STATISTICAL SIGNIFICANCE IN CROP FERTILISER TRIALS IN RELATION TO THE PROFITABILITY OF APPLYING FERTILISER

J.A. Douglas and C.B. Dyson
Ruakura Agricultural Research Centre,
Hamilton

ABSTRACT

The broad aim of fertiliser trials on field crops is to determine whether the fertiliser is necessary and, preferably, what the best rate of application is. The necessity question has usually been coupled with testing the hypothesis that the observed treatment effect is real, that is, it has been accorded statistical significance at the orthodox level (5%). This paper sets out to examine some of the difficulties involved in applying the results of statistical tests to give advice on fertiliser use and suggests some ways of overcoming these difficulties.

STATISTICAL SIGNIFICANCE IN RELATION TO REPONSES TO FERTILISER.

The simple acceptance of statistical significance of a fertiliser treatment effect as the criterion on which to recommend fertiliser use can be misleading for both very precise and imprecise results. Wheat trials in particular can show up very fine yield differences as significant and in such situations the value of the response in grain yield can be as low as half the cost of the fertiliser in terms of amount of grain required to pay for it. Such a result makes nonsense of associating a significant statistical test value with a firm recommendation. Nevertheless, where the least significant difference at the 5% probability level (LSD 5%) is less than the yield equivalent cost of the fertiliser any response which could be economic must necessarily be statistically significant. The LSD 5% and the cost of the fertiliser are in fact in reasonable harmony in current wheat trials where precision is good (CV's range from 2 - 8%) and of the order of 8 replicates of main effects are used. This means that the penalty for recommending or not recommending the fertiliser according to whether or not the response exceed the LSD 5% is small — nett returns from applying or not applying the fertiliser are similar. In less precise trials the basic problem arises that unsubstantiated (non-significant) effects are economic. That is, the recorded non-significant yield increase has a higher value than the cost of the fertiliser used.

This phenomenon is clearly demonstrated in the case of nitrogenous fertiliser trials on maize (Fig. 1). Here CV's are commonly between 5 and 15% so that with a much higher general level of yield than with wheat, the LSD's are of the order of three times as great. An application of 100 kg/ha of urea is capable of producing a payable response which has practically no chance of achieving significance at the 5% level in the traditionally designed factorial randomised or incomplete block field trials with eight or even sixteen replicates of the nitrogen treatments. In this situation even though we have sufficient yield increment to pay for the fertiliser (at today's costs and prices) we are quite uncertain as to whether the observed responses to fertiliser are real. The "response" is far from orthodox, significance being little over half the LSD 5% but since it is practically double the cost of the fertiliser, the penalty for a wrong decision is large and so the dilemma for the adviser is clear.

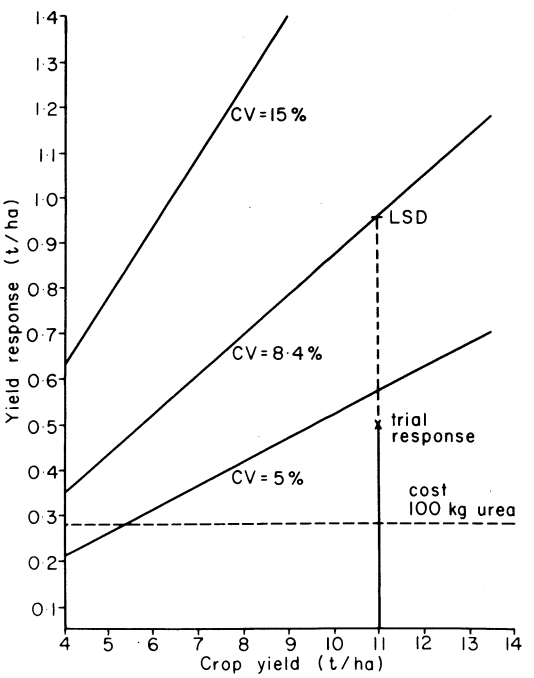

Figure 1: LSD 5% levels for yield responses in 8 replicate trials at 3 CV levels together with the specific response in one trial in relation to the LSD and the cost of fertiliser.

Ways to make the LSD a more useful indicator are discussed in the rest of this paper.

LOWERING THE LSD IN THE FIELD.

Orthodox field trials of randomised or incomplete block designs investigating up to six factors have been developed consistently towards the limit of their efficiency, given adequate internal and external guard areas. Enlarging plot size is expected to reduce between-plot variation at fairly uniform sites but at variable sites the resulting larger block size may offset the advantage. By employing more replicates one can reduce LSD's to any arbitrary level but the cost in terms of time and material to conduct such a trial may be prohibitive.

The regression approach, using a wide range of fertiliser rates, does not of itself improve the prospects of showing the effect as real. It is not necessarily easier to show a rising regression line than it is to show a significant step with a highly replicated 2 level trial. Its benefit is to permit optimisation when curvilinear regression is used on fertiliser rates. When the regression approach is used in a systematic design, however, there are prospects of increased efficiency particularly on row crops. Fertiliser rates can be increased fractionally from row to row so that internal guard plants are not needed and thus block size can be kept small. Unfortunately such designs are far from robust and even though they have been used successfully to investigate plant population effects (Dyson and Douglas, 1975) they require individual plant care and a high labour input.

LOWERING THE LSD BY CHANGING CONFIDENCE LEVELS

In scientific studies on the effect of various fertilisers on crops we are seeking to establish beyond reasonable doubt that an investigated effect is "real", that is, under repeated testing we shall achieve a similar result. In this situation it is appropriate to use a 2-tailed significance test which range from moderately ($p = 0.05$) to thoroughly stringent ($P = 0.001$). These traditional levels of significance may, however, be quite inappropriate when offering advice on fertiliser use and by adopting a less stringent approach the trial LSD's can be lowered to be more in line with economic thresholds.

It is unclear to us what level of significance advisers are prepared to work at. It really relates to how often an adviser is prepared to give wrong advice. In Fig. 2 the effect of changing the confidence level on the maize trial result illustrated in Fig. 1 is shown. By changing the probability level from 5% to 33%, we find the response to the urea is now greater than the LSD 33% level. The major change in attitude using this approach is that we have increased the chance of being wrong from 1 in 20 (LSD 5%) to 1 in 3 (LSD 33%).

Traditionally, significance tests have been 2-tailed, this analysis being appropriate when depressions need to be identified as clearly as responses. If we are only interested in responses then it is appropriate to change to a 1-tailed significance test. This change further reduces the LSD levels compared to the 2-tailed tests (Fig. 2), and in our example brings the LSD 33% below the yield response required to pay for the fertiliser.

FERTILISER ADVICE FROM INDIVIDUAL TRIAL RESULTS

In this paper we seek a strategy which enables decisions on fertiliser use to be made whilst at the same time minimising the overall penalty for making wrong decisions about individual farmers crops. We have shown that by changing our approach to the use of lower confidence levels and 1-tailed tests of significance we can bring the LSD levels more in line with the crop yield responses which relate to the cost of the fertiliser application.

Clearly any significant response below the yield required to cover fertiliser costs is non-profitable but as the response increases beyond the fertiliser cost yield margin, the likelihood of obtaining a profit increases. This is illustrated in Fig. 3 for an LSD 33% level. A maize grain yield response of 0.3 t/ha (Point A — Fig. 3) to 100 kg/ha urea just pays for the cost of the fertiliser. As a basis for advice in similar situations, in only half of the instances will the response to urea be profitable. We would not recommend the use of urea. At a recorded yield response of 0.4 t/ha (Point B — Fig. 3) in a crop of 10 t/ha with a trial CV% of 5 and eight replications, we can say that two farmers in three in a similar situation would be expected to show a profit and we would recommend applying the fertiliser.

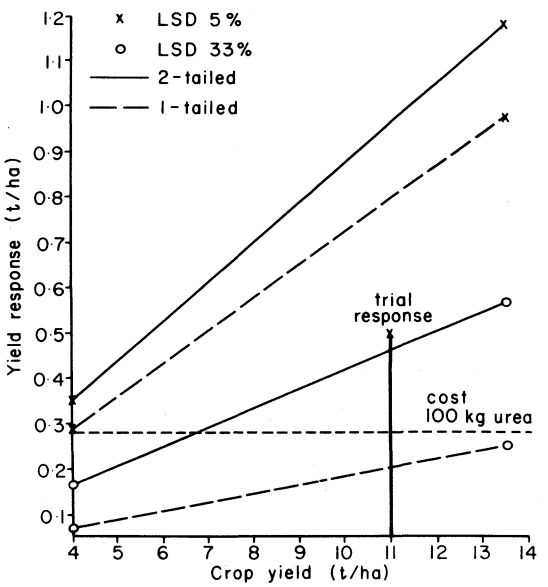

Figure 2: The effect on the LSD of changing from a 2-tailed to a 1-tailed test and lowering the confidence levels in relation to the example given in Fig. 1.

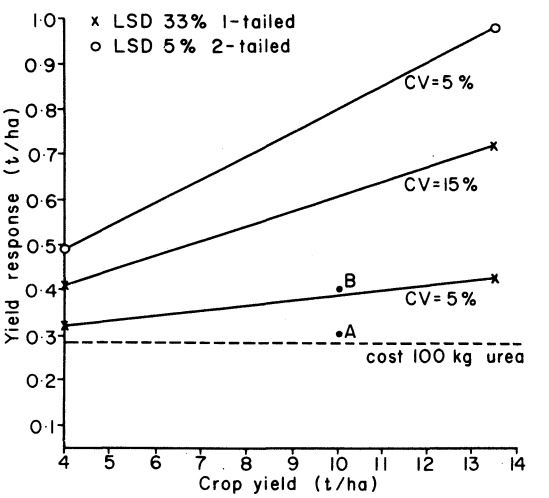

Figure 3: An example of the use of trial LSD's to examine the probability of a profitable yield response following application of 100 kg/ha urea to a maize crop.

FERTILISER ADVICE ON A DISTRICT APPROACH.

When fertiliser recommendations are sought for a cropping region rather than on an individual trial basis, the approach can be very different. Firstly, we do not necessarily expect the effect of a 2 level treatment to be repeatable from site to site. In the absence of detailed investigations we have an anticipated site x treatment interaction to contend with. Such an interaction would be expected to be greater than the pooled within-site variation from a conventional regional programme. Thus to attempt to improve within-trial precision is to adopt a faulty approach since the decision for the region is based not on the significance level for the individual trial but on the consistency across sites. Thus rather than strive for greater individual trial precision it is arguably more efficient to run a greater number of simple trials to ensure a better coverage of the district variation in response patterns. These trials can be simpler to the point of double replication of examinable effects with analysis being on the series of trial results.

The overall response can be assessed in the manner described in Fig. 3. Here the profit (in either dollar or yield terms) from each site is analysed by a t-test and a 1-tailed LSD % of one's choosing applied. The danger of setting the LSD at 33% is appreciated in this context, and one's long term reputation in giving advice must be considered. The cost of this approach is the loss of a viable statistical analysis for each trial which is of interest in identifying sub-sets of trials responding differently. Broad advice can be obtained from such a programme and this approach has been recommended by several workers (e.g. Hauser, 1970; Middleton, 1976).

Where critical parameters to fertiliser responses have already been identified and quantified by in-depth programmes, there is the capability of using a regression approach to individual farmer's paddocks. Covariates from individual sites can be plugged into a regression equation describing district fertiliser response patterns and a strategy for advice gained. The validity of such estimates is limited by the weakest covariates in the model. Such an approach is being developed for use by maize farmers and a simple model is being offered this season (K.W. Steele, *pers comm.).* The problem of identifying "real" responses has arisen in this context and has clarified the need for appraising very carefully the criteria for calculating LSD's.

CONCLUSIONS

To give sound advice on fertiliser use on crops, the trial LSD's have to be at a level similar to or below the yield required to pay for the fertiliser. Given an ability to obtain trial CV% of below 10%, a realistic basis for advice can be obtained by lowering the confidence levels and changing to a 1-tailed test of significance. A response is tested for profitability by relating the level of response to the likelihood of the response being greater than that required to pay for the fertiliser.

This approach to trials in which a sensitive cost factor is involved could have wider implications than on crop fertiliser trials alone.

REFERENCES

Dyson, C.B., Douglas, J.A. 1975. Comparison of systematic spacing and randomised block designs in a maize population study. *Proceedings Agronomy Society of N.Z. 5:* 45-48.

Hauser, G.F. 1970. *Soil Bulletin No. 11.* FAO, Rome.

Middleton, K.R. 1976. Fertiliser Research in New Zealand. *N.Z. Agricultural Science 10, (4)* 156-160.