STATISTICAL NOTES FOR AGRICULTURAL WORKERS

NOTE ON THE OPTIMUM SHAPE AND SIZE OF PLOTS FOR SUGARCANE EXPERIMENTS IN BIHAR*

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INTRODUCTION

THE influence of shape and size of plots on the accuracy of comparison is now well-established. Statistical analysis of uniformity trial data has shown that the optimum size and shape for field experiments depends chiefly on the distribution of the fertility gradient in the experimental area, as well as on the nature of the crop under test. Usually there is, however, a best plot size for each crop which is more or less the same for different localities unless there exist marked differences in the nature of the soil. Thus rice experiments in Bengal, Assam and even Ceylon show that the best plot size for variety trials lies between 1/40th and 1/80th acre. In sugarcane trials, Sayer, Vaidyanathan and Iyer [1936] found a plot size of 1/20th acre to be the most suitable for un-irrigated sugarcane ; Sayer and Krishna Iyer [1936] observed that the percentage variation can be diminished by increasing the plot size up to 1/27th acre.

Another important point may be noticed here. In unformity trials, the smallest plot size is almost invariably found to be the most efficient. But the smallest plot size is usually inconvenient for agricultural operations. Thus in a sugarcane experiment conducted by Mitra and Phukan in Jorhat (Assam) the highest precision was found for small plots containing only single rows, 13 feet long and separated from one another by 3 ft. furrows.

MATERIAL FOR THE ANALYSIS

The material for the present investigation was obtained from a variety trial experiment with four types of sugarcane, viz., Co 213, Co 210, Co 326 and Co 331, in Bihar. These were laid out in the form of a regular chess-board type of arrangement. The individual plots measured 45 ft. × 45 ft. and contained fifteen rows of plants each 45 ft. long, placed 3 ft. apart. At harvest the rows were divided into 15 units of length, each equal to 3 ft. ; and the yield and number of canes in these units were recorded for the whole

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experiment. Each plot thus gave 225 readings of cane yield and another 225 readings of plant number, so that there were altogether 3,600 observations of cane yields and 3,600 of plant number.

ANALYSIS OF CONCOMITANT VARIATION

Fisher [1937] has shown that " the precision of an experiment may be greatly increased by equalizing, among the different treatments to be compared, certain potential sources of error ". In the present investigation the yield in each row length of 3 ft. was noted along with the number of canes in the strip. An analysis of the number of canes shows that there are appreciable differences from strip to strip. Different parts of the experimental area were clearly exposed to various types of inequalities ; in the first place, the soil fertility varied from one part to another ; accidental injuries to plants were also of a local character. Assuming therefore that the number of cane is a measure of the inequalities present in the different strips, it is possible to increase the ultimate accuracy considerably. If there is no theoretical objection to comparing the yields of cane based on equal number of plants in the different plots, the method of study appropriate for this purpose is Fisher's Analysis of Covariance. This method has been adopted throughout in this paper. For a proper assessment of its potentialities the analysis of actual yield and of adjusted yield are both given side by side at every stage.

COMPARISON BETWEEN VARIETIES

The analysis of variance and covariance and of adjusted yields are given below in Table I.

TABLE I

Analysis of variance and covariance of the 4 × 4 Latin Square

x = Cane number y = Cane yield

	D. F.	x^2	xy	y^2	Adjusted y^2	D. F.
Rows	3	51,086	70,879	1,04,136	..	..
Columns . . .	3	29,288	40,021	70,188	..	..
Varieties . . .	3	1,44,655	3,63,225	26,01,677	17,13,098	3
Error	6	26,256	38,946	98,165	40,398	5
Total .	15	2,51,285	5,13,071	28,74,166	..	..
Variety + error . .	9	1,70,911	4,02,171	26,99,842	17,53,496	8

The mean values of cane number and of cane yield (actual and adjusted with standard errors) are given in Table II, for each variety.

TABLE II

Mean values of number and yield of cane

Variety	$\bar{x}$	$\bar{y}$	Adjusted $\bar{y}$
Co 213	1,916	3,498	3,726
Co 210	2,169	3,866	3,719
Co 326	2,074	3,648	3,642
Co 331	2,121	4,551	4,475
General mean	2,070	3,891	3,891
Standard error		63·96	44·94
S. E. per cent		1·64	1·15

The standard error of mean yield of a variety based on four replications has been decreased from 1·64 to 1·15 per cent of mean as a result of using the covariance between yield and number of canes. Hence the standard error per plot of size 45 ft. × 45 ft. (containing fifteen rows of plants of length 45 ft. each) is reduced from 3·28 per cent of mean to 2·30 per cent. The problem now is, how far the error of the experiment can be minimised by changing the shape and size of individual plots. For this purpose, we shall take up various shapes and sizes of plots by using different combinations of the unit row strips.

It should be noted here that the estimate of error for comparison of the varieties will not be unbiassed as the design of the main plots was of the systematic chess-board type, but the estimate of error for smaller plot sizes will be quite valid.

COMPARISON OF DIFFERENT SHAPES AND SIZES OF PLOTS

With the material of the present experiment, it is possible to estimate errors for 225 different shapes and sizes of plots by suitably combining the fifteen divisions of each row and the fifteen rows of each plot. In the present report we shall consider the analysis for twenty-five combinations of five row lengths (3, 9, 15, 30 and 45 ft.) with five numbers of rows (1, 3, 5, 10 and 15).

The analysis of variance and covariance for the minimum plot size are shown in Table III.

TABLE III

Analysis of variance and covariance for the unit plot-size " 3 feet-one row "

	D. F.	x^2	xy	y^2	Adjusted y^2	Mean y^2	Mean adjusted y^2
Between plots .	15	1,117	2,280	12,774	..	..	..
Within plots .	3,584	46,897	90,038	1,82,580	9,715	50·9431	2·7114
	3,599	48,014	92,318	1,95,354			

The standard error of actual yield per plot of three feet row length is thus 7·14 lbs., and since the mean yield of plot size is 17·29 lbs., the error is 41·30 per cent of mean. The corresponding values for yield adjusted for plant number are 1·65 and 9·54 respectively. The reduction of error is very marked. The standard error in lb. per plot of all the twenty-five combinations are shown in Tables IV and IV (*a*).

TABLE IV

Standard error in lb. per plot for varying plot sizes

Actual yield

No. of rows	Length of rows				
	3 ft.	9 ft.	15 ft.	30 ft.	45 ft.
1	7·14	11·49	14·75	20·96	27·33
3	12·84	23·99	25·06	35·74	56·11
5	17·46	29·41	35·79	52·43	59·78
10	29·64	52·30	68·14	93·72	95·67
15	37·19	59·65	79·89	99·18	127·91

TABLE IV (*a*)

Standard error in lb. per plot for varying plot sizes

Adjusted yield

No. of rows	3 ft.	9 ft.	15 ft.	30 ft.	45 ft.
1	1·65	3·89	3·34	5·42	6·62
3	4·68	14·45	16·53	10·38	35·64
5	3·75	11·86	9·39	11·62	13·55
10	6·14	11·98	16·14	39·50	63·36
15	7·38	15·01	22·62	57·97	89·89

As the plot size increases, there is a more or less proportionate increase in the yields of individual plots. The actual standard error in lb. per plot naturally increases, but if these errors are expressed as percentages of their respective mean yields as shown in Tables V and V (*a*) it is found that the percentage variability between plots steadily diminishes as the plot size is increased. The same thing is more clearly seen from Tables VI and VI (*a*) where the errors have been expressed as percentages of the error of the smallest plot size (three ft. rows).

TABLE V

Standard error per plot in per cent of mean

Actual yield

No. of rows	Length of rows				
	3 ft.	9 ft.	15 ft.	30 ft.	45 ft.
1	41·30	22·15	17·06	12·25	10·54
3	24·70	15·42	9·56	6·96	5·75
5	20·20	11·34	8·28	6·13	4·61
10	17·03	10·02	7·83	5·44	3·66
15	14·34	7·67	6·16	3·86	3·29

TABLE V (*a*)

Standard error in lb. per plot for varying plot sizes

Adjusted yield

No. of rows	Length of rows				
	3 ft.	9 ft.	15 ft.	30 ft.	45 ft.
1	9·54	7·50	3·86	3·17	2·55
3	9·02	9·29	6·19	2·03	1·32
5	4·34	4·57	2·17	1·36	1·04
10	3·53	2·29	1·85	2·29	2·43
15	2·85	1·93	1·74	2·26	2·31

TABLE VI

Standard error per plot as per cent of the standard error of the unit plot (three feet-one row)

Actual yield

No. of rows	Length of rows				
	3 ft.	9 ft.	15 ft.	30 ft.	45 feet
1	100·00	53·63	41·31	29·66	25·53
3	59·81	37·34	23·15	16·85	13·92
5	48·91	27·46	20·05	14·84	11·16
10	41·23	24·26	18·96	13·17	8·86
15	34·72	18·57	14·92	9·35	7·97

TABLE VI (*a*)

Standard error per plot as per cent of the standard error of the unit plot (3ft.—one row)

Adjusted yield

No. of rows	Length of rows				
	3 ft.	9 ft.	15 ft.	30 ft.	45 ft.
1	23·10	18·16	9·35	7·68	6·17
3	21·84	22·49	14·99	4·91	3·20
5	10·51	11·06	5·25	3·29	2·52
10	8·54	5·54	4·48	5·54	5·88
15	6·90	4·67	4·21	5·47	5·59

Thus with plots of one row only, the standard error of actual yield for row lengths of 3 ft. is as high as 41·30 per cent of mean ; as the length is increased, the error diminishes and ultimately for 45 ft. rows, this is only 10·54 per cent of mean. With two rows per plot, there is again a steady diminution of error as the row lengths are increased but the rate of fall is a little lower than in the case of one row plots. A similar decrease will be noticed in all the other cases.

The standard error of adjusted yield also registers similar movement.

Again, if the length of rows is kept constant while the number of rows is increased, there is also a steady decrease of errors, but this is not so marked as that for the increase in row lengths. Justesen [1932], working with potatoes, also observed that a much lower standard error is obtained when the lengths of the plots are increased than when the widths are increased correspondingly. He attributes this to " slicing up " of local differences when long plots are used, so that the differences are more distributed over different plots than is the case when the plots are wider.

EFFICIENCY OF PLOT SIZE

We have seen that the relative variability diminishes as the plot size is increased ; but as the total experimental area cannot be indefinitely increased, the number of replications with bigger plots is necessarily smaller. There are therefore two opposing factors at work in determining the final precision of a given plot size. If the size is bigger, there is a lowering of error and hence an increase in precision ; but as replication is decreased, there is a diminishing precision, inversely proportional to the square root of the number of repetitions. To arrive at the effective error for comparison, therefore, we must multiply the standard error of a given plot size by the square root of the number of unit plots contained in it. This is shown in Tables VII and VII (*a*) expressed as per cent of effective standard error of actual yield for unit plot size.

TABLE VII

Effective standard error per plot as percentage of the effective standard error of the unit plot

Actual yield

No. of rows	Length of rows				
	3 ft.	9 ft.	15 ft.	30 ft.	45 ft.
1	100·00	92·91	92·42	93·80	98·81
3	103·59	112·02	89·66	92·29	93·83
5	109·36	106·35	100·22	104·93	96·65
10	130·37	132·87	134·07	131·70	108·57
15	134·47	124·83	129·13	114·51	119·49

TABLE VII (*a*)

Effective standard error per plot as percentage of the effective standard error of the unit plot

Adjusted yield

No. of rows	Length of rows				
	3 ft.	9 ft.	15 ft.	30 ft.	45 ft.
1	23·10	31·45	20·90	24·25	23·89
3	37·82	67·47	58·04	26·95	21·46
5	23·50	42·87	26·26	[illegible]	21·82
10	27·02	30·36	31·65	55·40	72·00
15	26·73	31·34	36·44	67·00	83·85

If we compare Tables VI and VI(*a*) with Tables VII and VII(*a*) we find that the larger plots are really not so efficient as they had appeared before. Thus in the case of actual yield if the effective standard error of the 3 feet-one-row plot is supposed to be 100, that for the 45 feet-one-row plot is nearly 99 per cent; but in Table VI, the two standard errors were 100 and 25·53 respectively. The reason for this is very simple: with 3 ft. rows, we may have fifteen replications within the same area as is required for one plot of 45 ft. row. Hence from the point of view of accuracy alone, there is not much to choose between plots of 3 ft. rows and 45 ft. rows.

Many workers have discussed the problem of effective errors in terms of efficiency. Thus Kalamkar [1932] defines " efficiency " as a quantity measuring the total information supplied for a given area. It is calculated by multiplying the variance per plot by the number of ultimate units contributing to the total of that plot and taking the reciprocal. Taking the efficiency of the smallest plot as 100, the efficiency of other plots is shown in Tables VIII and VIII (*a*).

TABLE VIII

Efficiency of plots of different shape and size relative to efficiency of unit plot

Actual yield

No. of rows	Length of rows				
	3 ft.	9 ft.	15 ft.	30 ft.	45 ft.
1	100·00	115·84	117·08	113·66	102·42
3	93·21	79·73	124·40	117·38	114·58
5	83·60	88·42	99·56	90·84	107·10
10	58·82	56·59	55·63	57·66	84·84
15	55·30	64·48	59·97	76·28	70·07

TABLE VIII (*a*)

Effective standard error per plot as percentage of the effective standard error of the unit plot

Adjusted yield

No. of rows	Length of rows				
	3 ft.	9 ft.	15 ft.	30 ft.	45 ft.
1	100·00	53·95	122·04	90·74	93·50
3	37·28	11·72	15·84	73·47	115·87
5	96·62	29·03	77·44	98·63	112·08
10	73·14	57·89	53·27	17·39	10·29
15	74·74	54·36	40·19	11·89	7·59

We notice from Table VIII that there is a marked fall of efficiency as the width of the plot is increased. It will be seen, however, that there is no marked fall of efficiency as the length of the rows is increased. Maximum precision is given by plots containing three rows each 15 ft. long.

But Table VIII (*a*) strangely enough condemns this plot size as one of the least precise. The two plot sizes which have come out consistently efficient in both Tables are each having length 45 ft. and width three rows and five rows. In fact, if smaller plots are difficult to work with, 45 ft.-five row plots with an area of 1/64th acre may be safely recommended for future trials.

REFERENCES

Fisher, R. A. (1937). 'Statistical Methods for Research Workers.' (Sixth Edition), pp. 275-90. Oliver and Boyd

Justesen, S. H. (1932). *J. Agric. Sci.* **22** (2), 366-72

Kalamkar, R. J. (1932). *J. Agric. Sci.* **22** (2), 373-85

Sayer, W., Vaidyanathan, M. and Subramania Iyer, S. (1936). *Ind. J. Agric. Sci.* **6**, 684-714

Sayer, W. and Krishna Iyer, P. V. (1936). *Ind. J. Agric. Sci.* **6**, 917-29

STUDIES ON THE HOT FERMENTATION PROCESS FOR THE COMPOSTING OF TOWN REFUSE AND OTHER WASTE MATERIAL

* II. SOME FACTORS INFLUENCING THE EFFICACY OF THE PROCESS

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It is well known that the biological decomposition of plant materials is influenced greatly by factors such as the degree of moisture, temperature, the presence of available nitrogen, the degree of aeration, presence of inoculum, etc. These factors also influence the course of decomposition occurring in compost heaps ; and their importance is specially great in the hot fermentation process, since a special feature of this method is the intensive aerobic oxidation concentrated within the first five or six days, after which the mass is packed up anaerobically. It is, therefore, essential that the optimum conditions for rapid decomposition be known and secured even from the beginning.

The experiments described below were carried out under controlled conditions in concrete cisterns coated with cement inside so as to prevent leakage of the liquid constituents. Street sweepings and night-soil were used as compost materials and the influence of the following factors on the rate of composting were examined :—

(1) Use of different proportions of soil, night-soil, leaves and moisture ;

(2) temperature changes during composting ;

(3) variations in the relative periods of preliminary aerobic and subsequent anaerobic fermentation ;

(4) influence of added chemicals, e.g., calcium carbonate, superphosphate, sodium nitrate, ammonium sulphate and calcium cyanamide ;

(5) comparison of the quality of composts prepared in cemented cisterns, underground pits and overground heaps : and

(6) influence of prior fermentation of street sweepings before the addition of night-soil.

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