

REPORT

Insightful analysis and clear reporting can optimise outcomes from chemical efficacy trials.

Dr John Rogers, Research Connections and Consulting
PO Box 350, Toowong, Queensland 4066, Australia
Phone/Fax: +61 (0)7 3720 9065, Mobile: 0409 200 701
Email: john.rogers@rcac.net.au, Web: www.rcac.net.au

Abstract

To demonstrate the benefits of insightful statistical analysis and clear reporting, data representative of two chemical efficacy experiments were analysed in two ways: (a) as individual data sets for each sampling date, and (b) as restricted maximum likelihood (REML) meta-analyses. The two approaches produced clearly different results. The first approach showed differences between the Untreated Control and the chemical treatments, but lacked the power to consistently separate the chemical treatments. The REML meta-analyses showed the same differences between the treatments and the Untreated Control, but also provided clear discrimination between chemical treatments. Additionally, the second approach provided statistical tests of the consistency of treatment performance over trials, and the uniformity of the length of the control period provided by treatments. This case study reveals the benefits of taking a considered and insightful approach to the analysis and reporting of chemical efficacy data. These benefits may be especially valuable for trials to be used for pesticide registration, including series of experiments and trials laid out in repeated-measures designs or 2-dimensional arrays.

Introduction

Crop-protection product development is a complex process, and at times, trial reports do not properly reflect the value contained in competently conducted trial programs. This can sometimes be because consultants do not have access to the most appropriate statistical analysis software, or because aspects of the data make analysis difficult, e.g. missing plots. Alternatively, circumstances arise where data needs to be resubmitted to registration authorities. In all of these situations, a fresh statistical analysis of the data and a clear and insightful report by an experienced crop-protection scientist can provide fresh understanding of product efficacy, and so facilitate the registration process. This report presents a case study of the benefits of adopting such an approach.

Materials and methods

The data used in this study was representative of pesticide efficacy data, be it insect, disease or weed counts, and was based on real data from the author's files. The data represents two chemical screening experiments that evaluated the four products against an untreated control in a randomised block design with four replications and a repeated-measures data structure. Pre-treatment insect counts were taken, as were counts at 7, 14 and 21 days after treatment (DAT).

The data were analysed using GenStat V9.1. To simulate a commonly encountered approach to analysis of efficacy data, the data sets were analysed using analysis of variance (ANOVA) for each experiment and date separately. Then as part of a more insightful approach to analysis, a step-wise set of restricted maximum likelihood (REML) analyses were undertaken. The final REML analysis combined all of the pre-treatment and post-treatment data from both trials into a single analysis.

Results

The 'standard' analysis

The results of the first analysis is presented in Table 1. No pre-spray treatment effects were detected ($P > 0.05$), indicating that the random allocation of treatments to plots was accomplished effectively. During the post-treatment sampling period, there were significant treatment differences. All chemicals had significantly lower insect populations than the untreated control at all post-treatment assessments in both trials. However, the discrimination between the chemicals is patchy at best, with differences between the chemical treatments recorded only at Day 7 in Trial 1, and Days 7 and 21 in Trial 2. On those occasions, Chemical 4 was inferior to Chemical 3, but Chemicals 1 and 2 were different from neither Chemical 3 nor 4.

Table 1: Standard results from chemical-trial data analysis.

Trial and Treatment	Pre-treatment (insects m ⁻²)*	Post-treatment (insects m ⁻²)**		
		Day 7	Day 14	Day 21
<i>Trial 1</i>				
Chemical 1	30.8 a	4.9 bc	4.1 b	4.5 b
Chemical 2	18.3 a	3.2 bc	4.5 b	2.9 b
Chemical 3	16.1 a	1.8 c	2.2 b	1.8 b
Chemical 4	22.5 a	9.9 b	7.6 b	9.4 b
Untreated control	26.5 a	51.0 a	55.8 a	50.7 a
SE of difference	9.70	3.26	3.15	3.86
<i>Trial 2</i>				
Chemical 1	35.6 a	5.4 bc	3.6 b	4.5 bc
Chemical 2	49.4 a	4.3 bc	3.4 b	3.7 bc
Chemical 3	49.3 a	2.8 c	2.0 b	2.7 c
Chemical 4	35.2 a	9.2 b	8.2 b	7.3 b
Untreated control	42.9 a	53.9 a	52.8 a	50.8 a
SE of difference	11.94	2.65	3.83	1.97

*Pre-treatment, F-test in ANOVA not significant, so no pair-wise testing performed.

** Within each experiment and sampling date, means followed by the same letter are not significantly different (Ryan/ Eniot-Gabriel/ Welsch multiple range test, experimentwise P = 0.05).

A more insightful presentation of the same data

Table 2 presents the results of REML analyses of the same data. Initially, separate analyses were done of each trial to provide residual variance estimates for the combined analysis. This also indicated that the inclusion of pre-treatment counts as a covariate may increase the power of the analyses.

Table 2: Results from REML meta-analyses of the data presented in Table 1.

Treatment	Post-treatment (insects m ⁻²)*
Chemical 1	2.145 (4.10) c
Chemical 2	1.958 (3.33) cd
Chemical 3	1.609 (2.09) d
Chemical 4	2.992 (8.45) b
Untreated	7.241 (51.93) a
SE of difference	0.1932

* Data transformed by $\sqrt{(x+0.5)}$ prior to analysis. Equivalent (back-transformed) means are presented in brackets. Means followed by the same letter are not significantly different (sequentially acceptable step-up Bonferroni procedure with experimentwise probability P = 0.05).

The final meta-analysis combined all pre- and post-treatment data into a single analysis. The pre-treatment count was a highly significant covariate (Wald statistic/d.f. = 10.84, d.f. = 1, P < 0.001). The results (Table 2) show clear and unambiguous treatment effects, including some discrimination between the chemical treatments. Chemical 4 was inferior to all other chemicals and Chemical 3 was superior to Chemical 1, conclusions not possible from the analyses in Table 1.

The REML meta-analyses also provide additional information not obtainable from Table 1. This in-

cludes that the performance of the chemicals was consistent over the two trials (Wald statistic/d.f. = 0.06, d.f. = 6, P = 0.99), and that the chemicals did not differ in their period of control, up to 21 days after treatment (Wald statistic/d.f. = 0.34, d.f. = 12, P = 0.98).

Discussion

The contrast between the two analyses presented here is obvious. Treatment differences in the second analysis are unambiguous and easily interpreted, even if Table 2 is quickly skimmed. Additionally, this integrated analysis demonstrates the markedly greater power to separate the various chemical treatments, compared to the more standard presentation.

Another advantage of the more refined analysis is that it is possible to obtain formal statistical tests of the consistency of the treatments' performance over a series of experiments. Where performance is consistent for some treatments but not others in a series of trials, then additional testing is possible to identify the specific treatments that are behaving inconsistently. Similarly, the approach demonstrated here can provide formal statistical testing of any variation in the length of the control period recorded in efficacy experiments.

The analytical approach advocated here is especially valuable for data to be used in pesticide registration applications because it extracts the maximum amount of information from competently conducted field-trial programs, including series of experiments and trials laid out in repeated-measures designs or 2-dimensional arrays.