STATISTICAL TECHNIQUES FOR EXPERIMENTS WITH COCONUT

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Abstract: The statistical techniques followed in experiments with annual crops and perennial crops are essentially the same. However, while experimenting with perennial crops, the problems faced with are somewhat different from those with annual crops. Difficulties arise because of the perennial nature of the crops, long duration of experiments, large size of the plots, lack of uniformity in the experimental material, differences in the pre-bearing period coupled with long bearing period, time lag between application of treatments and manifestation of their effects etc. Even among perennial crops, coconut gives yield throughout the year unlike in many other crops. Recent studies have shown that the annual yield data of coconuts followed a skewed distribution, thus necessitating suitable transformations, to satisfy some of the assumptions involved in the statistical analysis of data. Conclusions drawn from experiments can also differ, depending on the method of compilation of annual yield data. Year to year variation is more pronounced in the case of calender year tabulation, as compared to agricultural years. Also achieving greater homogeneity between plots, within a block, by creating greater heterogeneity within plot has been found to be the best design approach.

In this paper an attempt has been made to review the work done in India and abroad in estimating the optimum plot size for field experiments, pooled analysis of data relating to long term experiments, efficiency of covariance analysis, yield forecasting methodologies, regularity of bearings, indexing the severity of disease symptoms, etc.

INTRODUCTION

The statistical techniques followed in experiments with annual crops and perennial crops are essentially the same. However, while experimenting with perennial crops, the problems faced with are somewhat different from those with annual crops. Difficulties arise because of the perennial nature of the crops, long duration of experiments, large size of plots, lack of uniformity in experimental material, differences in pre-bearing age, time lag between application of treatments and manifestation of their effects, large error variance, etc. Even among perennial crops, coconut stands separate, because nuts are harvested throughout the year, whereas in many other crops, fruiting is only seasonal. In this paper, an attempt has been made to compile the work done in India and abroad on the field lay-out of coconut experiments, analysis of data and interpretation of results and other techniques like yield forecasting methodologies and indexing the severity of disease symptoms.

FIELD LAYOUT OF EXPERIMENTS

Field experimentation techniques in fruit trees and other perennial crops have been discussed in detail by Pearce (1976), Choudhary *et al.* (1979) and Anon. (1986). Daniel (1984a, b) and Daniel and Bonnat (1987) have also specifically dealt about field experimentation techniques in oil palm and coconut.

1. Size and shape of plots and blocks

Compact blocks with uniform plots is a prerequisite for field experimentation. Smith (1938) gave an emperical relationship between variance and size of the plot. He defined the variance law as $Y = ax^{-b}$, where Y is the variance of the yield per unit area, based on plots of x units, a is the variance per plot of unit area and b is the characteristic of the soil and measure of correlation among contiguous units. In the case of trees and bushes, Pearce (1955) modified this relationship as $Y = V_1/x + V_2x^{-b}$, where V_1 (variance between individual trees) and V_2 (variance between single trees due to position) correspond to the genetic and environmental components of total variation. In tree crops, because of the wider spacing adopted, rows and columns become important, and therefore, generalisation of Smith's formula, in the form $Y = ar^{g_1}c^{-g_2}$ has also been attempted to study the row-wise and column-wise heterogeneity. While the CV of plots decreases with increase in plot size, this decrease is not proportionate. Consequently, an increase in the number of replications, with a reduced plot-size, if necessary, leads to more precise comparison of treatments. In crops where genetical component of variation is important, importance has to be given to this also, while forming plots. Number of replication is generally decided on the basis of available experimental area, the residual degrees of freedom required, the possiblity of losing some of the plots due to mishaps, and the efficiency required for estimates.

Work on optimum plot size for coconut was first done in Sri Lanka. Based on the uniformity trial data for 360 trees for one year, Joachim (1935) suggested 18-20 trees as the optimum for field trials. The CV of these plots was around 14% and for treatment differences of 15% to be considered significant, six replications were required. Pieris and Salgado (1937) also arrived at similar conclusions, based on the data for 300 coconut palms for two years. Recently many attempts have been made to study the optimum plot size for WC Tall, D x T and T x D palms under Kerala conditions. In the absence of uniformity trial data, in some cases, fertilizer trial data have also been used, after eliminating the treatment effect, by the method suggested by Ray *et al.* (1973). Data from two locations in the west coast have shown that for D x T palms, the per unit decrease in CV was minimum when the plot size exceeded eight palms (Nambiar, 1986a). Similar results were obtained for WC Tall palms also (Nambiar, 1986b). Analysis of data for T x D palms for four years has shown that a plot size of six palms is optimum, when the data are considered for individual years, and 3 to 4 when the data are considered for four years together (Anon., 1986).

Optimum plot size has been studied from the point of view of bienniality also. Abeywardena (1964) observed that with increased plot size, the effect of bienniality is nullified. It was significant for less than four palms and has suggested that six palms should be the minimum plot size for avoiding any significant bias in the interpretation of single year's data. Even with six palm plots, the CV could be kept within 10% with the aid of calibration, indicating the possibility for further reduction in plot size, in coconut experiments.

In annual crops, the plant to plant variation is mostly due to environmental reasons. In tree crops, because of their outbreeding nature, genetical factors play an important role. Shrikhande (1958) has suggested that when the plot size is four or less, it is advantageous to give importance to genetic component.

Alforja *et al.* (1978) have shown that for fertilizer experiments with polybagged coconut seedlings, significant results were obtained with 12 seedling plots.

2. Formation of blocks and plots

Blocks are arranged in such a way as to maximise differences between blocks, whereas plots are arranged within blocks as to minimise the differences among them. In annual crops this is generally achieved by clubbing together contiguous plots into blocks. In many of the tree crops, genetical component of variation is of sizable magnitude compared to the environmental component. Shrikhande (loc. cit.) has found that, in the case of coconut, the genetic and environmental components are in the ratio of 2 : 1 or 3 : 2, though Pankajakshan (1960) has later shown that environmental component is more important, when the data are considered in blocks of four or more years. For smaller plots also the genetical component is more important. Shrikhande (loc. cit.) had tried alternate methods of reducing the within block variation and increasing within plot variation, by controlling environmental and genetic components of variation, separately and in combination (Table 1).

This study has clearly brought out that the methods 2 and 3, which aim at controlling the genetic variation are more effective than method 1, which aims to control the environmental variation. He has recommended the last two methods, if the treatments to be applied are such that when a treatment is applied to a tree, the neighbouring trees are not affected. If on the grounds of practical convenience or cost considerations these methods are unsuitable, it is advisable to use method 1 with covariance.

Table 1. Coefficient of variation corresponding to plot mean and plot error (Shrikhande, 1958)

Plot size	Method 1	Method 1 with covariance	Method 2	Method 2 with covariance	Method 3	Method 3 with covariance
A. Block F of Pilicode						
1	35.22	26.82	24.27	24.36	35.22	26.82
2	27.76	20.53	16.94	16.91	22.20	19.01
4	25.26	15.54	9.96	9.99	10.54	10.05
6	15.73	11.93	9.24	8.78	13.43	11.07
8	14.58	7.64	8.99	8.99	12.04	9.89
B. Field 1 of Kasaragod						
1	37.13	19.05	20.27	20.26	37.13	19.05
4	26.05	12.37	10.12	10.19	12.07	8.80
8	21.51	10.21	7.06	7.07	9.15	9.41
12	18.11	5.57	6.94	6.06	3.98	3.77

Method 1: control of environmental variation alone. The land is divided into compact blocks and within each block, the adjacent trees are grouped to form plots. Method 2: control of genetic component of variation alone. Trees are grouped on the basis of past yield records and blocks are formed with palms of similar yields. Method 3: combination of methods 1 and 2. The land is divided into compact blocks and trees are arranged within blocks according to their past yields.

Saraswathi (1986) suggested an alternate method of grouping of palms, having marked yield differences. Based on the principle of negative intra-class correlation present among the experimental units within a plot, she suggested a method of grouping of palms having marked yield differences. This method was found to reduce the within block variation, by increasing the within plot variation.

3. Border effect and guard rows

Owing to border effect, the yield or other characters of the plants near the borders differ from those at the centre of the plot. In varietal trials the border plants of a more vigorous variety gain in competition with plants of neghbouring plots of less vigorous variety, whereas the advantage is not available to the plants in the inner portions of the plot, or under normal field conditions. To a certain extent, this anomaly can be avoided by proper orientation of plots. Similarly, in manurial trials, the manure from manured plots might seep into the adjoining plots and may vitiate the treatment effect. Apart from the possible introduction of a bias in the comparison of treatments, these border effects could lead to an inflation of error variation by increasing heterogeneity among plots. To overcome these problems, non-experimental guard rows are usually suggested.

Iyer (1958) examined the yield data from a coconut manurial experiment laid out in randomised block design, in nine-tree plots, and found that mean yields of border trees and central trees did not differ. Hence he suggested that the data obtained from all the nine trees in each plot can be used with advantage for analysis, instead of the data from the two central trees only. This is not unexpected in the light of the results (Kushwah *et al.*, 1973) from root studies, where it was noticed that 75% of the roots are confined to an area of 2 m radius around the bole of the palm. Patel (1938) has also pointed out that the surface roots at a few feet around the bole of the palm are concerned with the absorption of mineral nutrients. However, where no guard row has been provided between irrigated and unirrigated palms, have given the indication that the palms in unirrigated plot are getting benefits from the irrigation in the adjoining plot.

ANALYSIS OF DATA AND INTERPRETATION OF RESULTS

Coconut experiments are generally of long-term nature. In the case of fertilizer experiments on adult palms, it generally takes a minimum of three years for the effect of treatments to manifest on yield. Muliyar and Nelliat (1971) have reported that the effect of phosphorus treatment was not seen for the first nine years. In the case of field trials involving the comparison of different varieties, the experiments will have to run for at least 15-20 years. In most of these cases, the comparisons are made on the basis of yield of nuts (or copra or oil). Therefore, the method of compilation of annual yield, validity of assumptions involved, whether the annual data or cumulative data are to be analysed, duration of the experiment, reducing the error variance by calibration or covariance analysis, etc. are all important.

1. Analysis of yield data

Shrikhande (1958) amd Mathew and Jose (1988) have pointed out that coconut trees show a marked biennial bearing habit, giving high and low yields over successive years. Since all the trees are not usually in the same phase of yield in a year, the analysis of yearly records of individual trees of any experiment may be misleading. The average yield of a coconut tree, over an even number of consecutive years represents a good index of its performance and should be utilized in the analysis of data on coconut trees. Mathew and Kumar (1984) have also pointed out that pooling the data for consecutive years reduces the experimental error by over 60%. They have suggested to use the progressive average yields for analysis, instead of analysing the annual yield data every year.

Patterson (1939) has given the methodology for the pooled analysis of data, when the experiment has run for a certain number of years. Since the yields in the same plot in successive years are usually correlated, the experimental error in one season is not independent of that in another season. In comparing the over all yields of treatments, this difficulty is overcome by first finding for each plot the total yield over all the years. These totals are analysed by the method appropriate to the design that was used. This method provides a valid error for testing the overall treatment effects. Thus the analysis of variance table will be of error (a) error (b) type, in which the former is used to assess the the aggregate difference between treatments for the whole period covered by the experiment, and the latter to measure any differential response of the treatments of the varying seasonal condition.

2. Compilation of annual yield

In many of the perennial crops, yield is obtained during a specific period of the year only. But in the case of coconut, nuts are harvested throughout the year, about 60% of the total yield being obtained in the first half of the calendar year. Two different methods of compilation of annual yield data have been noticed – one based on calendar years (January to December) and the other based on crop year (July to June). Recent studies by Mathew *et al.* (1986) have shown that the year to year variation is more pronounced in the case of calendar year tabulation, as compared to crop years. This is because, when the yield data are considered on the basis of crop years, one half year of high yield is combined with a preceding or succeeding half year of low yield, or viceversa, or the two half years coming together are of medium yield, thus reducing the year to year fluctuations. But in the case of calendar years, two half years of high yield, or two half years of low yield are coming together, thereby increasing the year to year variations. With the help of experimental data, it has been shown that conclusions drawn can be different, depending upon the method of compilation of yield data (Table 2). Whatever be the method of compilation, since the differences narrow down when two year averages are taken, they have recommended the analysis of mean yield for two consecutive years, over the analysis of annual yield.

3. Calibration and covariance analysis

The use of pre-treatment data in the analysis of covariance as well as the idea of calibration, for reduction of experimental errors, are in vogue since the 30s. Both these methods of analysis are intended to control the genetic variation, which is usually of greater magnitude in tree crops. As already explained, the advantages of calibration and covariance analysis have been compared in coconut by Shrikhande (loc. cit.). Reduction in experimental error could be achieved through calibration. Somewhat similar results could be obtained through covariance analysis also. Combined use of both the methods did not result in any further improvement, over what was obtained from any one

Table 2. Genotype-cum-fertilizer trial : Pooled analysis of data, based on two different methods of compilation of yields - Summary of ANOVA (MSS) (Mathew *et al.*, 1986)

Source of variation	df	Crop-year data (1978-79 to 1983-84)	Calendar year data (1979 to 1984)
Replications	2	894.77	1338.50
Genotypes	2	5571.17**	4651.59**
Fertilizers	2	35990.72**	32474.39**
Geno. x fert.	4	833.35	778.95
Error (a)	16	667.61	620.90
Years	5	7717.16**	27168.90**
Geno. x years	10	94.15	2423.23**
Fert. x years	10	320.46**	1897.27**
Geno. x fert. x years	20	64.67	537.01**
Error (b)	90	105.05	244.34

** Significant at $P = 0.01$

of them alone. Iyer (1958) observed that the consideration of experimental years in sets of two or more years and use of last three pre-expermiental years' data as concomittant variate will help in detecting treatment differences most efficiently. Abraham and Kulkarni (1963) have also examined the period of pre-experimental data to be used for covariance analysis. Their study of the yield data for 20 years showed that the correlation between any two years yields decreases as the number of years separating the two years, increases. They found that about two years data immediately prior to the experimental period were sufficient for covariance analysis. Abeywardena (1970) has also observed 30 to 50% reduction in experimental error, by using two years' pre-experimental yield as calibrating variate. Studies conducted at CPCRI have also confirmed the above findings (Mathew and Kumar, 1984). They had studied the inter-relationship between the yields obtained in different years. Coefficients of correlation, of the form r_{piq}, were calculated for the yields of trees between an earlier period of p (= 0, 1, 2, 3, 4 & 5) years and a later period of q (= 0, 1, 2, 3, 4 & 5) years, separated by an interval of i (= 0, 1, 2, 3, 4 & 5) years. Though the yields obtained in different years were highly correlated, the relationship was comparitively weak when the annual data for immediately preceding and succeeding years were considered, probably due to the alternate bearing tendency shown by some of the palms. Compared to this, the correlation was much higher, when there was a gap of one year, between the two years under consideration. When data for groups of years were considered, the coefficients of correlation were found to go up to 0.9. Only marginal decreases in values were noticed when the gap separating the earlier and later periods was increasing. They also reported substantial reduction in variance and consequent improvement in efficiency, when pre-experimental yield data were used in covariance analysis. Use of two years' pre-ex-

Table 3. Measurements of central tendency (mean), skewness (b_1) and kurtosis (b_2), for the yield data of coconut (Mathew and Kumar, 1984)

Year	Original data			$\sqrt{x + 10}$ transformation	
	Mean	b_1	b_2	b_1	b_2
1967	48.8	0.98**	4.41*	0.22	2.88
1968	44.2	0.83**	3.61	0.05	2.54
1969	40.2	0.88**	3.92*	0.16	2.79
1970	53.6	0.78**	3.26	0.16	2.55
1971	47.6	1.41**	7.43**	0.33*	4.07*
1972	58.2	0.73**	3.64*	-0.06	3.06
1973	50.1	0.95**	4.35**	0.18	3.01
1974	41.4	0.97**	4.09*	0.20	2.84
1975	55.0	0.52**	3.26	-0.01	2.51
1976	43.4	0.81**	4.05*	0.13	2.88

* Significant at $P = 0.05$ ** Significant at $P = 0.01$

perimental data was found to almost double the efficiency, compared to what was obtained with single year's data. Based on this, they have suggested the use of progressive average yields for analysis, instead of analysing the annual yield data every year. Similar study by Abeysinghe (1986) has also shown that two-year pooled pre-experimental yield on four tree plot produces consistent calibration and reduces the experimental error mean square by about 73%. This brings down the mean coefficient of variance to 9.7% from its pre-calibration levels of 36 on one-tree plots and 18 on four-tree plots.

4. Transformation

For the valid application of tests of significance in the analysis of variance, an important assumption is that experimental errors are independently and normally distributed with a common variance. This in other words means that in an experiment-free material, the data should be normally distributed. Studies conducted by Mathew and Kumar (loc. cit.) have shown that the distribution of annual yield of coconut is always positively skewed and leptokurtic, generally following a Pearson Type IV distribution (Table 3).

This was due to the presence of a proportionately higher percentage of palms, giving below average yield. In the years of low production, skewness was found to be more and leptokurtic. Among the different transformations tried, square root transformation of the form $\sqrt{(x + 10)}$ was found to be the best, to bring the data to a near normal form. Such a transformation was necessary even when data for consecutive years were pooled or when palms were considered in groups.

5. Duration of experiments

Duration of the experiment generally depends on the objective of the study. In the case of varietal evaluation studies, the trial may have to continue for 15-20 years. In the case of fertilizer experiments, it may have to run for at least 10 years. Mathes (1980) studied the yield data obtained over 20 consecutive years, from a fertilizer trial carried out in a mature coconut plantation and found that the inter-annual correlation coefficients between successive pairs of years first increased, then reached a plateau, increased again and ended in an asymptote. From the eighth year onwards, these correlations remained stationary. On the basis of these results, an 8 to 10 year experimental period has been recommended to be sufficient to determine the full response of fertilizers.

YIELD FORECASTING METHODOLOGIES

Coconuts are generally harvested about 8-12 times a year. In reseach institutes and other well maintained farms, while it may be possible to monitor each of the harvests and get data on the annual yield, this may not be easy in the case of crop cutting experiments and trials in cultivator's gardens. From Philippines it has been reported (Anon., 1973) that by counting every single nut, mature as well as young ones, hanging on the tree, one can get a fair idea about the number of nuts that can be expected from the tree in a year's time. Reynolds (1979) has suggested selecting 10% of the palms in an area and counting (using binoculars) all large nuts (more than 10.0 to 12.5 cm in length) to obtain a mean figure for large nuts and multiplying the same by the number of palms/ha and increasing it by a percentage factor of 35% to compensate for not counting the smaller nuts, to get a fairly accurate estimate of annual coconut production per hectare. Mathew *et al.* (unpublished) have conducted detailed studies for four years on the number of nuts present on the crown at any time of the year and the yield of nuts in the coming one year, under rainfed Kerala conditions, for WC Tall palms. At Kasaragod, November-December was found to be the best period for estimating the annual yield and have suggested the following regression equation for the purpose: $Y = -0.527 + 0.914 X$, where Y is the estimated annual yield and X is the count of nuts in the different stages of maturity, on the crown, at the time of observation. Under Kayamkulam condition, the best period was found to be January to March, and the corresponding equation was $Y = -3.0804 + 0.8879 X$. Workers like Abeywardena (1968) and Kumar *et al.* (1984) have also suggested multiple regression models, for forecasting the annual yield of coconuts, based on weather variables, for selected periods of the year, during the year of harvest and the preceding one or two years.

Based on the correlation between partial harvest data and annual yield, Balakrishnan *et al.* (unpublished) have found that by adopting a technique known as component sampling, the precision of yield estimates can be greatly improved in coconut.

INDEXING THE SEVERITY OF DISEASE SYMPTOMS

The necessity for quantifying the severity of disease symptoms is felt when comparing the intensity of the disease in different genotypes and locations, and when field control trials are laid out, which may involve evaluation of different treatments. In the case of coconuts, attempts were first made in this direction by George and Radha (1973) in indexing the severity of root (wilt) disease. They suggested a method involving the scoring of all the leaves in the crown, for flaccidity, necrosis and yellowing, giving different weights for the symptoms. Separate formulae were given for indexing young palms and adult palms. Nambiar and Pillai (1985) tried to simplify this procedure and suggested that scoring the leaves in any one of the five spirals can be adopted without loss of information. For Tatipaka disease seen in Andhra Pradesh and Tanjavur wilt seen in Tamil Nadu, similar methodologies have been given by Ramapandu and Rajamannar (1983) and Gunasekharan *et al.* (1986), respectively. Recently, Mathew *et al.* (unpublished) have developed a methodology for indexing the disease severity in stem bleeding affected coconut palms, based on lesion size and score for tapering.

SUMMARY AND CONCLUSIONS

a) The present thinking is to go for small plots, with more number of replications. A plot size of six to eight palms seems to be adequate, for the usual field trials, from the point of view of low variability and for reducing the effect of bienniality.

b) Genetic variablity is of importance in coconut. Calibration and covariance analysis have been proved to be advantage in coconut experiments. Two year pre-treatment yield data are adequate for covariance analysis.

c) For field experiments, grouping of palms having marked yield differences reduces the within block variation, by increasing the within plot variation.

d) With the wide spacing adopted for coconut, and the concentration of roots near the bole of the palm, border palms can be avoided for most of the experiments. However, at least in certain soil types, when irrigation is one of the treatments, necessity of guard rows has been felt.

e) Conclusions drawn from experiments can vary depending on the method of compilation of annual yield data.

f) When yield of nuts is one of the characters to be analysed, pooling the data for consecutive years is advantageous.

g) Annual yield data of coconut palms can be estimated using the count of tender nuts in the crown.

h) Methods are available for quantifying the severity of some of the diseases, based on easily observable characters.

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