Estimate of Space Occupied Proposed as a Measure of Sugar Beet Stands

G. W. DEWING[1]

When sugar beets were hand thinned predominantly single-plant hills were left in the thinned stands. The basic spacings between those single-plant hills might vary from grower to grower and different workers seldom attained exactly the same spacing. However, the spacing of the thinned stand usually approximated that desired by the grower and was reasonably uniform for any given field. Under these conditions any statement of the stand which included the basic spacing and the number of plants in a given length of row gave a reasonably accurate picture of the plant population of that field.

The increasing use of machines for thinning the sugar beet crop has changed our concept of an acceptable thinned stand of sugar beets. Basic spacings are much less than with hand thinning and the individual hills may contain one, two, or several plants. Good yields have been obtained by growers from a rather wide range of plant populations. It is probable that very good to near maximum yields may result when plant populations are only sufficiently reduced to permit most plants to make relatively small, but marketable beets. It is also probable that equally good yields may occur from stands with many fewer plants so distributed that most of the space and available plant food will be used to produce, in that case, relatively large beets.

When 2-plant and multiple-plant hills occur in the stand in appreciable numbers, as is usually the case in machine-thinned stands of sugar beets, it appears obvious that the number of plants in a given length of row is an inadequate measure of the stand. The distance between hills in a machine-thinned stand may, and usually does, vary from very little to considerable, depending on how often a beet plant-containing hill is left in each of the small blocks between the successive strokes of the cutting knives of the machine. Thus, the row space that could be completely used by a single hill may contain more than one hill. The number of hills in a given row length of such a stand is, probably, a better measure of the population than the number of plants, but still falls short of being an accurate measure of the stand.

It is the purpose of this paper to propose an estimate of the space actually occupied by the sugar beet plants present in a machine-thinned stand as a measure of the plant populations of such stands.

Before such an estimate can be made it is necessary to make some assumptions on the use of space by sugar beet plants. Tolman, Johnson and Bigler (4)[2] and Deming (2) have reported experiments which indicate

[1] Agronomist, Field Crops Research Branch, Agricultural Research Service, United States Department of Agriculture. Agronomic research with sugar beets at Fort Collins, Colo., is in cooperation with the Airronomv Section of the Colorado Agricultural F.xoeriment Station. Colorado Agricultural Experiment Station Scientific Paper No. 439.

[2] Numbers in parentheses refer to literature cited.

that the effect of row width on yield of sugar beets was essentially independent of the number of plants in the row. Therefore, the spacing between rows may be safely ignored and the estimate of space occupied can be based on the distribution of sugar beet plants within the row. Coons (1) has reviewed European and American literature reporting the effect of space relationships on the sugar beet crop.

There is general agreement that when space is fully occupied it makes little difference how many plants are present, provided each of them has sufficient room to produce a beet of marketable size. In general, the crops from thick stands have slightly higher sucrose content than those from thin stands. This tends to compensate for small losses from beets of unmarketable size when the upper limits of plant populations have not been seriously exceeded. Therefore, in arriving at an estimate of space occupied we may assume that the only limit on the total number of plants in a given length of row is that most of them must have sufficient space to develop a root of marketable size. If more than this number of plants is present in an appreciable portion of the field it is only evidence of a poor job of thinning. Such a condition is of infrequent occurrence and as growers gain experience in machine thinning it will be even less likely to occur.

It remains to define the maximum space between hills in the row at which the beet plants will presumably fully use the plant food, moisture and room at that location. American growers of sugar beets more or less agree that 12 inches between hills in the row is an optimum spacing. There is less general agreement on a permissible maximum spacing. Tolman (5) reported that under some conditions yield could be maintained as spacing in the row was increased to 15 inches between hills and that "Yields begin to decline as spacing within the row is increased to 20 inches." Deming (3), reporting on experiments at Fort Collins, Colorado, states that when approximately full stands were maintained the differences in yield from 8, 12- and 16-inch spacings in the row were negligible. Spacings used by sugar beet growers in the Colorado-Nebraska-Wyoming area have varied appreciably and many excellent yields have been harvested from stands with row spacing in excess of the assumed optimum of 12 inches.

On the basis of this evidence it is tentatively assumed that sugar beet plants will fully occupy the space within the row when the maximum space between hills approximates 16 inches. However, as a matter of convenience, in the actual measurement of spaces undertaken in 1953 and reported in Table 1 no "Lost space" was recorded unless the space between hills was 18 inches or more. Thus, all spaces between hills up to and including 17.5 inches were ignored in collecting the data. All spaces of 18 inches or more were noted, 16 inches subtracted and the remainder recorded as unoccupied space. The total of inches of unoccupied space in each plot was subtracted from the total inches of row for the plot to obtain the total inches of row occupied by beet plants and from this value percent of occupied space was calculated.

After thinning the experimental sugar beet plots on the Agronomy Farm at Fort Collins, Colorado, in 1953, the spaces between hills of the inside (for harvest) rows of two variety tests were measured and unoccupied space for all plots recorded. Counts of hills in the same plots were also made. From these records percentage of space occupied and hills per 100 ieet of row were calculated as estimates of the thinned stands. These estimates of stand for the agronomic evaluation test of leaf spot and black root-resistant varieties were statistically analyzed by the analysis of variance for a Latin square. A summary of these data is given in Table 1.

Table 1.—Thinned Stands of Sugar Beets; Agronomic Evaluation Variety Test, Fort Collins, Colo., 1953. Stands Recorded as: (1) Hills Per 100 Feet of Row, (2) Percent of Row Length Occupied by Sugar Beet Plants. Data Given as 8-Plot Averages.

Column, row or variety number	Stand as hills for			Stand as occupied space for		
	Columns	Rows	Varieties	Columns	Rows	Varieties
	(hills per 100 feet of row)			(percent space occupied)		
1.	102.4	99.5	100.9	94.5	93.5	93.5
2.	103.3	108.0	106.8	94.7	94.2	95.4
3.	103.9	102.1	102.0	95.0	93.7	93.5
4.	98.3	100.7	102.1	93.3	92.5	94.1
5.	104.6	100.3	109.1	93.9	95.2	95.8
6.	105.9	106.4	102.0	94.4	95.4	94.1
7.	103.5	107.0	102.5	94.6	94.8	93.5
8.	109.3	107.4	105.9	94.9	95.9	95.3
Mean	103.9	103.9	103.9	94.4	94.4	94.4
F. value[1]	6.14**	8.25**	5.56*	[2]	3.30**	2.45*
2 x the S.E. of a Diff.	3.5	3.5	3.5	1.8	1.8	1.8
S.E. of mean in % of the gen. mean	1.20	1.20	1.20	0.66	0.66	0.66

[1] Designated F. value at 5% level with **, and 1% level with *.
[2] Ve exceeds Vc.

The plots in this 8 x 8 Latin square were 30 feet in length and 8 rows in width. The initial stands were good and fairly uniform. A moderately weedy condition extended across the field rows of the test at about "Row 4" of the summary table. The test was thinned by four laborers who worked one row at a time in pairs or singly on various portions of the experiment. No record was made of the rows worked by different individuals, though it was noted at the time that the spacings being used by the laborers varied from about 8-10 inches by two teenagers to approximately II inches by the two experienced older workers. The subsequent count of hills showed that full stands varied from about 31-33 hills to well over 40 hills per 30-foot plot row. It is known that the two teenagers worked more of the plots represented in "Columns 6-8" of the table than they did of the balance of the experiment.

When hills per 100 feet of row were used as the estimate of stands in this test the F value for columns, rows and varieties each exceed the one percent point for probable significance. Conversion of the estimates of stand to space occupied materially reduced the variability in this test. In the case of columns Ve exceeded Vc and the F values for rows and varieties, while still exceeding the one percent point and the five percent point, respectively, are less than half as great as when hills were used as the measure of stand.

Since stands in this test were relatively good, as evidenced by the variety means and the general mean, some further comment may be warranted. As the number of hills in a given length of row would be influenced by the basic spacings used by the different laborers the differences, if any, would be found in the column means of the table. The F value for columns indicates that highly significant differences for hills did exist. However, when space occupied was used as the estimate of stands no significant differences between column means were found.

The estimate of space occupied would probably be of the most value as a measure of stands obtained by machine thinning. Usually an appreciable portion of the hills in machine-thinned sugar beets contains more than one plant and there is less uniformity of the space between hills than with hand-thinned stands. Both of these factors tend to make estimates of stand based on counts of plants or hills more or less unrealistic. Unfortunately data on the stand of a machine-thinned field of sugar beets by all three methods of estimating stand were not obtained. It seemed possible that some of the populations studies conducted at Fort Collins in previous years had some of the characteristics of a machine-thinned stand. It was found that stands for all plots of the populations study conducted in 1949 had been recorded as the condition of each hill, i.e., 1, 2- or 3-plant hill or blank hill, in sequence for each row of the plots. Since 8- and 12-inch spacings and various combinations of blanks, 1-, 2- and 3-plant hills were used in this experiment part of the variables to be expected in machine-thinned stands were probably represented in these plots. However, 8 inches was the minimum spacing of any treatment in this experiment and thus there were none of the very close spaced hills often present in machine-thinned stands.

Obviously it was now impossible to measure the spaces which were between the hills of these plots and it was, therefore, necessary to assume that the planned spacings, 8- or 12-inch respectively, had been attained. Using this assumption and the definition of unused space previously given the total hills, total plants and occupied space for each plot were calculated. This study was of eight treatments grown *in* six randomized blocks. The plots were 60 feet in length and 8 rows in width. All data are from the six inside rows of each plot. Since, by definition, all space is occupied unless the distance between hills exceeds 16 inches single skips in 8-inch stands were ignored; two adjacent skips charged with 8 inches of unused space, etc.

In the case of 12-inch spacings single skips were charged with 8 inches of unused space, two adjacent skips charged with 20 inches, etc. Data for stands as hills, plants or occupied space for this experiment are presented in Table 2. The recorded yields of roots are added in the last column of this table as of possible interest.

As Ve exceeds Vb for all three estimates of stand and the block means have been omitted as of no probable interest. Since the treatments in this test were designed to obtain large stand differences the F values for the three estimates of stand, while very great, are probably of little importance. In this case the conventional analysis of variance for a random block test gave little information on the three estimates of stand, except that the space

Table 2-—Thinned Stands and Acre Yields of Roots, Populations Study, Fort Collins, Colo., 1949. Stands Expressed as: (1) Hills Per 100 Feet of Row, (2) Plants per 100 Feet of Row, (3) Percent of Row Length Occupied by Sugar Beet Plants. Data Given as 6-Plot Averages.

		Treatments				Stands; expressed as			
		Hills per 100 feet of row							
No.	Spacing in row	Blank	1-plant	2-plant	3-plant	Hills per 100-ft.	Plants per 100 ft.	Occupied space	Acre yield roots
	(inches)	(numbers)				(number)	(number)	(percent)	(tons)
1.	12	0	100	0	0	99.4	99.4	97.7	19.74
2.	8	0	150	0	0	136.5	136.5	97.9	19.25
3.	8	50	60	30	10	106.1	159.3	89.5	17.14
4.	12	0	70	25	5	98.9	132.4	97.2	18.52
5.	12	20	56	20	4	82.5	110.6	84.5	19.07
6.	12	30	49	18	3	71.9	96.4	77.2	18.81
7.	12	40	42	15	3	60.3	81.7	64.7	16.75
8.	12	50	35	13	2	52.4	70.6	60.1	16.48
	Mean					88.5	110.9	83.6	18.22
	F. value (for blocks)[1]					[2]	[2]	[2]	8.78**
	F. value (for treatments)					310.43**	116.57**	156.50**	7.33**
	2 x the S.E. of a Difference					4.4	7.8	3.4	1.30
	S.E. of mean in percent of the general mean					1.76	2.50	1.43	2.53

[1] Designated F. value at 5% level with **

[2] Vc exceeds Vb.

occupied estimate resulted *ix* the lowest standard error value and a lower difference lor probable significance than either of the other methods ol estimating stands.

However, examination of the treatment means of the stand estimates shows some interesting comparisons. Taking first the 8- and 12-inch full stands of single-plant hills, the plant or hill count estimate indicated that the 12-inch spacing fell only six-tenths of a percent short of averaging a "perfect stand while the same estimate indicated that the 8-inch spacing was 9 percent short of a perfect stand. When occupied space was used as the measure of stands for these two treatments equality of the stands was indicated. Incidentally, the yields of roots were also approximately the same for both. Presumably most of the skips in the 8-inch stand were one-hill skips and did not effect the estimate of occupied space and also probably had little effect on the yield.

Another case is that of the 8-inch stand in which one-third of the hills were skips and two fifths of the remaining hills contained 2 or 3 plants each. In this case the estimate of stand by hills indicated slightly more than a full stand by the conventional standard of 100 hills per 100 feet of row and if the estimate based on total plants is used a thick stand was indicated. However, when space occupied was used as the estimate of stand for this treatment it became obvious that it was not a full stand and that only about nine-tenths of the area was actually used to produce the crop while the other tenth was unproductive. The yield of roots was also significantly lower than the yields from full stands; an added indication that space was not fully used by the sugar beet plants.

In the case of the last four treatments given in the table, all 12-inch spacing, but with different proportions of blank hills and with 1, 2 or 3 plants in each beet-containing hill, it is obvious that the stand estimates based on total plants, while comparable among themselves, are quite misleading. The stand estimates based on total hills arealso comparable among themselves and since the basic spacing for all hills was the same they are fairly good estimates of the actual stands. However, the estimates of space occupied by the stands of these four treatments are probably just as accurate as those based on total hills and show that the actual stands were slightly better than indicated by the latter method.

Conclusion

The proposal to use an estimate of the space occupied by the plants as a measure of thinned stands of sugar beets is advanced. Some of the assumptions that must be made to obtain such an estimate are discussed. Examples are given to indicate that the method is more accurate than estimates of stand based on either the total plants or total hills in a given length of row. This estimate of space occupied will probably be most useful as a measure of stands of machine-thinned sugar beets. More evidence is needed on this point.

Literature Cited

(1) COONS, G. H.
1948. Space relationships as affecting yield and quality of sugar beets. Proc. Amer. Soc. Sugar Beet Tech. 1948: p. 252-268.

(2) DEMING, G. W.
1948. The effect of variations in row width and plant populations on root yields and sucrose percentage of sugar beets at Fort Collins, Colo. Proc. Amer. Soc. Sugar Beet Tech. 1948: p. 280-281.

(3) DEMING, G. W.
1942. Relative yields of reduced stands of sugar beets planted at a normal date and of replanted sugar beets. Proc. Amer. Soc. Sugar Beet Tech. 1942: p. 197-202.

(4) TOLMAN, BION; JOHNSON, RONALD; BIGLER, J. A.
1948. Row widths and sugar beet production. Proc. Amer. Soc. Sugar Beet Tech. 1948: p. 282-286.

(5) TOLMAN, BION.
1946. Population and distribution studies with sugar beets. Proc. Amer. Soc. Sugar Beet Tech. 1946: p. 177-184.