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TREATMENT-BY-TIME INTERACTION IN COCONUT EXPERIMENTS[1]

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ABSTRACT

The appropriateness of split-block analysis and multivariate analysis for testing treatment-by-time interaction in coconnt experiments were discussed and illustrated with experimental data from an agronomic and a breeding trial. It was shown that inference drawn through these procedures not necessarily he the same, emphasizing the need for testing the assumptions and making a judicious choice. The split-black analysis is suggested whenever the assumption of equal variances (at each time) and equal covarianccs (between pairs of time) hold good but on violation, alternative methods are to he followed; the easiest being the multivariate analysis.

INTRODUCTION

Treatment comparisons in majority of coconut experiments, regardless of breeding or agronomic in nature, are based on the yield observed as the number of nuts harvested. Conventionally, the cumulative yield upto a specified age of the crop is taken for the analysis of breeding trials, while the average annual yield based on an even number of consecutive years (to average out the effect of biennial low-or high-yield) for the agronomic trials. Analysis of variance procedures are then employed for making treatment comparisons; covariance analysis by taking pre-treatment yield as the concomittant variable is followed for experiments started on bearing palms. Besides the overall comparison of treatments within specific periods, inference on treatment-by-time interactions may also be of interest in certain situations. Examples to the latter include treatment comparisons across seasons, biennial bearing and genotype-by-environment interaction. Several procedures were suggested to answer questions of this kind, of which the univariate split-block ANOVA (Pearce, 1953) and repeated measurements MANOVA (Cole and Grizzle, 1966) are being widely used. The analysis suggested by Rowell and Walters (1976) using the summary statistics that are contrasts over time can be considered as a part of the latter method but having the advantage of easy interpretation. The utility of these methods for the analysis of data from long term coconut field experiments is discussed here.

MATERIALS AND METHODS

Coconut yield data from two experiments, one from an agronomic trial and the other from a breeding trial, conducted at CPCRI, Kasaragod were used for this study. (i) *Agronomic trial:* This experiment was laid out during 1965 with treatments consisting of factorial combination of three fertilizer levels and three cultivars in a RBD with three replications. Further details on this have been given in Nelliat et *al*. (1978). The monthly harvest data for the period January, 1985 to June, 1990 were subjected for the analyses. (ii) *Breeding trial:* This

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trial was laid out in 1972 for the evaluation of 11 coconut cultivars. The experimental design was RBD with two replications. The yield data upto 1991 was used for this study.

Split-block analysis. Based on the nested (or heirarchical) structure of repeated measurements within experimental units, the error terms of interest in this approach are the Error (a) - representing variation among experimental units with regard to averages (or sums) over time. and the Error(b) - representing variation among observations within experimental units. This ANOVA is different from that of a split-plot for one additional source of variation viz., replication x time.-Govinda lyer (1958) followed this procedure to analyse a fertilizer experiment on coconut. Since the 'sub-plot classification' (time) is not randomized, it becomes necessary to test the assumption of equal variances (at each time) and equal covariances (between pairs of time) to justify the use of split-block analysis. Box (1950) provided the following criteria for testing this assumption of symmetry. Let v be the df of the error variance-covariance matrix S of order p (i.e. there are p measurements per experimental unit); when the assumption holds, the test statistic

$(1-A_1)M$ follows a chi-square distribution with f_1 df, where

$A_1 = \{p\ (p+1^2)\ (2p-3)\}/\{6v\ (p-1)\ (p2+p-4)\}$

$M = -\ v\ \ln A$

$A = \text{determinant}\ (S)/\{[\bar{s}_{ii}+(p-1)\bar{s}_{ij}]\bar{s}_{ii}-\bar{s}_{ij}]^{p-1}\}$

$\bar{s}_{ii}$ = average of variances

$\bar{s}_{ij}$ = avenge of covariances

$f_1 = (P^2+p-4)/2.$

Repeated measurements *MANOVA*. This procedure is identical with the usual multivariate analysis of variance (MANOVA) and the treatment x time interaction effects are tested based on an appropriate 'sets of contrasts'. If m is the number of parameters to be estimated from the design and p the number of repeated observations, then there are m x p unknown parameters which can be arranged in the form of a matrix ξ. Tests of hypothesis of interest are then constructed by formulating two matrices L and R such that $L\ \zeta\ R = O$. For testing the treatment effects, choose the rows of L as the coefficients of relevant contrasts and R as a column vector with all its p elements equal to 1; corresponding treatment x time interaction effect can be tested by choosing the columns of R as the coefficients of the p - 1 linearly independent contrast vectors; and for testing the time effect, chose L as a row vector of unit elements and R as the matrix of p - I linearly independent columns (Cole and Grizzle, 1966). In practice, however the linear transformation (contrasts) of the multiple observations are made first and the analysis of treatment x time interactions is then carried out. This approach is followed in the 'MANOVA repeated measurements' procedure of SPSS (Norusis and SPSS, 1992). Independent comparison among the contrasts are possible when orthonormalized contrasts (e.g., orthogonal polynomials) are used as the linear functions. The number of such contrasts that can be formed with p measurements is p-1. Appropriate contrast(s), need not be orthogonal always, may be formed for testing specific hypothesis (e.g., bienniality) which are then referred to as the summary statistics.

RESULTS AND DISCUSSION

The coconut yield and price are subject to seasonal variation. In Kerala, the coconut prices are more during December to May compared with the prices in June to November (CPCRI, 1992; Jacob Mathew, 1984). A significant interaction effect between treatments and these seasons may therefore be of economic importance. This was tested for the agronomic experiment by taking six-monthly yield in succession during the period June 1985 to May 1990. The covariance matrix of the resulting ten consecutive yields was estimated and the value of the Box's (1950) test statistic was obtained as 95.6 with 53 df. The x^2 test showed significant departure from the assumption of equal variances and covariances ($p < .001$). This indicated the invalidity of split-block ANOVA for testing the treatment-by-season interactions in the experiment. Tests of cultivar (C), fertilizer (F) and C x F interaction effects (the whole plot part of the analysis) are however valid regardless of this assumption but does not fall as an objective of this paper.

When the assumption of split-block analysis does not hold, an alternative approach is the multivariate analysis of variance. Appropriate contrasts are to be chosen to infer on specific relationships; orthogonal polynomials are adequate for many situations (Rowell and Walters. 1976). The nine orthonormal polynomial contrasts of the ten seasonal observations were analysed and the results were summarised under "RP-MANOVA" in Table 1. For comparison, the results of univariate split-block analysis (SB-ANOVA) were also provided. As expected, the inference on interaction effects were not always in agreement between the two analyses. For example, the F x time (T) interaction was found to be significant ($p < .01$) as per SB-ANOVA, but not significant according to RP-MANOVA. A close examination of means of the three levels of fertilizer suggests that their ordering within any season was more or less the same. The rank variances for the three levels were worked out to be 0, .3 and .3.

Since the F x T interaction in this experiment has economic importance, it is necessary to investigate in detail. Test for overall trend in increasing yield with time can be examined by analysing yields summed over pairs of time periods and the extent of seasonal changes by studying the differences (Rowell and Walters, 1972). The assumption of univariate analysis was found to be violated with respect to the five sums of yields of adjacent seasons as well as with the differences. Subsequently multivariate analysis was performed by using orthogonal polynomial contrasts. The F x T interaction was not significant in either of these cases, confirming further that the seasonal changes are mostly uniform among the three fertilizer levels. However, the C x T interaction was found to be significant with regard to the differences, implying that seasonal changes among the cultivares are of different magnitude during the period of study (i.e., June 1985 to May 1990). On obtaining a significant interaction effect, further investigations may be made by examining the individual contrasts. The linear and quadratic contrasts (trends) were found to be significant with regard to the C x T interaction when analysed for difference of pairs of seasons. For both these components, Chandrasankara was found to be different from the other two cultivars.

Table 1. Significant levels of Pillai's trace statistic of RP-MANOVA and F statistic of SB-ANOVA corresponding to treatment by time interactions of the agronomic trial*

	Response as number of nuls obtained for					
	Ten seasons		Five Agri. Years (July 1985 to Jan 1990)		Five Calendar Years (1985-1989)	
Sources	RP-M	SB-A	RP-M	SB-A	RP-M	SB-A
Fert. x Time	.17	.00	.19	.17	.07	.04
Cultiv. xT	.05	.00	.07	.00	.00	.00
F x C x T	.14	.03	.09	.01	.46	.01

* Among the multivariale test slalistics. Pillai's lrace is most powerful and robust (Norusis and SPSS. 1992). Similar conclusions could be drawn with the other two multivariate lest statistics - Hotelling's trace and Wilks' lambda.

Obviously the meaning and interpretation of treatment by time interaction depend upon the definition of time. For example, Jacob Mathew *et al.* (1989) showed by following split-plot (not split-block) analysis of variance procedure that treatment interactions with year was different according to the method of compilation of annual yield of coconut viz., agricultural year (July to June) and calander year. For neither of these compilations, the assumption of SB-ANOVA was found to hold good (during the period January 1985 to June 1990). The alternative procedure, RP-MANOVA is therefore appropriate. For comparison, the results are shown in Table 1.

In breeding trials, testing cultivar x year interaction is of importance as agroclimatic conditions are known to have influence on nut production. However, only limited work on coconut is reported in this regard. A common error in the analysis of this kind of data as pointed out by many authors (e.g., Hall, 1975) is the choice of an incorrect factorial model with year as one of the factors: A split-block model, is in fact the appropriate one. Such incorrect model specification in the analysis of cultivar x year interaction in coconut has been made by Patil *et al.* (1991).

One of the prime considerations in breeding trials is to have the evaluation with the shortest possible time. The intra-and inter-cultivar variation in pre-hearing period and the increase of nut production on advancement of bearing years pose problems in direct comparison of coconut cultivars in the early years of bearing. To overcome this, Muralidharan et *al.* (1993) converted the yield of second and later years of bearing on first year basis. Following this procedure the yield data of the breeding experiment during the priod 1986 to 1991 was first corrected for the differential bearing age and analysed for cultivar x year interaction. The chi-square test of equal variances and covariances (Box's rest) was attempted. The analysis revealed that cultivar x year interaction is significant ($P < .01$) which justifies the need for comparison of coconut cultivars for phenotypic stability. When the assumption of SB-ANOVA holds good, the use of RP-MANOVA is not recommended as it has less power - the probability of rejecting the null hypothesis when it is false (Cole and Grizzle, 1966). It is of interest to note here that the Pillai's trace statistic corresponding to the cultivar x year interaction in the RP-MANOVA was not significant, however, the other two multivariate test statistics (Hotelling's trace and wilks' lambda) were highly significant.

A known causative factor of cultivar x year interaction in coconut is the bienniality. Rowell and Walters (1976) suggested that treatment comparisons for bienniality could be made by analysing the yield differences between successive years. The SB-ANOVA was found to be adequate for annalysing the yield differences obtained from the three pairs of years. Differential bienniality among cultivars were indicated from the significant cultivar x time (pairs of years) interaction. For an absolute measure of bienniality of a palm, however, the Hublin's index - the average of ratios of absolute difference between adjacent years to corresponding sum - seems to be more ideal. The cultivar x time interaction was found to be not significant when response was taken as sum of successive years. Contrary to this, the interaction was significant when the data was analysed without any correction for bearing age and hence indicates the appropriateness of the procedure followed for correcting the data.

The procedures described in the foregoing are most general and hence best suited for the preliminary analyses. For reasons of loss of power of the test, split-block analysis may be preferred over multivariate analysis whenever the assumption of equal variances and covariances hold good. For applying the multivariate procedure, it is necessary that the number of time points are not exceeding the number of design parameters. Because of these restrictions - over parameterization and power consideration - methods based on the exact structure of the error variance covariance matrix of the observations over time need to be explored.

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