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STUDIES IN SAMPLING TECHNIQUE: CEREAL EXPERIMENTS.

I. FIELD TECHNIQUE.

By A. R. CLAPHAM, M.A., Ph.D.
(*Rothamsted Experimental Station, Harpenden, Herts.*)

(With One Text-figure.)

Preliminary experiments carried out in the summer of 1928 had indicated that sampling methods might be used to obtain a satisfactorily precise estimate of the yield of small cereal plots (1). It was thought desirable to test the method more thoroughly, and to compare the estimates with figures obtained by large-scale methods. Accordingly samples were taken from all the plots of the three Rothamsted cereal experiments of 1928, the plots later being harvested with a binder in the ordinary manner. Samples were also taken from the 16 plots of a small experiment on barley at Wellingore, Lincs., but no direct measurement of total yield was made for these plots. There were 210 plots in all, but of these 50 were sampled in four sections, corresponding with minor differences in manurial treatment; so that the total number of plots dealt with amounted to 360. The large-scale method, however, treated each of the 50 as a single plot, and thus provided only 210 yield figures.

The method.

The sampling method was Method (*a*) of the earlier paper on cereals (1): 20–32 metre-lengths of drill were cut at randomly located points in each plot, with the restriction that half the number should be cut from each half of the plot; or, in the case of the 50 Rothamsted barley plots, one-quarter of the number from each of the four sections into which the plots were divided. Since the metre-lengths, apart from this restriction, were located independently, they represent the constituent "sampling-units" of the sample (2).

Number of sampling-units.

The earlier work had shown that 30 metre-lengths of drill from a plot 1/40th acre in area, might be expected to give a yield estimate with a standard error of about 5 per cent. This figure would vary comparatively little with the size of the plot over a considerable range, unless the field were very heterogeneous; as the area increased, slightly larger samples would be required to give the same accuracy. It was therefore decided to take 30 metre-lengths from the 48 plots of the oats experiment, whose area was 1/40th acre; and 8 from each quarter, or 32 in all, from each of the 50 plots of the barley experiment, where the area was again 1/40th acre. The 96 plots of the wheat experiment were only of about 1/55th acre, and it was considered sufficient to take only 24 metre-lengths from each.

It will be noticed that only 8 metre-lengths were taken from each quarter of the barley plots, whereas to get a yield estimate with standard error as low as 5 per cent. a considerably larger number would have been necessary. The reason for this apparent change of standard is best seen from a consideration of the plan of the experiment. There were two 5 × 5 Latin squares, giving 50 plots of 1/40th acre. In one of the squares the treatments were:

1. No nitrogen
2. Sulphate of ammonia
3. Muriate of ammonia
4. Cyanamide
5. Nitrate of soda

(2–5: To give 0·2 cwt. of N per acre.)

In the second square urea replaced "no nitrogen," and the dressings were at the rate of 0·4 cwt. of N per acre.

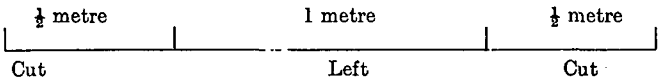
The arrangement of the plots in Latin squares ensured that each treatment should occur on five different plots.

Now one quarter of each plot received no further treatment; a second quarter received muriate of potash at the rate of 0·5 cwt. K_2O per acre; a third superphosphate at the rate of 0·6 cwt. of P_2O_5 per acre; and a fourth both these treatments. Then the direct comparison of the effects of potash and phosphate is made between means of 100 quarter-plots; while interactions between these manures and the various nitrogenous treatments will be tested on means of 20 quarter-plots (except with "no nitrogen" and "urea," where there are only 10). These numbers are halved where the interactions between potash and phosphate are being studied, or where the two levels of nitrogenous manuring are treated separately.

Now since these large numbers of quarter-plots contribute to the various comparisons, individual estimates of yield from the quarter-plots need not be found with so high a degree of accuracy as from the whole plots. It was consequently considered sufficient to take only 8 metre-lengths from each. The justification for this lowering of the standard of accuracy will be seen in the results.

STRUCTURE OF SAMPLING-UNITS.

The sampling-unit, as has already been stated, was a metre-length of drill. The constituent half-metres were not, however, contiguous, but were separated by an interval of one metre. The measuring-rod was thus of the form shown in the figure. Horizontally projecting nails marked the ends of the half-metre-lengths which were to be cut.



The advantage gained by this division of each sampling-unit into two separated units lies in the increased representativeness of the resulting sample, and can be measured directly by appropriate statistical methods, provided that the weights of produce from the individual units are recorded. This was not done in the present series of experiments, but had previously been done on a number of occasions, the results then obtained justifying the method. The statistical procedure is an analysis of variance, and consists in comparing the variation *between* whole-metre-lengths with that between their constituent half-metre-lengths: that is, with that *within* metre-lengths. If the former is the greater to an extent, which would not often occur merely by chance, it is concluded that more information about the crop would have been obtained had the half-metres been completely scattered, instead of being grouped in closely associated pairs. If on the other hand the two variations do not differ significantly, it is concluded that no information has been lost by the association.

The actual test experiments consisted in comparing the variation between and within metre-lengths; first, where constituent half-metres were immediately contiguous; and secondly, where an interval separated them. The measure of variation employed is R. A. Fisher's "Mean Square," and comparisons are effected by means of the "z" test (3).

As an example, the analysis is given for counts of shoot-number made on June 29th, 1928. 32 metre-lengths of drill were selected at random from a small plot of wheat, and separate counts were made of the shoots in each half-metre-length. There were thus 64 observations in all, and the 63 degrees of freedom were divided into 31 for the differences between whole-metre lengths, and 32 for differences between the constituent half-metre-lengths of the same metre-length.

	Degrees of freedom	Sum of squares	Mean square	z
Between metre-lengths	31	1733·7	55·93	—
Within metre-lengths	32	725·5	22·67	0·4514
Total	63	2459·2	—	—

The 5 per cent. point of z is 0·2361, so that mean square "Between metre-lengths" is significantly greater than that "Within metre-lengths," and there is a loss of information as compared with that obtainable from the same number (64) of independently located half-metres.

On July 5, 1928, counts of ear-number were made on the same wheat, but using a dissected 4-ft.-length instead of a metre-length of drill as the observational unit (Fig. 1).

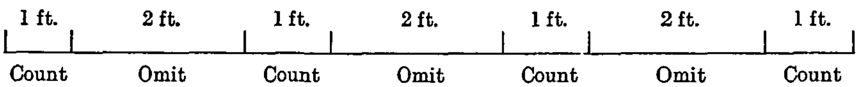


Fig. 1.

	Degrees of freedom	Sum of squares	Mean square	z
Between 4-ft.-lengths	16	361·37	22·59	—
Within 4-ft.-lengths (= between 1-ft.-lengths in the same 4-ft.-length)	96	1811·75	18·87	0·0900

Here the 5 per cent. point of z is 0·2763, and 1-ft.-lengths within the same 4-ft.-length do not resemble each other appreciably more than do 1-ft.-lengths from different 4-ft.-lengths. There is thus no loss of information when the increased labour of completely independent location is avoided.

A similar result was obtained when the sampling-unit consisted of two half-metres separated by a metre, and this pattern was accordingly adopted.

LOCATION OF SAMPLING-UNITS.

In determining the points at which sampling-units were to be cut, two numbers were chosen, one representing a drill-row, and the other a distance along the plot in paces. If there were n drill-rows in a plot, and 30 sampling-units were required from each plot, 30 numbers from 1 to $(n - 2)$ were chosen at random, by the use of Tippett's "Tables of Random Sampling Numbers" (5). To each of these was added 1, so that there were 30 numbers ranging from 2 to $(n - 1)$, representing 30 independent selections of a row other than an edge-row (the number of the row being counted from the edge-row for convenience). Now to each of the first 15 there was assigned at random a number from 1 to $(m-1)$ and to each of the second 15 a number from 0 to $(m-2)$, where m is the length of a half-plot, in paces. This ensured that no crop should be cut within 1 pace from the ends of the plot. The first 15 pairs of numbers were then allocated to one half-plot, and the remaining 15 to the other half-plot. The procedure in the field was then to start at the end of the plot and walk the required number of paces down a certain row, and to place the measuring-rod with its end just touching the toe of the forward foot. To minimise trampling of the crop, the pairs of numbers for each half-plot were arranged in ascending order of paces along the plot, so that there was steady progress in this direction, although it was still necessary to cross from one row to another. When the 15 metre-lengths had been taken from one half-plot, the counting of paces for the second set of 15 was started from the middle of the plot—*i.e.* at the boundary between the half-plots.

Harvesting of the sampling-units.

The produce of each sampling-unit was cut about an inch above the ground with large scissors, and the two half-metre-lengths tied together into a single sheaflet. Before tying the heads were thrust into a perforated paper bag, and this was secured by means of the string of a label which indicated the plot and the serial number of the sampling-unit. It was found unnecessary to tie at any other point since the bag covered about a third of the length of the sheaflet. The sheaflets from a plot were tied into a single sheaf, which was suspended from the roof of a well-ventilated room.

The paper bags were 7-lb. sugar bags, as supplied to grocers, and were of fairly thick and strong yellow paper, glazed externally. Thirty-two holes, just small enough to prevent a cereal grain from passing, were punched in each bag, to ensure rapid drying of the heads.

A few samples were found to be mouldy when examined before threshing, but these were in all cases very weedy, and were probably cut when the corn was slightly damp. It is expected that with an increase in the number of perforations, and more care in cutting only when the crop is quite dry, there will be no trouble from this cause.

WEIGHING AND THRESHING.

The sheaflets were weighed before threshing, and the grain after threshing, the difference, corrected for the weight of the bag, string and label, being taken as straw. The balances were supplied by Messrs W. and T. Avery, of Birmingham, and were direct-reading machines with charts graduated from 0 to 100 gm. at intervals of 1 gm. An adjustable air-damping device made weighing a very rapid process, since the pointer was almost dead beat.

The electrically driven bench thresher and winnower is described in the next paper.

LABOUR.

Table I compares the labour expended per plot in harvesting the three Rothamsted experiments by large-scale and by sampling methods respectively. The large-scale methods consisted in cutting with a binder, stooking, carting to the threshing machine, threshing, and weighing the produce. Time spent in supervising these operations is also included in the estimates. It must be borne in mind, however, that the exceptionally dry summer of 1929 made it possible to thresh all experimental produce in the field, the labour of stacking being entirely saved and that of carting much reduced in consequence. It is estimated that the large-scale figures would be almost doubled in a normal season.

Table I. *Man-hours per plot.*

	Large-scale method	Sampling method
1. Oats experiment	1·67	2·25
2. Wheat experiment	1·69	1·95
3. Barley experiment	2·18	2·36

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