for sugar reaches two cents and above per pound, f.o.b. Cuba, and remains there for a period of 30 days. With an increase to two cents per pound the quotas will be automatically increased by five per cent. With a Cuban price of 2¼ cents per pound f.o.b. Cuba, an additional 2½ per cent of the quotas will be permitted at the discretion of the commission. In the event prices advance to 2½ cents per pound, an additional five per cent of the export quotas, including the 2½ per cent given in the second case above, must be released for export.

The International Sugar Council, located at The Hague, is the permanent council to administer the working of the plan. Four regular meetings are to be held annually and especial meetings are to be called at the request of two or more nations or by the chairman.

In the case of Java, the necessary legislation was passed requiring licensing of exports, and an embargo was placed on unlicensed sugar exports. The period for which the Javan law is effective has not been specified.

The votes according to the Chadbourne plan are distributed as follows: Cuba, 25; Java, 30; and the European countries, 25. A total of 55 votes are necessary for effectiveness on measures before the council.

Needless to say, the sugar beet growers not only of the United States but of the world felt that the price of sugar had decreased to almost unbelievable lows. The yearly average price on raw sugar has decreased from an annual average of 12.06 cents per pound in 1920 to an average of 1.32 cents for the first nine months in 1931.[2] This plan gave the sugar producers new assurance that the price of sugar would be reasonable.

Present Conditions. The tariff on sugar has been lowered. The sugar beet industry in the United States is receiving compensation from the Agricultural Adjustment Administration Board at Washington, D. C. These payments are based on processing taxes on sugar and are similar to those paid to other agricultural industries.

Although thousands of acres of land in the United States are geographically suited to beet cultivation, the economic success of the industry is dependent largely upon the stability of a reasonably high price for sugar. Since the industry requires much hand labor and expensive methods of cultivation, the cost of production is so high that beet sugar in the United States cannot compete with cane sugar from foreign countries without a protective tariff.

[2] *Sugar Index*, August 4, 1931, p. 122.

THE DEVELOPMENT OF THE NORTH PLATTE VALLEY AS A RESULT OF IRRIGATION AND INTRODUCTION OF SUGAR BEETS

CULTURAL FEATURES

The cultural features in the Great Plains beet region have developed remarkably since the introduction of irrigation and the sugar beet. Instead of being a region of prairies and grazing lands, it is now dotted with towns, farms, and cities connected by good lines of communication. The towns and cities are equipped with electric lights, efficient water systems, and other modern civic developments. Modern machinery and automobiles are part of all farm equipment. Nearly all of the contract beet laborers own cars; many of the workers commute either daily or weekly between their homes in the towns and the farms on which they work. The people in towns and rural communities are in constant touch with current affairs in the world and with each other by radio, telephone, and rural mail delivery. Since the development in the North Platte valley is typical of that in other sections of the Great Plains beet areas, it will be used as a type for this study.

Changes in Density of Population. The density of population in Scotts Bluff County increased 147.9 per cent from 1910 to 1920 and 38.3 per cent from 1920 to 1930; in Morrill County, 99.6 and 8.7 per cent respectively. The average increase in population in Scotts Bluff and Morrill counties was 123.75 per cent from 1910 to 1920 as contrasted with 8.7 per cent for the state as a whole, and 23.5 per cent average increase in Scotts Bluff and Morrill counties from 1920 to 1930 and 6.3 per cent for the state (Table 25).[1]

TABLE 25.—*Population Changes in Typical Beet Producing Counties in Nebraska Compared to Changes in the State as a Whole 1910 to 1930*

Unit	Population	Population	Per cent Increase	Population	Per cent Increase
	1910	1920	1910-20	1930	1920-30
Scotts Bluff County...	8,355	20,710	147.9	28,644	38.3
Morrill County	4,584	9,151	99.6	9,950	8.7
Average	6,469	14,931	123.75	19,297	23.5
Nebraska, State	1,192,214	1,298,372	8.7	1,377,963	6.3

The difference in the distribution of population between the beet areas of the North Platte Valley and the surrounding territory is significant

[1] Bureau of Census Reports, *Population*, Washington, D. C., 1930.

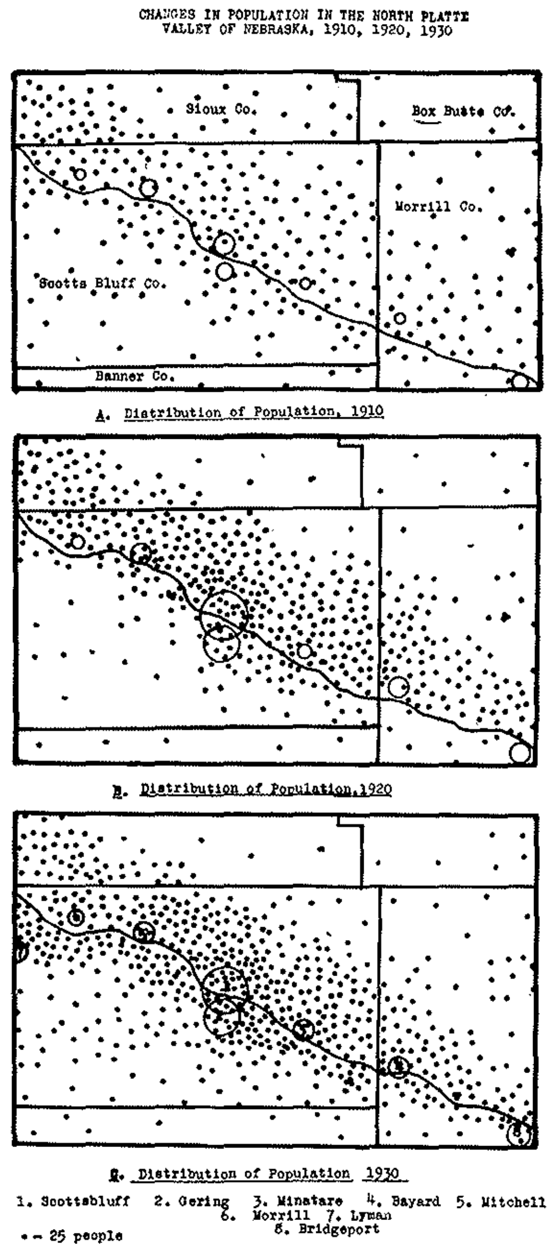

FIG. 35.—Changes in Population in the North Platte Valley of Nebraska, 1910, 1920, 1930.

(Figure 35). In 1910, the major portion of the people lived on the north side of the North Platte River. The Great Western Sugar factory at Scottsbluff was the only factory in the valley. In 1920, the density of population had increased greatly north of the river, because more land had been opened to irrigation, and three additional sugar factories had been erected; namely, at Gering, Bayard, and Mitchell. From 1920 to 1930, the population north of the river continued to increase. Because of new irrigation projects, many people had settled on the south side of the North Platte River. Beet sugar factories were erected at Mitchell, Minatare, and Lyman between 1920 and 1930. The cities and towns in which sugar factories are located have had steady increases in population. The changes in population in some of the principal towns in the North Platte Valley of Nebraska are indicated in Table 26.[2]

Table 26.—*Changes in Population in Some of the Principal Towns in the North Platte Valley of Nebraska*

Town	1910	1920	1930
Scottsbluff	1,746	6,912	8,465
Gering	627	2,508	2,531
Mitchell	640	1,298	2,058
Bayard	261	2,127	1,559
Bridgeport	541	1,235	1,421
Minatare	338	660	1,079
Lyman	....	....	656

The density of population in the counties growing sugar beets in Nebraska manifested the greatest increase in population from 1910 to 1920, the period of most extensive development in the beet industry and the establishment of other agricultural enterprises in a new farming region (Table 27).

Table 27.[3]—*Acreage of Beets in Two Leading Beet Producing Counties in Nebraska 1910 to 1930*

County	1910	1920	1930
Scotts Bluff	2,219	33,076	50,796
Morrill	2	9,253	12,657
Average	1,110	21,165	31,726

Under normal conditions an increase in population in the beet regions in the future may be expected, but the increase probably will not be nearly so great as it was from 1910 to 1930. The population has become

[2] *Idem.*
[3] Bureau of Census Reports, *Agriculture*, Washington, D. C., 1930.

established because the beet industry has been established and is not expanding to any great extent. However, should the prices of beets decrease so much that the farmers cannot afford to raise them, the sugar industry will decline, and many people will leave the regions because of lack of work. On the contrary, if economic conditions should improve so as to demand an increased supply of American beet sugar, a larger acreage would be planted and consequently an increased number of workers in the beet region would be required. The latter would be possible only by a favorable tariff, federal assistance for the industry, and availability of land. The latter is not a large problem because much land in the North Platte Valley can be used for the growth of beets which is now given to other crops.

Educational Facilities. The educational problem concerning the beet workers' children is one which commands consideration. The children lose considerable school time because they must leave school before the completion of the spring term in order to assist in thinning, and they return to school after the session begins, because of the beet harvest. The interruptions retard them, and other members of the school are also delayed in their work when late pupils arrive. To remedy this situation, summer or vacation schools have been established for the beet workers' children. They begin about seven weeks prior to the usual opening of school in September. The term is usually six weeks in length, the period between the thinning and the harvesting seasons. The beet workers' children must either attend these schools during the summer and return to the regular school in the autumn after harvest, or they must begin school in the autumn at the opening of the regular session.

The attitude of both parents and children towards education has changed. Now children generally do not wish to leave school until they have completed the eighth grade, and many of them enter high school; some attend college. Superintendent Nelson of Gering, Nebraska, states that some of the beet workers' children are among the best students, musicians, and athletes in his school and that the children of foreign parentage are rapidly becoming Americanized.

Health of Children. The question concerning the physical condition of children who work in the beet fields as compared with the non-beet workers has often been raised. The following extract and table of vital statistics from the report of the school nurse at Scottsbluff give a direct answer to this question:

> "We have three elementary schools in which approximately 10 per cent of the children are beet workers. We have two schools in which 70 per cent of the children are beet workers and we have three schools in which 90 per cent of the children are beet work-

ers. We will group these schools according to the per cent of beet workers and designate them as A, B, and C. The following figures show that considering all types of defects there is very little difference between beet workers and non-workers; what advantage there is, being in favor of the beet workers as shown by the smaller per cent of defectives in the school with 70 per cent of beet workers. The percentages of defective eyes, ears, nose, and throat are decidedly in favor of the beet workers; defective teeth slightly to the disadvantage of the beet workers; all figures pertaining to weight decidedly in favor of the beet workers." (Table 28).[4]

TABLE 28.—*Vital Statistics of School Children at Scottsbluff, Nebraska*

	Per cent of children in school who are beet workers		
	A 10	B 70	C 90
Enrollment	569	698	290
Normal children	45 %	57 %	45 %
Defectives showing any of the defects named below	55 %	43 %	55 %
Eyes	13 %	6 %	4.4%
Ears	3.3%	1 %	1.4%
Nose and throat	19 %	11 %	13 %
Teeth	34 %	33 %	42 %
Standard Weight	50 %	63 %	76 %
Below standard, yet normal	33 %	24 %	14 %
Below standard, more than 10% below normal	2.3%	4 %	1.5%
Above standard	10 %	8 %	8.6%
Above normal, more than 10% above standard	3 %	2.5%	0.6%

The grammar schools in both country and city are quite well standardized. One-room schools and many two-room schools are found in the rural districts. The children generally do not travel long distances to school, as practically all areas in the sugar beet districts are fairly densely populated. The instruction in the rural schools of the beet areas is the same as that given in other country districts.

All of the cities and towns of the Great Plains beet region have good high schools, many of them being four-year accredited high schools. The junior high school is common in the region.

Near this region, excellent universities, teachers colleges, and agricultural colleges furnish facilities for higher education. A number of students go to more remote educational institutions. Among the best schools serving this region are the universities of Colorado, Nebraska, Wyoming, the Agricultural College at Fort Collins, Colorado, and the State Teachers College at Greeley, Colorado. At most of these schools, special attention

[4] Report from Superintendent E. L. Rouse, Scottsbluff Public Schools.

is given not only to general instruction but also to research and experimental work in the sugar beet industry. The Fort Collins Agricultural College and State Teachers College at Greeley, particularly, and various agricultural experiment stations, are devoting much time and study to the improvement of the sugar beet.

In some of the Mexican and German-Russian community centers, Americanization and English language courses are taught. Many of these classes are well attended by the beet workers.

Conclusion. In conclusion, it may be stated that beet raising and community welfare are closely related. The introduction of sugar beets into the agriculture of a region adds a type of stability to agriculture that is not found in other agricultural regions. Beets cannot be raised economically unless careful attention is given to every operation from plowing to the delivery of the crop. This requires much hand labor, consequently large acreages cannot be produced without the importation of labor because the local supply does not usually meet the demand. A given area devoted to beet production provides employment to several times as many workers as the same area would were it devoted to hay or grain production. During winter, many people are given employment in the factories, and many others are employed in the feeding and handling of the thousands of sheep and cattle. For this reason the number of workers who remain in the beet areas throughout the year is relatively large. The intensive character of the crop, therefore, promotes a denser population, which has many advantages. Cities are developed, educational facilities are improved, more desirable social opportunities are available, and lines of communication are extended, thereby reducing to a minimum some of the chief disadvantages of rural life.

SUMMARY

The annual acreage of sugar beets in Nebraska varies from 65,000 to 95,000 and the tonnage ranges from 850,000 to 1,065,000.

Nebraska usually ranks second or third among the states in sugar beet production. During the 10-year period from 1923 to 1932, it ranked second in yield with an average annual tonnage of 932,000 and third in acreage with an annual production of 74,000 acres. During the same period, Colorado ranked first with an average annual tonnage of 2,365,000 and an average annual acreage of 198,000.

Sugar beets can be grown successfully in western and central Nebraska largely because of excellent topographic, soil, and climatic conditions, and the availability of water for irrigation.

From a topographic point of view, the terraces and some of the floodplains along the North Platte, Platte, and Republican rivers are well adapted to beet cultivation because these land forms are quite extensive and relatively level, but usually with sufficient slope to insure good drainage.

The silty and very fine sandy loams, especially of the Tripp and Mitchell series, are commonly deep, fertile, and easily tilled. The yields of beets in these soils vary from 15 to 20 or more tons per acre.

The climatic conditions, rainfall excepted, are especially suited to the growth of sugar beets containing from 14.5 to 16.5 per cent sugar. In fact, the climatic factors approach the optima required by beets. These favorable conditions in Nebraska are as follows:

1. The average temperature during the growing season (June, July, and August) ranges from 65° to 70° F.
2. Very few days have temperatures above 95° F.
3. The fairly large diurnal range and the cool nights are conducive to the elaboration of sugar and its storage in the plant during the growing and maturing season.
4. The length of the growing season varies from 120 to 145 days.
5. Plenty of moisture, in part supplied by irrigation, is available during the period of growth.
6. In general, the harvest season is relatively dry with an abundance of sunshine, an essential combination for the manufacture and storage of sugar in the plant. This is also an asset in harvesting the beets.

Careful studies show that the sugar content in beets grown in the semiarid regions generally varies inversely with the average temperature in the growing season and inversely with the total autumn rainfall, especially in Octobeo and November.

Although physical environmental conditions, especially climate, are vital factors in producing beets with high sugar contents, good agricultural practices are perhaps more important in securing good yields. The yield of beets in some areas increased from an average of 11.17 tons per acre from 1919 to 1924 to an average of 13.27 tons per acre from 1925 to 1930, an increase of 20 per cent. During the same period, the average sugar content remained about the same.

The development of the sugar beet industry in Nebraska has been an important factor in the settlement of the irrigated sections. The industry is beneficial in many ways.

1. The sugar beet usually is a good cash crop.

2. Through crop rotation and by careful methods of cultivation, it adds fertility and improves the tillability of the soil.

3. It brings additional income to the community from the sale of sugar, by-products, and from the sale of cattle and sheep fattened on beet tops and by-products from the factories.

4. The intensive character of beet cultivation requires much labor and, therefore, supports a denser population than other types of agriculture in the state can support.

5. Educational, recreational, cultural, and social conditions have been improved remarkably because of the increased number and size of cities, the denser population, and the greater concentration of wealth.

6. Because of the transfer of large quantities of raw and refined materials, excellent lines of communication have been developed.

7. The close relations existing between the growing of sugar beets and the beet sugar industry have developed a desirable cooperation among growers and manufacturers because the factories are dependent upon the farmers for a supply of good beets and the growers are dependent upon the manufacturers for a market.

8. The intensive cultivation required in the growth of beets, the price guaranteed to the farmers for beets, and the assured markets are, as a rule, reflected in more stabilized agricultural and economic conditions than generally prevail in areas devoted to grain production.

Finally, although thousands of acres of land in the United States are geographically suited to beet culture, the economic success of the industry depends largely upon the stability of reasonably high prices for sugar. Since the production cost of beet sugar is much higher than that of cane sugar, beet sugar cannot compete with cane sugar produced in foreign countries without a protective tariff, or some form of subsidy or bounty.

ACKNOWLEDGMENTS

The author acknowledges her indebtedness for much data pertaining to the sugar beet industry to Mr. Lyman H. Andrews, Manager, Great Western Sugar factory, Lyman, Nebraska; to Mr. C. V. Maddux, Labor Commissioner, and to Asa C. Maxson, Agriculturist, Great Western Sugar Company; to Mr. C. G. Carpenter, United States Bureau of Agricultural Economics; Doctors George A. Coons, A. W. Skuderna, and Robert Rands, Division of Sugar Plants, Bureau of Plant Industry, Washington, D. C.; to Doctor Thomas A. Blair, United States Weather Bureau at Lincoln for climatological data; to the librarians in the Congressional and Agricultural libraries in Washington, D. C., and to librarians at New York and Boston; and to several sugar manufacturing companies. The pictures were obtained through the courtesy of the Conservation and Survey Division of the University of Nebraska, and the kindness of Mr. L. H. Andrews, Mr. A. L. Hartburg, and Mr. H. T. Ferrel.

She further wishes to express her gratitude to Doctor George E. Condra, to other members of the Conservation and Survey Division, and to all others who have given encouragement and aid in the preparation ot this bulletin.

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