MANOVA PROCEDURES WITH RANDOMIZED COMPLETE BLOCK DESIGN: A CASE STUDY OF SELECTED VARIETIES OF SUGARCANE.

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ABSTRACT
Multivariate analysis of variance may be adopted in any specified experimental designs involving two or more response variables. Further, we may exploit multivariate analysis of variance technique when experimental materials is either homogenous of heterogeneous. For instance when experimental materials is satisfactorily homogeneous we have completely randomized design. This paper therefore presents a four MANOVA procedures for analyzing designed experiments namely, Hotelling's T square, Wilk's Lambda, Pillai-Bartlett and Ray's greatest characteristic root. Each of these four procedures involves the solution of a determinantal equation to obtain the characteristic roots of the sums of squares and sums of products for the appropriate sources of variation be it of the systematic and/or random type. A data set on forty four varieties of sugarcane obtained from a study conducted at the National Cereal Research Institute, Badeggi was used to illustrate the utility of these four MANOVA procedures. The design used for the experiment is of the randomized complete block type in that the two periods of harvest constitute two distinct blocks.
Keywords: Characteristic root; MANOVA; Sugarcane Varieties; Sums of Squares and Product Matrix.

INTRODUCTION.

Statistics is a science that deals with the analysis of data and the process of making decision. The statistical tool for studying differences between means, on some particular variable of distinct groups of subject is often referred to as Analysis of variance. An observation arising from specific levels or combinations of levels of a number of independent random variables, may be thought of being normally, identically and independently distributed with mean zero and constant variance σ^2; these are the basic conditions required for univariate ANOVA. But where the single response variables is replaced by several response variables with the same conditions as in the univariate case, then multivariate analysis of variance becomes a better alternative to the use of separate univariate ANOVA for each of the several contending response variables. The superiority of multivariate ANOVA model is strengthened when the pairwise correlation coefficient between the contending response variable simultaneously approach zero (see, for example Adeleke & Salawu, 2004). On the other hand if all the contending response variables are pairwise highly correlated this may suggest the use of univariate ANOVA model by considering only one of the response variable as being representative of all. Experimental data were obtained in respect of two response variables for two periods namely before the dry season and before harvest at maturity, that is ten months after planting. Each of these two periods constitutes a block in the experiment. Subsequently, laboratory tests were carried out at the National Cereal Research Institute (NCRI) Badeggi to determine specific values for the two types of chlorophyll content (that is chlorophyll A and B) of harvested sugarcane leaves. We therefore have to incorporate the two response variables in respect of chlorophyll A and B respectively, thereby leading to the use of multivariate analysis of variance (MANOVA).

INTRODUCTION TO ANALYSIS.

Here we shall among other things distinguish between Univariate and Multivariate analysis. Furthermore, four multivariate test procedures are enumerated and clearly described in this section.

UNIVARIATE ANALYSIS OF VARIANCE (ANOVA)

Hand and Taylor (1987): states that Analysis of variance is a statistical tool for studying differences between the means or any other appropriate parameter estimate on some particular variance of distinct group of subjects. Infact ANOVA allows the extension of the two group t – test to several groups, these groups may be treatment type, social – economical groups or religion or any other more complex classification. Anova is a method for splitting the total variation of a data set into meaningful components that measure different sources of variations. These sources of variation are due to experimental error and also one or more systematic sources of variation. Both components are indeed independent and follow the chi-square distributions with the appropriate degrees of freedom. For the univariate ANOVA case the model of the form

$X_{ij} = \mu + \alpha_i + b_j + e_{ij}$

is assumed and it will be convenient to represent the terms used for sums of squares with the following identities.

Total sums of square $$SS_T = \sum_{i=1}^{t}\sum_{j=1}^{b}\left(X_{ij} - \bar{X}_{..}\right)^2 \quad (1)$$

Sum of squares treatments, $$SS_{TR} = b\sum_{i=1}^{t}\left(\bar{X}_{i.} - \bar{X}_{..}\right)^2 \quad (2)$$

Sum of squares blocks, $$SS_{Bl} = t\sum\left(\bar{X}_{.j} - \bar{X}_{..}\right)^2 \quad (3)$$

Sum of squares error $$SSE = \sum\left[\left(\bar{X}_{ij} - \bar{X}_{..}\right) - \left(\bar{X}_{.j} - \bar{X}_{..}\right)\right]^2 \quad (4)$$

Note that equations (1), (2) (3) and (4) are related and this relationship is expressed by equation (5) that follows

$$SS_T = SS_{TR} + SS_{BL} + SS_E \quad (5)$$

MULTIVARIATE ANOVA

There are several Multivariate tests of significance, but we shall consider in this project four commonly used ones, namely Hotelling's T-square, WILK'S Lambda (λ); Pillai – Bartlett trace (U) and Roy's Greatest characteristics Root (GCR).

HOTELLING T- SQUARE

This is the most common traditional test for two independent groups. The related statistics called Hotelling's trace is credited to Lawley Hotelling. To convert from the Trace coefficient we multiply it by the factor 'N - g', where N and g denote respectively the sample size and number of groups. The Hotelling's T- square and its linear combinations respectively are given in equations (6) and (7) below.

$$F = \frac{n - P + 1}{P}\,\frac{T^2}{n} \sim F_{p,\, n - P + 1,\, S.} \quad (6)$$

Considering, two samples, the Hotellings T^2 for the corresponding Multivariate situation is defined as,

$$T'^2 = \left(n_1^{-1} = n_2^{-1}\right)^{-1}\left(\underline{\bar{Y}_1} - \underline{\bar{Y}_2}\right)' \underline{S}^{-1}\left(\underline{\bar{Y}_1} - \underline{\bar{Y}_2}\right) \quad (7)$$

where

$$(n_1 + n_2 - 2)\, S = (n_1 - 1)\, S_1 + (n_2 - 1)\, S_2$$

Thus, the general definition of a Hotelling's

$$T^2 = V Z^T A^{-1} Z \quad (8)$$

Where Z and A are independently distributed as $N_q(o, n)$ and $W_q(V, n)$ respectively.
It has F – distribution $F_{q,\, V-q+1}$ with the indicated degrees of freedom.

WILK'S LAMBDA (Λ):

This is the most common traditional test when there are more than two groups formed by the independent variables. It is a measure of the differences between groups of the centriod (vector) of means on the independent variables. The smaller the Lambda (Λ), the greater the differences. The Bartlett's (U) transformation of Lambda is then used to compute the significance of the lambda. The t – test, Hotelling's

T^2, and the F – test are special cases of Wilk's lambda. The distribution of Wilk's lambda for certain values of p and k are given in Table 1.

Table 1: DISTRIBUTION OF WILK'S LAMBDA (Λ)

Number of variables	Number of treatments	Statistics	Distribution
P=1	$K \geq 2$	$\left(\frac{N-K}{K-1}\right)\left(\frac{1-\Lambda}{\Lambda}\right)$	$F_{K-1, N-K}$ Where, $N = \sum_{i=1}^{N} N_i$
P=2	$K \geq 2$	$\left(\frac{N-K-1}{K-1}\right)\left(\frac{1-\sqrt{\Lambda}}{\sqrt{\Lambda}}\right)$	$F_{2(K-1);(N-K-1)}$
$P \geq 1$	K = 2	$\left(\frac{N-P-1}{P}\right)\left(\frac{1-\sqrt{\Lambda}}{\sqrt{\Lambda}}\right)$	$F_{2;N-P-1}$
$P \geq 1$	K = 3	$\left(\frac{N-P-2}{P}\right)\left(\frac{1-\sqrt{\Lambda}}{\sqrt{\Lambda}}\right)$	$F_{2P;2(N-P-2)}$

PILLAI – BARTLETT TRACE (U)

This is the sum of explained variances on the discriminant variates which are the variables which are computed based on the canonical coefficients for a given sets of roots; therefore a large value by convention indicates significant differences. Pillai –Bartlett trace (U) is therefore expressed as equation (9) below.

$$U = \frac{T_G^2}{N_1 + N_2 - 2} \qquad (9)$$

where T^2 is the Hotellings T – square. N_1 and N_2 are samples. Λ_1 is the largest roots.

ROY'S GREATEST CHARACTERISTIC ROOTS (G C R).

This is similar to the Pillai Bartlett trace, but is based only on the first (and hence most important) root. Specifically, let Λ_1 be the largest eigen value then. Roy's greatest characteristic root is given as Equation (10).

$$GCR = \frac{\Lambda}{1-\Lambda} \qquad (10)$$

Roy's largest root sometimes also equated with the largest eigen value as in SPSS'S General Linear Model procedure. G C R is less robust than the other tests in the face of violations of the assumption of multivariate normality.

TEST OF SIGNIFICANCE CONCERNING MANOVA PROCEDURES

Consider the hypothesis of the form:

$$H_0 : \underline{\mu}_1 = \underline{\mu}_2 \cdot \quad \cdot \underline{\mu}_k$$

$$H_1 : Not \quad H_0$$

Then we shall reject H_o at a significance level α if for the case of:

a. Hotelling:

$$T^2 > T^2(P, N-1) \text{ or } \frac{(N-P)T^2}{P(N-1)} > F^{\alpha}_{(P,N-p)} \qquad (11)$$

b. Wilks:

$$\Lambda < U^{\alpha}(P,1,N-1) \text{ or } \frac{N-P}{P} \bullet \frac{1-\sqrt{\Lambda}}{\sqrt{\Lambda}} > F_{(P,N-P)} \qquad (12)$$

c. Roy:

$$\theta_s = \frac{\lambda_1}{1+\lambda_1} > \theta^{\alpha}(s,m,n) \text{ or } \frac{N-P}{P} \bullet \frac{\theta_s}{1-\theta_s} > F_{(P,N-P)} \quad (13)$$

d. Pillai:

$$U^{(s)} \frac{T_o^2}{N-1} = \lambda_1 > U_o^{s}(s,m,n)$$

or

$$\left(\frac{N-P}{P}\right)\left(\frac{T_o^2}{N-1}\right) > F^{\alpha}(P,N-P) \quad (14)$$

Equations (11), (12), (13) and (14) can be represented by the relations

Hotelling's T^2

$$T = \sum_{i=1}^{s} \lambda i$$

Wilk's: (Λ)

$$\Lambda = \prod_{i=1}^{s} \frac{1}{1+\lambda_i}$$

Roy:

Largest root $= \lambda_{Largest}$ and

Pillai: (v)

$$v = \sum_{i=1}^{s} \frac{\lambda_i}{1+\lambda_i}$$

Timm H. N (1975) States that employing any of the above test statistics, the same conclusion would be reached concerning the acceptance of null hypothesis.

CONSTRUCTION OF MANOVA TABLE

We shall consider a population or treatment say $\prod_1, \prod_2, ..., \prod_2 ... \prod_K$ with the sample $x_{11} ... x_{1N};\ x_{i1} ... x_{i.N}$ $x_{Ki} .. X_{KNk}$.

If we assumed a model of the form $X_{ij} = \mu + \alpha_i + e_{ij}$

$X_{ij} \sim N_P(\mu, \Sigma)$ and $\sum_{i=1}^{k} N_i \alpha_i = 0$

Sums of squares as used in the case of univariate ANOVA are replaced here by sums of squares and product matrix (SSPM). However, for the design of concern in this paper we shall present the appropriate SSPM as equations (15) through (17).

Total sum of squares and cross products

$$SSCP_T = \sum_i \sum_j (X_{ij} - X)(\overline{X}_{ij} - X)^I \quad (15)$$

treatment sum of squares and cross products

$$SSCP_{tr} = \sum_i N_i (X_i - \overline{X})(\overline{X}_i - \overline{X})^I \quad (16)$$

Error sum of square and cross products

$$SSCP_E = \sum_i \sum_j (X_{ij} - X_i)(X_{ij} - X_i)^I \quad (17)$$

Note that equations (15), (16) and (17) are related and this relationship is represented by equation (18) as follows.

$$SSCP_T = SSCP_{tr} + SSCP_E. \qquad (18)$$

The analysis of variance table for Multivariate setting, with a single systematic source of variation, is given below in a compact form as table 2.

Table 2: MANOVA TABLE FOR COMPLETELY RANDOMIZED DESIGN

Source of variation	Degree of freedom	Sum- of- Squares and Cross-Products (SSCP)
Treatment	K – 1	$T_B = \sum_{i}^{K}\left(\overline{X}_i - \overline{X}\right)\left(\overline{X}_i - \overline{X}\right)'$
Residual (Error)	N – K	$T_W = \sum_{i}\sum_{j}\left(\overline{X}_{ij} - \overline{X}_i\right)\left(\overline{X}_{ij} - \overline{X}_i\right)'$
Total	N – 1	$T_B + T_W = \sum_{i}^{K}\sum_{j}^{N_i}\left(\overline{X}_{ij} - \overline{X}_i\right)\left(\overline{X}_{ij} - \overline{X}_i\right)'$

Finally, the model sums of squares and cross products ($SSCP_{TR}$) are expected to gauge the relationship between the dependent variables as influenced by the experimental manipulation, and the residual cross products ($SSCP_E$), measure the relationship between the dependent variables as it is affected by individual differences or error in the Model. In this paper however we shall consider the total Sum-of-Square and Cross Products Matrix with two dependent variables and so all of the SSCP Matrices will be 2 x 2 Matrices. In general for p response variables the resulting matrices will be of dimension p x p.

DATA ANALYSIS.

The experiments were conducted between the period of March to December, while sugarcane leaves were collected at two periods that is, before dry season and before harvest (ten months after planting). Sampled sugarcane leaves were examined in the laboratory for the amount of two types of chlorophl namely chlorophl *a* ad *b* respectively. It should be noted that chlorophl *a* and *b* are indeed essential for the growth and development of sugarcane stalk.

DATA REPRESENTATION

The data for this study are secondary data obtained through laboratory experiment conducted by the research unit of the National Cereal Research Institute, Badeggi. The experiments were conducted to determine the chlorophyll content of sugar cane leaves. Forty four different varieties of sugarcane were of interest and chlorophyll content a and b were determined by the use of the Spectrometer. However, the experimental data to be utilized in this paper were obtained by exploiting the relations given as equations (19a) (19b) below.

- Chlorophyll a = $10.3k_1$ - $918k_2$ (19a)
- Chlorophyll b = $19.7k_2$ - $3.87k_1$. (19b)

The values 10.3, 0.918, 19.7, and 3.87 in Equations (19a) and (19b) are fixed values for the measuring instrument, while k_i's are the different values obtained from the reading of the various varieties. The values obtained for the whole experiment are given in Appendix I.

FORMAT FOR DATA ANALYSIS

First we verify the measurements obtained in respect of Chlorophyll a and b for their consistency with the expression given as Equations (19a and b) before appropriate analysis were carried out. In particular various Multivariate tests procedure are implemented for the data that were obtained at two different periods namely before dry season and before harvest. Correlation analysis was used in this study to examine weather the two types of chlorophyll namely chlorophyll *a* and chlorophyll *b* are correlated.

MULTIVARIATE ANALYSIS OF VARIANCE

We shall exploit the various multivariate tests to analyze the data of concern in this paper so as to demonstrate their suitability. Note that we consider the two periods of harvests as blocks and consequently the appropriate design is of the randomized complete block type. Therefore, Table 3 below presents the resulting multivariate analysis of variance table.

Table3: MANOVA FOR THE CHLOROPHYLL CONTENT OF SUGAR CANE LEAVES

SOURCE OF VARIATION	DEGREE OF FREEDOM	SUM-OF-SQUARES AND CROSS PRODUCT (SSCP)
Variety (Treatment)	43	$B^* = \begin{pmatrix} 1.787E+12 & 9.083E+09 \\ 9.083E+09 & 4.178E+10 \end{pmatrix}$
Period (Block)	1	$B^{**} = \begin{pmatrix} 8.495E+10 & -9.106E+09 \\ -9.106E+09 & 976220190 \end{pmatrix}$
Residual (Error)	131	$W = \begin{pmatrix} 5.532E+12 & 9.066E+09 \\ 9.066E+09 & 1.273E+11 \end{pmatrix}$
TOTAL	175	$T = \begin{pmatrix} 7.40E+12 & 9.04E+09 \\ 9.04E+09 & 1.70E+11 \end{pmatrix}$

The results in Table3 is used to calculate the characteristics roots of the equation $\left|BW^{-1} - I\lambda\right| = 0$

But,

$$W^{-1} = \frac{1}{7.041E+23}\begin{pmatrix} 1.273E+11 & -9.066E09 \\ -9.066E+09 & 5.532E12 \end{pmatrix}$$

$$= \begin{pmatrix} 1.808E\ 13 & -1.288E\ -14 \\ -1.288E\ 14 & 7.857E\ -12 \end{pmatrix}$$

$$\text{Then } B^*W\text{-}1 = \begin{pmatrix} 1.808E-13 & -1.288E-14 \\ -1.288E\ 14 & 7.857E\ -12 \end{pmatrix}\begin{pmatrix} 1.787E+12 & 9.083E+09 \\ 9.083E+09 & 4.178E+10 \end{pmatrix}$$

$$= \begin{pmatrix} 0.32297 & 1.104E-03 \\ 0.04835 & 0.328148 \end{pmatrix}$$

Thus,

$$\left|B * W^{-1} - I\lambda\right| = \begin{pmatrix} 0.32297 & 0.001104 \\ 0.04835 & 0.3281480 \end{pmatrix} \begin{pmatrix} \lambda & 0 \\ 0 & \lambda \end{pmatrix}$$

$$= \begin{pmatrix} 0.32297 - \lambda & 0.001104 \\ 0.04835 & 0.328148 - \lambda \end{pmatrix}$$

$$0 = (0.32297 - \lambda) \qquad (0.328148 - \lambda) \qquad (5.3378E\ 05)$$

That is, $\lambda^2 - 0.651117 \lambda + 0.10592858 = 0$

$$\lambda = \frac{0.651118 \pm \sqrt{(-0.651118)^2 - 4(1)(0.10592858)}}{2}$$

2

$$= \frac{0.651118 + 0.015503}{2}$$

$$\lambda = \begin{pmatrix} \lambda_1 \\ \lambda_2 \end{pmatrix} = \begin{pmatrix} 0.3333 \\ 0.3178 \end{pmatrix}$$

Hence, we shall compute the value of the appropriate test statistics as follows

(a) Pillai's trace:

$$V = \sum_{i=1}^{s} \frac{\lambda_i}{1 + \lambda_i}$$

$$= \frac{0.333}{1.333} + \frac{0.318}{1.318}$$

$$= 0.2498 + 0.2413 = 0.491$$

(b) Wilk's Lambda

$$\Lambda = \prod_{i=1}^{2} \left(\frac{1}{1 + \lambda_i} \right)$$

$$= \frac{1}{1.333} \times \frac{1}{1.318} = 0.569$$

(c) Hotelling's (T^2)

$$T^2 = \sum_{i=1}^{2} \lambda_i$$

$$= 0.333 + 0.318 = 0.651$$

(d) Roy's largest root

$$\lambda_i = 0.333$$

The calculated values are the same with the values obtained from the SPSS output in Appendix 1 (see variety effect component). For each of the test procedures, the decision rule is to reject H_0 if calculated F is greater than tabulated $F_{86,262;\ 0.05} = 1.209$. Meanwhile, we shall use the values obtained above to determine the test statistic for the four multivariate procedures in what follows:

(a) Pillai's Trace, we first calculate

$$T_0^2 = (N-2)\lambda_1$$
$$= 174 \times 0.333 = 57.942$$

Hence, the corresponding Pillai' s test statistic is calculated as follow;

$$\frac{(N-P-1)T_0^2}{P(N-2)} = \frac{132}{43 \times 174} \times \frac{57.942}{1} = 1.022$$

(b) Wilk's Lambda

$$\frac{N-K-1}{K-1} \times \frac{1-\sqrt{\Lambda}}{\sqrt{\Lambda}} = \frac{131}{43} \times \frac{0.246}{0.754} = 0.994$$

(c) Hotellings

$$T^2 = 85.01275$$

$$\frac{N-K-1}{K-1} \times \frac{T_0^2}{N-2} = \frac{132}{43} \times \frac{57.942}{174} = 1.022$$

(d) Roy's largest root

$$\theta_s = \frac{\lambda_1}{1+\lambda_1} = \frac{0.333}{1.333} = 0.2498$$

That is, $\frac{N-K-1}{K-1}\left(\frac{\theta_s}{1-\theta_s}\right) = \frac{132}{43} \times \frac{0.2498}{0.7502} = 1.022$

From the computation above it is observed that the computed values in respect of each of the test statistic is less than the corresponding table value. Hence for each of the test procedures we accept the null hypotheses and conclude that the forty-four varieties of sugar cane are the same with respect to the measurement made on the two types of chlorophyll.

Next, we shall consider the block effect by solving the determinant equation of the form $|B^{**}W^{-1} - \lambda I| = 0$

But from Table 3:

$$W^{-1} = \begin{pmatrix} 1.808E\ 13 & -1.288E-14 \\ -1.288E\ 14 & 7.857E\ -12 \end{pmatrix}$$

$$B^{**}W-1 = \begin{pmatrix} 8.495E & -9.106E+09 \\ 0.04835 & 0.328148 \end{pmatrix} \begin{pmatrix} 1.808E\ 13 & -1.288E-14 \\ -1.288E\ 14 & 7.857E\ -12 \end{pmatrix}$$

and

$$\begin{pmatrix} 0.0155 & -0.0726 \\ -0.0017 & 0.0078 \end{pmatrix}$$

$$\begin{pmatrix} 0.0155 & -0.0726 \\ -0.0017 & 0.0078 \end{pmatrix}\begin{pmatrix} 0 & \lambda \\ 0 & \lambda \end{pmatrix}$$

$$\begin{pmatrix} 0.0155-\lambda & -0.0726 \\ -0.0017 & 0.0078-\lambda \end{pmatrix}$$

1.2 $(0.0155-\lambda)(0.0078-\lambda) \quad - \quad 1.2342E-40 \quad = \quad 0$

$1.209E-04-0.0233\lambda + \lambda^2 - 1.234E-04 = 0$

$\lambda^2-0.0233\lambda - 2.50E-06 = 0$

$$\lambda = \frac{0.0233 \pm \sqrt{(-0.0233)^2-4(1)(-2.50E-06)}}{2}$$

$$= \frac{0.0233 \pm \sqrt{5.4289E-04+1.00E-05}}{2}$$

$$= \frac{0.0233 \pm 0.0235}{2}$$

$$\lambda_1 = \frac{0.0233+0.0235}{2} = 0.0234$$

$$\lambda_2 = \frac{0.0233-0.0235}{2} = -0.0003$$

But in what follows we shall determine the values of the four MANOVA procedures and their corresponding test statistics.

(a) Pillai's trace:

$$\nu = \sum_{i=1}^{2} \frac{\lambda_1}{1+\lambda_2} = \frac{0.0234}{1.0234}+\frac{0.0003}{0.9997}$$
$$= 0.0229-0.0003 = 0.0226$$

and the corresponding test statistic is:

$$\left(\frac{N-P-1}{P}\right)\left(\frac{T_0^2}{N-2}\right) = \frac{131}{2} \times \frac{4.0716}{174} = 2.0241$$

(b) Wilk's Lambda

$$\Lambda = \prod_{i=1}^{2}\left(\frac{1}{1+\lambda_i}\right) = \frac{1}{1.023} \times \frac{1}{0.9997}$$

$$= 0.9775 \text{ x } 1.000 = 0.978$$

and the corresponding test statistic is:

$$\frac{N-P-1}{P}\left(\frac{1-\Lambda}{\Lambda}\right) = \frac{173}{2} \times \frac{0.022}{0.978} = 1.946$$

(c) Hotelling's (T^2)

$$T_o^2 \sum_{i=1}^{2} \lambda_i \quad = \quad 0.23 - 0.0003$$

$$= \quad 0.227$$

and the corresponding test statistic is:

$$\left(\frac{N-P-1}{P}\right)\left(\frac{T_o^2}{N-2}\right) = \frac{173}{2} \times \frac{0.227}{174} = 2.0241$$

(d) Roy's

$\lambda_i \quad = \quad 0.023$

and the corresponding test statistic is:

$$\theta_s = \frac{\lambda_1}{1+\lambda_1} = \frac{0.0234}{1.0234} = 0.0229$$

$$\frac{N-P-1}{P}\left(\frac{\theta_s}{1-\theta_s}\right) = \frac{173}{2} \times \frac{0.0229}{0.9771} = \frac{4.055}{2} = 2.0272$$

Note that the hypotheses of interest are; H_0: $\underline{\mu}_1 = \underline{\mu}_2$ versus H_1: $\underline{\mu}_1 \neq \underline{\mu}_2$ and the corresponding Decision Ruleis to Reject Ho if calculated F is greater than tabulated F. for the interest here however the tabulated $F_{2,173;\,0.05}$ =2.996. Hence for each of the test procedures we accept the null hypotheses that the two periods used as blocks are not the same with respect to the measurements made on the two types of chlorophyll.

CONCLUSION

The results of analysis as extracted from the SPSS ouput are presented as Appendix I. In fact the results in reference are based on randomized complete block design with the two periods of before day season and before harvest being considered as blocks. Results of analyses that were obtained by the number of determinant equations gave the computed test statistics for Pillai, Wilks Lambda, Hotellings and Roy's to be 1.022, 0.099, 1.022 and 1.022 respectively and these values are less than the corresponding tabulated F, that is F86, 262 = 1.21. We therefore accept the null hypotheses and conclude that there are no significant differences between the vector of means of the forty-four varieties of sugar cane. Furthermore, test concerning the introduction of periods as blocks, give values of the test statistics for Pillai, Wilks Lambda, Hotellings and Roy's as 3.0241, 1.946, 2.0241 and 2.0272 respectively. Since these values are respectively less than the tabulated F, that is $F_{2,173;\,0.05}$ = 2.996, we therefore conclude that there is a significant difference between the vector of means of the two periods with respect to the two types of chlorophyll, namely chlorophyll a and b respectively. The significant tests concerning the use of randomized complete block design using the four test procedures respectively indicated that the introduction of blocks is not desirable, this is as a consequence of the acceptance of the null hypothesis.

Furthermore correlation coefficient between the two dependent variables of concern in this study is obtained to be appropriately zero. The result indeed justifies the use of multivariate analysis of variance for the experimental data that are of concern in this study. It should be noted that strong correlation between the variables would suggest that one of the variables may be substituted for the other and thereby making the univariate ANOVA preferable. In summary the four MANOVA procedures led to the same decisions in respect of the sugarcane varieties and periods that were used as blocks; this is as aresult of the acceptance of the null hypothesis in the case of the former and the latter. In particular, the four MANOVA procedures reveal that the forty four varieties of sugarcane are not significantly different and the two periods are also not significantly different. In essence varieties of sugarcane of concern in this study are found to be equally good and the use of periods as blocks has not been found to be desirable.

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APPENDIX Ia

DATA FOR CHLOROPHYLL CONTENT OF SUGAR CANE LEAVE: BEFORE DRY SEASON.

REPLICATE I		REPLICATE II	
Chlorophyll a	Chlorophyll b	Chlorophyll a	Chlorophyll b
16.44	6.133	12.61	5.283
12.048	7.633	8.532	3.878
16.688	5.633	15.773	1.816
9.027	9.557	17.952	5.875
19.193	-0.342	16.318	0.546
13.708	5.088	16.581	2.925
17.457	5.847	16.484	5.458
11.670	4.519	14.456	2.717
15.520	4.194	16.527	0.623
17.525	10.467	11.465	3.260
23.549	13.915	16.240	4.390
11.105	7.518	20.136	4.163
20.871	3.384	11.357	7.327
19.635	5.803	11.494	0.482
13.897	3.411	12.851	3.940
10.931	4.313	15.787	1.946
11.837	4.417	16.675	0.257
11.335	3.444	16.149	0.687
15.048	8.688	18.661	6.518
15.316	8.355	8.031	10.906
25.327	16.191	17.714	4.028
14.621	4.377	15.027	3.964
13.040	8.339	15.114	4.444
13.601	4.780	18.241	1.837
24.040	22.033	12.390	7.752
18.246	6.519	21.552	0.283
14.363	5.810	18.532	-0.286
20.256	6.596	12.846	1.638
13.044	4.351	10.029	7.593
16.951	6.076	22.082	-4.135
11.204	4.965	14.032	1.599
6.465	4.152	13.055	4.773
16.123	18.620	16.403	4.366
13.929	5.334	20.734	2.197
9.325	5.743	13.193	0.056
9.232	10.533	6.118	-1.215
10.482	5.031	17.471	3.171
14.707	7.752	12.452	-0.982
10.742	7.054	15.508	6.193
14.286	7.445	11.741	4.298
8.178	4.108	16.513	1.131
13.514	10.329	12.404	2.443
17.509	23.189	21.534	3.929
9.675	2.152	11.720	2.584

APPENDIX Ib

DATA FOR CHLOROPHYLL CONTENT OF SUGAR CANE LEAVE: BEFORE HARVEST.

REPLICATE I		REPLICATE II	
Chlorophyll a	Chlorophyll b	Chlorophyll a	Chlorophyll b
8.516	8.142	16.044	7.0755
12.606	11.793	9.575	14.286
19.371	24.716	18.692	13.009
9.346	13.560	15.045	8.534
7.488	10.425	18.784	16.904
18.845	20.791	8.590	11.115
17.546	18.279	18.444	22.025
22.651	27.296	14.755	16.502
17.727	16.120	13.573	25.791
14.455	20.543	22.561	16.840
21.720	19.904	8.103	9.188
18.813	20.183	12.484	20.065
9.495	13.194	13.091	14.630
16.805	15.499	13.066	20.601
18.246	-5.120	24.869	26.811
13.335	15.700	30.207	3.264
14.244	13.345	19.323	9.250
12.291	10.092	24.023	7.437
14.477	14.206	25.234	16.164
16.095	14.004	18.784	12.781
14.783	25.240	20.136	17.635
23.847	19.879	20.712	30.676
18.079	15.078	30.496	-2.942
27.550	23.578	20.669	33.131
18.991	24.839	28.944	30.371
30.454	-2.036	25.953	31.785
15.872	9.250	24.715	17.966
21.231	29.320	19.859	30.320
11.943	21.235	19.637	17.261
21.415	18.645	11.663	26.605
6.160	8.757	26.396	21.844
12.722	12.775	22.546	32.155
1.542	8.382	17.258	11.206
28.990	29.386	11.700	31.450
9.173	10.547	16.231	15.870
11.717	17.198	18.424	23.097
16.604	18.730	11.885	7.283
15.139	6.951	13.687	11.619
14.005	14.770	14.348	13.074
11.322	9.372	19.731	19.819
8.357	14.840	29.592	16.463
10.604	23.823	28.734	34.862
28.423	30.044	5.289	3.335
5.571	21.795	13.218	17.543

APPENDIX II

Multivariate Tests[d]

Effect		Value	F	Hypothesis df	Error df	Sig.	Noncent. Parameter	Observed Power[a]
Intercept	Pillai's Trace	.023	1.507[b]	2.000	130.000	.225	3.013	.316
	Wilks' Lambda	.977	1.507[b]	2.000	130.000	.225	3.013	.316
	Hotelling's Trace	.023	1.507[b]	2.000	130.000	.225	3.013	.316
	Roy's Largest Root	.023	1.507[b]	2.000	130.000	.225	3.013	.316
VARIETY	Pillai's Trace	.491	.992	86.000	262.000	.507	85.289	.993
	Wilks' Lambda	.569	.984[b]	86.000	260.000	.524	84.644	.993
	Hotelling's Trace	.651	.977	86.000	258.000	.541	83.999	.992
	Roy's Largest Root	.333	1.015[c]	43.000	131.000	.459	43.665	.909
PERIOD	Pillai's Trace	.023	1.512[b]	2.000	130.000	.224	3.024	.317
	Wilks' Lambda	.977	1.512[b]	2.000	130.000	.224	3.024	.317
	Hotelling's Trace	.023	1.512[b]	2.000	130.000	.224	3.024	.317
	Roy's Largest Root	.023	1.512[b]	2.000	130.000	.224	3.024	.317

a. Computed using alpha = .05

b. Exact statistic

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

d. Design: Intercept+VARIETY+PERIOD

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power[a]
Corrected Model	CHLOROPA	1.9E+12[b]	44	4.3E+10	1.008	.471	44.337	.910
	CHLOROPB	4.3E+10[c]	44	9.7E+08	1.000	.484	44.001	.907
Intercept	CHLOROPA	8.5E+10	1	8.5E+10	2.015	.158	2.015	.291
	CHLOROPB	9.6E+08	1	9.6E+08	.991	.321	.991	.167
VARIETY	CHLOROPA	1.8E+12	43	4.2E+10	.984	.509	42.325	.896
	CHLOROPB	4.2E+10	43	9.7E+08	1.000	.483	42.996	.903
PERIOD	CHLOROPA	8.5E+10	1	8.5E+10	2.012	.158	2.012	.291
	CHLOROPB	9.8E+08	1	9.8E+08	1.005	.318	1.005	.169
Error	CHLOROPA	5.5E+12	131	4.2E+10				
	CHLOROPB	1.3E+11	131	9.7E+08				
Total	CHLOROPA	7.5E+12	176					
	CHLOROPB	1.7E+11	176					
Corrected Total	CHLOROPA	7.4E+12	175					
	CHLOROPB	1.7E+11	175					

a. Computed using alpha = .05

b. R Squared = .253 (Adjusted R Squared = .002)

c. R Squared = .251 (Adjusted R Squared = .000)

Between-Subjects SSCP Matrix

			CHLOROPA	CHLOROPB
Hypothesis	Intercept	CHLOROPA	8.508E+10	-9.050E+09
		CHLOROPB	-9.050E+09	962774450
	VARIETY	CHLOROPA	1.787E+12	9.083E+09
		CHLOROPB	9.083E+09	4.178E+10
	PERIOD	CHLOROPA	8.495E+10	-9.106E+09
		CHLOROPB	-9.106E+09	976220190
Error		CHLOROPA	5.532E+12	9.066E+09
		CHLOROPB	9.066E+09	1.273E+11

Based on Type III Sum of Squares

Residual SSCP Matrix

		CHLOROPA	CHLOROPB
Sum-of-Squares and Cross-Products	CHLOROPA	5.532E+12	9.066E+09
	CHLOROPB	9.066E+09	1.273E+11
Covariance	CHLOROPA	4.223E+10	69206890.4
	CHLOROPB	69206890.4	971681833
Correlation	CHLOROPA	1.000	.011
	CHLOROPB	.011	1.000

Based on Type III Sum of Squares

Post Hoc Tests
VARIETY
Homogeneous Subsets