Evaluation of Field Test Data For Comparisons of Sugar Beet Planters

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Present development of sugar beet planting equipment and methods has as its objective the production of planted or thinned stands of sugar beets with a minimum of labor and cost which will be suitable for production and harvest. A simple method of evaluation of field test data for comparison of results obtained with different sugar beet planters is becoming more and more necessary as development work on the equipment continues and the planters are improved. No uniform or standard method of evaluation, particularly of seedling distribution, is now used throughout the industry and some of the methods which have been used either do not enable direct comparisons between planters because seeding rates or seedling stands differ or require considerable computation and are not readily understood and interpreted by many who are concerned with tests of planters.

There are two distinct objectives of tests of beet planters and planting methods. One is to investigate and improve the effectiveness of planters or methods on seed germination. The other is to investigate and improve those characteristics of planters which effect distribution of seedlings. These objectives are sometimes confused or lost sight: of and a set of planter plots will be put in with equipment varying both characteristics of planters so that the results are interrelated, and clear cut differences in either seed germination or seedling distribution cannot be shown. Tn general it would seem desirable in making planter tests to study one variable at a time, for example, seed germination characteristics, and while so doing to keep all other variables constant, like seed distribution, seeding rate, seed, and speed.

Evaluation of Data on Germination Characteristics

In planter tests to investigate the effectiveness of planting equipment or methods on seed germination, we are interested only in one objective. That is to compare or increase the percentage of the viable seeds or germs which produce seedlings. Only a small percentage of the seeds which would have produced seedlings under greenhouse or seed laboratory conditions arc germinated in many field plantings. Tn Northern Colorado under normal conditions the average percentage of the viable germs which produce seedlings usually ranges from 30 to 50 percent, though by improving germination conditions this has ranged up to 90 percent with exceptionally favorable conditions.

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A simple expression or comparison of the percentage of seedlings germinated from those possible from the seed planted is the only data evaluation necessary in this case. The measure which is being used for this planter characteristic is the percentage of field emergence, which is the percentage of potential germination and gives a value directly comparable for different equipment or sets of germination conditions; data have shown that for segmented seed there is no correlation between percentage of field emergence and seeding rates used.

The only field counts which are therefore necessary for comparisons of this type of plantings are several counts of the number of seedlings per 100 inches of row. Seeding rates need to be determined carefully at the time of planting, and the potential or possible seedlings per 100-inch length of row can be calculated from the seeding rate and a laboratory germination test of the seed. The laboratory test should include both the percentage of germination of. the seed segments and the number of sprouts produced per viable segment. The percentage of field emergence can be determined from the average of the seedling counts and the possible number of seedlings per 100 inches at the seeding rate used.

If desired, statistical analysis can be used to determine whether differences in percentages of field emergence are significant. Seedling counts on 100 inch lengths of row usually have considerable variation, the standard deviation averaging about 20 percent of the count in the seeding rate range used for segmented seed. This means that Io show actual average differences of 10 percent between two counts as significant it will be necessary to make 32 seedling stand counts. Where several different germination treatments are compared and analysis of variance is used in the statistical analysis, less seedling counts per treatment will still show 10 percent differences to be significant. Probably not less than about 16 counts should be made on each treatment in any case and preferably 20 or 24.

Evaluation of Seedling Distribution Data

Planter tests to investigate the differences in seed and seedling distribution are the ones which present by far the biggest problem in evaluation of data. Several different methods of evaluating seedling or germination stands or seed distribution by planters have been used. The chief objective of one group of these methods has been to enable suitable set-ups of mechanical blocking or thinning equipment. The purpose of the other group has been to compare seed or seedling distribution of planters. Because of the major differences in methods being used, a standardized or uniform method could well be adopted.

Mervine (i)[2] developed the first definite method of evaluation

[a]JtaIit; numbers in parentheses refer to literature cited.

of beet planter field germination stands in 1931 for use in set-up of mechanical blockers. It consisted of expressing the field germination stand as the percentage of inch-lengths of beet row containing one or more seedlings, the counts being 100 inches long, and the value came to be generally used as "percent stand." In 1936 and 1937 when development work on single seed planting was begun, I used first singles per 100 inches and later percentage of beet containing inches which were singles in seeking for a method of evaluating the planter data and comparing planters. In 1938 and 1939 when the grease board method of laboratory planter testing was developed, I used frequency-seed distribution curves for evaluating the planter data, using the percentage of seed spacings in a plus and minus band about the mean spacing as a measure (2).

In 1943 Brooks[3] developed a method of evaluation of seed or seedling distributions, using an approximation of the standard deviation of each set of data from a planting or grease board test as a dispersion factor. This method has been modified since by Brooks and Baker.[4] Cannon[5] developed a somewhat similar method in 1943, except that an approximation of the coefficient of variation or standard diviation divided by the mean spacing was used to evaluate the data, lie uses it only for grease board tests, however, and has not suggested it for field planting data.

This last season we developed and used a modification of the method of evaluation used formerly on single-seed and segmented seed planter tests. With this method the percentage of the beet seedlings which are single plants is used as a measure of the quality of the planting. The planter which produces the highest percentage of singles, other things being the same, is considered to be the best and producing the best seedling distribution. A single plant is taken as one that is single in a 1-inch length of beet row ; this is the commonly used measure of a single.

This method may not measure or evaluate the uniformity of seedling distribution as such perhaps, but it does measure that characteristic of a sugar beet planting in which we are most interested in connection with mechanized thinning, that is single plants. However, it does partially or indirectly measure seedling distribution as double seed-segments in planter seed cells and crossed trajectories as the seeds fall result in decreased percentages of single seedlings which are measured by this method. Furthermore the percentage of seedlings

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wliich are singles or, as it is usually called, the percentage of singles is easily understood and interpreted, readily calculated from several seedling stand counts, and can be directly compared where seed, seeding rates, germination conditions, and planter speed are the same. The stand counts necessary are simple and can be made by one man; the office calculation is not difficult or elaborate. If desired, statistical analysis of the data can be made, and the differences required for statistical significance can be determined.

The percentage of singles obtained with any one planter set-up varies with different seed, seeding rates, sets of germination conditions, or planter speed. Therefore if different planters, or planters with different conditions or seed, are tested, the percentages of singles have to be adjusted along correlation curves before direct comparisons can be made. Tests were made this past spring which gave data for determining the relationships between the percentage of singles and the different, variables so that procedures and curves have been worked out for making comparisons between planters even though the planting conditions were not kept constant. These are explained in the following pages, but in general when tesling planters for uniformity of seedling distribution, it is desirable to keep everything else as nearly constant as possible.

The seedling or germination stand counts needed are made with a 100-inch counting stick graduated in inches with lines across the stick. No numbering of inches is necessary. The stick is laid down along a beet seedling row and the cross markings assumed to extend on across the beet row. A count is made of the total number of seedlings in the 100-inch length of row and recorded. Then a count is made and recorded of the number of single seedlings in the same 100-inch length, a. single being only one seedling in a 1-inch length of row. With this method of counting, two singles may actually be less than 1 inch apart if they are in separate inch lengths of stick but on. opposite sides of the dividing line. However, the method is commonly used and seems to work out satisfactorily, and if, when the stick is dropped at random for a count, several successive seedlings seem to occur on the dividing lines between inches, the stick can be slipped along a half inch or so before the count is started. This is seldom necessary and the stick should not be moved along the row after the count is started. The two counts, that is the total seedlings and the singles per 100 inches, can be made simultaneously after some practice if a hand counter or tally register is used. To do this the total seedling count is made mentally and whenever a seedling is encountered which is a single, the tally register is clicked. At the end of the 100-inch count, the mental count of total seedlings is recorded and the number of singles is taken from the tally register and recorded.

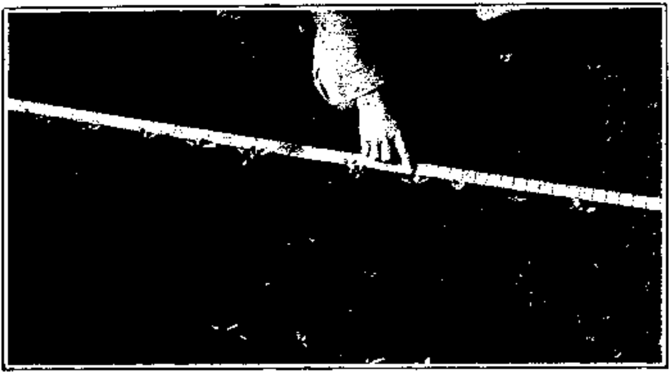


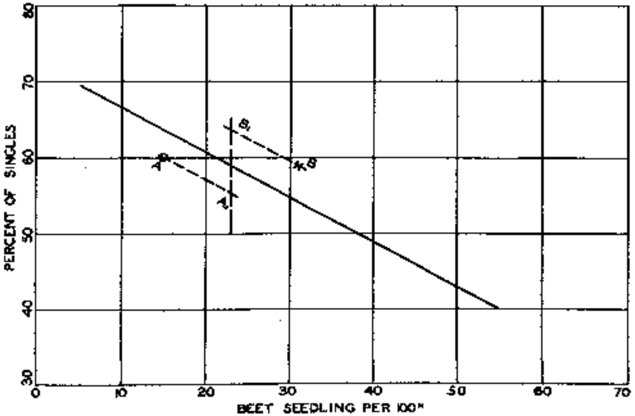
Figure 1.—The seedling stand counts needed for planter comparisons are made with a lOO-inch stick graduated in inches.

If the counts are to be used for determining set-ups for mechanical blocking or thinning equipment also, as is sometimes the case, a third count can be made of the beet-containing inches. If this is done the total seedling count should be made first and recorded and then the beet-containing-inch and singles counts made simultaneously using the tally register. This makes the beet-inch and singles counts conform since it. is sometimes necessary to decide whether two seedlings are in the same or separate inches. This beet-inch count is not used in evaluation of the seedling distribution.

In making the stand counts, as in making them for the germination studies, 16 1o 24 counts should be made on each planting, depending on the uniformity of the stands. With this number of counts and several plantings being compared, 10 percent actual differences can be shown to be statistically significant by analysis of variance of the data. The percentage of the seedlings which are singles in each stand count is calculated and all the percentages of singles for each planting are averaged. The average percent singles for different plantings can be compared directly if all planting conditions except the distribution are kept constant. It usually takes a difference of 6 or 7 percent to be significant at the 95-percent level of significance.

Usually all planting conditions cannot be kept the same and some further calculations are necessary to make direct comparisons between percentages of singles with different plantings. One of the things which affects the percent singles obtained with any particular planter is the seeding rate used. With seed distribution mechanism and all other planting conditions the same, the precentage of singles decreases as the seeding rate increases. Theoretically this should not be true at very light seeding rates and with exactly spaced seed, but with the seeding rates normally used for segmented seed and the planters which have been developed so far with their occasional double seed segments and crossed seed drop trajectories, the decrease throughout the range used has been found to be practically a straight line decrease.

The relationship between the percentage of singles and seeding rate is shown in figure 2 which was prepared from a set of planter seedling distribution data this last, spring. The data were analyzed by analysis of covariance to eliminate the differences from different planters, and the curve shows the average slope or decrease in percent singles as the seeding rate increases for all the planters tested. Equipment, seed, and germination conditions were kept constant for each planter test as the seeding rate was changed. The seeding rate is shown as seedlings per 100 inches rather than pounds per acre or seed cells or seed segments per foot because the stand count data are taken that way and the curve is more readily useable. On the set of plots from which these data were taken the precentage of field emergence averaged approximately 35 and with the 7/64 to 9/64 and 7/64 to 10/64 segmented seed used, the 2 pound per acre seeding rate (with 20-inch beet rows) produced about 11 seedlings per 100 inches, the



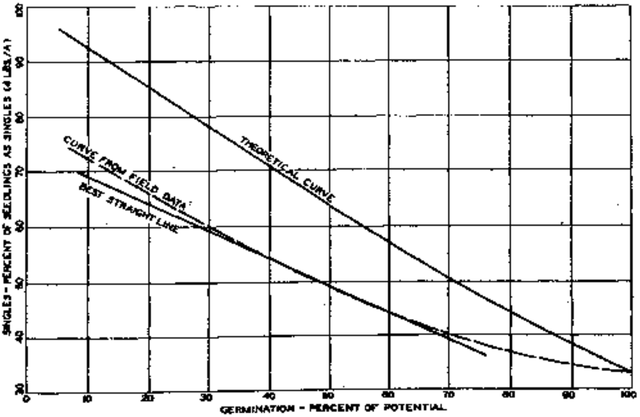
4-pound rate with its approximate 2-inch cell spacing about 22 seedlings, and the 6-pound rate 33 seedlings. The slope of this curve is -.6 which means that on the average for any of the planters tested the percentage of singles decreased .6 of 1 percent for each increase of one in the number of seedlings per 100 inches, In general the test data for any particular planter set-up when plotted would define another line parallel to the one shown on figure 2 and above or below it, depending on whether it was a better or poorer distribution than the average.

It can be seen from figure 2 that planter comparisons should be made at the same seeding rate or seeding stand. However, it frequently is not possible 1o secure exactly the same seeding rates with two planting mechanisms being compared. The proceedure for adjusting the percent singles to an average or desired seedling stand for direct comparison is as follows: Determine the difference between the observed seedling stand and the average seedling stand for all tests or the seedling stand at which comparisons are desired. Multiply this difference by .6 and add this product to the observed percent singles if adjusting to a smaller seedling stand or subtract it from the observed seedling stand if adjusting to a larger seedling stand. This is equivalent to following up or down from the observed percent singles, going parallel to the curve in figure 2 to the average or desired seedling stand for comparison.

For example, suppose the averages for two planters A and B are 60 percent singles at 15 seedlings per 100 inches and 59 percent singles at a 31 seedling stand respectively. Comparisons will be made at the average seedling stand of 23 per 100 inches. The difference between either stand at A or B and the average stand is 8 seedlings per 100 inches. This difference multiplied by .6 gives 4.8 which is added to B and subtracted from A. The adjusted percent singles for A is 55.2 percent at A_1 and for B is 63.8 percent at B_1. When these two adjusted values are compared, B produced 8.6 percent more singles, a difference which probably would be significant. The average slope of -.6 for the curve in figure 2 can be used for approximating other planter test comparisons. Other sets of data from planter tests in previous years have given slopes of -.64 and -.72 when similar sized segmented seed was used. Probably a better average slope to use when none has been determined is -.65. If seeding rates are not greatly different, the error in adjusting percent seedlings with any value from -.6 to -.7 would be small.

Another variable or condition encountered on planter seedling distribution tests which effects the percentage of singles obtained with any particular planter is the percentage of field emergence or potential germination obtained. This is readily understood when we remember that all our segmented seed or seed processed in other ways contains a certain percentage of segments which contain double or multiple viable germs. If germination conditions are very favorable this double segment is more likely to produce a double seedling than if the germination conditions are poor.

The relationship between percent singles and percentage of field emergence has been determined from a set of data taken on one set of our planter plots last spring. This set of plots was planted with the same planter, seed, and planter speed. Nothing was changed which would change the seed distribution, but a number of changes, such as different depth of planting, different press wheels, and different furrow opener characteristics, were made which gave a wide range of percentage of potential germination. The data were analyzed and the curves showing the relationship are shown as the two lower curves in figure 3. One, as indicated, is the best estimated curve to fit the data. The other is the calculated best straight line and fits the data very closely through the range in which we are concerned. The slope of the straight line is -.51 which means that as the percentage of field emergence increases by 1 percent, the percentage of singles decreases by .51 of 1 percent. Where seeding rates and other conditions of planter seedling distribution tests are kept constant, but the percent of potential germination varies, the per-



centages of singles can be adjusted to an average or desired germination level by using the straight line curve or the -.51 slope of the curve. The procedure for adjusting the percent singles is the same as that previously described for adjusting percent singles to average seeding rates.

It may happen on some tests that adjustments in percent singles will have to be made because of differences of both seeding rates and field emergence. In this case the adjustment for different field emergence percentages should be made first and when the percent singles is adjusted to an average germination percentage, the seedling stand should be converted to the proportionate seedling stand at the average germination percentage. Then the adjustment in percent singles can be made for different seeding rates by using the seedling stand at the average germination percentage and proceeding as explained using figure 2.

The relationship between percent singles and percentage of potential germination was considered from the theoretical approach last fall by Leach.[6] In the absence of field data he considered the theoretical relationship between the two based on the assumption that seed germs of single and multiple germ segments had equal probability of producing seedlings in the field. The location of the upper curve of figure 3 is determined in this manner from the percentage of single and multiple viable segments in the seed used in this test. The seed was a 7/64 to 10/64 segmented seed with 51 percent of the viable segments as singles, 43 percent as doubles, and 6 percent as triples. As can be seen from the two curves of figure 3, the actual percentage of singles falls short of the theoretical. Apparently if germination or vitality or other conditions are favorable for one germ of a multiple germ segment to produce a seedling, there is a greater probability of the other germ producing a seedling than the green of a random single germ segment.

Another very evident factor which influences the percentage of seedlings which are singles is the seed used. If one 7/64 to 9/64 seed has 80 percent of the viable seed units as singles and another has only 60 percent singles, it is obvious that a planter using the seed with 80 percent singles will produce a higher percentage of single seedlings, other things being equal. One set of our planter tests last spring contained plantings with a number of different seeds used in the same planter. All variables except seed size and plate to accommodate the seed were kept constant. The data from this planting enable a determination of the relationship between percentage of singles and

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the sprout count of the seed. All seed was used with plates having cells 1/64 inch larger in diameter than the largest size seed, that is 11/64 inch cells for 7/64 to 10/64 seed, and so on. As most of our processed seed, that is segmented, decorticated, or screened seed, contains some triples, it is more convenient and exact to express the sprout count of a seed as the average number of sprouts per viable unit, for example 1.45, rather than as the percent singles.

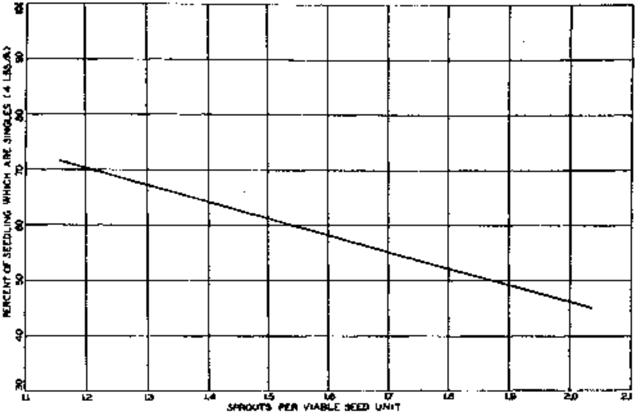
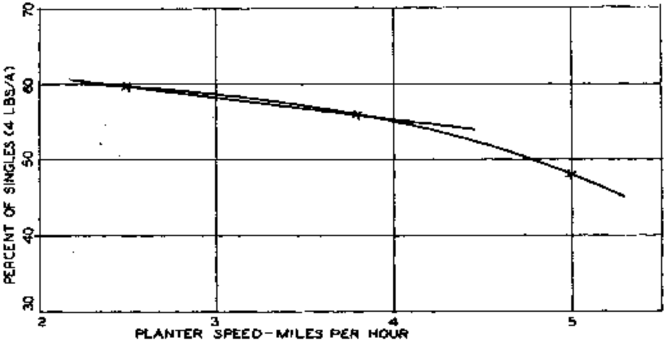


Figure 4 shows the relationship between percent singles and sprout count of seed as determined from this set of data for a 4 pound per acre seeding rate.

Curves for lighter or heavier seeding rates would he above and below that shown. The data show that throughout the range of sprout count in which we are concerned, a straight line seems to represent the relationship very well. The slope of the curve is -30.0 which means that as the sprout; count increases, for example from 1.0 to 2.0 sprouts per viable seed unit, the percentage of the seedlings which are singles decreases 30.0 percent. In a more usable form the relationship is 3.0 percent decrease in percent singles for each increase of .1 in sprouts per viable segment. With this relationship it is possible to make approximate direct comparisons between percent singles obtained with different planters using different seed by adjusting the percent singles as explained for adjusting percent singles with different seeding rates.



The percentage of singles obtained with a planter also varies with changes in planter speed. Figure 5 shows the relationship as determined from ovir last spring's planter data. The percentage of singles drops off faster as the planter speed increases, but at speeds ranging up to around 3½ miles per hour the decrease in percent singles as planter speed increases approximates a straight line with a slope of -2.9. This means the percentage of singles decreases 2.9 percent as the planter speed is increased 1 mile per hour in this range, other things being equal. This is an adjustment of percent singles which should not have to be made because planter speeds can be kept constant for a set of plots. However, it is of practical value to know that planters produce smaller percentages of singles as planting speeds increase, particularly at higher speeds of 4 to 5 miles per hour.

This method of evaluation of planter seedling distributions may seem to become overly complicated after consideration of the above relationships between percent singles and planting conditions. However, it should be remembered that the use of some or all of the adjustments in percent singles can be avoided if every effort is made to keep all other planting conditions constant while planter seedling distribution is being investigated. These adjustments are explained here to show that they can be made and how they are made in case it is necessary.

A brief explanation should be given of why we are using the percentage of seedlings which are singles rather than the formerly used percentage of beet-inches which are singles. The germination stand counts for the latter can be more rapidly made and the use of a slower stand count should be justified to be accepted. Data from different plantings have shown that with either method of counting, the percentage of singles decreases as the seeding rate or seedling stand gets heavier. Therefore comparisons should be made at the same seeding rates, and direct comparisons without adjustment of percent singles can be made only when the seedling stand counts are used.

A simple example will best illustrate this point. Suppose each of two planters puts in 4 pounds of seed and produces 25 seedlings per 100 inches of beet row. One gives 17 singles and 4 doubles and the other 9 singles and 8 doubles. The planter with 17 singles has 21 beet-containing inches of which 81 percent are singles. The other planter has 17 beet-inches of which 53 percent are singles. No direct comparison is possible because The beet-inch stands are different. However, with the first planter 68 percent of the 25 seedlings are singles, and with the second 36 percent of the 25 seedlings are singles, and a direct comparison is possible.

In comparing the percent-of-singles method of evaluating planter-seedling stands with that using the combination of standard deviation and chi square or the standard deviation alone, it seems there are several objections to the latter which are overcome by the former. In the first place the counts required by the latter are considerably more elaborate, take two men, and are much slower to make. With the other method counts can be made by one man in one pass along the row- when using a tally register and only two entries need be made per 100-inch count. Then the office calculation for the percent-of-singles method is simpler, particularly so if the planter tests are made as they should be. keeping all variables constant except the one being investigated. If variables develop, the most likely being percentage of field emergency, with different planters using different, furrow openers, planting depth, press wheel type, or press wheel presure. the adjustment of percent singles can be made and the calculation is still shorter and simpler than of the standard deviation and chi square.

After it is calculated, the dispersion coefficient, which is used for comparing distributions with the standard deviation-chi square method, is not readily understandable or interpretable to many who are making planter tests. On the other hand the percentage of singles is quite readily understood and can be interpreted in relation to thinning. Furthermore, if it is desired to make statistical comparisons of results after the data are analyzed, differences required for statistical significance at the 95- or 99-percent level cannot be determined for the standard deviation-chi square method of evaluation, but they can be determined with the percent-of-singles method.

Another major objection to the use of a method of evaluation of field distributions of seedlings which uses the standard deviation is that the frequency-distribution curve of seedlings spacings is very badly skewed. The curves for seed distributions on a grease board are. badly skewed to begin with and in the field the seedling distribution curves are much worse because of gaps resulting from failure of seed to germinate. The result is that the major portion of the standard deviation or its square, the variance, is made up of the data from a few large gaps.

A specific case will best illustrate the point. These data are taken from a typical planting of 7/64 to 10/64 segmented seed in a good plate planter at 4.33 pounds per acre. The cell spacing or forward travel of the planter per cell was 2.18 inches but the cell fill was 118 percent so the average seed spacing was 1.84 inches. Sixteen 100-inch counts on a total of 133 feet of row showed 386 seedlings or an average seedling spacing of 4.15 inches. The standard deviation of the seedling distribution calculated according to Cannon's method was ±5.596 and the variance or square of standard deviation was 31.32. Forty-eight percent of this variance resulted from six gaps of 24, 29, 32, 37, 38. and 45 inches in the row. Seventy percent of the variance came from gaps of 15 inches or over when the average seed spacing was 1.84 inches. A grease board test with this planter did not show any skips greater than 7 inches at this seeding rate and skips over 5 inches rarely accurred.

These large gaps are faults of germination, when the seed is not being abnormally ground or otherwise damaged and it was not in this planting, and a planter distribution should not be penalized for poor or ununiform germination conditions. Therefore to use a value for evaluation of the seedling distribution nearly half of which results from 1.6 percent of the seed spacings or six seedling gaps, the smallest of which is 13 times the average seed spacing, does not seem justified. This argument is applied here only to field seedling stands and not to grease board tests. On the grease boards, the gaps are a result of poor seed distribution.

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