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# STATISTICAL NOTES FOR AGRICULTURAL WORKERS.

## NO. 4.—RICE AND POTATO EXPERIMENTS AT SRINIKETAN (AGRICULTURAL DEPARTMENT OF THE VISVABHARATI), 1931.

BY

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### INTRODUCTION.

The Sriniketan Farm is situated in the Birbhum district of Bengal, at a distance of about 1½ mile from Bolpur station of the E. I. Railway. Paddy and potato form two of the staple crops of this locality. On account of their economic importance these two crops were selected by the authorities of the Department of Rural Reconstruction of the Visvabharati for a preliminary experiment in 1931. Owing to limited financial resources it was decided to restrict the size of the fields to two *bighas* and one *bigha* (⅔ and ⅓ acre) for paddy and potato respectively.

The experimental fields were laid out on virgin soil and the experiments were conducted by Messrs. Hashim Ali, Santosh Behari Bose, and Visvanath Chatterjee under the general direction of Mr. Gour Gopal Ghosh.

Fisher's method of Randomized Blocks was used in designing the lay-out which was prepared in the Statistical Laboratory of the Presidency College. The statistical analyis was carried out by Mr. Subhendu Sekhar Bose and other workers of the same laboratory.

### PADDY.

The Sriniketan Farm lies in a raised undulating country with a sandy soil and a sub-soil of red laterite. The soil is very poor in organic matter, and has little retentive power. Climatic conditions are comparatively dry for Bengal, the normal rainfall in this region being about 50 in. per year of which 39 in. fall during the monsoon months of June, July, August, and September. The monthly distribution is given below in Table R. The soil is of the kind usually called "high poor" land for paddy.

TABLE R.

*Normal rainfall in Bolpur in inches.*

| | in. | | in. |
|---|---|---|---|
| January . . . . . | 0·41 | July . . . . . | 11·14 |
| February . . . . . | 0·72 | August . . . . . | 10·74 |
| March . . . . . | 0·93 | September . . . . | 8·00 |
| April . . . . . | 1·06 | October . . . . | 3·32 |
| May . . . . . | 3·84 | November . . . . | 0·55 |
| June . . . . . | 9·43 | December . . . . | 0·05 |

*Varieties.*—Much of the land in the Birbhum district belongs to this "high poor" type. But large tracts of "medium" and "low" lands also occur in the same district. In fact, such lands exist in the immediate neighbourhood of the Sriniketan Farm. For the preliminary experiment it was, therefore, decided to try 3 varieties specially suited for these three types of land.

Red Aus is an early variety mostly grown on "high poor" land. On account of its early character it is largely used for actual consumption in the villages when the supply of paddy runs low. It also leaves sufficient time (and moisture in the soil) to enable a *rabi* crop being grown on the same field.

Kashiphul is grown on "medium" land, and is a comparatively late variety. The yield is higher, and the quality of the grain much better than Red Aus. It is usually grown on much better land, and a second crop of potato or onion is usually taken from the same field.

Dudkalma is a late, high-yielding variety grown on "low" land. The grains are fine and fetch higher prices than either Red Aus or Kashiphul, and are usually exported from the villages for outside sale.

*Manures.*—Owing to the virgin character of the soil cow-dung was applied heavily to all the plots at the rate of 10 baskets (1 basket =20 seers) per plot of 39 ft. × 12 ft. or 15·5 mds. per *bigha* or 46·4 mds. (166·6 tons) per acre.

Two fertilizers were tried. Ammophos was applied at the rate of 4 *ch.* per plot or 6 seers and 12 chittacks per *bigha* or 40·5 lbs. per acre at the time of pudding on the 25th and 26th July, 1931.

Sulphate of ammonia was given as a top dressing at the rate of 3 *ch.* per plot, *i.e.*, 5 seers 1 *ch.* per *bigha* or 15 seers 3 *ch.* per acre at the time of hoeing on the 1st and 2nd September.

The size of the field for the paddy experiment was about 2 *bighas* or $\frac{2}{3}$ acre. It was divided into 6 blocks each consisting of 9 plots of size 39 ft. × 12 ft. ($\frac{1}{3}$ *bigha* or $\frac{1}{9}$ acre each approximately). The 3 varieties with 3 manures (including 1

control) were distributed at random within each block, so that each treatment with each variety was replicated 6 times. Details are shown in Table I.

TABLE I.

*Paddy experiment in Bolpur 1931-32. Yield of grain in* chattaks *per plot of* $\frac{1}{3^{0}}$ bigha.

| *Treatment* | | I | II | III | IV | V | VI | Total |
|---|---|---|---|---|---|---|---|---|
| *Red Aus* | Ammophos. | 112 | 128 | 118 | 128 | 92 | 152 | 730 |
| | Amon. sulph. | 168 | 116 | 144 | 100 | 100 | 80 | 708 |
| | Control | 106 | 84 | 68 | 156 | 156 | 128 | 698 |
| *Kashiphul* | Ammophos. | 112 | 81 | 108 | 96 | 53 | 48 | 498 |
| | Amon. sulph. | 61 | 98 | 58 | 86 | 65 | 98 | 466 |
| | Control | 97 | 86 | 92 | 80 | 99 | 66 | 520 |
| *Dudkalma* | Ammophos. | 134 | 112 | 116 | 114 | 101 | 128 | 705 |
| | Amon. sulph. | 125 | 106 | 110 | 102 | 56 | 110 | 609 |
| | Control | 62 | 60 | 99 | 90 | 58 | 87 | 456 |
| | Total | 977 | 871 | 913 | 952 | 780 | 897 | 5,390 |

*Progress of the experiment.*—The field was prepared and laid out in June just before the break of the monsoon. As no experiment with fertilizers had been carried out in this field so far, there was no question of any residual effects from previous season.

The dates of various operations are given below.

TABLE II.

*Dates of operations.*

| Operation | Red Aus | Kashiphul | Dudkalma |
|---|---|---|---|
| 1. Sowing | 15th June | 15th June | 29th June |
| 2. Transplanting | 25th July | and 26th July | (all varieties) |
| 3. Ammophos | „ | „ „ | „ |
| 4. Amon. sulphate | 1st September | „ 2nd September | „ |
| 5. Weeding and hoeing | 1st, 2nd and 3rd September | | „ |
| 6. Flowering | 26th September | 24th September | 3rd November |
| 7. Harvesting | 31st October | 16th November | 7th and 8th December |

The yield of grain in each plot is shown in figures in Table I.
The analysis of variance is given in Table III.

TABLE III.

*Analysis of variance.*

| — | Degrees of freedom | Sum of squares | Mean square | Standard deviation | ½ Log$_e$ (mean square) |
|---|---|---|---|---|---|
| Varieties . . . | 2 | 11867 | 5933·50 | 77·03 | 4·3442 |
| Manures . . . | 2 | 1879 | 939·50 | 30·65 | 3·4227 |
| Differential response of varieties to manures | 4 | 3806 | 951·50 | 30·85 | 3·4290 |
| Treatment . . . | 8 | 17552 | 2194·00 | 46·84 | ... |
| Blocks . . . . | 5 | 2670 | 534·00 | 23·11 | ... |
| Errors . . . . | 40 | 22574 | 564·35 | 23·76 | 3·1678 |
| Total . | 53 | 42796 | 807·47 | 28·42 | |

We find that the mean variance for fluctuations between "blocks" is 534·00 against a residual variance of 564·35. It is clear, therefore, that the division into "blocks" has not helped in any way in eliminating the effect of soil heterogeneity. It is possible that the variations in fertility in different portions of the field are not systematic.

We may now proceed with Fisher's *z*-test of significance for comparison of the different variances.

Let $S_1$ and $S_2$ be the two variances under comparison. Then "$Z$" is defined to be $\frac{1}{2}$ ($\log_e S_1^2 - \log_e S_2^2$) where the logarithms are natural, *i.e.*, calculated to the base "e". These values are given in the last column of Table III.

For example for "varietal" differences we have $\log_e 5933{\cdot}5 = 8{\cdot}6884$ and for residual errors $\log_e 564{\cdot}35 = 6{\cdot}3356$; so that the difference of the natural logarithms is 2·3528, and '$Z$' is given by half the difference or 1·1764. It will be noticed that the two variances are based on 2 and 40 degress of freedom respectively.

In the same way we obtain the value of '$Z$' (and the corresponding degrees of freedom) for "manurial" differences, as well as for the "differential action of manures."

TABLE IV.

*Values of 'Z'.*

| | $n_1$ | $n_2$ | Observed | Expected 5 per cent. |
|---|---|---|---|---|
| Variety . . . . . | 2 | 40 | 1·1764 | 0·5866 |
| Manure . . . . . | 2 | 40 | 0·2549 | 0·5866 |
| Differential response . . | 4 | 40 | 0·2612 | 0·4789 |

The observed values of '$z$' are shown in Table IV. We can easily find the corresponding critical values from Fisher's Table VI (Statistical Methods for Research Workers, 1932, p. 224-27). For example, for $n_1=2$ and $n_2=40$. we notice that the other critical values of '$z$' are obtained in the same way, and shown in column 5 of Table IV.

For varietal trials the 5 per cent. value of '$z$'=·5866. This implies, that, in case the varietal differences are really *nil*, the observed value of '$z$' will exceed ·5866 only once in twenty trials. But the observed value is 1·1764. That is, the odds are more than 20 to 1 in favour of the varietal differences being real.

It will be noticed, however, that the "manurial" or "differential" effects cannot be considered significant. Full details of the different effects are given in Tables V-VII.

TABLE V.

*Mean yield of different varieties of paddy.*

| | *Chattaks* per plot | Maunds per *bigha* | lbs. per acre. | Per cent. |
|---|---|---|---|---|
| Red Aus . . . . . | 118·7 | 5·75 | 1379·89 | 118·8 |
| Kashiphul . . . . . | 82·4 | 3·99 | 957·90 | 83·5 |
| Dudkalma . . . . . | 98·3 | 4·76 | 1142·74 | 98·4 |
| Mean . . . . . | 99·8 | 4·83 | 1160·18 | 100·0 |
| S. E. . . . . | 5·6 | 0·27 | 65·10 | 6·0 |

It is clear from Table V that in the "high poor" land of Sriniketan Farm the yield of Red Aus comes out best, while Kashiphul is distinctly the worst. The difference between Red Aus and Kashiphul is 35·3 per cent., between Red Aus and Dudkalma 20·4 per cent., and between Dudkalma and Kashiphul 15·9 per cent., while the effective precision of the experiment is given by a standard error of 6·0 per cent. for a single mean based on 18 replications.

TABLE VI.

*Mean yield of paddy for different manurial treatments.*

| | *Chattak* per $\frac{1}{31}$ *bigha* | Yield in mds. per *bigha* | Lbs. per acre | Per cent. |
|---|---|---|---|---|
| Ammophos . . . . | 107·4 | 5·20 | 1248·5 | 108·0 |
| Ammonium sulphate . . | 99·1 | 4·80 | 1152·0 | 99·0 |
| Control (No manure) . . | 93·0 | 4·50 | 1081·1 | 93·0 |
| Mean . . . . . | 99·8 | 4·83 | 1160·2 | 100·0 |
| S. E. . . . . | 5·6 | 0·27 | 65·1 | 6·0 |

The effect of manures is not generally significant. Table VI shows, however, that the difference between ammophos and the control (no fertilizer) is quite large being 14·4 per cent. with a standard error of 6·0 per cent. This difference is suggestive, but the effect of sulphate of ammonia is inappreciable.

TABLE VII.

*Mean yield in chattaks per plot of* $\frac{1}{31}$ bigha.

| | Ammophos | Ammonium sulphate | Control | Mean |
|---|---|---|---|---|
| Red *aus* . . . . | 121·6 | 118·0 | 116·3 | 118·7 |
| *Kashiphul* . . . . | 83·0 | 77·8 | 86·7 | 82·4 |
| *Dudkalma* . . . . | 117·5 | 101·5 | 76·0 | 98·3 |
| Mean . . . . . | 107·4 | 99·1 | 93·0 | 99·8 |

Standard error of mean of 6 plots = 9·7.

Finally Table VII shows the full analysis for each variety and each manure. The effect of fertilizers is entirely negligible in the case of both red *aus* and *kashiphul*. *Dudkalma*, however, appears to show a definite response to sulphate of ammonia, and an increased response to ammophos. This result is interesting; *dudkalma* which requires a richer soil, appears to be able to derive a certain amount of additional nourishment from the chemical fertilizers. This point deserves further attention.

The results of the experiment may now be summarized. In the "high poor" land of the Sriniketan Farm, Red Aus appears to do best and Kashiphul worst, Dudkalma coming between the two. The effect of chemical fertilizers is not quite clear, being generally inappreciable. Dudkalma, however, appears to show better results with sulphate of ammonia, and still more so with ammophos.

On the technical side the division into "blocks" did not lead to added precision owing probably to the variation in soil fertility being unsystematic. The residual standard deviation is 23·76 chattaks per plot for a mean yield of 99·81 chattaks per plot or a standard deviation of about 23·8 per cent. This is very high and may be compared with a residual standard deviation only 6·7 per cent. in the Mandalay Paddy Experiments [1932]. Evidently the fertility of the Sriniketan field varies very considerably from plot to plot.

The effective precision of comparision is given by a standard error of 5·6 per cent. for a single mean based on 18 replications which does not compare very unfavourably with a standard error of mean of 3·1 per cent. in the C. P. Rice Experiments [1931] and 2·72 per cent. in the Mandalay Rice Experiments.

## Potato.

Like the rice experiment 3 varieties were chosen for the potato experiment. "Deshi" is an early variety largely grown in the locality and has good keeping qualities. "Patna" is a heavy yielding type with a bigger size of potatoes. "Darjeeling" is a special variety much favoured for both yield and quality.

The size of the field for the potato experiment was about 1 *bigha* ($\frac{1}{3}$ acre). It was divided into three blocks with 9 plots each of size 39 ft. × 12 ft. ($\frac{1}{3\frac{1}{3}}$ *bigha* or $\frac{1}{9\frac{1}{3}}$ acre). The lay-out is shown in Table VIII. This field also like the rice field was virgin soil.

### Table VIII.

*Lay-out and yield of potato experiment. Area of plot* = 39 *ft.* × 12 *ft.* = $\frac{1}{3\frac{1}{3}}$ *of a* bigha *or* $\frac{1}{9\frac{1}{3}}$ *of an acre* (*Yield in seers and chattaks*).

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| BX | AO | CY | CX | AO | BY | AX | CY | BO |
| 6—0 | 3—13 | 5—8 | 5—4 | 3—4 | 5—8 | 5—2 | 7—8 | 6—0 |
| AY | CX | BO | BO | CY | AX | BY | AO | CX |
| 4—4 | 6—6 | 6—8 | 5—2 | 4—2 | 2—10 | 4—8 | 2—8 | 10—4 |
| CO | BY | AX | AY | BX | CO | CO | BX | AY |
| 6—2 | 5—12 | 1—3 | 2—4 | 4—12 | 3—14 | 5—4 | 4—8 | 2—2 |

A—Darjeeling
B—Patna
C—Deshi

O=No fertilizer
Y=Potassium nitrate
X=Ammonium phosphate

All the plots were treated with cow-dung at the rate of 10 baskets or 20 seers per plot or 15·5 mds. per *bigha*, *i.e.*, 16·6 tons per acre. The artificial fertilizers used were ammophos at the rate of 1 seer 9 chattaks per plot, *i.e.*, 42 seers 3 chattaks per *bigha* or 3 mds. 6 seers and 9 chattaks per acre and potassium nitrate at the rate of 1 seer 14 chattaks per plot or 1 md. 10 seers and 10 chattaks per *bigha*, or 3 mds. 31 seers and 14 chattaks per acre.

The seeds were sown on the 14th and 15th November, 1931, at a distance of 9 in. in rows placed 1 ft. 9 in. from one another. The chemical fertilizers were applied and earthed on the 25th and 26th December. "Deshi" and "Patna" varieties were harvested from the 3rd to the 5th February 1932, and the "Darjeeling" variety as late as the 23rd March owing to the late development of the tubers. The actual yield in seers and chattaks are given for each plot in Table VIII.

One most important to be noted in this experiment was the complete absence of artificial irrigation. Rainfall was also scanty, the actual amount being *nil* in December and January.

The analysis of variance is given in Table IX.

TABLE IX.

*Analysis of variance (Potato).*

| | Degrees of freedom | Sum of squares | Mean square | S. D. | $\log_e$ (mean square) |
|---|---|---|---|---|---|
| Varieties . . . . | 2 | 10095 | 5047·50 | 71·04 | 8·5265 |
| Manures . . . . | 2 | 614 | 307·00 | 17·52 | 5·7268 |
| Differential response of varieties to manure | 4 | 3443 | 860·75 | 29·34 | 6·7581 |
| Blocks . . . . | 2 | 1374 | 687·00 | 26·21 | ... |
| Errors . . . . | 16 | 9123 | 570·20 | 23·88 | 6·3460 |
| Total . | 26 | 24649 | 948·04 | 30·79 | .. |

The "Z" values are given in Table X.

TABLE X.

*Values of "Z"*

| — | $n_1$ | $n_2$ | Observed | Expected 5 per cent. |
|---|---|---|---|---|
| Variety . . . . . | 2 | 16 | 1·0925 | 0·7788 |
| Manures . . . . . | 16 | 2 | 0·6194 | 1·4830 |
| Differential response . . . | 4 | 16 | 0·4121 | 0·5505 |

The varietal differences may, therefore, be considered definitely significant, while the effect of manures is negligible.

The mean yield for each variety is shown in Table XI.

TABLE XI.

*Mean yield of different varieties of potato.*

| — | In chattaks per plot | In mds. per *bigha* | In lbs. per acre | Per cent. |
|---|---|---|---|---|
| Darjeeling | 48·2 | 2·33 | 560·33 | 64·0 |
| Patna | 86·4 | 4·18 | 1004·40 | 115·0 |
| Deshi | 91·5 | 4·43 | 1063·69 | 121·0 |
| Mean | 75·4 | 3·65 | 876·53 | 100·0 |
| S. E. | 7·96 | 0·38 | 92·54 | 11·0 |

It is clear that *without irrigation*, Deshi and Patna are likely to give much better results than Darjeeling.

Table XII shows the failure of fertilizers in the absence of irrigation. Ammophos gives slightly better yield, but in view of the magnitude of the standard error no weight can be attached to the result.

TABLE XII.

*Mean yield of potato under different manurial treatments.*

| — | Chattaks per plot | Mds. per *bigha* | Lbs. per acre | Per cent. |
|---|---|---|---|---|
| No manure | 70·6 | 3·42 | 820·7 | 94·0 |
| Potassium nitrate | 73·8 | 3·57 | 857·93 | 98·0 |
| Ammonium phosphate | 81·9 | 3·96 | 952·09 | 109·0 |
| Mean | 75·4 | 3·65 | 876·53 | 100·0 |
| S. E. | 7·96 | 0·38 | 92·54 | 11·0 |

Table XIII shows full details of the yield.

TABLE XIII

*Mean yield of potatoes in* chattaks *per plot of* $\frac{1}{81}$ *acre.*

| —— | No manure | Pot. nitrate | Ammon. phos. |
|---|---|---|---|
| Darjeeling . . . . . | 51·0 | 46·0 | 47·7 |
| Patna . . . . . | 94·0 | 84·0 | 81·3 |
| Deshi . . . . . | 66·7 | 91·3 | 116·7 |

S. E.=13·78.

The effect of fertilizers on "Darjeeling" and "Patna" is if anything harmful, while "Deshi" appears to have gained considerable benefit from them.

The division into blocks in this case also does not give any advantage, showing the patchy or non-systematic character of the soil heterogeneity. This accounts for a high residual standard deviation of 23·87 chattaks per plot or expressed as a percentage of the mean yield of 75·41 chattaks per plot, a residual variation of 31·7 per cent. This is considerably higher than the residual variation of 23·8 per cent. found in the case of the paddy experiment.

## CONCLUSION

Both the paddy and potato experiments illustrate a simple method of combining varietal and manurial trials in the same field. Fisher has emphasized the importance of such combined experiments. They are not only more efficient in the sense that they can supply replies to two sets of questions—varietal and manurial—at the same time, but are also capable of throwing light on the differential response of varieties to manures which cannot be studied in any other way.

## REFERENCES

Mahta, D. N. and Dave, B. B. (1931). *Ind. J. Agric. Sci.* 1, 351.
Robertson, H. F. (1932). *Ind. J. Agric. Sci.* 2, 63.