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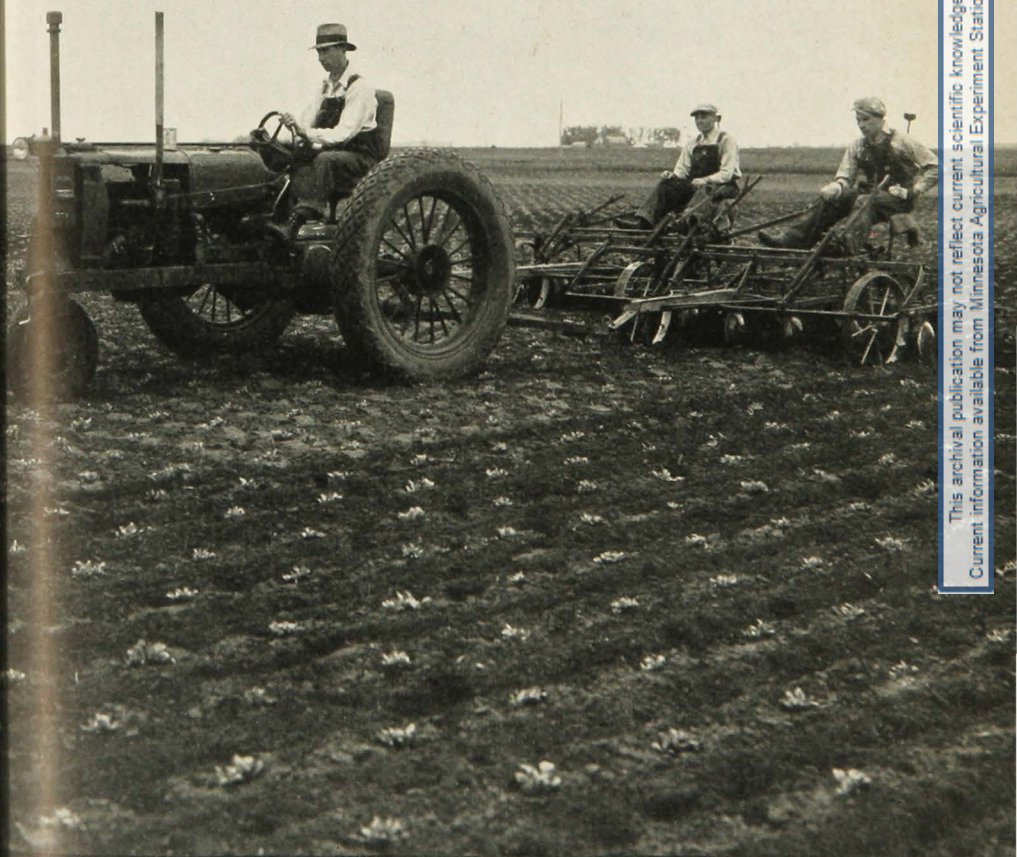
J. O. CULBERTSON



UNIVERSITY OF MINNESOTA
AGRICULTURAL EXPERIMENT STATION

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Sugar Beet Culture in Minnesota[1]

J. O. CULBERTSON[2]

INVESTIGATIONS with sugar beets dealing with a number of questions of agronomic importance were begun in 1888 at the Minnesota Experiment Station. These were reported in Minnesota Bulletin No. 56[3] in 1898. The results of early tests of sugar beets are reported by counties in Minnesota Bulletin No. 27,[4] issued in 1893. Minnesota Special Bulletin No. 90,[5] issued in 1924, included not only a general discussion of production problems but also a section devoted to the cost of production. Circular 46,[6] describing methods of control for leaf-spot, and circular 57,[7] showing how seed treatment may influence stand and yield favorably, were issued by the Agricultural Extension Division of the University of Minnesota in cooperation with the Division of Sugar Plant Investigations, Bureau of Plant Industry, U. S. Department of Agriculture. Farmers' Bulletin 1637,[8] "Sugar-Beet Growing in the Humid Area of the United States" gives information applicable to a considerable extent to Minnesota conditions.

Figure 1 shows the distribution of acreage grown in Minnesota in 1938. Two distinct sugar-beet growing areas are indicated, one along the Red River in the northwestern part of the state which grew a total of 17,013 acres and one in the south-central area with a production of 18,582 acres. An additional 9,990 acres were grown outside the state and processed at the East Grand Forks factory, while the beets grown from 6,650 acres in southern Minnesota were processed at Mason City, Iowa.

Two beet-sugar factories now operate in the state, one in Chaska, built in 1906, and one at East Grand Forks, erected in 1926. Of the 1,030,000 acres on which, under the Sugar Act of 1937, benefit payments were made, the proportionate share allotted for Minnesota factories in 1939 was 40,572 acres, 26,483 for the East Grand Forks territory and 14,089 for the Chaska district.

[1] The investigations upon which this publication is based were conducted in cooperation with the University of Minnesota Agricultural Experiment Station and the American Crystal Sugar Company. Data prior to 1936 were taken by F. R. Immer, formerly associate geneticist, Division of Sugar Plant Investigations, Bureau of Plant Industry, U. S. Department of Agriculture. Figures 3, 5, 6, 8, and 9 were supplied through courtesy of the American Crystal Sugar Company.

[2] Assistant agronomist, Division of Sugar Plant Investigations, Bureau of Plant Industry, U. S. Department of Agriculture.

[3] Snyder, Harry and Boss, Andrew. *Sugar Beets.* Minn. Agr. Expt. Sta. Bul. 56. 1898.

[4] Snyder, Harry. *Sugar Beets.* III. Minn. Agr. Expt. Sta. Bul. 27. 1893.

[5] McGinnis, F. W. *Sugar Beets in Minnesota.* Minn. Spec. Bul. 90. 1924.

[6] LeClerg, E. L. *Control of Leaf Spot of Sugar Beets.* Minn. Ext. Cir. 46. 1934.

[7] LeClerg, E. L. *Treatment of Sugar Beet Seed Increases Stand and Yield.* Minn. Ext. Cir. 57. 1937.

[8] Lill, J. G. *Sugar-Beet Growing in the Humid Area of the United States.* U. S. Department of Agriculture Farmers' Bul. 1637. 1939.

CLIMATIC REQUIREMENTS

Sugar beets may be produced successfully only where climatic conditions as well as soil are favorable. Both temperature and moisture supply must be moderately high for practical sugar-beet production, and long hours of daylight favor a high sugar content. Cool temperatures toward the end of the growing season with large differences between day and night temperatures tend to produce beets with high sugar content. Sugar beets are grown most successfully where the mean temperature during the growing months is approximately 70° F.

The amount and distribution of rainfall is of great importance. Too much rain delays spring planting and proper cultivation, while drouth seriously affects growth. Two to four inches of rainfall every month of the growing season seems most favorable for sugar-beet production. The sugar percentage is depressed for several days after heavy rains because of dilution of the plant juice. Dry weather during ripening materially increases the sugar percentage of the beet because the plant juice becomes more concentrated.

The mean growing temperature in the Red River Valley district is slightly below the optimum temperature for sugar-beet production, but the long period of daylight and the great variation in temperature from day to night are conducive to high sucrose content of the beet. The annual rainfall of the area, which averages approximately 21 inches, is also less than the optimum, and frequent periods of drouth during the summer may curtail yields. In spite of deficiencies in temperature and rainfall, profitable yields are produced which compete successfully with other farm crops grown in the area.

In south-central Minnesota, the mean temperature is favorable during the growing season and rainfall is slightly more abundant, averaging more than 26 inches annually. The average yield of 9.64 tons per acre for the Chaska district for the 10 years, 1929-1938 inclusive, is appreciably higher than the average of 7.53 tons for the East Grand Forks district during the same years. This is in part due to more favorable temperature and more abundant rainfall.

SOIL REQUIREMENTS

While it is true that sugar beets have been profitably grown on a wide variety of soils, better crops are obtained on the darker colored, heavier soils of Minnesota. Clays, clay loams, and silt loams have given consistently higher yields than the lighter colored, sandier soils especially when the latter are low in organic matter and nitrogen. Beets grown on sandy soils usually suffer more from drouth and hot weather than beets grown on heavier soils.

Most beets in Minnesota are grown on soils ranging from heavy clay loams to fine sandy loams. In the Red River Valley Fargo clay loam, Fargo silt loam, Bearden silt loam, and Bearden loam predominate. In south-central Minnesota the predominating soils used for beets are Clarion loam, Clarion silt loam, Webster silt loam, and Webster silty clay loam.

Soils with an unfavorably high water table or which are poorly drained are not used for sugar beets. The use of tile drains or open ditches may improve the water relations in such soils so that they will be suitable for sugar-beet culture. Poorly drained soils favor the development of root-rotting diseases,

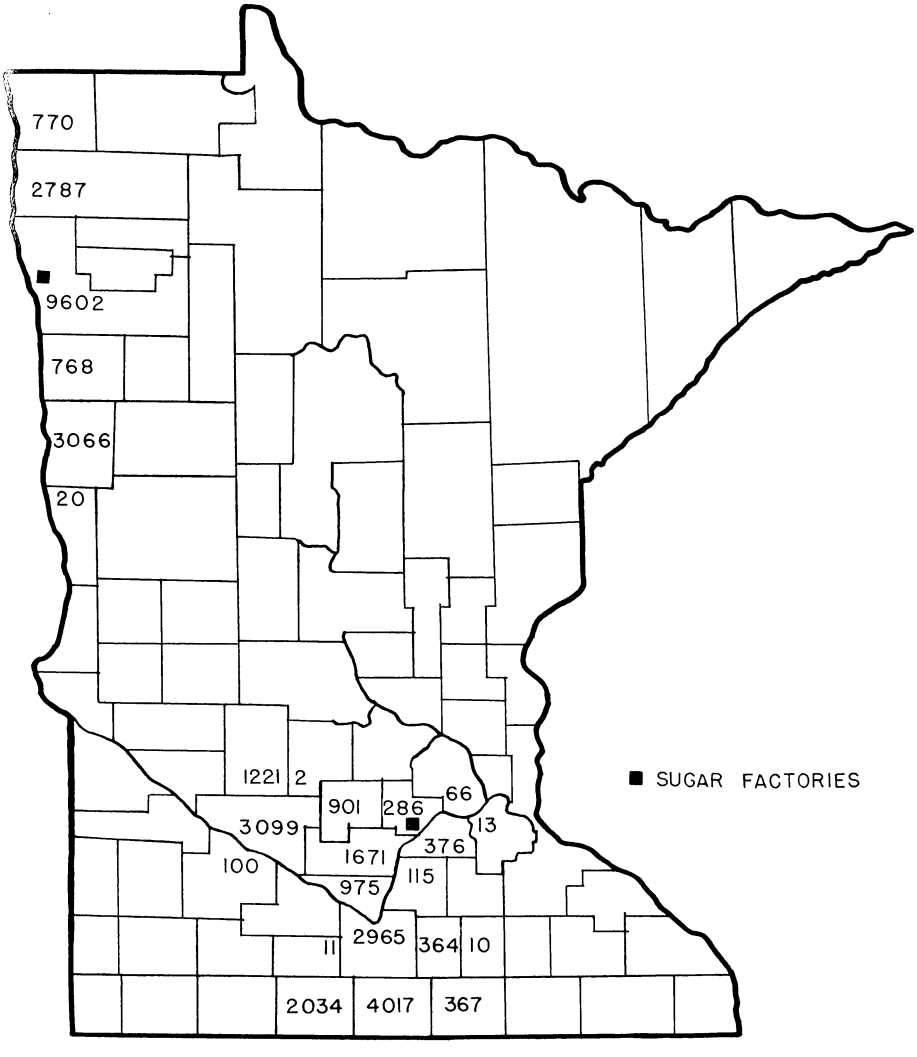

FIG. 1. SUGAR-BEET ACREAGE BY COUNTIES, GROWN IN 1938

and losses ranging from a few scattered plants to a complete failure of the crop have been observed. The drainage of tight soils may be somewhat improved through the incorporation of organic matter and by growing deep-rooted legumes such as alfalfa or sweet clover in the rotation.

The sugar beet is a tap-rooted plant, sending one main root deep into the soil, and anything that interferes with this deep penetration may cause ill-shaped roots often resulting in an excessive number of rather large lateral roots which break off in handling and represent an appreciable loss in ton-

nage. If there is a high water table, the ends of the roots sometimes become diseased early in the summer. Later the water table may recede sufficiently so that the plants recover and develop lateral roots near the point of recovery. Hard pan or heavy plow sole may produce a root of poor shape or even cause the roots to push above the surface of the soil. This results in a large crown and subsequent wastage when topping.

ROTATIONS USING SUGAR BEETS

A well-planned farming system includes an orderly scheme of crop rotation, which is employed to provide definite beneficial results not only to a given crop but also to all crops grown. The major benefits to be derived from a good system include: (1) control of weeds; (2) conservation of soil fertility; (3) addition of nitrogen and organic matter from barnyard manure or green manure; and (4) control of injurious insects and plant diseases. A satisfactory rotation should, therefore, include a cultivated crop in which weeds may be destroyed, a crop of relatively high value per acre to which barnyard manure and commercial fertilizer may be applied profitably, a soil-building crop such as alfalfa or sweet clover, and a "smother" crop, i.e. one which by its rank growth retards the growth and vigor of weeds.

In the sugar-beet producing area of the Red River Valley, these requirements are satisfactorily met by either of two rotations, the first using sugar beets, small grain, and sweet clover and the second including potatoes in addition to the crops used in the first rotation.

Rotation 1—This rotation provides for clean tillage of the sugar-beet crop and the control of weeds. Cross-cultivation and hand hoeing, as later described, leave the fields free of weeds at harvest time. The sugar-beet crop is relatively high in value per acre and available barnyard manure or commercial fertilizer may be used profitably with this crop. After the beets are dug in the fall, the ground is left in good condition for spring sown small grain and sweet clover. Either wheat or barley may be grown the second year as a nurse crop for the sweet clover. This serves as a good smother crop and utilizes labor to advantage in the early spring and mid-summer. The third year the sweet clover is plowed under in June as a green manure crop, thus increasing the organic matter and nitrogen in the soil as well as improving soil tilth. During this third year the field is kept fallow by working as needed with a duckfoot cultivator. This fal-

Rotations for the Red River Valley

	Rotation 1	Rotation 2
First year	Sugar beets	Sugar beets
Second year	Small grain with sweet clover	Small grain with sweet clover
Third year	Sweet clover—summer fallow	Sweet clover—summer fallow
Fourth year	Sugar beets	Potatoes
Fifth year		Sugar beets

lowing aids in the control of weeds and the conservation of soil moisture. The ground is left somewhat ridged at the last working to hold winter snow. Such a field is ready to be worked early in the spring and a good seedbed may be prepared easily for the sugar-beet crop.

Rotation 2—This rotation is essentially the same as the first rotation. The use of potatoes the fourth year provides one more cultivated crop in which weeds may be destroyed. The soil is then fall-plowed and left rough to hold moisture and is prepared readily for sugar beets the following spring.

Both of these rotations are used by successful beet growers in the Red River Valley and have been found very satisfactory.

In the Minnesota River Valley region, as well as in southern Minnesota, alfalfa is widely grown and is the most important soil-building crop. Alfalfa plantings are usually left from 4 to 6 years before plowing up, and the rotation of alfalfa over the farm takes a considerable period of time and a shorter rotation is used for other crops.

Rotation for Southern Minnesota

First year	Corn*
Second year	Sugar beets
Third year	Small grain†
Fourth year	Corn

* Corn may be planted following alfalfa.
† Barley, spring wheat, or oats.

In this rotation corn is grown the first year either for silage, fodder, or canning corn. Harvest is sufficiently early to permit fall plowing in preparation for sugar beets the second year. If the corn follows alfalfa immediately it is not manured. Barnyard manure may be used on the sugar-beet crop the second year, especially if there has been no alfalfa on the land for several years. The third year a crop of small grain is grown. Sweet clover may be planted with the grain and plowed under in the spring of the following year as a green manure for the corn crop.

PREPARATION OF THE SEEDBED

In order to produce profitable crops, careful attention must be given to the preparation of a suitable seedbed. All the operations leading up to the finished seedbed ready for planting should be planned in such a manner that: (1) All weed growth is destroyed and stubble or trash on the land carefully turned under; (2) a firm contact is established between the furrow slice and the unplowed subsoil with a minimum of air pockets; (3) the seedbed is firm and has about an inch of mellow soil on top; (4) the soil surface is left in such condition that soil blowing will not injure the tender plants; and (5) in the course of preparation of the field for planting, soil moisture is conserved.

In Minnesota it has been observed that fall plowing is better for beets than spring plowing, and sugar-beet growers should arrange their crop sequence so that beets are planted on fall-plowed land. Fall plowing permits stubble or trash to decompose during the winter; the soil has sufficient time to settle so that the furrow slice resumes firm contact with the subsoil; the soil warms up sooner in the spring, and a seedbed can be prepared earlier, facilitating early planting.

In the southern part of the state where sugar beets frequently follow corn that has been cut for silage or canning sweet corn, the stubble should be thoroughly disked before plowing.

This aids in obtaining complete coverage of the stubble and hastens decomposition so that little difficulty with trash need be experienced in the spring. The land should be left rough through the winter to prevent blowing and also to catch and hold the fall and early spring rain and winter snow. Freezing and thawing will help mellow the clods and, when worked down in the spring, there will be few air pockets where serious moisture losses may occur.

The general practice of planting sugar beets on sweet clover fallow or black summer fallow in the Red River Valley insures a desirable seedbed, since the land is plowed in June, allowing plenty of time for the sweet clover to rot and for the soil to become mellow before beets are planted the following spring. If a duckfoot cultivator is used during the summer, the soil is firmly packed underneath and the top soil is left slightly rough, preventing excessive blowing and providing a means of catching snow. In the spring three or four light harrowings will prepare the seedbed for planting without disturbing the lower portion of the seedbed. This shallow spring preparation prevents excessive loss of soil moisture.

Although spring plowing is not recommended, conditions may be such that spring-plowed land must be used. Plowing should be done only when the soil moisture is not so high that large clods are turned up which cannot be broken down later. If soil conditions permit, early spring plowing leaves more time in which to prepare a good seedbed.

Plowing 6 to 8 inches deep is generally satisfactory. Shallower plowing, especially on heavy soils, may not permit the roots to develop normally. It is also difficult to cover stubble or trash properly by shallow plowing. In certain fields that have not been plowed deeply in previous years and in which deeper plowing is advisable, the depth may be increased one inch at each plowing. This prevents turning up too much subsoil at one time. The depth of spring plowing will be conditioned to some extent by the type of soil and moisture content at the time of plowing. It is especially important that spring plowing be done to such a depth that proper contact with the subsoil is established and that air pockets and large clods are avoided.

The first operation in the spring is generally thorough disking. If the soil is unusually mellow, it will be advantageous to have the disk well weighted and the blades at slight angle so that they will cut deeply and thus help to firm the soil. A second disking a few days before planting will destroy early spring weed growth and reduce the amount of work in cultivating and hoeing later in the season.

A spring-tooth harrow may be used in place of a disk if the field contains quack grass, as the roots will be brought to the surface and allowed to dry out somewhat, and less trouble will be experienced in controlling the quack grass during the summer. On the spring-plowed land it may be necessary to go over the field with the disk several times in order to break up the clods and pack the seedbed sufficiently. Just before planting a spike-tooth harrow should be used to level off the ridges left by the disk. If this is done at an angle to the direction of planting, the marker trace may be more easily followed. Sometimes it may be necessary to use a cultipacker and drag to break up hard clods or to secure the desired

firmness for the seedbed. A light drag or, with lighter soils, a meeker may be used to smooth the surface. Care should be taken that the surface is not left too fine or too level so that blowing soil may damage the young plants after emergence. It is a generally accepted rule that the finished seedbed should be firm enough so that a man will not sink in deeper than one half to three quarters of an inch while walking across the field.

The preparation of the seedbed should be timed in such a way that it is completed and ready for planting just as soon as the danger of heavy frost is past.

PLANTING

The sugar beet is a biennial, i.e. it does not produce seed during the first year of growth but accumulates food in its roots that is used for seed production the following year. This stored food is chiefly in the form of sucrose. A longer growing season permits greater growth of the roots with a larger total production of sugar. Early planting, by providing a longer growing season, produces higher yields than late planting.

Date of planting tests were conducted at Waseca during the three years 1931 to 1933, inclusive. These tests were replicated from five to eight times. In 1931, three dates of planting, early, medium, and late, were used; in 1932, medium, late, and very late dates were included; while in 1933 four dates, early, medium, late, and very late, were used in the test. The early, medium, late, and very late dates were approximately April 25, May 4, May 18, and June 2, respectively.

The yields obtained from these tests as shown in figure 2 were obtained from normally competitive beets and

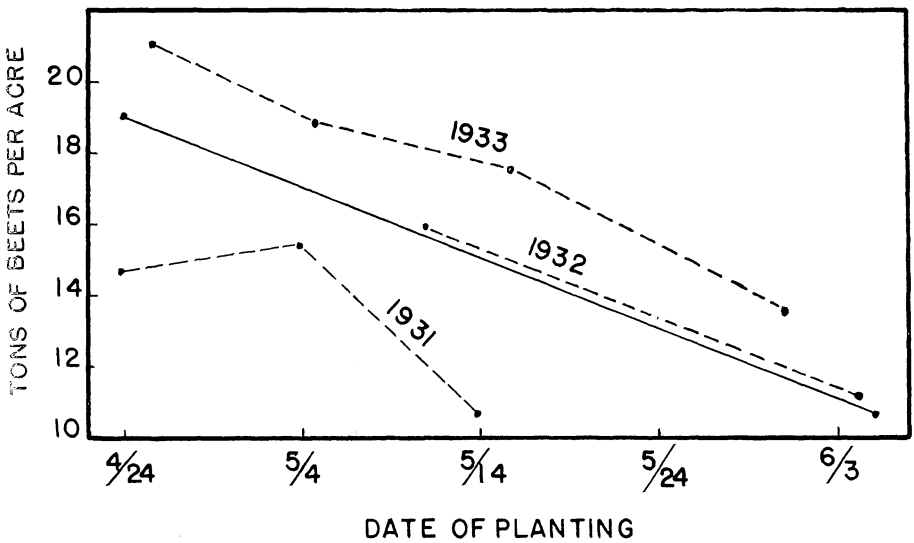

FIG. 2. THE EFFECT OF DATE OF PLANTING UPON THE YIELD OF SUGAR BEETS GROWN AT WASECA
The dotted lines show the results obtained for each of the three years, 1931-33, while the solid line shows the average of the three tests. Yields refer to 100 per cent stands of fully competitive beets spaced 20x12 inches.

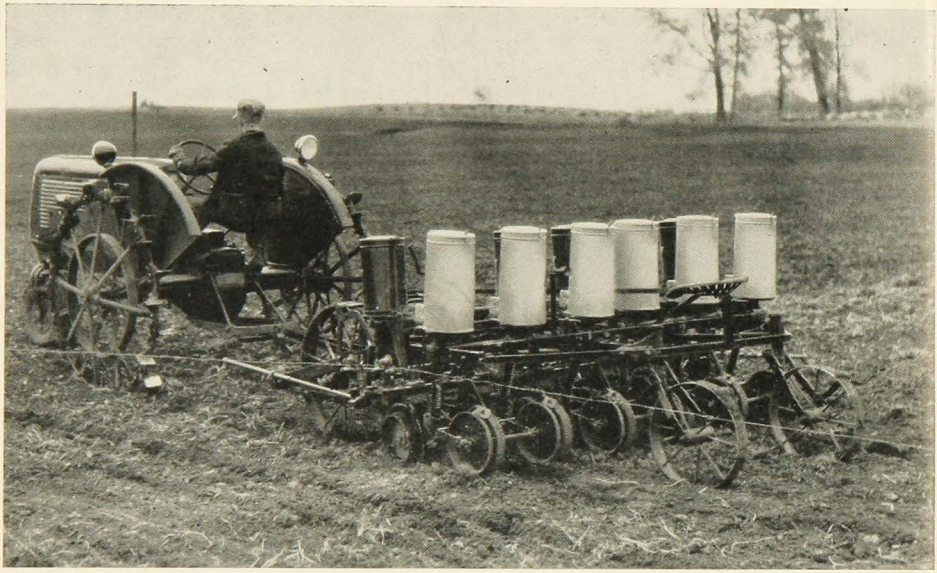

FIG. 3. SIX-ROW TRACTOR-DRAWN SUGAR-BEET SEED PLANTER OF THE CHECK-ROW TYPE, EQUIPPED WITH A FERTILIZER ATTACHMENT

computed on the basis of 100 per cent stand. The dotted lines connect the yields obtained for each of the three years while the solid line indicates the average for the three tests. In the 1931 test, the medium date yielded slightly more than the early date, but the late planting was much reduced in yield. In the 1932 and 1933 tests, the trend of yields was markedly downward as planting was delayed. The average, as indicated by the solid line, shows an appreciable reduction in yield as planting date was delayed. It may be concluded from these data that early planting, if the seedbed has been properly prepared, is highly advantageous.

Three types of planters are in general use in Minnesota, continuous-row, hill-drop, and check-row planters. Each type has certain advantages. The continuous-row planter drops the seedballs in a solid row and is usually set to plant 12 to 20 per foot of row. This type of planter is most satisfactory for close spacing because there are several plants in every foot of row, and the desired spacing can be secured. The hill-drop planter places the seedballs in clumps from 8 to 16 inches apart in the row, 12 inches being most common. This type of planter insures accurate spacing and results in a considerable saving in seed. More than one half of the sugar-beet acreage in the state is, however, planted with the check-row planter, which drops the seedballs in hills, usually at intervals of 18 inches. The drop is controlled by a wire such as is used for check-rowed corn. Thus the crop can be cultivated in both directions. This method of planting has several advantages in that less seed per acre is required, and cross-cultivation is as easy as cultivating in the direction of the planted rows. When large acreages

are involved and thinning is delayed, the ability to cultivate in both directions makes controlling weeds less difficult and reduces the damage from delayed thinning. Cross cultivation also improves the mechanical condition of the soil and tends to prevent the formation of cracks along the row in dry periods, therefore reducing the loss of soil moisture. On the other hand, it must be borne in mind that close spacing is impossible with check-row planting.

The rate of planting varies with the type of planter and the condition of the seedbed. On well-prepared fields 5, 8, and 15 pounds of seed usually are required, respectively, for the check-row, hill-drop, or continuous-row planters to insure a good stand. If the seedbed is cloddy or uneven or if moisture is insufficient for prompt germination, the rate should be increased somewhat. The rate of planting also depends to some extent upon the size of the seedballs and the percentage of germination, more seed per acre being required for exceptionally large seedballs or for seed of low germination.

Normally the seed should be planted one inch deep. Shallower planting allows the soil to dry out too much around the seed and, as a result, may delay germination. Too deep planting, on the other hand, may make it difficult for the tender seedlings to break through the soil, and the small amount of food material stored in the seed may be exhausted before the young plant becomes established and able to care for itself. By properly adjusting the press wheels, the soil is pressed down firmly over the seed, preventing serious drying out of the soil. A uniform planting depth may be secured easily on a well-prepared seedbed that promotes prompt, uniform germination.

Care should be taken at all times to make certain that the planter is working properly and that the drill does not become clogged.

SPACE REQUIREMENTS

The sugar-beet plants should be spaced in such a way as to make the best use of the soil fertility and moisture available and yet permit economical handling of the crop. The date of planting and the type of beet grown also influence spacing. A wider interval between plants is necessary for tonnage type beets or on fields low in fertility and moisture. Closer spacings should be used on fields of high fertility and moisture and on all late-planted fields.

The commonly accepted spacing has been 12 inches between plants and 20 inches between rows, allowing 240 square inches per plant. This space allotment is still common where continuous-row or hill-drop drills are used. However, with the use of the check-row drill, the space allotment is generally 18x18 inches.

It is a fact, demonstrated many times, that within reasonable limits both the acre yield and quality of the beets are improved by close spacing. Although the individual roots are somewhat reduced in size as a result of keener competition, the greater number of plants per acre more than compensates for the difference, and the gross returns per acre are larger, on an average, from close spacings. On the other hand, wider spacing permits certain economies in labor and handling costs which must be considered in determining the most economical spacing to use. Many sugar-beet growers in Minnesota, especially in the Red River Valley, believe

that the yields from check-row planting are practically the same as from 20x12 inch spacing and that the greater ease in handling the crop more than compensates for any decrease in yield due to the fewer number of plants per acre obtained by check-row planting.

Tests were conducted at Waseca and East Grand Forks in 1932, at Waseca in 1933, at Waseca and Crookston in 1934, at Waseca in 1937, and at Chaska in 1938 to obtain information regarding the most satisfactory spacing interval to use. These tests were each replicated from five to eight times. All plots were carefully blocked in such a way that accurate spacings were obtained. At harvest time, yields were based upon those beets in each plot which conformed strictly to the allotted space and were growing under conditions of full competition.

The average yields from the various spacings are shown graphically in figure 4. Average yields of 18.81, 14.52, 12.76, and 12.38 tons per acre were obtained from 16x8, 20x12, 18x18, and 22x20 inch spacings, respectively, using the data from normally competitive beets to compute yields on the basis of 100 per cent stand for each space interval. Close spacings are shown to yield more than wide spacings over a period of years. It should be pointed out, however, that close spacings are difficult to obtain, require more supervision of hand labor, and cannot be handled as cheaply as wider spacings such as 20x12 or 18x18 inches.

STAND VS. YIELD

When the desired spacing has been determined, it is important to secure a uniformly good stand. Many factors are involved in securing and maintaining a full stand of plants. These include proper seedbed preparation, quality of seed, rate and manner of planting, blocking, thinning, cultivation, and disease control.

A well-prepared seedbed which insures prompt germination, provides sufficient moisture, does not crust readily, and is free from weeds will do much to insure a good initial stand.

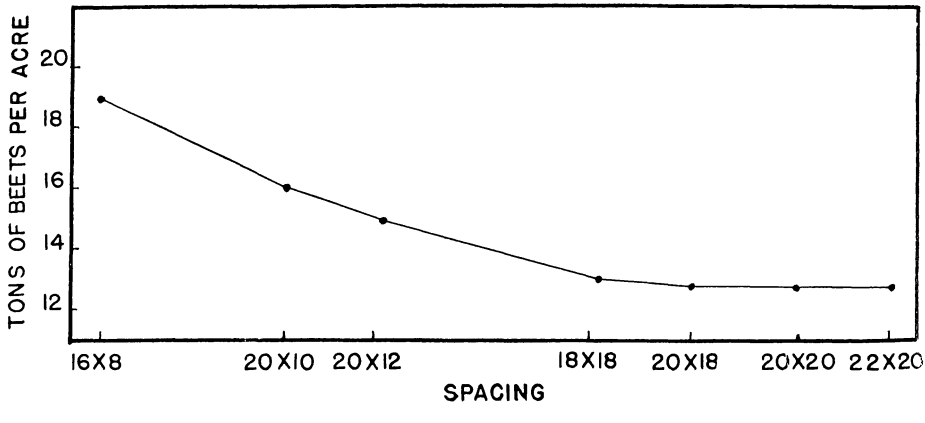

FIG. 4. THE AVERAGE ACRE YIELD OF ROOTS IN TONS FROM 7 TRIALS AND 7 SPACE ALLOTMENTS, AS OBTAINED FOR ROW WIDTH AND ROW INTERVAL SHOWN (DATA OBTAINED FROM NORMALLY COMPETITIVE BEETS AND COMPUTED ON BASIS OF 100 PER CENT STAND FOR SPACE SHOWN)

If the soil is too loose or too cloddy, it dries out quickly and germination may be incomplete. If the surface has been worked too fine, blowing soil may destroy the stand when the tender plants have just emerged. On a crusted soil a spiketooth harrow, provided the slant given the teeth is carefully checked as to effects being obtained, may save a stand which would be lost otherwise.

Only seed of high quality and germination should be planted. In most cases the factory supplying the seed has made germination tests and, in some instances, has recleaned the seed to insure high quality.

The rate of planting should be adjusted to the size and germination of the seed. Planting too much seed is wasteful and may result in so great early competition between plants that growth is retarded. The setting of the planter should be such that the seed is planted at a uniform depth, in moist soil, well covered, and the soil firmly packed about the seed.

Careful attention to blocking and thinning will insure a uniformly good stand in fields where the initial stand is satisfactory. Some loss of plants is bound to occur as a result of hoeing and cultivation. Supervision of labor and attention to the setting of the cultivating machinery will, however, reduce losses of this type to a minimum.

In Colorado[9] tests have shown that the elimination of blank spaces in the stand was of greater importance in determining final yields than the width between rows or spacing within the rows.

When a single beet is missing, the surrounding plants benefit to some extent because of the larger area from which they may draw moisture and plant food. In order to determine the extent of this benefit samples were taken from one grower's field near Fisher, Minn. in 1937 and from two fields near Fisher in 1938 and from two fields near Kanawha, Iowa in 1938. These fields had been planted with a check-row drill using 18x18 inch spacing.

Table 1. Expected Loss in Yield for Various At-harvest Stand Percentages

Plants per acre	Percentage of perfect stand	Loss in yield* per cent
10,000	51.6	22.7
12,500	64.6	16.6
15,000	77.5	10.6
17,500	90.4	4.5

* The percentage loss in yield is calculated on the basis of 47 per cent loss for a single missing plant. Actually the loss would be even greater, since in many skips more than a single plant would be missing.

In these tests the weight of the beet second from the skip and fully surrounded by beets was taken as the theoretical yield of the missing plant. Average values were determined from the four beets adjacent to and on the four sides of the skip as well as for the four beets diagonal to the skip. The average value determined from the competitive or check beets was 1.51 pounds, and that from the beets adjacent to the skip 1.65 pounds, while that from the diagonal beets was 1.57 pounds. The average recovery was therefore .14 pound for each of the four adjacent beets and .06 pound for each of the four diagonal beets, or a total recovery of .80 pound or 53 per cent. Thus, the loss from a single skip was found to be 47 per cent. Obviously, the loss from two or more beets in a place would be even greater.

[9] Brewbaker, H. E. and Deming, G. W. *Effects of Variations in Stand on Yield and Quality of Sugar Beets Grown under Irrigation.* Jour. Agr. Res. 50:195-210. 1935.

In an 18x18 inch planting, there are 19,360 beets per acre in a perfect stand. However, few fields are found with over 15,000 plants at harvest and some fields may have no more than 10,000 plants or even fewer. Table 1 has been prepared to show the loss in yield for fields planted 18x18 inches when the stands at harvest are from 10,000 to 17,500 plants per acre.

This table indicates that serious losses in yield result from poor stands. A good stand of beets at harvest time is often the factor which determines a profitable crop.

A more intensive test was conducted at Waseca over the 5-year period from 1934 to 1938. Four-row plots were uniformly planted with a continuous drill in 20-inch rows. At thinning they were uniformly blocked and thinned to 12 inches within the row. Surplus plants were then removed at random from every row in each plot to leave stands of approximately 20, 30, 50, 60, 70, 80, 90, and 100 per cent. At harvest time all the roots in all plots except the 100 per cent stand plots were dug and weighed. Since it is impossible to have a perfect stand at harvest, only those beets under full competition were harvested and weighed, and the yield of a full stand calculated for the 100 per cent stand plots.

The data from these tests are given in table 2. On an average, the yield increased from 5.57 tons to 15.24 tons as stand density increased from 22.2 to

Table 2. The Relation of Percentage Stand at Harvest to the Yield of Roots in Tons per Acre and the Percentage Sucrose in the Beet

Harvest Determination	5-year Average	Individual Years				
		1934	1935	1936	1937	1938
Stand (per cent)	22.2	19.8	28.9	21.4	20.3	20.5
Yield (tons)	5.57	3.83	5.21	7.32	4.05	7.44
Sucrose (per cent)	13.63	16.06	11.45	13.64	15.34	11.66
Stand (per cent)	34.2	28.2	44.1	32.3	37.9	28.4
Yield (tons)	7.55	5.17	6.51	9.54	7.87	8.64
Sucrose (per cent)	13.78	16.29	11.32	13.89	15.42	12.00
Stand (per cent)	50.8	46.6	56.2	52.2	56.2	46.6
Yield (tons)	10.02	7.35	7.82	12.19	11.18	11.58
Sucrose (per cent)	14.07	16.72	11.78	14.31	15.18	12.36
Stand (per cent)	58.6	54.8	58.8	60.7	63.1	55.5
Yield (tons)	11.06	8.45	8.37	12.86	12.53	13.09
Sucrose (per cent)	14.27	16.95	11.88	14.63	15.50	12.37
Stand (per cent)	66.4	62.1	64.3	67.1	74.1	63.4
Yield (tons)	11.44	8.82	8.50	12.41	13.65	13.82
Sucrose (per cent)	14.29	16.88	11.79	14.98	15.62	12.19
Stand (per cent)	72.8	67.8	67.2	75.4	79.1	74.7
Yield (tons)	12.35	9.56	10.39	13.12	13.54	15.16
Sucrose (per cent)	14.59	17.16	11.92	15.27	15.98	12.60
Stand (per cent)	75.9	75.0	56.5	79.2	89.1	79.8
Yield (tons)	12.33	9.44	9.25	13.69	14.47	14.80
Sucrose (per cent)	14.51	17.04	12.16	15.06	15.83	12.47
Stand (per cent)	100.0	100.0	100.0	100.0	100.0	100.0
Yield (tons)	15.24	12.07	15.54	15.37	15.00	18.22
Sucrose (per cent)	14.69	17.09	12.35	15.35	15.94	12.70

FIG. 5. HILL-DROP PLANTING SHOWING THE REGULAR SPACING OF HILLS AT 12-INCH INTERVALS ALONG THE ROW

100 per cent. It may also be pointed out that greater competition improved the quality of the crop since the percentage sucrose in the beet also increased from 13.63 for a 22.2 per cent stand to 14.69 per cent for a full stand as an average for the five years.

THINNING

Thinning or singling of the plants is done to provide adequate space in which the plant may grow and reach its normal development. If a check-row or hill-drop planter has been used, the plants will be growing in small clumps at intervals along the row and the spacing is determined by the setting of the drill. Thinning in such cases consists of leaving the best single plant in each hill and pulling out the extra plants. When a continuous-row planter has been used, it is customary to cut out portions of the row, leaving small clumps of plants at regular intervals which are later thinned to a single plant. This blocking may be done by hand with a hoe, or it may be done with a mechanical cross-blocker. In cross-blocking beets mechanically, a cultivator is set up so that it cuts out portions of the row and leaves a block of approximately four inches in which the plants are undisturbed. The space between these clumps may vary from 8 to 12 inches depending upon the interval desired between plants. The blocker is operated across the rows, and the blocks are then thinned to a single plant. Cross-blocking has two distinct advantages in that it results in a sav-

FIG. 6. CULTIVATOR EQUIPPED FOR CROSS BLOCKING

ing of hand labor and it also provides a cross-cultivation which helps in the control of weeds. Hand blocking may be preferable where the pre-thinning stand is poor since the blocker may adjust the spacing interval to allow for irregularities in stand.

Successful production of sugar beets requires careful attention at thinning time. When the desired spacing between plants has once been determined, strict supervision of labor is required to see that a full stand of plants is obtained. As has been pointed out previously, there is a close relationship between stand and yield, and careless thinning may result in a decreased yield.

The time, in relation to the size of the plant, when blocking and thinning is done is important. If done too early the labor required is greatly increased, and, if germination has been partly delayed, some plants will come up after thinning is completed. Delayed thinning results in increased competition and slower growth. When the plants have reached a comparatively large size before they are thinned more damage results to the roots of the remaining plants and a longer time is required for recovery and the resumption of normal growth.

Tests were conducted at Waseca and East Grand Forks over a period of three years to determine the effect of delayed thinning upon the yield and quality of the beets produced. Plots were thinned when in the 2-, 4-, 6-, 8-, and 12-leaf stages. Figure 7 shows the

average tonnage and pounds of indicated available sucrose per acre obtained from four tests at Waseca from 1930 to 1933, inclusive, and two tests at East Grand Forks from 1930 to 1931, inclusive. These yields are based upon 100 per cent stand of normally competitive beets. The average yields obtained from these 6 tests were 15.00, 14.36, 13.61, 12.72, and 10.58 tons for plots thinned in the 2-, 4-, 6-, 8-, and 12-leaf stages, respectively. In these tests there was an appreciable reduction in tonnage due to delayed thinning.

Figure 7 also shows that as thinning was delayed the yield of indicated available sucrose per acre was decreased. When the plants were thinned in the 2-, 4-, 6-, 8-, or 12-leaf stages, the production of indicated available sucrose was 3927, 3786, 3645, 3504, and 3233 pounds per acre, respectively.

It has been shown that the large beet at thinning time produces a large beet at harvest time. This may be due to any one of several causes or to a combination of causes. The large beet at thinning time may have had the advantage of early germination, it may be less subject to competition with surrounding plants, or it may be genetically superior. Large plants are also less likely to be diseased and more able to survive than smaller plants. Whatever the cause, increased yields of up to two tons per acre have been obtained by the selection of large plants at thinning time compared to unselected plants. Sugar-beet growers can well afford to insist that thinners leave only large plants.

CULTIVATION

The primary purpose of cultivation is to destroy weed growth. In making adjustments of the cultivator this purpose should be kept in mind. Weeds remove a large amount of plant food and soil moisture which is needed by the beet plants for their own growth. If proper attention has been paid to destroying weeds during the period of preparing the field for planting, the later work of cultivation will be facilitated. Weeds should never be allowed

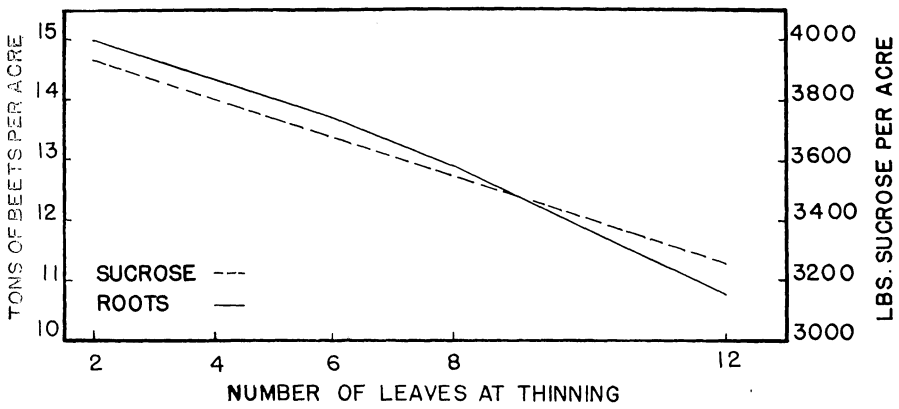

FIG. 7. EFFECT OF THINNING IN THE 2-, 4-, 6-, 8-, OR 12-LEAF STAGE UPON THE YIELD OF ROOTS AND INDICATED AVAILABLE SUCROSE (DATA OBTAINED FROM NORMALLY COMPETITIVE BEETS AND COMPUTED ON BASIS OF 100 PER CENT STAND)

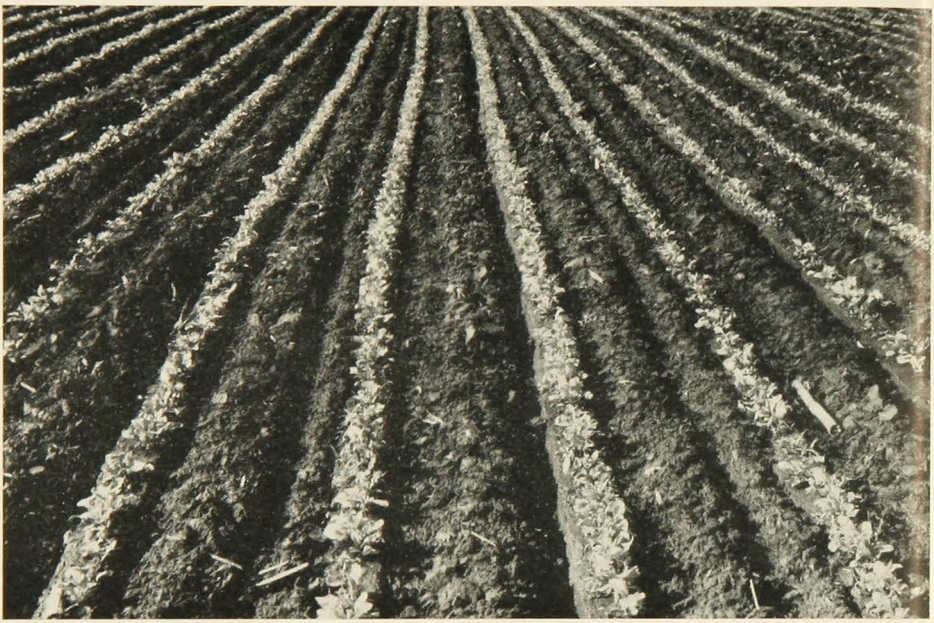

FIG. 8. THE FIRST CULTIVATION HAS EFFECTIVELY DESTROYED WEED GROWTH, BUT HAS LEFT THE SOIL PUSHED AWAY FROM THE PLANTS

The use of proper shovels in the center of the row would push the soil back against the plants and prevent loss of moisture.

to reach an appreciable size before cultivation is begun. The sooner weeds are killed, the more plant food and moisture there will be for the beet crop. It is much easier to destroy weeds when they are small and do not have well-developed root systems.

The first cultivation is usually done soon after the plants have emerged from the ground. This not only destroys weeds but it helps break up any crust that may have formed and allows the plants to grow more readily. Several types of cultivating tools are usually available, and the grower should use those which are best suited to the particular needs of plants at the time the cultivation is being done. A good practice is to use the disks and duckfeet for the first time over. These disks can be adjusted closely on either side of the row and set to throw the soil out slightly. A duckfoot shovel of suitable width can be used in the middle of the space between the rows. If these tools are carefully set, it is seldom necessary to use shields. The entire space between the rows can be thoroughly covered and the soil will not be pushed away from the row leaving a narrow ridge to dry out. Later cultivations are made by substituting knives for the disks, and, as the plants grow, these knives must be set wider apart so that the plants will not be injured. In hard soils a smaller, sharp-pointed shovel sometimes called a bull-tongue may be used in the middle of the rows. This type of shovel penetrates deeply and helps break up hard soil.

The depth of cultivation should be about two inches in ordinary soils. This is most effective in destroying weeds, does not injure the feeding roots, and leaves a good surface mulch to catch and hold the moisture when rains come.

Where the check-row type of planter has been used, tractor-powered cultivators are common. These cultivators normally cultivate six rows at one time. In such cases the second cultivation is across the planted rows. This type of cultivation is more efficient than cultivation in only one direction and saves hand labor and hoeing.

The frequency of cultivation required will depend upon the rate of weed growth and the general condition of the soil. If successive crops of weeds follow each other closely, cultivation of necessity must be equally frequent. Usually four to five cultivations are satisfactory to keep down weed growth. Prolonged cultivation, after the leaves begin to cover the row, may be harmful since many leaves may be broken off. If the soil becomes hard or crusted, it should be cultivated to break up the crust and allow rain to soak into the soil more readily.

It is usually necessary to hand hoe the crop once or twice during the summer. In clean fields where the preparation of the soil and the first cultivations have been done carefully, one hoeing to remove the large weeds is ordinarily sufficient.

HARVESTING

The sucrose stored in the root of the sugar beet is reserve food which the plant normally uses for the next year's seed production. While some of the plant food produced during the summer is transferred to the root as it is formed, there is an appreciable increase in the storage rate as cooler weather begins in the fall. The root also keeps increasing in weight until frost kills back the tops. Since the farmer is paid on a basis of the weight of the roots produced and also on the average sugar content of the beets from all the fields in his vicinity, it is important that harvesting be delayed as long as there is not too great danger of the ground freezing so hard that harvesting cannot be completed. Growers with large acreages usually begin harvesting earlier than those having fewer acres to handle. Ordinarily representatives of the beet-sugar company sample enough fields in each locality during late summer and fall so that they know when the percentage of sucrose is sufficiently high to commence harvesting the crop.

A beet lifter is used to loosen the beet sufficiently so that it may be pulled easily from the soil. Horse- or tractor-drawn lifters may be used. Where the acreage is large, two-row tractor lifters may be employed and considerable time saved. As soon as the beet is lifted it begins to lose weight as the moisture in the root dries out. This loss becomes appreciable after a period of a few hours. It is advisable to finish the harvesting operations and have the beets delivered to the dump as soon as possible once they are lifted.

The toppers follow the lifter closely and pull up the roots by the tops. If the stand is thin or the beets small in size, they are thrown together in piles. Usually 12 rows are thrown together in a windrow across the field, and the beets are then topped from these windrows. By first piling or windrowing the beets, much of the soil which interferes with topping and loading is knocked

off, the laborers do not have to walk so far to perform the topping, and the roots naturally fall into convenient piles for loading. The leaves and part of the crown are removed by cutting at right angles to the axis of the beet at the lowest leaf scar. It is often the practice to drag a weighted V-shaped sled across the field to smooth down a place on which to pile the topped beets, which then are loaded into trucks or wagons with specially designed beet forks. When the load is delivered at the dump a further portion of the dirt is screened out and weighed back into the empty wagon or truck and returned to the farmer. Samples are taken from each load and all remaining dirt is removed with brushes. This is done to determine the percentage of tare to be assessed against the weight of the load delivered at the dump. When soil moisture conditions are such that the dirt clings tightly to the roots it may be necessary to load the truck or wagon by hand, knocking off more of the dirt as the roots are picked up.

When beets have been pulled from the ground and it is impossible to get them delivered to the dump in a reasonably short time, piles in the field may be covered with tops to prevent loss from freezing or from drying out. If loads are to be left on the truck or wagon all night, it is advisable to protect them from freezing in cold weather by covering with a canvas or by placing the load in some building that will afford the needed protection.

The tops and crowns of the sugar beets are valuable for feed and are highly regarded especially by cattle and sheep feeders. In topping the beets, care should be taken to save the tops as much as possible and avoid contaminating them with dirt.

FERTILIZERS

The cost of growing an acre of beets is about constant regardless of the tonnage produced, since such costs as plowing and preparation of the seedbed, planting, thinning, hoeing and cultivation are fixed charges. A large yield per acre makes the crop more profitable to the grower since it reduces the cost per ton. Yields of sugar beets may be increased not only by careful attention to the cultural practices, but also by increasing the fertility of the soil. Barnyard manure is in general a very satisfactory fertilizer and should be liberally used on soils where sugar beets are to be grown. Unfortunately most farms do not produce sufficient barnyard manure to maintain the original fertility of soil. Continued sale of crops from the farm removes plant food elements which must eventually be replaced if soils are to remain productive.

When barnyard manure is insufficient to maintain the organic matter content of the soil, green manure crops may be used to advantage for this purpose. Leguminous crops such as alfalfa or sweet clover are generally better green manure crops since they add not only humus but also nitrogen to the soil. In the Red River Valley many sugar-beet growers are following the practice of plowing under a crop of sweet clover early in the summer and then fallowing the rest of the season preceding the growing of sugar beets. Since the soils of the Red River Valley are high in both organic matter and nitrogen, it seems that a large portion of the increased yields following the plowing under of sweet clover must be due to the conservation of moisture as a result of subsequent summer fallow. In the southern portion of the state, the supply of organic matter and nitrogen in

many fields is not so high as in the Red River Valley, and green manure crops have been found beneficial even though they are not followed by a period of summer fallow.

Commercial fertilizers may be used to supplement barnyard manure. In most parts of Minnesota where beets are grown it has been found that the use of superphosphate increases yields profitably. This fertilizer may be purchased as superphosphate, double, and treble superphosphate carrying, respectively, about 16, 20, or 45 per cent available P_2O_5. The most profitable rate of application varies with different sections of the state and also varies from field to field. Heavier applications are needed in the Red River Valley than in the southern part of the state. In general, applications of 100 to 125 pounds double superphosphate (20 per cent P_2O_5) per acre are used in the Red River Valley and 75 to 100 pounds double superphosphate are most common in the southern sugar-beet growing area. From the evidence at hand, these rates of application are too low and double these rates would no doubt prove profitable in many fields. Whichever of the three kinds of phosphate fertilizer is used, the rate should be such that from 40 to 50 pounds P_2O_5 are applied in the Red River Valley and 30 to 40 pounds in southern Minnesota.

In many beet-growing areas outside of Minnesota it has been found profitable to use a complete fertilizer, i.e., one containing not only phosphorus but also nitrogen and potash. Tests in this state have been insufficient to prove definitely the general need for a complete fertilizer, but where they have been tried, increased yields have sometimes resulted.

Farmers wishing to experiment with a complete fertilizer may purchase a few sacks and drill it in the furrow with the seed in strips through the field. For each fertilizer mixture to be tried, there should be at least three strips each four rows or more wide through the field; these strips to alternate with three strips of superphosphate alone and three strips of unfertilized beets. The necessity of properly labeling these strips with sturdy stakes at the time the test is set up should not be overlooked. At harvest time each strip should be weighed separately and the yields from the different fertilizer treatments compared.

Beet-seed drills as purchased are usually supplied with fertilizer attachments or they may be obtained for drills now in use. These attachments can be set to plant the desired amount of fertilizer in the row or hill with the seed at planting time.

VARIETIES

Sugar-beet varieties may be classified on the basis of performance into three types, i.e., tonnage, intermediate, and sugar types. The tonnage type produces a large root and luxuriant top growth, while the sugar type produces a smaller root and top but considerably higher sugar content than the tonnage type. The intermediate type falls between the two extremes.

In tests conducted in 1930 to 1933 near Crookston and Waseca by the United States Department of Agriculture, Division of Sugar Plant Investigations,[10] the average yield for the tonnage, in-

[10] Skuderna, A. W., Immer, F. R., Cormany, C. E., Brewbaker, H. E., Lavis, C. A., Lill, J. G., Price, Chas., Culbertson, J. O., and Deming, G. W. *Evaluation of Sugar-Beet Types in Certain Sugar-Beet-Growing Districts in the United States.* U. S. Dept. Agr. Cir. 476. 1938.

termediate, and sugar types was 14.44, 14.06, and 13.19 tons per acre, respectively. The tonnage type produced .38 and 1.25 tons more beets per acre than the intermediate or sugar types with a difference of .29 tons required for significance. As an average for the four years and two locations, the sugar type produced 0.38 and 0.60 per cent higher sucrose than the intermediate or tonnage types, respectively, with 0.13 per cent being required for significance. The tonnage type outyielded the sugar type by 166 pounds indicated available sugar per acre and the intermediate type outyielded the sugar type by 149 pounds per acre. The difference required for significance was 86 pounds in each case.

Since growers are paid on a basis of total sugar produced, it is evident from these data that tonnage or yield types are best suited to Minnesota.

Until recently, the major portion of the sugar-beet seed used in this country was imported and growers were dependent upon foreign producers to supply types suited to their needs. With the development of varieties resistant to diseases, the domestic production of sugar-beet seed increased from 500,000 pounds in 1932 to 13,661,900 pounds in 1938. This is sufficient seed to plant about 75 per cent of the annual acreage, after making allowance for reserve seed stocks.

Varieties resistant to Cercospora leafspot, an important sugar-beet disease in southern Minnesota in some seasons, have been developed by the Department of Agriculture. Tests are under way to determine the suitability of these varieties in Minnesota. Steps are also being taken to produce varieties adapted to Minnesota conditions. As varieties superior to brands now in use are found as the result of careful testing, replacement of brands with improved types may be expected to take place promptly.

SUGAR-BEET BY-PRODUCTS[11]

Three by-products of value to livestock feeders result from the beet-sugar industry—beet tops, pulp, and molasses. While most beet growers realize that the beet tops are valuable as feed, in many cases they have not been utilized in the most efficient manner. Beet pulp and molasses are concentrated feeds and may be used to advantage to replace part of the grain in rations for cattle or sheep.

Tops—Sugar-beet tops include not only the leaves, but also an appreciable portion of the crown which adds considerably to the weight and feeding value of the tops. The yield of tops varies greatly in different fields and different localities. In fields where growth is luxuriant the green weight of the tops may equal the weight of the roots, while in other fields it may be only one half to three fourths that amount. It may be assumed that the average yield of tops per acre in Minnesota over a period of years is from 6 to 8 tons green weight or one to one and one-quarter tons dried tops. The feeding value of a ton of dried tops is equivalent to a ton of alfalfa hay. Thus, the crop of tops represents an appreciable value and should be utilized carefully.

Wherever possible the grower should plan to feed his own tops and return the manure produced to his fields. The several ways of handling and feeding

[11] Further information may be obtained from U. S. Dept. of Agr. Farmers' Bul. 1718. *Important Sugar-Beet By-products and their Utilization*, by A. W. Skuderna and E. W. Sheets.

beet tops include: (1) grazing by cattle or sheep immediately after harvest; (2) cock curing in the field to be fed during the winter; (3) preserving in large ricks; or (4) ensiling.

Grazing in the field immediately after harvest is the simplest means of feeding tops and under some conditions may prove to be the most practical. This method of handling requires the least work, and has the additional advantage that the manure is distributed evenly over the field. However, in wet weather a considerable portion of the crop of tops may be lost by being trampled into the ground or be covered by snow. The crowns contain laxative mineral salts and the length of time the stock are allowed to graze each day should be carefully limited. A large number of livestock is required to graze off even a moderately large field efficiently before bad weather sets in, and few beet growers in the Red River Valley feed sufficient stock to fully utilize the tops in a short time.

When the lifted beets have been piled in windrows, the tops are also left in windrows by the toppers. They may be gathered easily with a fork and built into small cocks for curing. When cured, the cocks may be hauled to the feed lots as needed during the winter or stacked immediately. Properly cured tops may be stacked in ricks, using alternating layers of straw and tops. These ricks should be 8 to 10 feet wide, 10 feet high and of any convenient length.

Beet-top silage has been found satisfactory for both beef and dairy cattle, but it is usually not suited for sheep. Either a concrete or stave silo or a pit silo may be used. The tops may be cut in an ensilage cutter, sometimes with straw added, or they may be placed in the silo without cutting. In either case they should be carefully packed. If a pit silo is used, satisfactory packing is accomplished by driving a team, truck, or tractor over the tops, after which the sides, ends, and top should be covered with a foot of chaffy straw to exclude air.

Ensiling is used chiefly where it is not possible to stack the tops after drying in the field.

Although beet tops are less valuable as fertilizer than as feed, it should be borne in mind that they make excellent green manure and wherever possible should be plowed under immediately after harvest if they are not to be fed.

Sugar-beet pulp and molasses—These two by-products are the residues arising from the extraction and refining of sugar. In the beet-sugar factory, the beets are sliced into cossettes similar in size to "shoestring" potatoes and the sugar is extracted. The wet fibrous mass remaining is the pulp. When all the sugar that can be crystalized out of the juice obtained from the beets is removed, the remainder consists of uncrystalized sugar and minerals, and is called molasses. Although some beet-sugar factories sell these two products, pulp and molasses, separately, it is the practice at some factories to mix the two together after which it is dried, sacked, and sold as molasses pulp.

Dried beet pulp or dried molasses-beet pulp may be substituted for up to one half the grain ration when cheaper, pound for pound, than grain for fattening cattle. The feeding value of these feeds is about equal to that of ground barley.

Dried beet pulp and dried molasses-beet pulp, because of their bulky nature and slightly laxative effect as well as their conditioning effect, are popular

feeds with dairymen. As a source of nutrients, pulp is of about the same value as corn or ground oats in the dairy ration. Beet pulp is especially valuable when silage or other succulent feed is not available in which case it may be even more valuable than corn. It is sometimes soaked in water to increase its palatability and succulence.

Sugar-beet pulp, with or without molasses, may also be used to replace half or less of the grain ration of fattening sheep when it costs no more than corn.