A METHOD OF CORRECTING TONNAGE OF SUGAR BEETS FOR VARIATION IN PER CENT STAND[1]

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There is an abundance of published data showing that as the number of beets per acre increases the tons per acre increases. It is common knowledge that 25,000 beets per acre evenly distributed gives a higher tonnage than 15,000 beets grown under the same conditions. The exact relationship, however, is not well understood by most research men. Consequently they can not make accurate and consistent corrections in tonnage for variations in per cent stand and erroneous conclusions may be the result. But necessity for comparable stands in experimental work has driven many research men to make some kind of a correction.

Several of these methods have been used quite generally at one time or another with varying degrees of success. One method is based on the assumption that the relationship is linear. The average weight per beet is calculated and multiplied by the desired number of beets per acre to give the pounds of beets per acre. The fallacy here is that the relationship is not linear, as will be pointed out later. Consequently, plots with a poor stand and relatively large beets are given an advantage over plots with a good stand and relatively small beets.

A common method of correcting for variation in stand is to use the total weight of all the beets from the areas of the plot where the stand is good. Some workers, however, prefer the "competitive beet" method. Competitive beets being those surrounded by other beets on all sides at appropriate distances as imposed by the experiment. Actual yield and competitive beet methods were studied critically by Nuckols(3)[3] who states that he does not endorse either method. There are instances, he further states, where actual yield should be used and other instances where competitive yields seem to be preferred.

One of the relatively new methods of correcting for variation in stand, as given by Snedecor(4), is based on covariance and is an improvement over some of the older methods.

The purpose of this paper is to present a practical and reasonably accurate method of correcting tonnage of sugar beets for variation in per cent stand where the distribution of the beets on the plot is fairly uniform.

Material and Methods

Two sources of data were used to study the relationship between tonnage and per cent stand in sugar beets. The first was in 1936 sugar beet variety test at East Lansing, Michigan. The second was data reported by Brewbaker (1) in 1937.

Thirty varieties at East Lansing were grown in three-row plots 26.6 feet long and the entire middle row only was harvested. Each variety was re-

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3. Figures in parenthesis refer to "Literature Cited".

plicated 10 times. Variety effect was eliminated by taking the deviation of each plot from the mean of the variety to which the plot belonged. A second degree curve, $y = a + bx + cx^2$, was then calculated from these deviations as the writer believed, from previous work, that the relationship between stand and yield was curvilinear rather than linear. It was expected that one or two extreme deviations might have too great an influence on the position of the ends of the curve but when compared with the curve from Brewbaker's data such proved not to be the case.

The data reported by Brewbaker were used also because they were the average of three years, rather than one, and the beets were grown under entirely different conditions; each plot was thinned to a definite per cent stand. These per cent stands covered a wide range, 11 to 110 based on 28,512 as 100 per cent, and were uniformly distributed along the curve, not grouped near the middle of the curve as was the case with the East Lansing data.

Presentation of Data

The two curves (figure 1) are strikingly similar even though the beets were grown under very different conditions. One curve is above the other, however, and indicates that the growing conditions at East Lansing in 1936 were superior to the average in 1934, '35 and '36 in Colorado. These curves are correct mathematically for the data used but are incorrect agronomically. The equation, as previously stated, is $y = a + bx + cx^2$ in which y = yield and x = per cent stand. The calculated values from the Colorado data are; $a = 3.688$, $b = .224$ and $c = .001$. If we make the per cent stand zero, $x = 0$, the equation becomes $y = 3.688$. In other words, when the per cent stand of beets on the plot is zero we have 3.688 tons per acre. This discrepancy may be explained, at least in part, by the difficulty in getting accurate tonnage data from small plots with poor stands.

If we assume that beets growing four feet apart have no competition with each other and that when there is no competition between beets the tonnage decreases directly as the number of beets decreases, the relationship between stand and yield is a straight line and a correction for the discrepancy in the curves can be made. This correction was made by drawing a straight line from 11 per cent stand, about equal to four foot spacing between plants, to zero. The fact that the curves in the very low per cent stand did not fall where they should, theoretically, does not seriously impair the practical value of these curves in correcting tonnage for variation in per cent stand, because the differences between the curves as they should be and as they are, are so small.

These curves illustrate very clearly that there is a definite relationship between per cent stand and tonnage in sugar beets and that the relationship is curvilinear even though the beets were grown in different environments. The two curves being as similar as they are, may be considered to be different environment-level variants of one basic relationship. This being the case, then other curves representing other levels of environment may be obtained from this basic relationship.

The data from Colorado was used to calculate the six curves shown in figure 2. These curves vary from the original only as the environment-level is superior or inferior to the original environment for sugar beet production. Environment includes all factors which influence tonnage such as natural variation in soil, fertilizer, cultural method, moisture and etc. Tonnage within

an environment varies only as the number of beets or per cent stand varies.

The practical use of these curves may be seen by an example. A plot has a 30 per cent stand and yields 10.29 tons per acre. What would the plot yield if it had an 80 per cent stand? Look up 30 per cent in figure 2 and follow the ordinate down to the actual yield of the plot, 10.29. The curve on which 10.29 is located is the "environment" in which this plot was grown. Follow this curve to the ordinate headed 80 per cent. The tonnage at this point is 15.26 which is the yield that may be expected without any change in the growing conditions of the beets. Another plot may have a yield of 10.0 tons with a 110 per cent stand. Follow the ordinate of 110 to the curve on which 10.00 is located. Then at the ordinate headed 80 per cent the corrected yield will be found as 10.17 tons per acre. The actual yield and the actual per cent stand of each plot is used to find the environment in which the plot was grown. Then any per cent stand and its corresponding tonnage may be chosen. Thus, in an experiment which involves many varieties or many treatments and each replication within a variety or treatment having a different per cent stand, all plot yields can be adjusted to the average per cent stand of all the plots or to any per cent stand desired. All plots are, therefore, made comparable insofar as per cent stand is concerned. For convenience in correcting field data 250 curves such as those shown in figure 2 were calculated and put in table form. A part of this table is shown in table 1.

This paper is given as a progress report and not as a final report. It is intended to present an idea which has practical value but further study should be made to determine more accurately the true relationship between stand and yield in plots with a low per cent stand. Also, in the data used, the maximum yield was obtained with about 26,000 beets per acre and as all the other environmental levels were calculated from the basic curve they all have the maximum yield with about 26,000 beets per acre. There is evidence (2) and (5) that where growing conditions are exceptionally good, more than 26,000 beets give the maximum yield while in very poor growing conditions less than 26,000 beets per acre give the maximum yield. Studies should be made to determine if the maximum yield always is with 26,000 beets or whether it varies with the environmental conditions. For average conditions, however, where the tonnage ranges from 5 to 20 tons and the stand is fairly uniform over the plot but the plots vary from 40 to 100 in per cent stand this method of correcting tonnage for variation in per cent stand is practical and fairly accurate.

Literature Cited

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Table 1. Tons of sugar beets at various percent stand and environment (curve number) levels

Percent stand	10	20	30	40	50	60	70	80	90	100	110
No. of beets per acre	2,851	5,417	8,554	11,120	14,256	17,107	19,958	22,810	25,661	28,512	31,363
Curve No.											
10	.40	.57	.69	.79	.87	.94	.99	1.02	1.03	1.02	1.00
20	.80	1.13	1.37	1.57	1.75	1.88	1.97	2.03	2.06	2.05	2.00
30	1.20	1.70	2.06	2.37	2.62	2.82	2.96	3.05	3.09	3.07	3.00
40	1.61	2.26	2.74	3.15	3.49	3.76	3.95	4.07	4.12	4.09	4.00
50	2.01	2.83	3.43	3.94	4.36	4.69	4.93	5.09	5.14	5.12	5.00
60	2.41	3.40	4.12	4.73	5.23	5.63	5.92	6.10	6.18	6.14	6.00
70	2.81	3.96	4.80	5.52	6.11	6.57	6.91	7.12	7.21	7.16	7.00
80	3.21	4.53	5.49	6.31	6.98	7.53	7.89	8.14	8.24	8.19	8.00
90	3.61	5.09	6.17	7.19	7.85	8.45	8.88	9.15	9.27	9.21	9.00
100	4.02	5.66	6.86	7.89	8.73	9.39	9.87	10.17	10.30	10.24	10.00
110	4.42	6.23	7.55	8.67	9.60	10.33	10.85	11.19	11.32	11.26	11.00
120	4.82	6.69	8.23	9.46	10.47	11.27	11.84	12.20	12.35	12.28	12.00
130	5.22	7.36	8.92	10.25	11.34	12.21	12.83	13.31	13.38	13.31	13.00
140	5.62	7.92	9.61	11.04	12.22	13.14	13.82	14.24	14.41	14.33	14.00
150	6.02	8.49	10.29	11.83	13.09	14.08	14.80	15.26	15.44	15.35	15.00
160	6.43	9.06	10.98	12.62	13.96	15.02	15.79	16.27	16.47	16.38	16.00
170	6.83	9.62	11.66	13.41	14.83	15.96	16.78	17.29	17.50	17.40	17.00
180	7.23	10.19	13.35	14.19	15.71	16.90	17.76	18.31	18.53	18.43	18.00
190	7.63	10.75	13.04	14.98	16.58	17.84	18.75	19.32	19.56	19.45	19.00
200	8.03	11.32	13.72	15.77	17.45	18.78	19.73	20.34	20.59	20.47	20.00
210	8.43	11.89	14.41	16.56	18.32	19.72	20.72	21.36	21.62	21.50	21.00
220	8.84	12.45	15.09	17.35	19.20	20.65	21.71	22.37	22.65	22.52	22.00
230	9.24	13.02	15.78	18.14	20.07	21.59	22.70	23.39	23.68	23.54	23.00
240	9.64	13.58	16.47	18.92	20.94	22.53	23.68	24.41	24.71	24.57	24.00
250	10.04	14.15	17.15	19.73	21.81	23.47	24.67	25.42	25.24	25.59	25.00

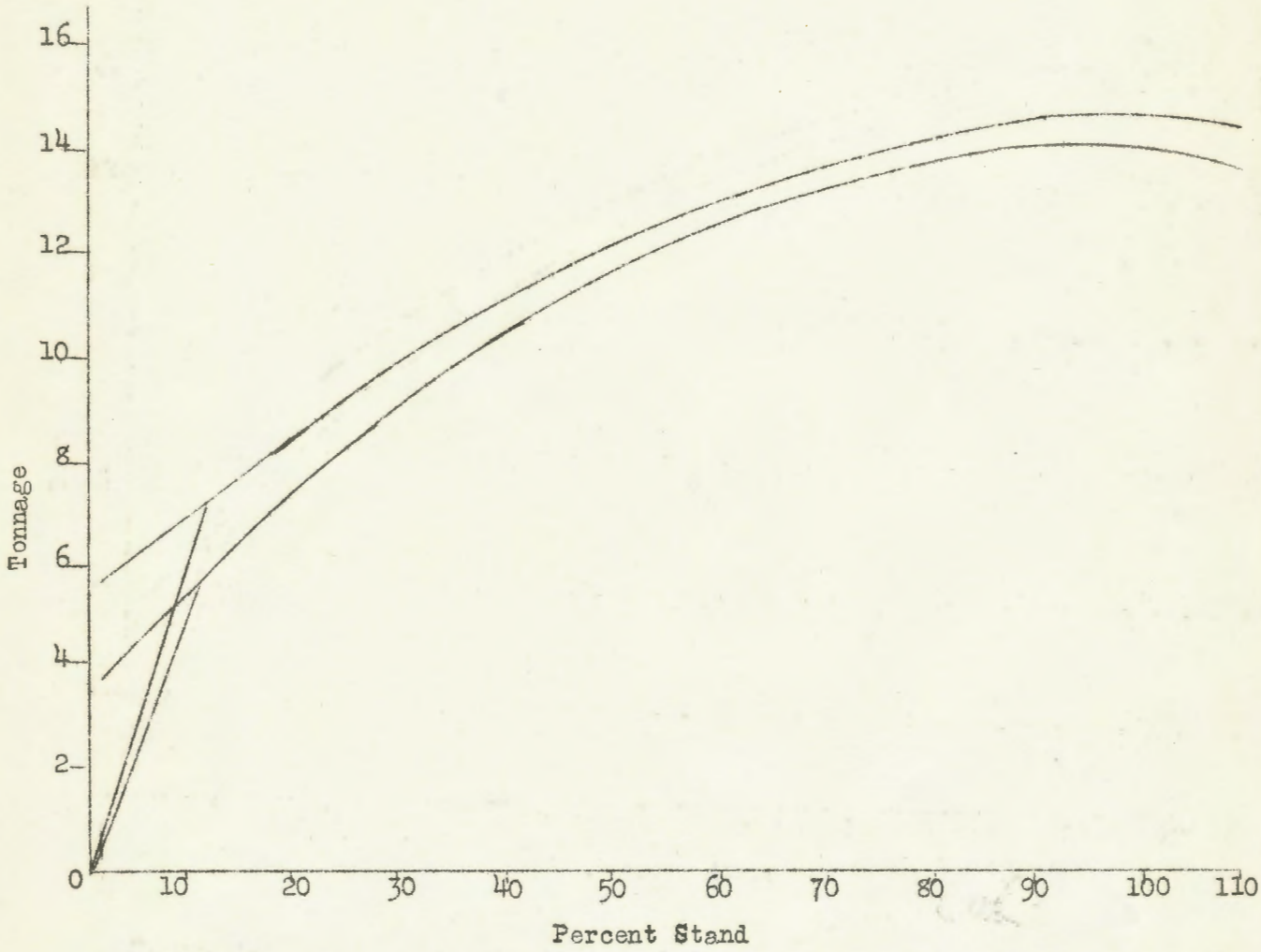

Figure 1. There is a definite curvilinear relationship between tonnage and percent stand of sugar beets even though the beets are grown in different environments. Upper curve is from data of beets grown in Michigan and lower curve is from data of beets grown in Canada.

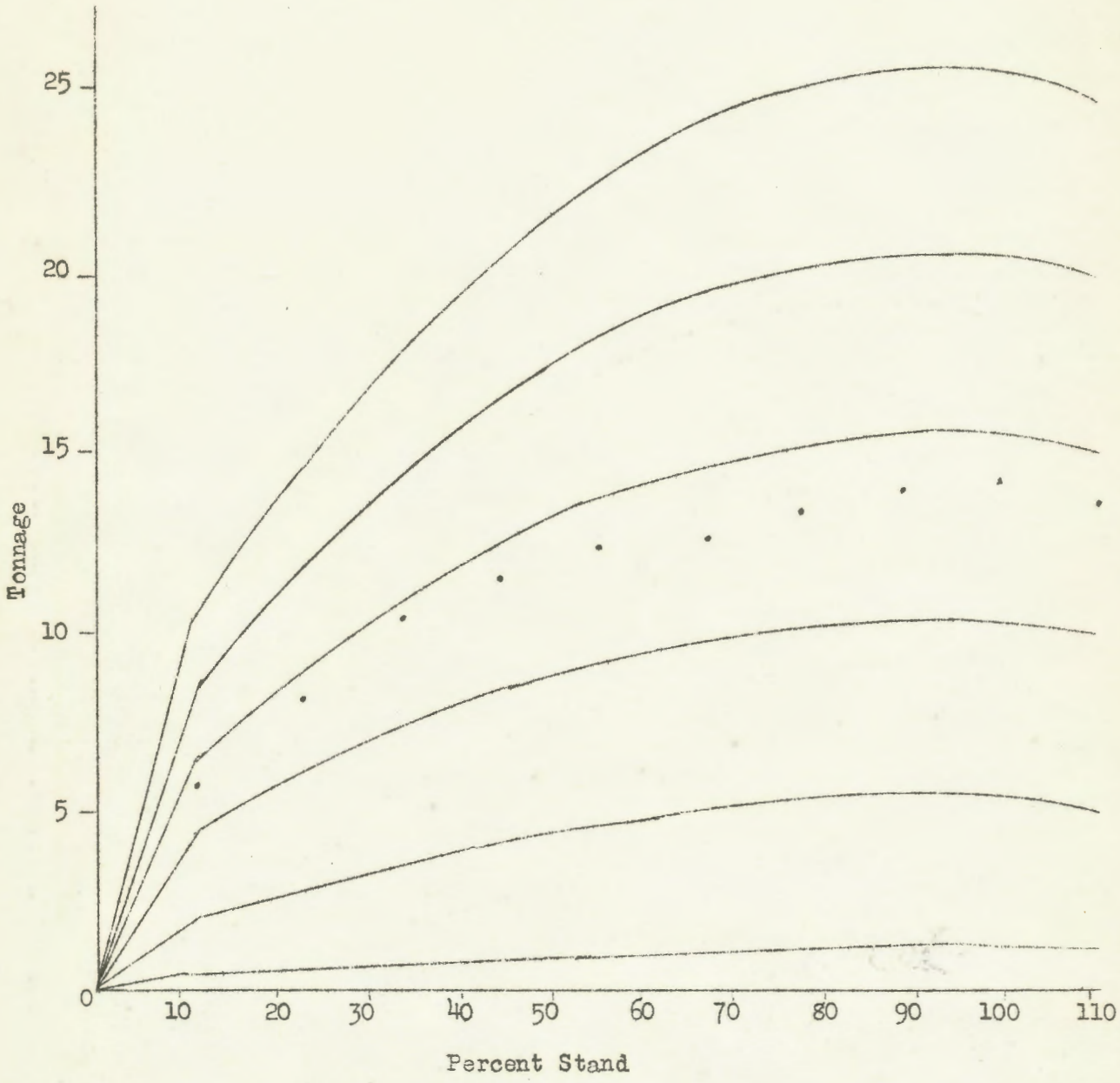

Figure 2. Each environment is represented by a curve which shows the tonnage when the percent stand of beets is varied. The dotted curve is the original data from which the other six curves were calculated.