Sugar Beet Populations in Relation to Yields

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Mechanization of operations in the culture of the sugar beet crop has top priority in sugar beet research today. The harvest of the crop by machines is apparently just around the corner. Hence there remains the elimination of hand thinning as the major requirement for the sugar beet to become a farm crop grown by typically American methods instead of an extensively grown truck crop. As mechanized operations are introduced to eliminate hand work in thinning sugar beets, the stands as left by the machines may not resemble the single plant patterns as are now commonly attained by good hand work. This article discusses the yields from sugar beet stands that are believed to be of the type likely to be obtained as mechanization to thin sugar beets is introduced.

The ideal initial stand of sugar beets would, of course, be a stand of vigorous single plants spaced uniformly at exactly the distance that would result in the maximum yield. There is rather general agreement that the fewest possible numbers of seedlings per unit area, that approach this ideal, and these distributed evenly in the row, constitute the best initial stand upon which to base, the elimination of hand work in thinning. Sheared seed and improvement in planter design represent the steps now taken in this direction.

Since the greatest efficiency of any modification of conventional hand thinning probably depends on thin initial stands, the use of the lowest seeding rate consistent with local conditions is indicated. When minimum seeding rates are used there will always be the hazard of more or less serious reductions of stand by unforeseen conditions. A very thin stand may produce a profitable crop, even if it is smaller and less profitable than the maximum crop which might have been produced by a good stand or by intensive hand culture methods, since savings in labor may compensate for much of the reduction in yield.

Plants growing in close proximity compete with each other for light, water, and plant nutrients. Experiments have indicated that when sugar beet plants were spaced at as great a distance as 40 by 40 inches this competition was eliminated. There was also a marked reduction in yield per acre from these 40 by 40 inch stands in comparison with stands spaced 10 by 20 inches. If any two men interested in the growing of sugar beets—let them be farmers, sugar company,

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or scientists—were chosen at random, it is probable that their opinions would differ as to the exact spacing of sugar beet plants from which maximum acre yields are obtained. However, there is general agreement that uniformity of spacing is essential for maximum yield. A large proportion of the sugar beet crop of northern Colorado and much of the crop in other regions is grown in rows spaced 20 inches apart and, as a working standard, a stand of 100 beets per 100 feet of row is generally accepted as a full stand. Consequently, for the purposes of this discussion, a full stand of sugar beets is defined as 100 plants per 100 feet of row, the rows being 20 inches apart, and a standard population is defined as approximately 26,000 plants per acre.

Experiments at Fort Collins, Colo.,- have given information on the effects of reduced stands on the yield of sugar beets, and the results of these experiments over a number of years, including 1943, have been summarized (i).[3] Briefly, these experiments indicated that yields of timely planted sugar beets with stands reduced to 70, 50, and 30 plants per 100 feet of row were approximately nine-tenths, three-fourths, and two-thirds, respectively, of a full crop, i. e. the crop of a full stand of 100 plants per 100 feet of row. Also a 70-percent stand of 12-inch spaced plants was compared with a 100-percent stand of plants with uniform 16-inch spacing, both stands having-populations of approximately 18,600 plants per acre. In this comparison the uniform stand outyielded the non-uniform stand by slightly more than 0.6 tons of roots per acre, this difference being probably significant. In all these tests the stands were obtained by hand thinning and the thinned stands were checked for the quality of the work. Thus these stands consisted of single plants with practically no two-plant or multiple-plant hills.

It is obvious that the elimination of conventional hand thinning will result in thinned stands of sugar beets with less uniform distribution of the plant population than could have been obtained by good hand work. The thinned stands of non-hand-thinned sugar beets will consist of one-plant, 2-plant, and multiple-plant hills and skips. The proportions of these types of hills and the uniformity of their distribution will depend upon the number and distribution of the seedlings in the initial stand and the quality of the work done. The average population will be greater or less than the standard population of 26,000 plants per acre.

[2]Agronomic investigations of the Division of Sugar Plant Investigations at Fort Collins, Colo., are cooperative with the Agronomy Section of the Colorado Agricultural Experiment Station and are conducted on the Agronomy Farm of the latter agency.

[3]Italic numbers in parentheses refer to literature cited.

Materials and Methods

The soil on which these rate of planting experiments and population studies were conducted was Fort Collins loam, light textured phase, and the general level of fertility was fairly high. Spring wheal preceded the beet crop. The wheat stubble received about 10 loads per acre of manure and was fall plowed. In both years the planting of the experiments was delayed by adverse weather in April, the planting dates being May 15, 1944, and May 8-10, 1945.

The weather and field conditions which affected germination of sugar beet seed were probably representative of the extremes which might occur in growers fields over a period of several years. These conditions were very unfavorable in 1944 and extremely favorable in 1945. Much of the seed planted in 1944 did not germinate until after a, heavy rain and hail storm on May 24 and final initial stands were very poor. Also in this year early emerging weeds were a source of plant competition until after the sugar beets were thinned the latter part of June. It was estimated that the initial stand at the time of thinning represented not to exceed 30 percent of the potential germination of the seed planted in 1944. In contrast, soil and weather conditions in 1945 were very favorable for prompt and vigorous germination of sugar beet seed as shown by the results of an emergence study in which 1,000 seed pieces each of a number of seed lots were planted on May 12. Included in the emergence study were the four kinds of seed used in planting the rate of seeding experiment. Laboratory germinations and field emergence of these four lots of seed were as follows:

1. Whole seed; laboratory germination 156 sprouts and field emergence 154.6 plants per 100 seed pieces.

2. Sheared seed; laboratory germination 112.75 sprouts and field emergence 107.6 plants per 100 seed pieces.

3. Pelleted seed; laboratory germination 53.25 sprouts and field emergence 67.6 plants per 100 pieces.

4. Graded whole seed ; laboratory germination 163.25 sprouts and field emergence 153.8 plants per 100 seed pieces.

It was estimated that field emergence from the sugar beet seed planted in the 1945 experiments was in general at a rate in excess of 90 percent of the potential germination of the seed lots used. The initial stands were comparable to the best stands which growers can expect from similar seeding rates under the most favorable conditions in any year. The emergence of early weeds in the 3 945 plantings was negligible.

The rate of seeding tests and the population study each consisted of six randomized replications of the treatments with plots eight rows in width and 60 feet, in length. The four inside rows of each plot were harvested for yield determinations and two 20-beet samples were taken from each plot for analysis to determine the percentage of sucrose in the beets. In 1945 the data obtained for sucrose content of the roots were erratic and the standard errors applicable to these values were unusually high. It is possible that for plots as large as these were and with beets varying considerably in individual size, as these beets did vary, the standard sampling technique was inadequate. For this reason it is probable that the best measure of yield from the treatments in these tests is the yield of roots rather than the indicated yield of gross sugar.

For the comparison of 20-iuch with 40-inch rows in 1945 there were four randomized replications of the treatments with plots 120 feet in length and of sufficient width to permit the harvest of four of the 20-inch rows or two of the 40-inch rows after discarding border rows which might have been affected by competition with the adjacent plot.

The whole area used for the populations- study was planted with one of the newer planters, sheared seed being planted at a very heavy rate of seeding on May 8. This test was blocked with long-handled hoe on June 18 and 19. Near perfect stands of blocks, most of which contained two or more plants, were obtained. Final thinning was on June 22, 23, and 25 by two-man teams. One of the men read the chart, of the stand, as previously determined by the drawing of random numbers, and the other reduced the blocked hills to the charted stand for each of the plots. The thinned stands obtained on all plots of this test very closely approximated the stands as planned both as to the distribution of the hills and the total populations of plants.

All treatments in the rate of seeding experiments, except those for which pelleted seed was used, were hand planted with Planet Jr. garden drills. The differences in rate of planting were obtained by using mixtures of dead and untreated seed in appropriate proportions. The dead seed for these mixtures was prepared by a hot water treatment. These seed mixtures were planted at a moderately heavy rate of seeding such that the live seed actually planted approximated the planned rate of planting for each treatment. Distribution of the live seed in the row was quite good as indicated by the distribution of the plants in the initial stands, but probably was not equal in uniformity to the seed distribution by some of the modern seed drills. The attained planting rates were calculated from the weight of seed used in planting each treatment. The numbers of viable seed pieces planted per foot of row were calculated from the weight of seed planted and the laboratory germinations of samples of the seed used.

No drill was available that would handle the pelleted seed without considerable grinding of the pellets or that would space individual pellets at the desired intervals. Therefore the pelleted seed was dropped by hand in furrows opened to a depth of about 1 1/2 inches and covered by drawing the soil back into this furrow. This method of planting was probably not comparable to the work of a drill equipped to handle pelleted seed and, particularly in 1945, germination and early growth of the seedlings from the pellets was not as good as from pellets which had been drill-planted in another experiment.

In both years the very thin initial stands in the rate of seeding experiments were thinned with long-handled hoe and the thicker initial stands were thinned in the conventional way with a short-handled hoe. The time used in thinning each plot was recorded. The initial stands from the lowest rates of seeding were left essentially as they emerged, since very few beet plants were cut out of these stands; only weeds were cut out in the thinning operation. Some plants were cut out in thinning the initial stands from the intermediate rates of planting, the best obtainable stand of hills being left. When the initial stands from the heavier rates of seeding were adequate, they were thinned with short-handled hoe to uniformly spaced single-plant hills.

In 1944, two treatments of the lowest rate of planting were included in the rate of planting experiment, the intention being to thin and weed one at the normal date of thinning and to leave the other without thining or weeding until the normal date of the first hoeing of the crop. However, initial stands were so thin and weedy that both treatments were weeded at the normal thinning date, all available sugar beet plants being left in each. Therefore treatments 5 and 6 of this experiment were essentially duplicates and while given separately in the summary of the test may be averaged for purposes of comparison of the lowest rate of seeding with the heavier rates of seeding in this experiment.

In the 1945 rate of seeding experiment each of the three lower rates of planting were seeded in adjacent duplicate plots in each replication for the purpose of supplementing the stand in one of each pair of these plots by planting a single piece of sheared seed in the blank hills when the plots were thinned. Since near perfect thinned stands were obtained in the plots seeded at the 2-pound rate, this supplemental planting was made on only one of each pair of plots seeded at the 0.5- and 1-pound rates. These supplemental plantings failed and therefore treatments 2 and 2a, 3 and 3a, and 4 and 4a, as given in the general summary of this experiment, were essentially duplications of the 0.5, 1- and 2-pound seeding rates, respectively, and have

been averaged in each case for comparison of these seeding rates with the other treatments of the experiment.

Much experimental evidence and the experience of growers have both contributed to the adoption of the 20-inch row width when the crop was thinned and harvested by hand. If hand labor is to be replaced with machines it may well be that a re-examination of row widths is in order. It may be found that some machinery, particularly harvesters, will work more efficiently in wider rows. The suggestion that wider rows be used for the sugar beet crop came to the attention of the staff at the Fort Collins station after the 1945 crop had been planted. However, certain parts of the experimental field which had been uniformly planted at a rate of approximately 2 pounds of sheared seed per acre were available for a perliminary comparison of 20-inch and 40-inch row widths. The 40-inch row width was obtained by cutting out every other one of the 20-inch rows for the 40-inch row plots.

Further details of the treatments used and the stands obtained will be given in the discussions of these experiments.

Population Study, 1945

Low planting rates, machine thinning, or any other method or combination of methods by which conventional hand thinning of the sugar beet crop is eliminated are certain to result in thinned stands which are more or less non-uniform in distribution. This population study was designed for the purpose of gaining information on the probable yields of sugar beets from such non-uniform stands. It seemed reasonable to believe that machine thinning of suitable initial stands could attain a proportion of 75 percent single plant hills in the thinned stand and that most of the other 25 percent of the hills would be doubles. Therefore the proportions of 75 percent singles, 21.5 percent doubles, and 3.5 percent multiples 3- and 4-plant hills) were adopted as the basis for the stands in this experiment. A treatment with a full stand and standard population of 100 single-plant hills per 100 feet of row was added as the check. The full experiment consisted of 10 treatments as follows : Treatment 1; the check. Treatments 2, 3, 4, 6, 8, 9, and 10; stands of 120, 100, 80, 70, 60, 50 and 40 hills per 100 feet of row, respectively,with 75 percent single-plant hills in each case. Treatment 5 ; a stand of 70 hills per 100 feet of row with 85 percent of the hills single plants. Treatment 7; a stand of 70 hills per 100 feet of row with only 65 percent of the hills single plants. Distribution in each plot of the varying kinds of hills—**1-plant,** 2-plant, 3-plant, 4-plant or blank, was at random as determined by the drawing of random numbers for every plot in the test. A summary of this experiment is presented in table 1.

Table 1.—Stands, acre yields of roots, sucrose percentage, and gross sugar production as obtained in sugar beet population study. The number of hills and plants per 100 feet of row as expected, as attained at thinning time, and as harvested are given. Eight row plots, GO feet long, with rows 20 inches apart. Fort Collins, Colo., 1945. (Data given as 6-plot averages).

Treatment			Stands per 100 fet of row								
	Hills per 100 feet	1-plant hills (per-	Expected		Actual thinned		No. of roots	No. of plants	Acre yield of roots	Sucrose per centage	Acre yield gross sugar
No.	of row	centage)	Hills	Plants	Hills	Plants	harvested	lost*	(Tons)	(Percent)	(Pounds)
1.	100	100	100	100.0	101.7	101.7	100.8	0.9	15.50	14.08	4,362
2.	120	75	120	154.0	117.1	154.8	142.9	11.9	15.01	14.30	4,291
3.	100	75	100	128.5	100.3	129.1	124.4	4.7	15.52	14.22	4,402
4.	80	75	80	103.1	70.5	102.3	99.2	3.1	14.51	13.48	3,913
5.	70	65	70	82.3	70.8	83.5	81.5	2.0	14.39	14.13	4,073
6.	70	75	70	90.2	69.8	89.9	87.9	2.0	13.78	13.09	3,609
7.	70	65	70	98.5	70.2	99.0	93.3	5.7	13.36	13.09	3,550
8.	60	75	60	77.1	60.1	77.4	74.5	2.9	13.25	13.02	3,456
9.	50	75	50	64.4	50.6	65.1	63.2	1.9	12,24	12,72	3,110
10.	40	75	40	51.0	41.1	52.8	52.0	0.8	11,99	12.49	2,974
	General mean of test								14.00	13.46	3,785
	F value								20.53**	5.60**	23.05**
	2.014 x the S. E. of a Diff. (odds of 19:1)								0.79 T.	0.81%	302 lb.
	2.630 x the S. E. of a Diff. (odds of 99:1)								1.03 T.	1.08%	404 lb.
	S. E. of M. in percent of general mean								1.92%	2.12%	2.80%

* Since actual loss of plants from thinning to harvest by death due to disease or accident, was negligible, the values given in this column approximate the number of plants per 100 feet of row which failed to produce roots of marketable size, approximately 1 inch in diameter at the crown.

Discussion

The acre yields from this test were not high but were very good for May 8 planting on this farm. In general, equal stands of hills produced simiJar yields of roots. The yields from the two treatments with, full stands of hills were almost identical though, treatment 3 had one-fourth more plant population than treatment 1. When stands were reduced to 70 percent of a full stand of hills, but with populations of 83.5, 90, and 99 percent, respectively, of a standard population, the yields of roots did not vary significantly.

Treatment 2 had 120 percent of a full stand of hills and approximately 150 percent of a standard population of plants. The yield of roots from this treatment was one-half ton per acre less than the yield of either of the treatments having full stands of hills. This difference is probably not significant, but does indicate that under the conditions of this experiment a full stand of 100 hills per 100 feet of row was sufficient to produce maximum yields.

Ft is possible to compare some of the treatments in the 1945 experiment with the yields of similar stands of single-plant hills in experiments conducted at this station in former years. The basis of comparison is the yields of the various stands expressed as percent of the full crop obtained from a full stand of 100 single-plant hills per TCO feet of row (the check treatment that was common to all the experiments). These comparisons are presented in table 2.

The average yield of roots from the 70-percent stands of single-plant hills was 9b' percent of the yield of roots from full stands in the first series of experiments (1937-1939) and 92 percent of the yield from the full stands in the second series (1941-1943). In the 1945 experiment the three treatments with 70-percent stands of hills with from 14 to 25 percent additional population, present as double- and multiple-plant hills, produced an average yield of roots that was 90.6 percent of the yield from the comparable full stand of single-plant hills. In 1937-1939 the average yield of roots from the 40-percent stands of single-plant hills was 78 percent of a full crop, while in the 1945 experiment the yield from the 40-percent stand of hills, with 25 percent additional population, was 76.8 percent of a full crop. In 1941-1943 the 50-percent stands of single-plant hills produced 80.3 percent of a full crop of roots and in 1945 the 50-percent stand of hills, with its 25 percent of additional population, produced 79 percent of a full crop.

In all these experiments the percentage of sucrose in the roots was lower as stands were reduced. There was no conclusive evidence from the 1945 experiment that the quality of the crop from reduced

Table 2.—Acre yields and sucrose percentage of different sugar beet stands expressed as percentage of a full crop; i. e. the yields and sucrose percentage obtained from comparable stands of 100 single-plant hills per 100 feet of row. Fort Collins, Colo., 1937-1945.

Hills per 100 feet of row	Percent 1-plant hills	Acre yields in percentage of acre yields of 100 single plants per 100 fet of row: Roots	Gross sugar	Sucrose Percentage
		1937-1939 (Data given as average of three 6-plot averages)		
(No.)	(Percentage)	(Percentage)	(Percentage)	(Percentage)
100	100	100.00	100.00	100.00
70	100	96.13	96.42	99.65
40	100	78.07	76.35	98.23
		1941-1943 (Data given as average of three 6-plot averages)		
100	100	100.00	100.00	100.00
70	100	92.04	89.63	97.13
50	100	80.20	71.72	94.41
30	100	64.03	57.48	89.78
		1937-1939 and 1941-1943 (Data given as 6-year average of averages)		
100	100	100.00	100.00	100.00
70	100	94.22	93.25	98.77
		1945 Population Study (Data given as 6-plot averages)		
100	100	100.00	100.00	100.00
120	75	96.84	98.37	101.56
100	75	100.13	100.02	100.00
80	75	93.61	89.71	95.74
70	85	92.84	93.42	100.50*
70	75	88.00	82.74	92.97
70	65	90.00	88.81	92.97
60	75	85.48	79.22	92.47
50	75	78.97	71.80	90.34
40	75	76.77	68.18	88.71
(Average of three 70-hill stands)		90.58	86.66	95.47

*This value is not in agreement with expectancy or other values obtained and may or may not be confirmed when additional data are obtained.

stands of hills was improved hy the additional population in two-plant and mulitiple-plant hills.

Summary of Populations Study

Under the conditions of this experiment at Port Collins, Colo., in 1945 the highest yields of sugar beets were obtained from full stands of 100 hills per TOO feet of row. There was no difference in the yields from a full stand of single-plant hills and a full stand with 75 percent of the hills containing single plants and 25 percent containing two or more plants per hill; the 25 percent additional population had no effect on yield.

When the number of hills was increased to 120 percent of a full stand with a corresponding increase to 150 percent of a standard population of plants, there was a small but non-significant reduction in yield. The evidence from this one test indicates that, with uniform distribution of hills, populations moderately in excess of the optimum of about 26,000 plants per acre will produce approximately a full crop of sugar beets.

When the stands of hills were reduced to 80, 70, 60, 50, and 40 percent of a full stand, there were associated reductions in yield. The yields from these reduced stands of hills, each with additional plant population in the two-plant and multiple-plant hills, were of approximately the same order as the yields from similar stands of single plant bills in previous experiments.

The evidence from this experiment strongly supports the conelusion that the yield of sugar beets is determined by the number and distribution of the hills in the thinned stand. Additional plant population due to the presence of two-plant and multiple-plant hills in the thinned stand of sugar beets had little if any effect on yields.

Rate of Seeding Experiment, 1944 and 1945

Summaries of the 1944 and 1945 rate of seeding experiments are presented in tables 3 and 4, respectively. Because of the extreme differences in the stands obtained in these two experiments, attributable to soil and weather conditions affecting germination of beet seed in the 2 years, data from the experiments must be considered separately. However, for convenience, details of the stands obtained and the yields of roots from these experiments are brought together in table 5.

Under the adverse conditions For germination of sugar beet seed in 1944, the stands from the low rates of 0.61, 0.73 and 1.16 pounds of sheared seed per acre were so poor that abandonment of the crop would probably have been justified. When 2.72 pounds of sheared seed were planted, 55 percent of a full stand of hills was saved, and from the 4.50 pounds per acre planting 67.6 percent of a full stand of hills was saved. It is evident that under these adverse conditions a seeding rate of at least 5 pounds per acre of good quality sheared seed would have been necessary to assure even a fairly adequate thinned stand.

Yields of roots from this experiment were considerably below normal yields for the district and somewhat lower than would be expected from late May planting on this farm. However, some of the relative yields from the different seeding rates are of interest. In this experiment the 1.16, 2.72, and 4.50 pound seeding, rates produced

Table 3.—Seeding rates, stands obtained, acre yields, and percentage sucrose of sugar beets planted at different rates of seeding. Fort Collins, Colo., 1944. (Data given as 6-plot averages).

Treatment	Planting rate		Stands*				Acre yields		
	Seed per acre (Pounds)	Viable seed pieces per foot of row	Initial	Thinned		Harvested	Roots (Tons)	Gross sugar (Pounds)	Sucrose (percentage)
				Hills	Plants	Roots			
5. Sheared; ½ pound	0.73	0.90	2.7	20.4	25.1	25.1	5.94	1,731	14.48
6. Sheared; ½ pound	0.61	0.75	1.6	14.2	16.9	16.9	4.73	1,330	13.96
7. Sheared; 1 pound	1.16	1.43	3.4	25.3	32.4	32.4	6.76	1,970	14.48
8. Sheared; 2 pounds	2.72	3.35	6.7	55.1	68.8	68.7	8.67	2,728	15.72
9. Sheared; 4 pounds	4.50	5.55	10.0	67.6	80.6	79.8	8.96	3,207	16.12
10. Sheared; heavy	7.36	9.07	22.0	.....	94.5	92.3	10.94	3,671	16.77
11. Whole; light	5.12	4.15	15.8	82.3	92.3	89.6	10.67	3,539	16.56
12. Whole; heavy	12.80	10.37	42.7	. .	102.8	99.9	10.74	3,606	16.79
	General mean						8.75	2,803	15.76
	F value						20.69**	27.88**	40.89**
	2 x the S. E. of a Diff. (odds of 19:1)						1.37 T.	453 lb.	0.47%
	S. E. of M. in percent of general mean						5.53%	5.71%	1.04%

*Initial stand given as plant-containing inches per RM) inches of row.
Thinned and harvested stands given as hills, plants, or roots per 100 feet of row.

Table 4.—Seeding rates, stands obtained, acre yields, and percentage sucrose of sugar beets planted at different rates of seeding. Fort Collins, Colo., 1945. (Data given as 6-plot averages).

Treatment	Planting rate: Seed per acre (Pounds)	Planting rate: Viable seed pieces per feet of row	Stands*: Initial	Stands*: Thinned: Hills	Stands*: Thinned: Plants	Stands*: Harvested: Roots	Acre yields: Roots (Tons)	Acre yields: Gross sugar (Pounds)	Acre yields: Sucrose percentage
2. Sheared; ½ pound	0.53	0.87	5.0	40.2	80.9	71.1	11.59	3.106	13.38
2a. Sheared; ½ pound	0.53	0.87	5.0	49.4	82.9	78.7	11.82	3,224	13.59
3. Sheared; 1 pound	1.10	1.61	10.4	78.6	130.2	116.4	13.53	4,010	14.82
3a. Sheared; 1 pound	1.10	1.61	10.4	78.9	131.2	115.2	13.42	3,884	14.46
4. Sheared; 2 pounds	2.40	3.50	19.8	97.8	160.1	98.8	15.02	4,307	14.36
4a. Sheared; 2 pounds	2.40	3.50	20.3	97.5	99.6	97.1	14.93	4,348	14.88
5. Sheared; 3 pounds	3.59	4.73	27.6	.....	101.7	98.8	15.10	4,315	14.32
6. Sheared; heavy	5.72	8.84	37.1	.....	100.0	99.8	15.22	4,334	14.24
7. Whole; heavy	14.79	12.84	39.8	.....	96.0	94.5	14.33	4,086	14.09
8. Whole; graded†	4.26	5.24	28.6	.....	99.7	99.0	14.27	4,207	14.72
General mean							13.77	3.924	14.28
F value							21.24**	16.60**	3.17**
2.008 x the S. E. of a Diff. (odds of 19:1)							0.86 T.	328 lb.	0.75%
S. E. of M. in percent of general mean							2.10%	2.53%	1.84%

•Initial stands given as plant-containing inches per 100 inches of row.
Thinned and harvested stands given as hills, plants, or roots per 100 feet of row.

†Whole seed as issued was regraded in a Clipper mill. The seed saved went through a 12/64 screen and over a 7/04 screen and was subjected to moderately heavy air blast. Germination rests indicate that average germination of the seed balls was raised 0 percent by this treatment. and that the percentage of seed balls producing one or two sprouts was raised from 69.75 to 79.25 percent.

Table 5.—Stands and acre yields of roots of sugar beets planted at comparable rates of seeding in 1944 and 1945, Fort Collins, Colo. (Data given as 6-plot averages).

Seed	Seeding rate		Stands*								Acre yield	
			Thinned						Harvested			
			Initial		Hills		Plants		Roots		Roots (tons)	
	1944	1945										
	(Pounds per A.)		1944	1945	1944	1945	1944	1945	1944	1945	1944	1945
Sheared	0.67†	0.53‡	2.2	5.0	17.3	47.8	21.0	85.4	21.0	74.9	5.34	11.70
Sheared	1.16	1.10‡	3.4	10.4	25.3	73.8	32.4	130.7	32.4	115.8	6.76	13.48
Sheared	2.72	2.40‡	6.7	20.0	55.1	97.7	68.8	99.9	66.7	98.0	8.67	14.06
Sheared	4.50	3.59	10.9	27.6	67.6	.....	80.6	101.7	79.8	98.8	9.06	15.10
Sheared	7.36	5.72	22.0	37.1	.....	.....	94.5	100.0	92.3	99.8	10.94	15.22
Whole	5.12	4.28	15.8	28.6	82.5	.....	92.3	99.7	89.6	99.0	10.07	14.27
Whole	12.80	14.70	42.7	39.8	.....	.....	102.8	96.0	99.9	94.5	10.74	14.53
							Difference required for signif. (19:1)				1.37	0.86

•Initial stands given as plant-containing inches per 100 inches of row.

Thinned and harvested stands given as hills, plants, or roots per 100 feet of row.

†1944 data are averages of averages of two plantings, one at 0.73 and the other at 0.61 pounds of seed per acre.

‡1945 data are given as 12-plot averages, since these treatments were planted in duplicate.

Where no data arc recorded for stand of hills, the thinned stands consisted of approximately all single-plant hills.

thinned, stands of 25.3, 55.1, and 67.6 percent, respectively, of full stands of hills. These stands contained 32.4, 66.7, and 80.6 percent, resepoetivoly, of standard popidations. The yields of roots from these three seeding rates wore 61.8, 79.3, and 91.0 percent, respectively, of the yield obtained from the approximately full stand obtained from the 7.36 pound seeding rale. Proportionally these yields were in fairly good agreement with the yields obtained from the 30, 50, and 70 percent stands of single-plant hills in the experiments conducted from 1937 to 1943. It is evident that the 20 to 25 percent additional plant population present in these stands as two-plant and multiple-plant hills did not contribute proportional increases to the yields of roots.

Under the extremely favorable conditions of 1945, the initial stands in the rate of seeding experiment varied from 5.0 plant-containing inches per 100 inches of row when 0.53 pounds of sheared seed per acre had been planted to an initial stand of 59.8 from the heavy seeding of whole seed. The 0.53 and 1.10 pound seeding rates were thinned with long-handled hoe, and 47.8 and 73.8 percent of full stands of hills, respectively, were obtained. These stands contained 85.4 and 130.7 percent, respectively, of standard populations. All the other rates of seeding in this experiment were hand thinned in the conventional manner with the short-handled hoe, and approximately full stands of well distributed single plant hills were obtained.

It was observed that the seedlings in the thick initial stands from the heavy seeding of whole seed were smaller and growing less vigorously when thinned. This difference was somewhat evident for about 3 weeks following thinning, and the slightly lower yield of this treatment may be attributable to the slower early rate of growth of these plants.

In thinning the plots planted at the 0.53 pound seeding rate, only weeds were cut out, all beet plants being left as they emerged. Only a few beet plants were cut from the thickest parts of the initial stands from the 1.10 pounds seeding rate. In the thinned stands of these two treatments there were approximately 43, 42, and 15 percent of one-plant, two-plant, and multiple-plant hills, respectively.

The yields of sugar beets obtained from, this experiment were not high but were very good for May 10 planting on this farm. As would be expected, the yields of roots from the practically equal and uniformly spaced stands of the three higher rates of seeding sheared seed were approximately the same. Yields from the similar stands obtained from the light seeding of graded whole seed and the heavy seeding of normal whole seed were slightly lower, but the differences were of doubtful significance. The average yield of roots from all

treatments with full stands was 14.84 tons per acre. Less than full stands of hills were obtained from each of the lower seeding rates of sheared seed, and the yields of roots were correspondingly lower. The yields of roots from the 0.53 and 1.10 pound seeding rates were, respectively, 11.70 and 13.48 tons per acre. These yields are of particular interest since they appear to have been determined by the number and distribution of 1 the hills in the thinned stand.

The thinned stand from the 0.53 pound seeding rate consisted of nearly half a full stand of hills containing 85 percent of a standard population. However, the distribution of this population was poor since only 41 percent of the hills were singles while 40 percent were doubles and 16 percent were multiples (three to seven plants). Distribution of the hills in the row was also poor since blanks in excess of 3 feet in length were not uncommon. The thinned stand obtained from the 1.30 pound seeding rate consisted of slightly less than three-fourths of a full stand of hills containing 130 percent of a standard population. This was essentially a population which was more than adequate, but it was poorly distributed since 42 percent, of the hills were singles, 43 percent doubles, and 15 percent multiples. Dislribution of the hills in the row was much better than in the case of the 0.53 pound seeding rate, but there were appreciable numbers of blank spaces of moderate length in all rows. Acre yields and sucrose percentages of the crops from the two low rates of seeding are compared with the average acre yield and sucrose percentage of the crops from the higher rates of seeding, having full stands and standard populations, in the 3 945 rate of seeding experiment and with the percentages of a full crop obtained from similar stands of single-plant hills in older experiments (3937-1943) in table 6.

In the older experiments with single-plant hills it was found that, on the average, a half stand would produce about three-fourths of a full crop and that a 70-percent stand would produce about nine-tenths of a full crop. Under the conditions of the 1945 rate of seeding experiment, 47.8 percent of a full stand of hills containing 85.4 percent of a standard population produced 78.8 percent of a full crop of roots, and a. 73.9 percent, stand of lulls containing 3 30.7 percent of a standard population produced 90.8 percent of a full crop. These yields are in striking agreement with the expectancies if it can be assumed that yield of sugar beets is primarily determined by the number of hills in the thinned stands. Apparently the additional population of plants, present in two-plant and multiple-plant hills, in the stands obtained from the low seeding rates in the 1945 experiment had little if any effect on the yields.

Table 6—Stands, acre yields, and sucrose percentage of the sugar beet crop from two low rates of seeding in comparison with the average stand, acre yield, and sucrose percentage of the five higher rates of seeding having full stands of single-plant lulls and with the percentage of a full crop obtained from similar stands of single-plant hills in other experiments. Rate of seeding experiment, 1945, and population studies, 1937-1943, Fort Collins, Colo.

			Acre yields					
			Roots		Gross sugar		Sucrose percentage	
Acre seeding rate (Pounds)	Stand							
	hills	plants	(Tons)	In percent of full crop	(Pounds)	In percent of full crop	(Percentage)	In percent of full crop
1945								
2.40 up*	98.9	99.5	14.84	100.00	4,283	100.00	14.44	100.00
1.19†	73.8	130.7	13.48	90.84	3,947	92.16	14.64	101.39
0.53†	47.8	85.4	11.70	78.84	3,165	73.90	13.49	93.42
1937-39‡	70.0	70.0		96.13		96.42		99.65
1941-43‡	70.0	70.0		92.04		89.63		97.13
1941-45‡	50.0	50.0		80.20		71.72		94.41

*1-year average of six 6-plot averages.

†1-year average of two 6-plot averages.

‡3-year averages.

Pelleted Sugar Beet Seed

IVlleted sugar beet seed as obtained from the Farmers and Manufacturers Beet Sugar Association was included at two rates of planting in the 1944 rate of planting experiment and at one rate of planting in the 1945 experiment. In 1944, emergence from the pelleted seed following a soaking rain on May 24, while rather poor as to the total seedlings which emerged, was relatively slightly better than emergence from sheared or whole seed planted in this experiment. In 1944 the seedlings from the pelleted seed were aparpently as vigorous as seedlings from other sugar beet seed. Under the favorable conditions for germination in 1945, the total number of seedlings emerging from pelleted seed exceeded the total germination recorded from pellets in the laboratory. However, in 1945 the seedlings from the pellets were slow in emerging and many were very weak and made slow.early growth. This slow emergence and weakness of the plants from the pellets are believed to be due to hand planting of the pellets in an open furrow, but the exact cause is not known.

The stands and yield from pelleted sugar beet seed and from comparable plantings of whole and sheared seed are presented in table 7.

Table 7.—Seeding rates, stands, and acre yields of roots of sugar beets grown from pelleted, sheared, and whole seed. Fort Collins. Colo., 1944-1945. (Data given as 6-plot averages.

Seed	Seeding rate 1944 (Pounds per A.)	Seeding rate 1945 (Pounds per A.)	Stands* Initial 1944	Initial 1945	Thinned Hills 1944	Thinned Hills 1945	Thinned Plants 1944	Thinned Plants 1945	Harvested Roots 1944	Harvested Roots 1945	Acre yield Roots (tons) 1944	Acre yield Roots (tons) 1945
Pellets	10" sp.	4" sp.	3.3	12.0	27.3	99.1	30.8	123.6	30.6	109.1	6.30	12.03
Pellets	6.30†	.....	25.1	.....	.....	.....	99.1	.....	96.4	.....	10.09	.....
Sheared	0.67‡	0.53	2.2	5.0	17.3	47.8	21.0	85.4	21.0	74.9	5.34	11.70
Sheared	1.15	1.10§	3.4	10.4	25.3	75.8	32.4	130.7	32.4	115.8	6.76	13.48
Sheared	8.20	5.72	32.7	37.1	.....	.....	102.5	100.0	100.8	99.8	9.88	15.22
Whole	16.87	14.79	62.3	59.8	..	.. ..	103.2	90.0	101.0	94.5	10.31	14.53
								Difference required for significance (odds of 19:1)			1.37	0.80

*Initial stands given as plant-containing inches per 100 inches of row.
Thinned and harvested stands given as hills, plants, or roots per 100 fete of row.
†Approximate weight of sheared seed pieces in the pellets planted.
‡1944 data are averages of two plantings, one at 0.73 and the other at 0.61 pounds per acre.
§1945 data given as average of duplicate plantings at these rates.
Where no data are recorded for stands of hills, the thinned stands consisted of approximately all single plants.

In 1944 the yields from pelleted seed were similar to the yields from comparable stands of sheared or whole seed. In 1945 the stands obtained by long-handled hoe thinning, which consisted of cutting out, weeds and some of the weakest plants where there had been emergence from four , or more consecutively dropped pellets, were not strictly comparable to the stands obtained from any of the sheared or whole seed plantings. The thinned stand from the pellets was similar to the thinned stand obtained from the 1.10 pound planting of sheared seed in that the distribution of the hills in the row was not uniform and the total population of plants exceeded a standard population. Since the low yields from the pellets in 1945 may be attributable to the abnormal conditions under which the pelleted seed was planted, little significance can be given to any comparisons with the yields from sheared or whole seed in the experiment.

These limited trials with pelleted sugar beet seed indicate that there was belter emergence of seedlings in the field from such seed than was indicated as probable by laboratory tests of its germination. It is also probable that the coatings used in pelleting this seed cannot be considered as entirely satisfactory.

Supplementary Planting

It has been suggested that sugar-beet stands could be improved by the planting of a single piece of sheared sugar beet seed in each blank hill at the time the crop is thinned. Tn 1945 duplicate adjacent plots were planted at each of the three lower rates of planting in the rate of seeding experiment. One of each pair was to have supplemental planting and the other to be left with the best stand obtainable from the original planting. Since a full stand was obtained from the original planting at 2.40 pounds of seed per acre, only the plots planted at 0.53 and 1.10 pounds per acre were used for the test of supplemental planting. The day that thinning of this test was completed, one of each pair of the plots planted at the two lower rates received a supplemental planting of a single piece of sheared seed in every blank hill. Emergence of seedlings from these seed pieces was prompt and it was estimated that plants emerged from more than three-fourths of them. However, when the experiment was cultivated and ditched for the first irrigation, in early July, a large proportion of these small seedlings were covered by dirt thrown on the rows by the cultivator shovels. A few of these plants persisted until harvest, but none were found at harvest which had produced a root of marketable size. In this experiment supplemental planting was a failure and it is doubtful if the method will be of any practical value as a means of repairing a thin stand of sugar beets.

Wide Rows

The initial stand of sugar beet plants on the area used for this experiment was too thin to obtain uniform distribution of single plants spaced less than about 8 or 9 inches apart in the rows. Therefore the experiment as conducted consisted of three treatments: (1) Full stand and standard population in 20-inch rows; (2) 12-inch spacing in 40-inch rows; and (3) 8-inch spacing in 40-inch rows. The populations of these treatments approximated 26,000. 13,000 and 20,000 plants per acre, respectively. Therefore these, three treatments may be regarded as: (1) A full stand with a standard population; (2) a 50 percent stand containing half a standard population ; and (3) a 50 percent stand containing three-fourths of a standard population.

Harvested stands, acre yields, and sucrose percentages of the sugar beet crop from this preliminary experiment with wide rows at Fort Collins are presented in table 8.

Table 8.—Harvested stands, acre yields, and sucrose percentage of sugar beets grown in 20-inch and 40-inch rows, Fort Collins. Colo., 1045. (Data given as 4-plot. averages).

Spacing (No	Roots harvested per A.)	Acre yields Roots (Tons)	Suc Gross sugar (Pounds)	rose percentage (Percent)
12" in 20-inch rows	26,423	16.40	4,740	14.49
12" In 40-inch rows	13,303	12.80	3,080	12.05
8" in 40-inch rows	20,295	12.29	3,182	12.94
General mean		13.83	3,668	13.16
F value		55.12**	42.74**	0.15*
2.447 x the S. E. of a diff.		1.04 T,,	493 lb.	1.72%
S. E of the M. in percent of the general mean		2.18%	3.88%	3.78%

Because of the excellent stands obtained and the large size of the plots the general reliability of this experiment was probably very good. The yield of sugar beets spaced 12 inches apart in 40-inch rows, half a standard population, was 3.6 tons of roots and 1,600 pounds of gross sugar per acre less than the yield from the same plant spacing in 20-inch rows; i. e. the yield of a full stand and standard population. Contrary to expectations, increasing the population in the wide rows by spacing the plants 8 inches apart in the row had no effect on the yield of roots but may have slightly improved the quality of the crop. If we assume that in either ease, 12-inch or 8-inch spacing, the sugar beet plants fully occupied the wide rows lengthwise of the rows,but that the cutting out of every other one of the 20-inch rows had reduced the total stand to 50 percent of a full stand, the yields of roots from the wide rows very closely approximate the ex-

pected three-fourths of a crop from half a stand. In this preliminary experiment 40-inch rows were too wide for the production of a full crop of sugar beets.

Summary and General Conclusions

If the growing of the sugar beet crop is to be completely mechanized it is probable that much lower rates of seeding must be used than has been customary when the crop was hand thinned. The experiments reported herein indicate that the minimum amounts of seed which will insure reasonably adequate thinned stands of sugar beets will vary between rather wide limits, depending on soil and climatic conditions present at the time of and immediately following the planting of the crop. In these experiments about 5 pounds per acre of good quality sheared seed would have been barely sufficient 1o produce a reasonably good thinned stand in 1944. Under the very favorable conditions of 1945 nearly perfect thinned stands were obtained from seedlings only slightly in excess of 2 pounds per acre, and approximately three-fourths of a full crop of sugar heels was grown from a seeding of only-0.53 pounds of sheared seed per acre.

Under the conditions of these experiments, maximum yields of sugar beets were obtained from uniformly distributed thinned stands of about 100 single-plant hills per 100 feet of row when the rows were 20 inches apart. A 25 percent increase in plant population, when 25 percent of the hills in a full stand were two-plant and multiple-plant hills, produced yields of roots and sugar which were practically identical with, the yields from a full stand of single-plant hills. When plant populations were increased 50 percent by increasing the stand of hills to 120 per 100 feet of row, with one fourth of the hills containing two or more plants per hill, there was a small reduction in yield. However, on the basis of the single test, this reduction in yield was not statistically significant.

In these experiments reductions in the stand of hills below a uniformly distributed stand of about 100 hills per 100 feet of row invariably resulted in a reduction in yield. Stands of hills varying from 40 to 80 percent of a full stand, but which contained two-plant and multiple-plant hills in sufficient numbers to raise the plant populations to from 15 to 35 percent above the populations of similar stands of one-plant hills, produced yields which were about the same proportion of a full crop as the yields from comparable stands of one-plant hills in previous experiments. Under the conditions of the experiment conducted in 1945 the yields from 70 percent stands of hills, of which 15, 25 and 35 percent, respectively, were two-plant and multiple-plant hills, were very similar and of about the same order as the yields to be expected from a 70 percent stand of one-plant hills. The

evidence from these experiments was that yields from stands varying from about 25 to 120 hills per 100 feet of row were determined by the number of hills and that additional plant population contained in two-plant and multiple-plant hills did not increase yields.

There are some indications that the harvesters now available will handle sugar beets from single-plant hills somewhat more efficiently than beets from two-plant and multiple-plant hills. It is also obvious that few sugar beets of marketable size will usually be produced in hills containing more than two or three plants. Therefore the thinned stand of sugar beets, by whatever method it is obtained, should consist of as high a proportion of single-plant hills as can be obtained from the initial stand of seedlings without reducing the total stand of well distributed hills below the maximum number obtainable up to a full stand.

Pelleted seed in limited tests in 1944 and 1945 did not give satisfactory stands.

Supplemental plantings in which sheared seed units were made to fill in gaps in the row did not give roots of marketable size.

Acre-yield of roots and of sugar from sugar beets grown in 40-inch rows with plants spaced either 8 inches or 12 inches apart in the row were significantly below the acre-yields as obtained from sugar beets grown in 20-inch rows with 12-inch spacings.

Literature Cited

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