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Statistical analysis of comparative field trials of acute rodenticides

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SUMMARY

The present method of analysis of data from comparative field trials of acute rodenticides was compared with two alternative methods of analysis, using computer simulation techniques. One of the proposed alternative analyses, the use of post-treatment census takes as a percentage of pre-treatment census takes in an analysis of variance, was found to be more accurate, to avoid a theoretical difficulty associated with the present method, and is computationally much simpler.

INTRODUCTION

Since the development of resistance to the anticoagulant rodenticide warfarin, considerable effort has been devoted to finding other compounds which will be effective in rodent control. Field trials of candidate rodenticides are an essential part of the screening procedure and many such field trials are comparative in nature, i.e. involve the comparison of a candidate rodenticide with a standard, or the testing of a rodenticide in different bait formulations (Rennison, 1976; Dubock & Rennison, 1977).

The methodology of rodenticide field trials is well established. If the rodenticide can be expected to give 100 % control of an infestation, and generally does so, and if lack of complete success can generally be ascribed to bait acceptability or physiological resistance to the poison, the methods described by Drummond & Rennison (1973) and Rennison (1977) are appropriate. In the case of single dose acute poisons, field trials are less straightforward because the degree of control that can be obtained varies, and is generally less than 100 % (Rennison, 1977). In these circumstances, the degree of control achieved must be estimated from the population sizes before and after treatment. To measure the effect of single-dose poison treatments, Chitty (1954) found that the maximum weight of bait eaten in a day by rodents can be used as an index of population size, and recommended that the relative sizes of rat infestations before and after poison baiting should be obtained by census baiting. Chitty (1954) estimated the success of the poison treatment by expressing the mean post-treatment census takes as a percentage of the pre-treatment census takes. This procedure is now widely adopted. Rennison (1976) showed that the use of pre-bait takes is an acceptable alternative to the use of pre-treatment census takes. The recorded weights of bait takes from

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such procedures will be referred to in the present paper as the pre-treatment census takes and the post-treatment census takes.

In a typical rodenticide trial several farms are used, each forming a single experimental unit, and a particular treatment replicated on several farms. After a pre-treatment census of the population, a randomly assigned control regime is implemented, at the conclusion of which a post-treatment census is carried out. The data collected from such trials are suitable for processing using simple techniques of analysis of variance.

The particular feature of such analyses as presently used (Rennison, 1975, 1976; Dubock & Rennison, 1977) is to treat the post-treatment census takes as the response variable in the analysis, and to correct for differing initial infestation sizes using the pre-treatment census takes as a covariate (referred to as method A in this paper). However, at least two variations of this analysis seem reasonable. The first (referred to as method B in this paper) is to express the post-treatment census takes as percentages of the pre-treatment census takes, and to use these as the response variable in an analysis of variance. The second (referred to as method C in this paper), it to use the difference between the pre- and post-treatment census takes as the response variable. In both Methods B and C pre-treatment census takes may additionally be used as a covariate, but in the case of method B, it seems intuitively unlikely that covariance analysis will have much effect, since the act of taking percentages will do much to correct for differing initial infestation sizes. Transformation of the percentages in method B is considered unnecessary.

Accurate assessments of the effectiveness of rodenticides are clearly of great importance, and the accuracy of analytical methods should be as great as possible. The purpose of the present study was to compare the accuracy of the above three methods of analysis of field trial data, using computer simulation techniques.

METHODS

It is reasonable to suppose that pre-treatment census bait takes, which represent the sizes of infestations on farms, have a distribution that is adequately modelled by the Normal or Gaussian curve. Furthermore, a rodenticide that will kill a percentage α of a rodent population results in post-treatment census takes that bear a simple relationship to pre-treatment census takes:

$$\text{post-treatment census} = \frac{(100-\alpha)}{100}\text{pre-treatment census} + \text{error},$$

where the error term represents random fluctuations in the proportion of the population killed, due to uncontrolled factors in the field. The error term is assumed in the present paper to be a Normally distributed random variable with zero mean and standard deviation σ_ε.

Large infestations on farms are more difficult to bait adequately, and this results in the apparent degree of control being reduced. The exact nature of the relationship is unknown, and will in any case vary, but in the present study this factor was accounted for by modifying the above relationship when simulated pre-

treatment census takes were higher than 2500 g. This was done by using the term $((100 - 0{\cdot}9\,\alpha)/100)$ instead of $((100 - \alpha)/100)$ in the model generating post-treatment census takes. Since in practice most infestations are not too large, this modification is not of great importance.

Using the above model, data sets were generated by computer to represent field trial data. In each simulated data set, two sets of pre-treatment and two sets of post-treatment census data were generated, to model a field trial in which two rodenticides are being compared.

Because of the generality of simple analysis of variance methods the conclusions drawn from such data are extendable to cases involving the comparison of several different treatments.

In practice, because considerable time and effort is required to treat a rodent infestation efficiently, the number of replicates selected for each treatment is quite small; thus sample sizes of 5, 10 and 20 were generated in the present model.

In each of the analyses described above, the percentage of the population killed (α) can be estimated by comparing post-treatment census takes with pre-treatment census takes (using the corrected means of the former when covariance analysis has been used). Since α has a known value in the model generating the data, the criterion by which the three methods of analysis were compared was the accuracy with which this value was estimated by the analysis.

Three series of simulations were performed totalling 180 data sets in all. The Normally distributed random variables specified in the model (i.e. the pre-treatment census takes and the error term) were generated using the method of Box & Muller (1958).

RESULTS AND DISCUSSION

First series of simulations

Eighty-four simulations were performed using a wide range of parameter values in the model. The mean of the pre-treatment census distribution varied between 1000 g and 2500 g, with standard deviations of 250 g and 500 g. The error standard deviation was specified as 250, 200, 100 and 50 g in successive simulations, and in all cases the difference in α values of the two simulated treatments was 10 %.

The results of these simulations are presented in Table 1. Each figure is an absolute error of estimation of α averaged for the two simulated treatments in each case.

The relative accuracy of the methods is more important than the absolute accuracy in the present context, since the latter is very dependent on the parameter values used in the model.

All methods showed broadly similar accuracy overall, Method B without covariance correction being the most accurate, and Method C the least accurate. The use of pre-treatment census takes as a covariate in Method B resulted in no improvement in accuracy, the errors of estimation, in fact, were slightly greater.

Table 1. *Results of the first series of simulations*

(Each figure is an absolute error of estimation of α, averaged over two simulated treatments in each case)

Standard deviation of error term ...		Method A 250	Method A 200	Method A 100	Method A 50	Method B: with covariance 250	Method B: with covariance 200	Method B: with covariance 100	Method B: with covariance 50
Mean and standard deviation of simulated pre-treatment census	n								
2500, 500	5	5·98	6·95	6·61	7·37	5·34	7·12	6·24	7·02
	10	8·44	6·82	6·81	6·99	7·91	6·23	6·13	6·55
1500, 500	5	10·99	3·00	3·18	4·22	11·03	2·29	2·80	3·30
	10	6·66	5·24	2·10	2·14	7·88	6·52	5·78	0·90
1000, 250	5	9·49	6·42	4·09	2·70	10·53	8·94	6·43	2·24
	10	4·00	3·96	1·31	1·98	5·04	4·94	1·78	1·87
1500, 250	5	6·04	6·58	2·23	1·76	6·19	5·46	2·76	1·04
Average error		5·15				5·37			

Standard deviation of error term ...		Method B: without covariance 250	Method B: without covariance 200	Method B: without covariance 100	Method B: without covariance 50	Method C 250	Method C 200	Method C 100	Method C 50
Mean and standard deviation of simulated pre-treatment census	n								
2500, 500	5	5·57	7·12	6·24	7·02	6·05	8·06	6·47	7·70
	10	7·91	5·57	5·54	6·55	8·42	6·72	6·65	6·89
1500, 500	5	10·06	2·18	2·69	3·27	8·72	2·23	3·34	7·66
	10	8·03	6·46	5·95	1·35	9·27	8·56	5·36	6·55
1000, 250	5	10·38	4·50	5·77	2·06	8·12	13·86	13·94	2·54
	10	4·80	4·92	1·85	1·88	4·57	4·16	4·24	2·11
1500, 250	5	6·34	4·65	2·60	1·01	5·97	3·95	3·72	8·57
Average error		5·08				6·59			

Second series of simulations

The 48 simulations composing the second series used parameter values suggested by the field data presented by Rennison (1976). Lower values for the standard deviation of the error term were used to confine the post-treatment census takes to values similar to those achieved in the field. The results are presented in Table 2 and are very similar to those in the first series, although the absolute errors of estimation are smaller because of the reduced standard deviation of the error term.

Third series of simulations

The model specified above reveals that for two rodenticides that are differentially successful, the relationships between post-treatment and pre-treatment census figures are different. This is contrary to the assumption of simple covariance analysis (Snedecor & Cochran, 1967), which is that a common slope β exists for the two treatments.

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Table 2. *Results of second series of simulations. Each absolute error is averaged for two treatments and three replications of each simulation*

Mean and standard deviation of pre-treatment census	Error standard deviation	n	Method A	Method B: with covariance	Method B: without covariance	Method C
750, 100	20	5	0·91	0·95	0·99	3·06
		10	1·10	0·76	0·95	1·90
		20	0·71	0·49	0·45	2·43
1500, 250	35	5	1·09	1·19	1·14	2·27
		10	0·90	0·94	0·94	1·63
		20	0·59	0·35	0·33	2·21
3000, 250	100	5	7·18	7·10	7·10	7·06
		10	8·22	8·14	8·14	8·20
		20	8·65	8·64	8·64	8·63
3000, 500	75	5	6·91	6·51	6·51	6·86
		10	6·63	6·26	6·30	6·54
		20	7·02	6·67	6·67	6·91
Average error			4·16	4·00	4·00	4·81

Table 3. *Results of third series of simulations*

(Each absolute error is averaged for two treatments and three replications of each simulation)

Mean and standard deviation of pre-treatment census	Error standard deviation	$\alpha_1-\alpha_2$	Method A	Method B: with covariance	Method B: without covariance	Method C
750, 100	20	20	0·62	0·44	0·56	1·64
		25	0·44	0·33	0·33	1·89
		30	1·24	0·50	0·62	2·40
	50	30	2·13	2·22	2·27	1·42
1500, 250	35	20	0·96	0·78	0·76	2·23
		25	1·23	0·79	0·78	1·97
		30	1·43	0·58	0·58	2·79
	100	30	2·90	1·83	1·97	2·36
3000, 250	100	20	8·99	8·96	8·96	8·90
		25	7·43	7·37	7·37	7·30
		30	6·91	6·96	6·96	6·91
	200	30	7·83	7·83	7·83	7·81
3000, 500	75	20	6·92	6·55	6·55	6·91
		25	6·35	5·45	6·11	6·92
		30	6·51	6·26	6·27	6·37
	150	30	5·79	5·85	5·85	5·83
Average error			4·23	3·92	3·95	4·60

If the difference between α values for two rodenticides is small, as in the first two series of simulations, this may be expected to have relatively little effect, particularly if the standard deviation of the error term in the model is large. Tables 1 and 2 suggest that this is the case. However, as the difference between α values for the two rodenticides increases method A may be expected to become less accurate.

The 48 simulations in the third series used α values differing by 20 %, 25 %, and 30 % in different simulations. The results are presented in Table 3. Particularly for lower pre-treatment census values, Method A in fact decreased in accuracy compared with Method B. The overall pattern of results remains the same, with Method B proving to be the most accurate method, and improving little when covariance analysis was employed.

CONCLUSIONS

The method currently used for the analysis of comparative rodenticide field trial data does not satisfy the assumptions of covariance theory if the above model is correct. This does not seem to be important when the difference between control rates for rodenticides is small but results in less accurate estimations of control rates for greater differences in α values.

Method B described in this paper appears to be generally more accurate, avoids the problems of theory associated with method A when used without a covariance correction, and is computationally much simpler. Given a Normal distribution of pre-treatment census bait takes, Method B will provide efficient estimates and multiple comparisons of rodenticide control rates, although it should be noted that under the above model, for widely differing α values, variances will not be heterogeneous.

It is concluded that a suitable method of analysis of field trial data of the type described in this paper is to use the post-treatment census takes, expressed as percentages of the pre-treatment census takes, as a response variable in analysis of variance calculations. This method does not seem to have any bias (in the statistical sense), judging from the results of the model used, and it is not considered necessary to transform the percentage values, since not enough is known of the form of the distribution of real data to suppose that a transformation is necessary in practice.

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