ECONOMICS OF MANURING

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IN a recent article[1] in the *Indian Farming*, Dr. W. Burns has raised two important questions regarding economic aspects of manuring, namely: 'Does manuring pay?' meaning thereby 'Does the money value of the additional crop exceed the price paid for the manure applied?', and 'what is the amount of manure that it would pay to apply?', given certain prices for manure and for produce. Dr. Burns has further stated that it would be advisable if the economic aspect of manuring crops was discussed with a precision that can be expressed in a table or a graph. The following method would appear to supply precise answers to the questions raised by Dr. Burns:

The appropriate statistical test to answer the first of the two questions is obviously the test of significance for profit which is the excess of the value of additional produce over the value of manure applied including the incidental charges of application, etc. For a given price of produce, the value of yield per plot is subject to the same experimental errors as the quantity of yield itself, so that if p is the price of produce per unit weight and u the error variance of yield per plot, the error variance of value per plot will be merely p^2u. The error variance of the mean value will be $\frac{p^2u}{r}$, r being the number of replications and that of the difference in mean values of manured over non-manured plots and hence that of the profit for a given price of manure will be $\frac{2p^2u}{r}$. The test of significance of profit is simply given by the quotient t of the profit by its standard error distributed in Fisher's well-known t distribution. If t is sufficiently large giving a large probability that profit as large or larger than the one observed would occur in future, it would indicate that manuring may be expected to pay for its cost. The whole validity of the approach follows by regarding the monetary value of yield rather than quantity as the measurable produce for manurial experiments. It is apparent that following the above approach a table or a graph or both can be readily constructed showing if it would pay to manure a crop at given prices for produce and for manure.

The precise determination of the optimum dose of manuring presupposes a known form of relationship between the value of extra produce and the dose of manure applied. Field experiments rarely include more than three to four doses of manuring, which are obviously too few to provide an adequate indication of this relationship. It appears, however, reasonable to assume that a second-degree parabola of the form $v = \alpha + \beta d + \gamma d^2$ with $\gamma - ve$, where v denotes value and d the dose of manure, would adequately represent the relation. It is a curve fairly extensively used to represent the relation in question and is clearly the one that common sense and facts support. The equation to the straight line giving the cost of manure is clearly $v = qd$, where q is the price per unit dose of manure. It will now be readily seen that the optimum dose is given by the point where the tangent to the value curve is parallel to the cost line for manure. In the notation used above the optimum dose d is given by $\frac{q-\beta}{2\gamma}$.

The standard-error of the optimum dose is readily derived. The value-curve can be alternatively written in the form

$$v = \bar{v} + b_1 \xi_1 + b_2 \xi_2$$

where $\bar{v}$ is the average of observed values, ξ_1 and ξ_2 are the orthogonal functions of d given by

$$\xi_1 = d - \bar{d} \text{ and } \xi_2 = \xi_1^2 - \frac{n'^2 - 1}{12}$$

and b_1 and b_2 are constants whose values are determined by the usual method of fitting a multiple regression equation. The sampling errors of b_1 and b_2 being clearly independent, the variance of the optimum dose is simply given by the variance of $\frac{q - b_1}{2b_2}$ which appears to be

$$\sigma^2 \left\{\frac{(\hat{d} - \bar{d})^2}{S(\xi_2^2)} + \frac{1}{4} \cdot \frac{1}{S(\xi_1^2)}\right\}.$$

The profit to be expected for any given dose of manure is clearly given by the ordinate of the value curve. It follows from what has been given above that its variance is simply the variance of $\bar{v}$ plus the quantity

$$\sigma^2 \left\{\frac{\xi_1^2}{S(\xi_1^2)} + \frac{\xi_2^2}{S(\xi_2^2)}\right\}.$$

The method outlined above has been illustrated in detail in an article to be published in the *Indian Journal of Agricultural Science*.

[1] W. Burns, *Indian Farming*, 1940, 1, 365.