Methods of Describing Regularity of Seed or Seedling Spacing

P. A. BROOKS and G. A. BAKER[1]

What method is best for measuring the regularity of spacing of seeds or seedlings is still not agreed upon. Only a few individuals are concerned with the setting-up of the varions methods, so it should be possible to establish a uniform practice if that is desirable. It is essential first to understand the differences in procedure of the different systems. Then in view of the different objectives it is necessary to decide how much extra work is justified beyond the simplest procedure by the advantages of uniform, general practice.

Three Typical Methods of Field Counting.—McBirney[2] single-handed, counts up along a 100-inch scale: (a) total number of seedlings, (b) total beet-containing inches, which is called "percent stand", (c) number of inches with only one seedling, called "singles", and (d) the largest gap in inches. This requires three trips along each 100 inches, but writing down the figures only at the end of each pass. The information so obtained is adequate to specify thinning by MervineV formula and gives a hybrid four-element indication of the distribution of spacings: numbers of scalar inches with zero, one and two or more seedlings per scalar inch and the longest run of blank inches. Such a field count is a sufficient procedure to describe irregularity relative to past experience as long as the mean spacing distance is about 1 inch, but the count tends to all singles as the mean spacing distance increases relative to the scalar unit.

Cannon[4] or Brooks classifies seedling count per inch and blank inches per space in a single pass along the tape but needs either an extra man to write for the observer or else a mechanical marker to keep place while the observer is writing down each count as he proceeds along the tape. Since no return pass is necessary, the ground covered per man-hour is not much different in this procedure than the former. The data obtained, however, gives all that McBirney wants and in addition provides a full-range picture of seedling distribution from the closest bunching to the biggest skip. This system of field counting requires slightly more office work (in totaling) to get McBirney's figures and modified statistical treatment to get the coefficient of variability.

[1] Agricultural Engineer and Assistant Statistician, University of California Agricultural Experiment Station, Davis, Calif.

[2]McBirney, S. W., Senior Engineer, USDA, Port Collins, Colo, (See his letter 2/24/45 to Roy Bainer)

[3]Mervine, E. M.. Agricultural Engineer, Colorado A & M College, Fort Collins, Colo.

[4]Cannon,' Rowland, Utah-Idaho Sugar Company, Salt Lake City, Utah.

McCreery[5] or Baker, by noting the number (or absence) of seedlings per inch in successive order, obtains all the information previously mentioned and in addition gels the order of occurrence. Their record would show the full range of spacing distribution and besides this would reveal possible successions of skips and multiples which is a characteristic more objectionable than the same skips or multiples evenly spaced. This method of field counting is as fast or faster than the Cannon-Brooks classifying count but requires much more office work in developing the data.

Various Objectives of Field Seedling Count. Merviue's field counts in connection with Ins studies of thinning far antedate our observations of seed spacing in our investigation of planter performance. Fundamentally Merviue's interest in seedling stands calls for a different criterion than for studies in the irregularity of spacing. His present field count procedure is naturally an amplification of previous seedling stand counting to include indicators of irregularity in spacing. This is sufficient for his purpose but not complete enough for direct comparison with our observations.

The method of counting adopted in Davis '} years ago Mas based on "standard deviation", a. the usual statistical measure of spread of distributions. This criterion of irregularity varied with mean spacing distance, s, so we took the next usual step and adopted "variance" as the measure of irregularity. This is the square of "coefficient of variability", o-/s.

The method of interpretation now proposed by Dr. Baker is a sound mathematical equivalent of our earlier attempts to measure displacement from expected position (of mechanical opportunities). This.also is based on variance, but he calls the o_D/s "coefficient of discrepancy, D", to distinguish it from the orthodox interpretation of the previous method. Unfortunately, Baker's uniform positions cannot be exactly identified with mechanical opportunities and the coefficient, therefore, is not independent of length of run.

There has always been some question in our own planter problem, however, as to what statistical criterion would be most appropriate. Thus the need for review goes beyond the differences between methods used by the US DA and ourselves. Two years ago when we were debating whether standard deviation was the best measure of irregularity of seed placement, the use of this common criterion was questioned because it did not penalize clusters of seedballs to the degree they seemed objectionable in comparison with skips. We suggested

[c]McCreery, N. II.. Agriculturist, retired; Great Western Sugar Company, Denver, Colo.

meeting this by the additional % application of the Chi-Square criterion, expecting that experience would eventually lead to a proper choice of proportional weight. Now, with the lighter seeding rates and more precise planters, clusters are no longer a serious problem and some experts ignore them altogether. They go so far as to ask for simply "how many inches per 100 have one or more seedlings?" This could be answered readily by the Mervine-MeBirney count of "beet-containing inches", possibly omitting their usual "single-seedling inches."

However, the very fact that there was a change in viewpoint (which perhaps made obsolete our specialized method of interpretation) is an argument in favor of using some standard statistical measure. The choice therefore lies between a standard description of irregularity and a shorter method using only part of the standard observations. Rather than abandon standard procedures we prefer to omit refinements previously called for, because as seed spacing increases the inherent error of measuring spacings by whole inches decreases and the uncorrected determination approaches the true standard deviation.

The established USDA method serves as a measure for irregularity of spacing because there is a natural relation between singles, multiples, and gaps under standardized conditions. McBirney suggests that '"after making a number of counts, an average of seedlings per beet inch (excluding singles) may show that the multiple seedling inches contain a constant number, either 2 or slightly more, and the total count of seedlings may be eliminated, calculating this from percent stand number of singles". We believe the same type of comparison might be used to correlate loosely the USDA method with ours. It seems to us, however, that the natural distribution changes with the treatment of the seed and seedbed, so one would always have to judge relative to past experience for given conditions.

For instance, at a 2-inch spacing distance, seed sheared to one germ each would produce 100 percent singles. The McBirney count would show identical "singles" and "percent stand". There would be no indication of the irregularity of gaps except the one largest. Only total skips would show as unfilled inches per 100 inches. For the same seed but planted at a 1-inch spacing distance, the USDA rating would show some doubles (where the seedballs were close to the inch-lines), many singles, a higher "percent stand", and, by subtraction, some blanks. The spacing in both cases might be practically perfect yet the count ratings would be very different. The USDA system noting blanks, singles, and doubles unrelatedly, would give a faulty indication of irregularity of spacing. We therefore think that whenever irregularity is to be measured one should use a more com-

SAMPLE TALLY AND CALCULATION FORM FOR SEED DISTRIBUTION

PLANTER: Cobbley
LOCATION: A.E. Lab – Davis
SETTING: 3.1 lbs/A. at 2 m.p.h.
SEED: U.S. 33-1415 thru 9 over 7/64
REMARKS: Dropped thru a 35/64" Chrome-moly Tube 15" Long

TEST NO: 7c p 1 of 2 pgs.
DATE: 1-14-44
OBSERVERS: Lewis & Bainer

A. TALLY: CATEGORY:	n/q	4/q	3/q	2/q	1/q		0qo	1qo	2qo	3qo	4qo	nqo	TOTAL
BOARD No. 1													58
BOARD No. 2													52
BOARD No. 3													56
BOARD No. 4 Etc.													54 Etc.
B. TOTAL SCALAR COUNT – 8 BOARDS.				16	410	SUB TOTAL	118	280	24	4			
C. NUMBER OF SCALAR UNITS.				16	410	C' 428	0	280	48	12			Ns* 768
D. SIZE OF ENDS; INCHES.	1/n'	0.25	0.33	0.5	1.0								Ns² 1346
E. AMOUNT OF ENDS; INCHES.				8.0	410	E' 418	F. END CORR. E'/C' = 418/428 = 0.98						
G. SPACINGS PER COUNT.	n'-1	3	2	1	0		1	1	1	1			
H. NO. OF SPACINGS. B×G.				16	0		118	280	24	4			N‡ 442
I. MEAN SPACINGS. s := C/H	768/442 = 1.74						J. n-1 THE INTEGER OF s-1 /=0, b-NEXT HIGHER INTEG.-s : 2-1.74=0.26						
K. SPACING SIZE, v, INCHES	1/n'	0.25	0.33	0.5	0		F 0.98	1+F 1.98	2+F 2.98	3+F 3.98	4+F	n+F	
L. DEVIATION (v-s) := K.-I.				1.24			0.76	0.24	1.24	2.24			
M. $(v-s)^2$:= L^2				1.54			0.58	0.06	1.54	5.02			
P. VAR. COEF. $Ns^2\ \sigma_s^2$:= H.×M.				2275			67.4	16.8	37.0	20.04			168.99
H'. EXPECTED SPACING FOR $\Sigma nqo = b \cdot N$; $\Sigma (n+1) qo = (1-b) N$				0	442		115	327					769*
P'. COR. VAR. COEF. $Ns^2\ \sigma_{os}^2$:= H'×M.				0	0		66.8	19.6	0	0			86.4
Q. v^2 := K^2	$(1/n)^2$	.062	.111	.25			0.96	3.92	8.87	15.82			
R. CHI SQUARE, $Ns\ \chi_s^2$:= P/Q.				111.0			70.2	4.17	4.17	1.26			190.91
R'. COR. CHI SQUARE $Ns\ \chi_{os}^2$:= P'/Q.				0			69.5	5.0					74.5

$\sigma_{os}^2 = 1/Ns^2 (\Sigma P - \Sigma P') = \frac{82.59}{1346} = 0.061$;

$\chi_{os}^2 = 1/Ns (\Sigma R - \Sigma R') = \frac{116.41}{768} = 0.151$

D.C. (DISPERSION COEFICIENT) $= \sigma_{os}^2 + 1/3\ \chi_{os}^2 = 0.061 + \frac{0.151}{3} = 0.111$

*VERIFY BY TOTAL LENGTH OF RUN

‡VERIFY BY TOTAL NO. OF SEEDS $(B)_1 \cdot \Sigma n'$

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prehensive field counting system than the Mervine-McBirney-USDA but possibly a more abbreviated office treatment than we previously recommended. Whether the more complicated position-counting of McCreery-Baker is worthwhile depends on how much need there is for more emphasis on the successive order of deviations.

Office Work in Treating Field Counts.—One of the main difficulties in rating planter performance was that the usual statistical procedures (including Mervine's) gave answers that varied with planter speed. Some of this variation is inherent in that with greater speed there is less crossing of seed trajectories as they issue from the drop tube, but most of the change was in the dimensional nature of the statistical criterion. Therefore we recommend using the non-dimensional form of variance, namely

$$\sigma s^2 = \sigma^2/s^2 = \frac{1}{Ns^2} \Sigma\ (v\text{-}s)^2. \qquad (1)$$

This is the square of the usual "coefficient of variability" (o/s), and gives a constant magnitude for a given distribution regardless of the size of the dimensional unit (if small enough to distinguish the irregularities). The proviso on the size of dimensional unit becomes less important as spacing distance increases retaining the scalar-inch as the unit.

All field counting procedures record the total count, N, and the length of row, L; hence the mean spacing distance, s = L/N, is always obtainable. Complications arise only in measuring the variable spacing distance, v, and in calculating the squares of the deviations from the mean, $(v\text{-}s)^2$.

Baker's criterion to include successive order uses the same basic system of deviations squared, as in the foregoing equation, but measures deviations of observed position X_i from, the position, i times s, where the seedling would be found if all were in uniform successive steps. His equation for coefficient of discrepancy is

$$D = \frac{\sigma_D}{s} = \sqrt{\frac{1}{Ns^2} \Sigma \left\{ X_i - (is + k) \right\}^2}. \qquad (2)$$

This is almost the same form as equation *(1)* out requires a calculation of best starting position, k, of the scalar-inch tape.

Once the classified or ordered field data is obtained, the closeness of approach to a true measure of irregularity depends on the method of working up the data, except that we are always faced with the inaccuracy due to the crudeness of using a scalar-inch as the least unit of measurement. If the accuracy of shortcut methods is judged by difference in result from that obtained by the full treatment (of the same criterion), the investigation of inaccuracy is most specific when applied to precise, successive observations of spacing distance. MeBirney has one set of data on seed placement observed to the nearest $^1/_8$ inch, and we have a few studies of the John Deere and Rassmann planters where seed spacing was measured to the nearest 1/10 inch. We do not know of field measurement of seedling spacing measured closer than in scalar-inch units with notation of multiples per inch.

Because all field counts are based on the scalar-inch we have interpreted the spacings between multiple seeds per inch as if in equal fractions: one-third inch each for three seeds in 1 inch. Then for the distance between seeds in adjacent scalar inches or separated by blank inches we have heretofore calculated, as recommended by Cannon, the mean "end correction", that is the average distance between seeds across a scalar-inch line. This is 1 inch if the beet-containing inches are all singles, but would be only one-fourth inch if all the beet inches had four seeds. This refinement fades in importance as mean spacing distance increases, so it may now be practical to omit the calculation of end correction.

To investigate this possibility we have recalculated about 40 examples and find that the variance tends to be higher but there are few changes in the order of rating. Table 1 gives eight samples which best show the trend as mean spacing distance increases.

Possible Drastic Simplification of Rating Method.—If the industry is now willing to work in units of "beet-inches", that is to observe only $\Sigma n'$ as the number of scalar inches containing one or more seedlings, and ignore the "or more", the statistical procedure would be very simple for determining the irregularity in the spacing distribution. For this the Cannon-Brooks field counting would need to note only the positions of the blank inches.

Table 1.—Examples of simplified determinations of variance of seed spacing distributions.

	Graded size inches	Total count N	Mean spacing s inches	Variances: σ_s^2 basic 1/10 in.	Variances: σ_{se}^2 end-corrected 1 inch	Variances: simplified 1 inch
John Deere plate 5/8/43		1122	1.386	0.780	0.657	0.728
		1110	2.81	0.700	0.671	0.682
		1028	5.64	0.630	0.624	0.625
		1002	11.94	0.348	0.344	0.344
Rassman whole seed 8/28/43	8-7/64	379	1.08	......	0.366	0.576
	9-8/64	277	1.42	......	0.208	0.262
	10-9/64	180	2.00	......	0.271	0.277
	11-10/64	81	4.88	......	1.080	1.080

Summary

We have attempted to explain the various methods now practiced for rating the regularity of seed or seedling spacing. The needs of the investigators are different and naturally call for the use of different statistical units of measurement. More detailed field observations are recommended to the ITSDA if the ratings by different systems need to be made inter-convertible. Considerable simplification is feasible in our office procedure, especially if mean spacing distance increases. Drastic simplification of both field count and office practice is possible if the industry is no longer interested in the number of seedlings in a given scalar inch.

Appendix: Scalar-Inch Method of Determining Seed or Seedling Distribution

As a. quick approximate method of rating single seed planter performance at a given seeding rate, counts with 100-inch scales ruled in inches can he made and interpreted as follows:

A. Place a 100-inch scale close to the row, to spot each seed or seedling within the (extended) rulings every inch. (Occasionally the projected inch lines will pass through a cluster of seeds, but the divided cluster will still yield reliable results).

B. For each inch, count the number of seeds or seedlings, or note their absence on a data sheet such as in example shown. Count a row long enough to include at least 400 seeds or seedlings.

C. Sum and calculate as outlined on example tabulation form to get a dispersion factor (approximate standard deviation), which is an indicator of seed or seedling distribution at the given seeding rate. Small values of this dispersion factor show good spacing. The dispersion factor is usually smaller for higher seeding rates and in general can be represented by a straight line over a considerable range of seeding rate.

D. In addition to laboratory tests of seed distribution, planters should be field-tested (with bags at. discharge opening), getting at least five runs of 1/100 acres each, taken occasionally during a travel of more than 1 mile, in order to observe (a) steadiness of feed-rate (in pounds per acre) and (b) seed damage (percent passing minimum screen of trial seed, by weight).

E. First simplification feasible when s exceeds 1 inch) is to omit end-correction sub totals C' and E', taking F=1.00. The next simplification is to omit correction for expected count H', P', and R' but this penalizes cases with b near 0.5.