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A Note on the Reduction of Variability in Perennial Experimentation

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SUMMARY

The feasibility of using certain alternative techniques for the control of error in perennial crop experimentation was examined. Nearest Neighbourhood Adjustment (NNA) was found to be an effective alternative to stratification. When results of calibration trials were also used along with NNA, the results were the most encouraging. Double covariance analysis using $X^{1/2}$ and side neighbours as concomitant variable resulted in an efficiency gain of over 200% over conventional analysis in cocoa where X represents pre-experimental yield. Data from the trials on other crops also responded in a similar pattern though with a relatively lesser degree of sensibility.

Key words : Blocked design, Covariance analysis, Calibration, Stratification, Auxiliary variate, Nearest neighbourhood adjustment, Moving block method.

1. Introduction

A characteristic feature of perennial crop experimentation is the presence of large amount of heterozygocity due to the differences in the genetic make up of the tree species of each experimental plot. The technique of calibration and covariance analysis is widely recommended in such situations (Prabhakaran and Nair [8]). However the utility of the approach depends solely on the existence of a possible linear relationship between the study variate and the auxiliary variate which is never warranted. A better method is to seek for suitable functional forms of the auxiliary variate exhibiting relatively stronger relationship with the study variate for possible inclusion in the linear model for covariance adjustment. It is also interesting to examine the feasibility of adopting an integrated approach utilizing the various direct and indirect error control methods for improving the efficiency of field experimentation on perennial crops.

The recent advances in spatial statistics suggest the possibility of using better alternatives to stratification. Nearest Neighbourhood Adjustment (NNA) is the most widely accepted technique in this direction. Pearce and Moore [1], Lockwood [2], Walter *et al.* [3], Vijay Katyal [4] and many others have provided evidence for the superiority of these techniques over stratification. The present study is primarily intended to examine empirically the suitability of these techniques in controlling spatial variability in perennial crop experimentation. An attempt was also made to study the relative efficiency of these techniques over conventional analysis both in the presence and absence of stratification.

The non-iterated and iterated NNA proposed respectively by Papadakis [5] and Bartlett [6] and the moving block method of Wilkinson *et al.* [7] constituted the three types of neighbourhood adjustments used for the study.

2. *Material and Methods*

Data generated from three field trials on cocoa, cashew and coconut were chosen for the present study. The field trial on cashew involved the evaluation of 16 cashew genotypes in three randomised blocks at the Cashew Research Station, Madakkathara. Seven methods of training cocoa plants in four randomised blocks generated the data of the cocoa trial by the Cadburys' Cocoa Project at Vellanikkara. In the case of coconut, the data gathered from the Balaramapuram spacing cum manurial trial which involved three levels of spacing and two fertilizer doses constituted the research material. Two years yield data immediately prior to the start of the experiment served as the calibrating variable in all cases, while total yield during the most recent two year period was the study variate.

Papadaki's non iterated NNA with three types of neighbourhood adjustments viz. (1) 'Side' (longitudinal) neighbours (I), (2) 'End' (latitudinal) neighbours (J) (3) 'All neighbours' (IJ) was applied to examine the feasibility of reducing experimental error independent of the blocking structure. Longitudinal NNA values were generated as

$$I_{km} = \frac{1}{2}\left(e_k, m-1+e_k, m+1\right)$$

e_{km} denote the residual of the 'km'th plot. Similarly latitudinal NNA consisted the generation of scores on the concomitant variable as

$$J_{km} = \frac{1}{2}(e_k - 1, m + e_k + 1, m)$$

In the case of all neighbour adjustment mean values of residuals of all the four neighbours surrounding the plot was used for making adjustments.

The different NN variables were incorporated in the simple linear model for analysis of covariance (ANCOVA) as

$$Y_{ij} = \mu + t_i + b_j + \beta X_{ij} + e_{ij}$$

where Y_{ij} is the observation recorded from the 'ij'th plot and μ, t_i, b_j, β, X_{ij} and e_{ij} respectively indicated, the general mean effect, treatment effect, block effect, partial regression coefficient, the type of NN adjustment and the random error component.

Bartlett's iterated NNA consisted in redefining the NN covariates at each stage on the basis of adjusted plot yields derived from Papadaki's procedure of the previous stage. The process is continued until two successive estimates of treatment effects more or less coincide. Moving block method consists in defining a new variate (Y_{ij}') as

$$Y_{ij}' = Y_{ij} - b\left(\overline{Y}_{nm} - \overline{Y}_t\right)$$

where Y_{ij} is the observation of the plot receiving the 'i'th treatment in the 'j'th block, $\overline{Y}_{nm}$ is the average yield of the neighbouring plots and $\overline{Y}_t$ is the corresponding treatment mean. Side neighbours in blocked designs alone were used in this study for this type of adjustment.

The efficiency of each technique over others was assessed in terms of percentage reduction in error mean square and the resulting variability was assessed through coefficient of variation.

Conventional covariance analysis with pre-experimental yield and its transformed versions (square root, logarithmic and reciprocal) was also attempted with a view to identify a suitable functional form for the control of genetic variability.

Multiple covariance analysis involving functions of pre-experimental yield and the various neighbour variables as covariates was also attempted in order to assess the extent of possible reduction in error mean square through the integrated approach of controlling variability.

3. Results and Discussion

There was considerable reduction in unaccounted variability in all the three sets of data by the application of covariance analysis (Table 1). Experimental data from the cocoa trial showed maximum response to covariance adjustment. Coefficient of variation of yield of cocoa declined from 37.38% with no covariance adjustment to 20.99% with covariance adjustment in the presence of stratification. The relative efficiency of covariance analysis over conventional analysis in cocoa was found to be as high as 325%. In the case of other two crops also, the procedure had given substantial reduction in error variance though of a lesser magnitude. With calibration and covariance adjustment randomised block design failed to bring about any substantial improvement in precision over completely randomised design. Thus it seems that field trials on perennial crops could be successfully laid out in completely randomized designs unless there is a strong evidence to think on the other way.

Table 1. Estimated coefficient of variation and relative efficiencies of various types of covariance adjustment methods in the presence and absence of stratification

Types of adjustment	Cashew				Coconut				Cocoa			
	CRD		RBD		CRD		RBD		CRD		RBD	
	cv	E	cv	E	cv	E	cv	E	cv	E	cv	E
NA	41.4	–	39.8	–	13.9	–	12.9	–	40.1	–	37.9	–
X	29.6	196	29.3	185	11.0	159	11.2	134	23.6	298	21.0	325
$\sqrt{X}$	29.1	202	28.8	191	10.2	184	10.5	150	23.3	306	20.5	340
log X	29.5	197	29.6	181	11.0	168	11.1	136	24.4	279	20.8	332
(X, log X)	29.6	196	29.3	184	10.9	164	11.1	135	23.6	299	21.0	325
X, $\sqrt{X}$	29.6	195	29.3	185	10.5	175	10.4	141	23.6	298	21.2	320
I	40.2	106	40.0	99	12.4	125	12.9	125	35.2	133	37.5	102
J	42.5	95	41.1	94	13.5	106	13.6	106	38.5	91	40.0	89
IJ	39.4	110	40.3	97	12.1	132	12.9	132	38.8	109	40.1	89
(X, I)	30.2	187	29.6	177	10.2	188	10.2	188	22.6	336	22.4	287
(X, J)	30.3	186	30.2	172	11.0	159	11.7	159	24.1	284	22.3	288
(X, IJ)	30.5	184	30.3	175	10.3	182	10.9	182	22.2	335	22.3	328
($\sqrt{X}$, I)	29.9	194	29.6	182	9.6	210	10.1	210	22.5	324	20.3	348
($\sqrt{X}$, J)	29.8	192	29.7	180	10.7	170	11.2	170	24.2	283	21.8	303
($\sqrt{X}$, IJ)	30.1	189	29.8	180	10.1	189	10.8	189	22.0	342	20.4	344

NA – No adjustment

X – Pre-experimental yield

I, J, (IJ) – NN covariates namely 'sides', 'ends' and 'all neighbours'

CRD – Completely randomised design

RBD – Randomised block design

cv – Coefficient of variation

E – Relative efficiency of the technique over the conventional procedure

(Variables given in bracket indicate those used as concomitant variables in double covariance analysis)

Among the three functional forms of the concomitant variable $X^{1/2}$ consistently gave better results. In the case of cocoa the gain in efficiency by using $X^{1/2}$ in covariance adjustment instead of X was particularly high (25%). However, double covariance with X and its varied functional forms as covariates did not bring about any added advantage over others.

Papadaki's NNA was found to be a better and viable alternative to stratification for the control of error. However, in the case of blocked designs the added advantage of NNA over conventional method of blocking was negligible and insignificant. The three NN covariates namely ends, sides and all neighbours failed to show a consistent performance. Sides gave better results with cocoa while all neighbour adjustment had an edge over others in trials with coconut and cashew. It was also observed that NNA in CED gave better control of error than that in RBD.

Table 2. Relative efficiency of various neighbour techniques over conventional analysis in CRD and RBD and the resulting variability

Crop	Design	Concomitant variables	Papadaki's non iterated		Bartlett's iterated		Wilkinson's moving block	
			E	cv	E	cv	E	cv
Cashew	CRD	I	106	40.2	124	37.1	157	31.8*
		IJ	110	39.4	122	37.5		
	RBD	I	99	40.0	112	37.6		
		IJ	97	40.3	102	39.5		
Coconut	CRD	I	125	12.4	160	10.9	137	11.0
		IJ	132	12.9	211	9.6		
	RBD	I	101	12.9	131	11.3		
		IJ	98	12.9	178	9.9		
Cocoa	CRD	I	133	35.2	143	34.1	114	35.5
		IJ	109	38.8	116	37.8		
	RBD	I	102	37.5	108	36.4		
		IJ	89	40.1	89	40.0		

E – Percentage relative efficiency of NNA over conventional analysis

cv – Coefficient of variation

* – Adjustment by the moving block method was based only on all neighbour covariates in randomised block design

An attempt was also made to compare the relative efficiencies of the various neighbour adjustment techniques over the conventional analysis. The results are presented in Table 2. Wilkinson's moving block method was found to be the best in the case of trials on cashew and cocoa in the presence of blocking while iterated NNA produced better results with coconut. The relative efficiency of the NNA techniques over conventional procedure ranged from 89% to 211%. This was almost in agreement with the results reported by Chetty [9]. Among the three crops, coconut showed the maximum response to NNA with more than 100% gain in efficiency, in the absence of stratification. However, no single pattern of neighbouring plots emerged as the most successful. Anyhow, the technique was very useful in reducing spatial heterogeneity and would serve as an effective alternative to stratification. However, as pointed out by Bartlett [6] when block effects were removed the advantage of the method over conventional procedure reduced considerably. Thus, these techniques are specifically suited to experiments laid out in CRD or in blocked designs with a relatively larger number of treatments especially when there is a lack of choice for the proper orientation of block layout.

When results from calibration trials were also used along with NNA the reduction in error was greater. Double covariance analysis involving $X^{1/2}$ and the 'side' neighbours product the best result. In the case of coconut the procedure resulted in an efficiency gain of 110% over conventional analysts while in cocoa the magnitude exceeded even 200%.

Thus there exists ample scope for improving the efficiency of field experimentation in perennial crops by the use of appropriate neighbouring techniques along with calibration.

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