Bulletin No. 156 - The Irrigation of Sugar Beets

F. S. Harris

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By F. S. HARRIS

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The Irrigation Of Sugar Beets

By F. S. HARRIS*

INTRODUCTION

The sugar beet crop during the last few years has come to be one of the most important sources of income for farmers in many sections of the country. The fact that the sale for the crop is certain at a price that is known in advance, in addition to the high type of farming that usually accompanies sugar beet raising, makes it probable that the sugar beet area will be considerably extended during the next few years.

In the United States the beet sugar industry has proved to be most successful and has found its greatest development under irrigation; in fact, most of the sugar beets of the country are now produced with the aid of irrigation water.

The expense of raising an acre of beets is so great that every condition should be as favorable as possible in order to prevent losses. Unless the soil and moisture conditions are favorable it is impossible to get a crop of sugar beets sufficiently large to pay the cost of production. The cost of raising an acre of grain is relatively low, and if the crop is poor the loss is slight; with beets the farmer cannot afford to have a failure.

These conditions make it especially desirable to understand the water requirements of the sugar beet plant. A little increase in yield adds considerably to the relative net profit of the crop.

It is impossible to give rules for irrigation that apply under all conditions, but it is believed that the experiments reported in this bulletin will be directly helpful to those having similar conditions, and they may offer some suggestions to those having different conditions.

LITERATURE REVIEW

The best amount of water to use, the proper time to apply it, the number of applications, and other problems connected

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*The author wishes to acknowledge his indebtedness to his assistants, A. E. Bowman, H. W. Stucki, and H. J. Maughan for faithfulness in connection with field work; to D. W. Pittman for help with the chemical analyses; and to N. I Butt for assistance in preparing the material for publication.
with the irrigation of sugar beets necessarily vary in different parts of the country and under differing soil conditions. In various places extensive experiments have been conducted on the water requirements of this crop, but in the review of the literature only those closely connected with the experiments that follow will be discussed.

McClatchie\textsuperscript{a} in Arizona found that if the seeding were done during the cool part of the year, the crop needed no irrigation for a month or two after planting, but if sown at the time of the warm weather of early fall the crop needed frequent watering until cool weather arrived. If planted in the warm spring weather irrigation was necessary during the entire period of growth. Earlier he\textsuperscript{b} found it advisable to irrigate the land before seeding and again when the plants were two or three months old. While much water increased the yield, it greatly reduced the percentage sucrose and the total yield of sugar.

In a government report of irrigation and drainage investigations\textsuperscript{c} in different states, data from Kansas show that with a seasonal rainfall of 13.7 inches the yields per acre of beets and sugar were higher from an irrigation of 5.31 inches on July 26 than from 5.7 inches applied April 12, although the percentage sugar was 1.2 higher for the early irrigation. The percentage purity was higher for the beets not irrigated. The Colorado results indicate that winter irrigation and early seeding favor a good stand. With observations on twenty fields irrigated in the usual way, the average amount of water applied during the season was found to be about 15.6 inches. Most farmers irrigated from one to four times with about 5.8 inches to an application. The total water used, including the rainfall, was not more than 24 inches, although some practised winter irrigation in addition. Cultivation as soon as possible after the water was applied was found to be absolutely essential to successful beet culture on this soil because of the crust formed by the water. Failure to cultivate deeply resulted in a "pinching" of the beet, which reduced the diameter and made it grow

\begin{itemize}
\end{itemize}
Fig. 1.—A good field of sugar beets in Cache Valley, Utah.

in old shapes. For Montana and Arizona, the irrigation season lasted from July 13 to August 17, during which time an average of 25.8 inches of water were used.

Observations by Schneidewind and others\(^d\) in Germany during the period from 1896 to 1906 show that although the yields are smaller, root crops are richer in carbohydrates and protein during dry years than during wet ones; hence the net influence of the weather is not so great as ordinarily thought. High-bred resistant sugar beets showed less variation in dry and wet years than common varieties.

Roeding\(^e\) from experiments in Colorado in 1906 found that a higher yield per acre was produced from about 11.3 inches of water applied in two irrigations than from larger quantities in

\(d\) Schneidewind, W., et al., Influence of Precipitation on Yield and Quality of Crops. Landw. Jahrb., 36 (1907), No. 4, pp. 574-581.

three or four irrigations. The irrigation of every row by means of lath boxes produced a yield 1.2 times as great as the irrigation of alternate rows by the same method, and nearly 1.5 times as great as the irrigation of every row by the open-furrow method. In 1908 about ten inches of water applied in two irrigations produced the highest percentages of purity and the yields were lower than where larger quantities were used in three or four applications. Keeping the soil continually wet reduced tonnage. The irrigation of every row resulted in a more economical use of water than the irrigation of alternate rows, while with either method the use of lath boxes saved considerable labor.

He showed sub-irrigation can be practised with good results on soils sufficiently impervious to permit strong lateral movement, but the loss was often so great by evaporation and seepage that this method was not, as a rule, so economical as surface irrigation. He concluded that too early irrigation tended to make a turnip-shaped beet and produced an unusually heavy growth of leaves without a corresponding development of root. If the water is withheld too long, the beet will begin to mature and so prevent its proper development later. As long as the leaves look fresh and healthy in the early morning, it is unnecessary to irrigate. Two to four applications of water should be sufficient on ordinary soils.

Orton states that the crop of the following season can unquestionably be benefited by late fall or early winter irrigation. "The beet crop for its proper growth and maturity requires a good supply of moisture during the planting and growing seasons, but it will not begin to store sugar in quantity until the beets have been subjected to a season of dry weather at the end of their growing period."

Knight says: "Fall-plowed land sometimes requires an application of water before seeding," but a poor stand generally results from an irrigation immediately after planting. Where spring watering is necessary, it should be done as early as possible and when the soil is sufficiently dry the land should

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be deeply cultivated. He later found that where beets received no irrigation until they failed to revive at night from the wilting of the day, an unsatisfactory crop resulted. With two-inch applications the beets in all stages of wilting showed a higher sugar content than those with four-inch or six-inch applications. The purity of the sugar was greatest in the beets irrigated only after all plants had wilted down once.

Dry weather throughout the rapid growing period in a humid region was found by Urban1 to permanently injure the sugar-forming ability of beets. The beets harvested after the dry spell had been broken gave a quality of juices that was unfavorable for the sugar manufacturers.

According to Townsend1, winter irrigation of beet land is highly beneficial where the precipitation at this season is light. If the seed-bed is dry it is much better to irrigate before seeding than to irrigate the crop up, especially in fields likely to crust after an irrigation. The beets should be carried as long as possible after they are up before watering so the plants will be forced to form long roots and, therefore, yield a high tonnage. The action and color of the plants are the best means of judging the time to irrigate and quantity of water to apply. Furrow irrigation is much better than flooding, especially for small beets since excluding the air from the beet roots for a few hours by flood irrigation causes the plants to suffer, particularly if a permanent crust of silt is formed.

Beckett2 in California found the yield of beets to increase with an increase in the water supply, but the sugar content was slightly lower with the larger quantities of water. Better yields were obtained under irrigation with early than with late seeding. The crop seeded early had a value of $54.25 when not irrigated, while that receiving two irrigations was worth $87.50.

At the Scottsbluff Sub-station in Nebraska, Knorr3 found

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the best results when beets were irrigated at such times as to keep
the plants in good growing condition from the time of thinning
until about three weeks before harvest. The irrigations should
be in moderate amounts and the soil never so dry that the plants
suffer for lack of moisture. It is desirable to cultivate the beets
in order to break the crust made by irrigating as soon as the
soil becomes dry enough. He also found that for sugar beets
receiving three irrigations during the growing season, a yield of
1.6 tons to the acre more was realized from land that had been
fall irrigated than from that which was only watered during the
growing season.

PREVIOUS WORK AT THE UTAH STATION

Ever since the establishment of the Utah station over twenty-five years ago, irrigation studies have been given considerable
attention, but the first important work on the irrigation of beets
was done by Widtsoe and his associates. According to Bulletin
80, published in 1902, sugar beets had a greater percentage of
moisture in the soil when they were first irrigated (about the
middle of June) than any of the other common crops grown.
The relative proportions of the constituents of the plant were
not found to be affected to any noticeable extent by irrigation,
although there was a tendency for the plants receiving most
water to contain the higher percentages of sucrose and a higher
purity. On a gravelly loam land receiving 20 to 27 inches of
water the beet yield was greater than with more or less, and
the lower quantity was best. The highest yield of dry matter
to the acre, and for each pound of water applied, was from the
plat receiving 20.17 inches of water in five equal irrigations, the
smallest being with 17.78 inches in eight irrigations. Better
yields were obtained by making the larger applications early
in the season than during the later period. A trial of one year
showed flooding to be better than furrow irrigation. Between
twenty and twenty-five inches of water yielded beets with high-
est sugar content.

m. Knorr, F., Experiments With Crops Under Fall Irrigation at the
Scottsbluff Reclamation Project Experiment Farm (1914), U. S. D. A.
Bul. 133, p. 17.

n. Widtsoe, J. A., et al., Irrigation Investigations in 1901 (1902),
Utah Sta. Bul. 80, pp. 67-199.
Bulletin 115° indicates that for the early season, beets exhaust the soil moisture less thoroughly and rapidly than the cereals and alfalfa, but more than potatoes. Beets needed their first irrigation when the soil contained more moisture than with the other crops. The water was used faster during August than during July or September. At the time of harvest, beets had exhausted the soil more thoroughly of water than oats, corn, or potatoes.

Field experiments reported in Bulletin 116° indicate a general increase in dry matter with increased applications of water up to 50 inches. The yield of dry matter for each inch of water decreased as the total water during the season increased. In pounds of water for a pound of dry matter there was an in-

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Fig. 2.—Beets shaped like 94 give a good yield and there is but little waste in topping. With beets shaped like 96 there is considerable waste. The shape can be affected by irrigation.

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crease from 569 for 15.25 inches of water to 1,186 for 60.25 inches. Nearly three times as large a yield of dry matter would be produced when 30 inches were spread over four acres as when it was applied to one acre.

Bulletin 117q shows sugar beets to gain nearly five tons to the acre when the amount of water was increased from five to ten inches, but when more than ten inches were given there was little increase in tonnage. An acre of land with 30 inches of water applied produced 20.82 tons, and when spread over six acres the same quantity of water gave a total yield of 82.68 tons.

Results given in Bulletin 118r definitely indicated that part of the yield of sugar beets was due to the water applied prior to the irrigation season, although such irrigations were not nearly so valuable as those added later. The percentage of well-shaped beets was higher when the water was applied at the usual times. Water added about a month after planting had a distinctive value in determining a high yield. It was very important that the applications be regulated to keep the soil uniformly moist during July and August. September irrigations had little value, less than two inches during this month being ample where the amount had been sufficient the two previous months.

With ordinary quantities of water to be applied, almost without exception, the greater the number of irrigations, using the same quantity of water, the larger the yields. It is believed that with fifteen inches of water, four irrigations are sufficient and three would be nearly as good. Applying five inches every other week during the irrigation season appeared to be the best practice. Although it is seldom wise to have more than two-week intervals between irrigations, the frequency of applications may be decreased as the total water applied throughout the season is increased.

Bulletin 119s shows a tendency, from the earliest to the lat-


est date of harvesting, for a decrease in the proportion of leaves as the quantity of irrigation water increased. Although the water in the whole plant and the leaves decreased as the water applied decreased, the moisture in the roots remained practically constant for each period irrespective of the quantity of water used.

Bulletin 120 brings out the facts that although there was only a slight increase in the percentage sucrose with the water applied up to 35 inches, the percentage of carbohydrates increased quite steadily with increased quantities of water used. The application of 50 inches in every case decreased the sucrose content. The percentage purity was lowest with the smallest quantities of water and highest with intermediate applications up to 20 inches. The per cent sucrose and purity were higher in October than in September.

Fig. 3.—Plats of beets in the experiment.

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DESCRIPTION OF THE EXPERIMENT

The experimental work reported in this bulletin was conducted on the Greenville Experiment Farm two miles north of Logan, Utah. The soil, which is a well-drained uniform clay loam to great depth, has been described in detail in Utah Station Bulletin No. 115. The land was manured every year and was plowed in the fall except one year when fall storms made it necessary to wait till spring. The land was planted alternately to beets and potatoes. The soil will hold about 22 per cent of moisture as a maximum under field conditions. The plats

Fig. 4.—Beets in the experiment being harvested. The flumes that carried the water are seen running across the field.

were 30 by 58.08 feet, which gives one-twenty-fifth of an acre each exclusive of a seven-foot space between the plats.

The water was measured by means of a Cipoletti weir and taken to the land in wooden flumes, where it was added to the beets by the flooding method. All the water was retained on the plats by banks around the edges. To a number of plats water was added each week during the growing season, but the time of applying water to most of the plats depended on the stage of development of the plants.

The sugar beet plant was divided into four stages as follows: First, just before thinning time; second, four weeks after thinning; third, when the beets averaged two inches in diameter;
and, fourth, when the beets were nearly—but not quite—ripe.

A five-inch irrigation was used as a standard at these stages. An application of this amount was given at each stage, at each two stages, at each three stages, and at all the four stages, thus giving quite a number of different combinations. It is possible, therefore, from the results obtained to determine which stages are best when either one, two, or three irrigations are used.

In the weekly irrigations one plat received one inch, another 2½ inches, another 5 inches, and another 7½ inches of water each week during the regular irrigation season.

The experiment was begun in 1912 and carried through 1913, 1914, 1915, and 1916, giving five years' results. Conditions during these years were made as uniform as possible in every respect. The record of precipitation during the first four years is given in Utah Station Bulletin No. 146. It averaged nearly 18 inches a year.

YIELD OF BEETS

Certainly the most important consideration in connection with irrigation, from the farmer's point of view, is its effect on the yield of the crop. Where beets are sold on a sliding scale the farmer is also interested in the per cent sugar contained; the sugar factory is always much interested in this item.

The yield of both roots and tops is reported, the quantity of tops being of very much less interest than that of the roots; yet the tops do have a decided value as a fertilizer when plowed under and as feed for stock. The yield of tops is expressed as tons of wilted tops to the acre.

In reporting these experiments, the results are separated into two divisions: (1) those from the plats receiving regular weekly irrigations, and (2) those from plats receiving water only at certain periods in the growth of the plants.

Figure 5 shows the five-year average yield of beets and tops on plats receiving no water, 1 inch weekly, 2½ inches weekly, 5 inches weekly, and 7½ inches weekly. It will be noted that the highest yield was obtained with one inch weekly, or an average total of 12.8 inches for the entire year. That receiving 2½ inches weekly, or 32 inches during the year, gave only slightly less yield; but where 5 and 7½ inches of water were applied weekly the yield was decidedly reduced. With the
Fig. 5.—Yield of beet roots and tops on plots receiving different quantities of irrigation water weekly. Average for five years.

Fig. 6.—Yield of beet roots and tops on plots receiving various quantities of irrigation water at different stages. Average for five years.
larger amount the yield was almost exactly the same as it was where no irrigation water was applied. The yield of tops bore about the same general relationship as the roots, except that with high water proportionately more tops to roots were produced than where no water was applied.

Figure 6 shows the average yield of roots and tops on plats receiving five-inch irrigations at various stages in the growth of the beets. The lowest yield was obtained where the land was irrigated after the seed was planted and before it came up. The yield with this treatment was decidedly less than it was where no water was given.

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

Upon examining the plats receiving two, three, and four irrigations, the value of irrigation water during the third stage is very evident. The highest yield was received where a total of 15 inches were applied. It will be remembered that in the weekly irrigations a higher yield was obtained for 12.8 inches than for 32 inches.

It seems, therefore, that the total requirements of sugar beets for irrigation water are not large, but the period of application is important.

**YIELD OF SUGAR**

Of greater real importance than the acre-yield of beets is the acre-yield of sugar since the sugar is the valuable part of the crop. Figures 7 and 8 give the yield of sugar in beets on plats receiving various quantities of water weekly and five-inch irrigations at certain periods respectively. These figures show the same general relations that were brought out in Figures 5 and 6.
Fig. 7.—Yield of sugar on plats receiving different quantities of irrigation water weekly. Average for five years.

Fig. 8.—Yield of sugar on plats receiving various quantities of irrigation water at different stages. Average for five years.
Figure 8 shows that when only a late irrigation was applied the total sugar was but slightly higher than where no water was applied. Where but two irrigations were given the second and third stages were decidedly the best. In fact, two irrigations at just the right time gave almost as good results as four. It will be noted that where three irrigations were given the lowest yield resulted when the third stage was left cut. The importance of this period is, therefore, seen whether one, two, or three irrigations are given.

**PER CENT SUGAR AND PURITY**

In Figure 9 both the percentage sucrose and the purity are shown to be somewhat higher in all the beets that were irrigated weekly than in those receiving no irrigation. The highest sugar content was in the beets receiving 2½ inches of water each week. Figure 10 shows the lowest sugar content, as well as

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*Fig. 9.—Per cent sucrose in beets and purity on plats receiving different quantities of irrigation water weekly. Average for five years.*
Fig. 10.—Per cent sucrose in beets and purity on plats receiving various quantities of irrigation water at different stages. Average for five years.

the lowest purity, to have been produced on the plat receiving water only when the beets were approaching maturity. The highest sugar content with a single irrigation was in the beets irrigated when about two inches in diameter.

### SIZE AND SHAPE OF BEETS

The average weight of beets under the different treatments is given in Figures 11 and 12, which show that the size of beets follows closely the relationships that have already been pointed out for yield. This was to be expected since the stand on all plats was practically the same in the spring and yield was largely, but not entirely, an expression of size. The size of beets irrigated only at the fourth stage was proportionately less than the yield would indicate.

The length of beets is also given in Figures 11 and 12. Figure 11 shows that where 7½ inches of water were given each week the length of beets averaged very slightly less than those receiving no water. The longest beets on the weekly irrigations were produced by one inch of water each week, but the differences due to the treatments were very slight.

Figure 12 shows that five inches of water applied at any period made the beets longer than those that were not irrigated.
Fig. 11.—Average weight and length of beets on plats receiving various quantities of irrigation water weekly. Average for five years.

Fig. 12.—Average weight and length of beets on plats receiving various quantities of irrigation water at different stages. Average for five years.
The longest beets were those irrigated at the first three stages. The very late irrigation had but little effect in lengthening the beets.

There is a popular idea among farmers that the first irrigation should be delayed just as long as possible in order to induce the beets to go deeply into the soil. In order to increase length, some even allow their beets to be positively injured by drought before applying water. The results reported here, which represent many thousands of careful measurements during five years show that the old idea is largely a fallacy.

In the ordinary good beet soil that is well drained an irrigation does not decrease the depth of penetration of beets; it rather assists them to go deeper. Of course this does not contradict the well-known fact that beets are likely to be shorter on a soil that is absolutely water-logged. This condition to a slight extent has already been pointed out where a total of 96 inches of water were applied.

![Graph showing percentage of forked beets and average height of tops on plats receiving different quantities of irrigation water weekly.]

Average for five years.
In view of these experiments, it seems folly to let beets suffer for want of water and be permanently injured in order to get them to root deeply.

The percentage of forked beets is shown, by Figures 13 and 14, to bear very little consistent relationship to the amount of water or the time of its application. In the weekly irrigation tests the beets that were not irrigated had the largest number of forked roots, while in the plats that had water applied at different periods the plat receiving water at the first stage only had the least number of forked roots. The greatest number was on plats irrigated early and late. The differences, therefore, are not consistent and the idea that any method of irrigation greatly increases the tendency toward forkedness seems unwarranted.

An examination of Figures 13 and 14 for the effect of treatment on the height of tops reveals a rather close relationship between this and the yield of tops which has already been discussed in connection with Figures 5 and 6.
SUMMARY

1. In this bulletin results of five years' experiments on the irrigation of sugar beets are reported.

2. When the beets were watered each week during the growing season, one inch of water weekly gave a higher yield than did more than this quantity.

3. When but one irrigation was given it was most effective when applied at the time the beets averaged about two inches in diameter.

4. Irrigating the land after the seed was planted and before the plants were up reduced the yield below that where no irrigation water was applied.

5. The least desirable time to apply water after the plants had begun to grow was just before the beets were ripe.

6. When the water was applied at the proper time, two or three irrigations of five inches each gave practically as good results as where more water was used.

7. Proportionately more tops were produced by the high and the later irrigations than by the opposite conditions.

8. The percentage sugar and the purity were higher in the irrigated than in the non-irrigated beets, except where the irrigation water was added very late.

9. The highest percentage of sugar resulted from irrigation water applied when the beets were about two inches in diameter.

10. Contrary to popular opinion, the length of beets was not increased by delaying the time of applying the first irrigation.

11. The percentage of forked beets bore no consistent relationship to the amount of irrigation water applied.

12. Irrigation water affected the average size of beets in practically the same manner that it affected the total yield.

13. Sugar beets do not require large quantities of irrigation water if it is properly applied, but they are sensitive as to the time it is given.

(College Series No. 49.)
## APPENDIX

<table>
<thead>
<tr>
<th>No.</th>
<th>Irrigation</th>
<th>Acre Yields Beets (Tons)</th>
<th>Per Cent Surcose</th>
<th>Per Cent Purity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>1 inch weekly</td>
<td>16.74</td>
<td>28.90</td>
<td>28.22</td>
</tr>
<tr>
<td>2.</td>
<td>2½ inches weekly</td>
<td>16.04</td>
<td>26.10</td>
<td>22.70</td>
</tr>
<tr>
<td>3.</td>
<td>5 inches weekly</td>
<td>12.70</td>
<td>20.50</td>
<td>18.13</td>
</tr>
<tr>
<td>4.</td>
<td>7½ inches weekly</td>
<td>7.21</td>
<td>18.10</td>
<td>16.43</td>
</tr>
<tr>
<td>5.</td>
<td>None</td>
<td>9.35</td>
<td>15.70</td>
<td>9.70</td>
</tr>
<tr>
<td>6.</td>
<td>6 in. after pltn. and before com. up</td>
<td>15.54</td>
<td>15.30</td>
<td>15.80</td>
</tr>
<tr>
<td>7.</td>
<td>5 inches at 1st stage</td>
<td>16.01</td>
<td>14.19</td>
<td>15.17</td>
</tr>
<tr>
<td>8.</td>
<td>5 inches at 2nd stage</td>
<td>12.59</td>
<td>14.63</td>
<td>17.45</td>
</tr>
<tr>
<td>9.</td>
<td>5 inches at 3rd stage</td>
<td>16.98</td>
<td>14.80</td>
<td>12.89</td>
</tr>
<tr>
<td>10.</td>
<td>5 inches at 4th stage</td>
<td>15.96</td>
<td>15.35</td>
<td>16.24</td>
</tr>
<tr>
<td>11.</td>
<td>20 in., 5 in. each at 1, 2, 3, 4 stages</td>
<td>18.73</td>
<td>20.28</td>
<td>20.70</td>
</tr>
<tr>
<td>12.</td>
<td>15 in., 5 in. each at 2, 3, 4 stages</td>
<td>20.39</td>
<td>27.00</td>
<td>30.30</td>
</tr>
<tr>
<td>13.</td>
<td>15 in., 5 in. each at 1, 2, 3, 4 stages</td>
<td>18.96</td>
<td>13.55</td>
<td>14.56</td>
</tr>
<tr>
<td>14.</td>
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### AVERAGE

<p>|  | 16.92 | 23.79 | 21.34 | 14.68 | 16.94 | 18.79 |
|  | 17.46 | 14.74 | 15.10 | 14.80 | 13.47 | 15.11 | 18.38 | 80.18 | 87.85 | 18.50 | 18.04 |</p>
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<th>No.</th>
<th>Av. Length of Beets</th>
<th>Av. Wt. of Beets</th>
<th>Lbs.</th>
<th>Per Cent Forked Beets</th>
<th>Sugar Per Acre (Lbs.)</th>
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**Av. Length of Beets:** 11.5

**Av. Wt. of Beets:** 9.5

**Per Cent Forked Beets:** 10.4

**Sugar Per Acre (Lbs.):** 11.6