ABSTRACT

The use of cyclic change-over designs which provide an efficient method for determining residual effects of the treatment of one crop on the succeeding ratoon crop are discussed. The designs enable these effects to be measured with a minimum number of plots which is important in the management of experiments where time of harvest is a treatment.

INTRODUCTION

In the Queensland sugar industry, harvesting is carried out over a 20 to 26 week period between June and December. This period coincides with the optimum sugar (c.c.s.) levels in the cane which rise continuously from the start of the season to a plateau in the mid-September to mid-October period. The decline in c.c.s. after mid-October is accelerated by periods of heavy rain.

Weather conditions during the harvest season are normally fairly dry, although some storm activity bringing isolated rains can be expected from October onwards. The main season in Queensland normally occurs between January and March.

In a crop such as sugarcane which is grown on the basis of a plant crop and several ratoon crops cut annually, the time of cutting of one crop influences the growth of the following ratoons. This factor combined with the seasonal pattern of c.c.s. in Queensland, is an important consideration in determining optimum strategies for maximizing sugar yield over a crop cycle. In addition, the possibility of fertilizer applied to one crop, be it below or above optimum levels, influencing the yields of the next ratoon crop cannot be overlooked.

This paper describes trial designs which BSES has utilized in the study of residual effects of the management of one crop on the following ratoon crop.

MATERIALS AND METHOD

Initial studies (Anon\textsuperscript{1,2,3}, and Chapman and Leverington\textsuperscript{4}) on crop cycles were carried out using a full factorial design, but because of practical difficulties
in burning and cultivating plots individually within the trial, the design was restricted to a three by three factorial with three times of harvest for the plant cane and three times of harvest for the first ratoons. Such a trial design provided information on the residual effect of the time of harvest for the plant crop, but was very specific in that it related to the particular climatic conditions of the year during which the test was conducted. Further information was gained by repeating the trial, but the design meant that the residual effect was measured in only one year out of the three during which the land was allocated to the experiment. In addition, three times of harvest gave little scope for determining whether residual effects and time of ratooning were related linearly or strongly curved towards the end of the season.

Balanced (BCO) and partially balanced (PBCO) changeover designs (Patterson and Lucas) were examined and were considered to have potential for the study of crop cycle strategies. In these designs as few as ten plots were needed to examine residual and direct effects of five times of harvest. Trials could be conducted for two or more ratoon crops and residual effects calculated after a specified number of periods have been completed.

Attention was drawn to the work of Davis and Hall who treated cyclic incomplete block (CIB) designs as changeover (CO) designs and developed a general method of analysis for a class of designs which they called changeover (CCO). In general these designs require even fewer units than those of Patterson and Lucas, but nevertheless possess average efficiencies for treatment, direct, and residual effects which compare very favorably. Some of the designs of Patterson and Lucas can be analyzed as changeover designs with increased efficiency.

Many different generating sequences for the cyclic designs are possible, and the efficiency increases with a greater number of periods in the design. The CCO design has the advantage that even though it may be designed for analysis after a large number, say four or five periods, analysis can be performed, although at lower levels of efficiency, from the second period onwards. In the processing of certain designs prematurely, singular matrices may be encountered during the statistical analyses, and consequently we have found it necessary to write a computer program which can predict when such problems will arise. In addition, this program defines the efficiencies of the various effects when analyzed at any particular harvest period. As with the designs of Patterson and Lucas, the CCO designs may be extended for an additional period beyond the normal design by repeating the treatment of the final period in the generating sequence. This has the effect of considerably increasing the efficiency of the determination of the overall treatment and direct effects. A typical example of the sequences and the efficiencies of a six-treatment design are set out below.

Cyclic changeover designs have now been used for crop cycling experiments with five and six times of harvest and ratooning and for nutritional trials with six levels of nitrogen application. Davis and Hall published generating sequences for up to 20 treatments and five periods, and it would appear that these CCO designs are particularly suited to experiments where a large number of treatments are involved.
TABLE 1. Treatment sequences and efficiencies of the CCO design used in nitrogen trials at Mackay. (Treatments 6, periods 4, blocks 2) (Generating sequence 0132, 0314, Davis and Hall[6])

<table>
<thead>
<tr>
<th>Treatment Sequence</th>
<th>Block 1</th>
<th>Block 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A  B</td>
<td>C  D</td>
</tr>
<tr>
<td>Crop Plant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>1  2</td>
<td>3  4</td>
</tr>
<tr>
<td>1R</td>
<td>1  2</td>
<td>3  4</td>
</tr>
<tr>
<td>2R</td>
<td>3  4</td>
<td>5  0</td>
</tr>
<tr>
<td>3R</td>
<td>2  3</td>
<td>4  5</td>
</tr>
<tr>
<td>4R*</td>
<td>2  3</td>
<td>4  5</td>
</tr>
</tbody>
</table>

Efficiencies

<table>
<thead>
<tr>
<th>Treatment (ignoring residual effects)</th>
<th>Direct effect</th>
<th>Residual effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>After 1R</td>
<td>matrix</td>
<td>30</td>
</tr>
<tr>
<td>&quot; 2R</td>
<td>51</td>
<td></td>
</tr>
<tr>
<td>&quot; 3R</td>
<td>81</td>
<td>57</td>
</tr>
<tr>
<td>&quot; 4R*</td>
<td>85</td>
<td>73</td>
</tr>
</tbody>
</table>

*Recommended where practicable to improve residual effect estimates.

RESULTS AND DISCUSSION

In an investigation by Leverington et al.[6] into the effects of time of ratooning on crop growth in the Burdekin area of Queensland, five times of harvest were scheduled as follows:

- early June
- end of July
- mid-September
- end of October
- mid-December

The trial was designed for three periods and after planting in 1973 was harvested as plant, first, second, and third ratoon in 1974, 1975, 1976, and 1977 respectively. The third ratoon treatments were a repetition of those set out in the second ratoon. Two blocks of similar design were planted adjacent to the first experiment of 1975 and harvested as plant, first and second ratoon crops in 1976, 1977 and 1978 respectively. The two experiments have been analyzed as separate
trials and also as a combined experiment after deleting the third ratoon results. Four variety sub-plots were included in each treatment pilot of these trials.

Highly significant residual effects of time of ratooning on yield of cane and sugar in the succeeding ratoon crop were obtained in both trials. These effects are shown in Figure 1. Although the trends were similar in both sets of data the magnitude of the effect was somewhat greater in the first trial than in the second. The difference is probably related to the rainfall patterns in the December to February period during which the trials were conducted. These effects emphasize the need for spreading trials of such a nature over a number of years to obtain a better estimate of the effects under long-term average conditions. The results of the two trials are also consistent in that they both predicted very little growth on a mature crop during the July to October period. A similar type of trial in the hotter more humid area of Tully in North Queensland, has shown similar effects of time of harvest on the growth of the succeeding crop but has also indicated that crops in that area gain appreciably in weight during the normal period of harvest.

While these trial designs have provided useful information on the growth of cane during the harvesting season and the effect of time of ratooning, the analyses carried out do not specifically indicate whether an age of crop factor is involved in either cane or sugar production during the period of the year under study. This is one deficiency in the design if such information is important.

The four varieties in the trials were analyzed separately and again consistent results were obtained between the two experiments. While all varieties were adversely affected by ratooning in the latter part of the season, the effect on some varieties was more severe than on others.

The CCO design in Table I was applied to a series of three trials on different farms in the Mackay district to investigate residual effects of high rates of nitrogen application to cane crops. In these the treatments were raised from 0 to 300 kg N/ha in increments of 60 kg. In each trial two blocks of six treatments were required for the design and these were duplicated to give additional precision to the means. To check the prediction of the residual and direct effects obtained from the CCO design, three plots ("check plots") in each block were included. To these nitrogen was applied each year at 60/180, and 300 kg N/ha respectively.

Results of all three trials were consistent in that highly significant effects of the nitrogen applications were obtained. However there was no evidence of any residual effect. The direct effects predicted were virtually identical with those obtained form the corresponding "check plots" in the trial.

Although these results have given us great confidence in the CCO design it is difficult to envisage that there would not be some adverse residual effect on growth resulting from the absence of nitrogenous fertilizer from all crops in a cycle of plant and three ratoon crops. The form of analysis carried out provides only first order interactions i.e. it determines residual effects from only the immediately preceding treatment and in these trials the effect of nitrogen...
deficiency in one year did not affect stool vigour sufficiently to cause a measurable effect the following year. However the trials did not include a repeat of the final period treatment which would have greatly improved efficiency of the residual analysis. In future trials of this nature, this additional period will be included where it is practicable to take the trial to fourth ratoon.

![Graph showing residual effect of time of ratooning on yield of sugar (t/ha).](image)

**FIGURE 1.** Residual effect of time of ratooning on yield of sugar (t/ha). Leverington and Hogarth “Cyclic” Change-over Designs for Agronomy Field Trials

**CONCLUSION**

Cyclic changeover designs provide a very useful tool for the sugarcane agronomist particularly when he is interested in trials which run for a number of ratoon crops. With a small number of plots the design enables a wide range of treatments to be studied in terms of both direct and residual effects.

To utilize the design efficiently it is desirable to examine a number of generating sequences to select ones which have the optimum levels of efficiency for the number of treatments required for the trial and for the periods when analyses are proposed to be carried out.
REFERENCES


DISEÑOS CICLICOS PARA ENSAYOS AGRONOMICOS DE CAMPO

K.C. Leverington y D. M. Hogarth

RESUMEN

Se discute el uso de diseños cíclicos que proveen un método eficiente para determinar efectos residuales del tratamiento de un cultivo en el subsiguiente cultivo de retoño. Los diseños permiten medir estos efectos con un mínimo de parcelas lo que es importante en el manejo de experimentos donde la época de cosecha es un tratamiento.