DETERMINATION OF THE SIZE AND SHAPE OF PLOTS FOR TRIALS ON CASHEW

BY
REMESH B. NAIR

THESIS

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DECLARATION

I hereby declare that this thesis entitled " DETERMINATION OF THE SIZE AND SHAPE OF PLOTS FOR TRIALS ON CASHEW" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship, or other similar title of any other University or Society.

R.B Nair

[illegible].B.NAIR

Mannuthy,
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CERTIFICATE

Certified that this thesis entitled "DETERMINATION OF THE SIZE AND SHAPE OF PLOTS FOR TRIALS ON CASHEW" is a record of research work done independently by Sri.Ramesh B.Nair, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

Mannuthy,

31.7.1981

SRI.P.V.PRABHAKARAN
CHAIRMAN,ADVISORY BOARD,
ASSOCIATE PROFESSOR OF
AGRICULTURAL STATISTICS
COLLEGE OF HORTICULTURE.

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RAMESH.B.NAIR

CONTENTS

INTRODUCTION

INTRODUCTION

Cashew botanically known as (*Anacardium occidentale* L) which is a native of Brazil was introduced to India by portugese about 400 years ago mainly to prevent soil erosion. Today it has got a relevent place among the commercial crops of our country. During the past 400 years it has spread to all the states in the Western and Eastern coasts of peninsular India. It is a hardy crop growing in a semi-wild manner in the poorest soils in southern states. In the existing plantations very little care and attention is paid in its culture. Besides India other important cashew growing countries in the world are Mozambique, Tanzania, Kenya and Brazil. Cashew is an important crop in the agricultural, industrial and commercial economy of the country, more particularly of the state of Kerala where the cashew processing Industry is concentrated employing about a lakh and half persons.

India is the largest producer of cashewnut. The most useful product of cashew tree in the world, the cashew kernal (Kaju) inside the nut is very palatable, highly nutritive and has a pleasing flavour.

It makes a significant contribution to foreign trade and is therefore an important earner of foreign exchange like tea, jute, and coffee etc. The export of cashew kernals and cashew nut shell liquid have earned over 100 crores of rupees annually in recent years. The presence of shell oil is a unique phenomenon. It is extracted during processing of cashew as a by product. The cashew nut shell liquid is actually the pericarp fluid. This liquid has a large number of utilisation in industry and allied fields. We are earning foreign money by exporting the shell liquid. Not only cashew kernal but all parts of the cashew tree are of considerable economic importance.

Kerala is the premier cashew growing state in India. The cashew processing industry was started in Kerala about 50 years ago and until recently India had almost a monoply in the international trade in cashew kernal. There are at present about 250 cashew processing factories in Kerala giving direct employment to a lakh and half persons. These factories require about 4.5 lakhs tonnes of raw cashewnut for working throughout the year. However we are producing only about 1 lakh tonnes of raw nuts at present and we are depending upon the african countries for the remaining quantities of raw material. With the establishment of cashew processing units in some of the major producing countries it has become difficult to import the raw nuts required for our processing factories. The only solution for the above problem is to increase the production of cashewnut by all means. Among the several reasons attributed to the low production and productivity of cashewnut, the important ones are less attention paid by the growers to the crop in spite of its high economic importance, inadequate fertilization and poor management practices. So all types of research like fertiliser trials plant protection trials etc are to be conducted for increasing the production of cashew in Kerala.

Certain experiments conducted at Vriddachalam have shown that the production of cashew trees can be considerably increased by the proper manuring and irrigation of trees and maintaining an optimum number of tree population per head. The use of NPK fertiliser has resulted in a ten fold increase in the yield of cashew. Thus there is the need of standardising the cultural practices in relation to cashew cultivation so as to get maximum profit for the cashew growers. Field experiments are being planned at different places with a view to meet this objective.

A field experiment can be successfully planned only if the experimenter has some idea regarding the variability of the experimental material. Cashew, being a perennial crop great care is to be paid in the lay out of experiments. In perennial crops individual trees are of prime importance because each tree occupies a very vast area. All these trees have very long juvenile phase and the time taken for flowering varies from tree to tree. The duration of bearing period, the time taken for stabilising the yield, the response to weather parameters etc also vary from tree to tree. Further, much of the variation is inherent in the tree itself and in general genetic variation is more predominant over positional variation.

All these factors must be taken into account in designing experiments on a perennial crop like cashew. Several methods of reducing variability are available for the experimenter which include the use of vegetatively propagated materials and seedlings raised from the same parental stock. But all these methods fail if an experimenter wants to superimpose a field trial on an existing orchard containing large number of trees of diverse genetic make up.

The tree to tree variation due to the effect of uncontrolled factors is called experimental error. Direct methods of controlling experimental error include such devices as replication local control, selection of uniform site for experimentation provision for border rows to eliminate border effect, proper orientation of plots and blocks, adoption of optimum sizes and shapes for plots and blocks etc. Analysis of data from a uniformity trial on the crop will give some idea regarding the nature and extent of the variability of the experimental material. The data from such a trial can be properly used for getting an estimate of experimental error, for fixing the number of replications required for getting a desired level of precision for finding the optimum size of shape of plots and blocks and also for the proper orientation of plots and blocks.

The experimental plot is the basic unit for the conduct of field experiments. Any experimenter who wish to conduct an experiment with a crop will have to start the experiment with a suitable plot size.

The size and shape of a plot can greatly affect the magnitude of experimental error in field trial. Too small plots may give unreliable results while unnecessarily large plots would result in a wastage of resources and time. Further the plots may be sufficiently large for normal cultural operations and farm practices. In general experimental error decreases as plot size increases. Increasing the number of replications rather than plot size is found to be more effective in improving the precision of the experiment. Among the several factors which affects the size and shape of plots the important factors are border effect, soil hetrogenity, scarcity of seeds and type of experiment.

Another factor which affects the experimental error is the size and shape of blocks, which is one of the simplest and effective ways of coping with soil hetrogenity. The variation among blocks can be removed from the experimental error through blodking. Thus the experimental error is reduced and precision of the expeiment can be increased. In arranging blocks in field and plot within blocks two points need attention. One is the necessity in certain types of trials such as those on cultivation, sowing dates etc of leaving room for agricultural implements at the end of a plot. The other point is that the arrangement of blocks should be such as to maximise differences between blocks whereas plots should be so arranged within blocks as to minimise differences among them.

In field experiments with cashew it is generally difficult to increase the number of replications from more than 4 or 5. Therefore other methods such as use of calibrating variables have to be adopted for increasing the accuracy of these experiments. Pre-experimental yields collected for a few years prior to the application of treatments were possibly serve as a useful calibrating variate. Optimum number of pre-experimental periods are to be determined so as to nullify the biennial tendency of cashew trees.

When the above mentioned direct methods for controlling experimental error fail or found to be less efficient there are certain indirect statistical methods for controlling the error. The techniques of calibration and analysis of covariance provide the best indirect methods of controlling the experimental error. The present investigation was undertaken with the objective of finding suitable size and shape of plots for field trials on cashew and indirect methods of controlling the experimental error. These studies will help the research worker in the efficient designing of field experiments on cashew and thereby increasing the production and productivity of cashew.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Eventhough comprehensive research on different problems concerning with field experiments on cashew have not been undertaken in India so far, studies on certain problems associated with field experiments on a very few plantation crops and vegetable crops have been carried out in different parts of India. A brief review of the work done so far on these aspects is furnished below under the following headings.

1. Size and shape of plots
2. Size and shape of blocks
3. Analysis of covariance and calibration
4. Number of pre-experimental periods
5. Correlation between contiguous units
6. Number of replications

1. <u>Size and shape of plots</u>

Govinda Iyer (1957) reported that a plot of 9 trees can be effectively used for manurial trials on coconut. The study also revealed that there was no significant difference in the mean yields of central and border trees and consequently there was no need for providing internal border rows in experiments with coconut.

According to Kulkarni and Abraham (1963) calibrating variates like pre-experimental yields could be used for efficient grouping of plots. Ram Babu *et al.* (1980) found from a uniformity trial on fodder that the coefficient of variation decreased with an increase in plot size upto 8 m^2 and consequently they recommended a plot size of 8m^2 for experiments with fodder crop.

Hatheway and Williams (1958) established the relation $E(\log V_x) = E(\log V_1) - B \log x$ where B is the regression coefficient of V(x) on log x, x is the number of units per plot V_1 is the variance among plots of size unity and V_x is the variance of mean per unit area for plots of size x units. This formula requires a finite population correction when the size of the block is small compared with the size of plot. Prabhakaran and Thomas (1974) reported that the shape of plot did not found to have any consistent effect on the CV. However for a given plot size long and narrow plots generally yielded lower coefficient of variation than square plots of the same dimension. With smaller plot sizes the effect of shape was more predominant. They recommended a plot size of 25 sq meters for conducting field trials on tapioca.

Abraham and Vanchani (1964) in field experiments with rice stated that coefficient of variation for 5 plot or 10 plot blocks decreased with an increase in plot size irrespective of the shape of the plots. Shape of plots did not show any consistent effect on plot variability. However plots elongated in West East direction showed less variability than plots elongated in North South direction. Narayanan (1965) found that minimum variance was obtained when number of recorded trees in a plot was in the region from 25 to 49 in field experiments with rubber. The use of smaller plots might be discontinued owing to the uneven distribution of tree loss while very big plots create difficulties with regard to the overall size of the experiment with consequent problems concerning site, blocking of treatments etc.

Pearce (1955) suggested a new function for determination of plot size on perennial crops which is $V_x = \frac{V}{x^b} + \frac{V_1}{x}$, V_x is the variance per unit area between plot of x trees and V_1 is the variance between individual trees. V is the variance between single tree and b is a constant lying between 0 and 1. The second component was a function of genetic variation while the first was a function of soil difference. He suggested to use larger plots as far as possible with enough error degrees of freedom. In experiments with a large number of trees in a plot was missing it was advisable to have either small plots or larger plots not medium size. According to him providing guard row was a mere wastage of material.

From a uniformity trial on coconut Pankajakshan (1960) seperated the genetic and environmental components of variations with the help of the equation $W=G+Ex^b$, W = pooled between mean square, x-plot size, b, G and E are constants. He found that the genetic and environmental components of the total variation between trees were in the ratio 3:2 for averages based on 2 years and 1:1 for 4 years. His studies also revealed that environmental component was more important for periods higher than 4 years and attains prominance in relatively large plots.

According to Agarwal *et al.* (1968) the plot size which requires the minimum experimental material for 10 per cent of standard error of the mean was defined as the optimum plot size in perennial crops. He recommended a plot of 6 trees for conducting field experiments with arecanut. Menon and Tyagi (1971) observed that in field experiments with mandarian orange the relative information per tree was maximum in the case of single tree plots and hence single tree plots were the most efficient ones. He further observed that incomplete block designs were more efficient in trials involving a large number of treatments and the device of confounding could be effectively used for reducing block size in field experiments with orange.

Sardana __et al.__ (1967) found that the optimum plot size for field experiments with potato was about 8.4m^2. Pahuja and Mehra (1981) suggested a simple modification to the well known smiths equation for determining the plot size, as $V_x = V_1/x^{b'}$ where $b' = b/2$, b is the constant in smiths equation, in field experiments with chick pea. The results of the experiments indicated that coefficient of variation showed no general trend with varying plot sizes. However with 4 replications maximum precision could be obtained from a plot size 1.5 m x 50 cm. But with this coefficient of variation a difference of less than 17 per cent of the mean could not be detected. Therefore larger plots were recommended so that difference of

10 to 15 per cent were detectable.

From one of the earliest uniformity trials conducted on cotton by Hutchison and Panse at indoore during 1933 using the variety Malvi, it was found that long and narrow plots laid out along the rows over plot of the same size and shape laid out across the rows were independent of the fertility gradiant.

Iyer and Agarwal (1970) found that in field experiments with sugarcane the cv decreased with an increase in plot size either in length or in bredth but the decrease was more rapid with increased length. For larger plot size, the shape of plots plays an important role further if longer diamension of plots is kept along the direction of the rows more precise results were obtained. They recommended a plot of size .0048 hectre and shape 7.32 m x 5.49 m for field trials on sugarcane.

Prabhakaran _et al._ (1978) observed that relative percentage information is maximum for single tree plots in field trials with banana and they suggested single tree plot for conducting field trials on banana.

Basing upon the results of a uniformity trials on black pepper Singh _et al._ (1958) reported that there was greater variation for larger plot than for smaller plots but the difference was not indicated when the size of a plot exceeded ten standards. They also found that single tree plot was optimum for conducting field experiments on black pepper. The experimental material required was larger in 4 plot blocks than in 8 plot blocks.

In tea Eden (1931) found a plot size of .056 acre as the most optimum for field trials. Paardekooper (1973) stated that smaller plot with more replications were always more efficient than larger plots with fewer replications. Single tree plots were always the most efficient and might be used for all experiments not requiring guard rows.

For arecanut nursery experiments Bavappa (1959) found 24 seedlings per plot to be optimum. In cardamom, hetrogenity between row was found to be significantly more than that between columns and as such formation of plots with more number of rows will give more homogenous blocks for experiments on that crop. George <u>et al.</u> (1979) reported that a plot size of 12 plants arranged in four row of three plants each for smaller blocks and 18 plants in six rows of 3 plants each for larger blocks has been recommended as the optimum. In the case of oil palm Webster (1939) recommended the plot size of 12 to 32 palms considering single year yield.

2. Size and shape of blocks

Kulkarni and Abraham (1963) reported that certain qualitative characters such as fertility gradiant can be made use of for formation of blocks. Ram Babu *et al.* (1980) on chick pea showed that block shape had no consistent effect on cv. Block efficiency decreased with increase in block size. The function $y = ax^{-b}$ was found to be good fit between block size x and coefficient of variation y.

Abraham and Vanchini (1964) in field experiments with rice stated that plots with a given size and shape, block efficiency gradually decreased with the size of the block. With block of the same size but at different shapes formed from plots of same size there was no apparent change in the efficiency of block within the range of block shapes tried.

Saxena *et al.* (1972) concluded that rectangular blocks with wider ratio between dimension was in general found to be more efficient than that with narrow ratio between dimensions. He also revealed that a block of 10 plots was suitable for conducting field trials on fodder. Agarwal *et al.*(1968) reported that the advantages due to blocks might be considered negligible when block efficiency was in the neighbourhood of one. Rambabu *et al.*(1981) found that block efficiency decreased with an increase in block size in field trials with natural grasslands. The shape of the block had no consistent effect on block efficiency.

In field experiments with mango crop blocks with more plots along the row gave a smaller cv as compared to blocks with lesser number of plots along the row (D Singh *et al.*,1958).

In black pepper compact block were found to be better than rectangular blocks, the difference was not appreciable with small plots but with plots exceeding 12 standards per plot considerable increase in the efficiency of compact block was evident. The increase in efficiency with compact block was not consistent with varying plot size and shapes (D Singh *et al.*,1968

3. Analysis of covariance and calibration

Govinda Iyer (1957) reported that in field experiments with coconut covariance analysis can be effectively used for reducing the experimental error.

According to Kulkarni and Abraham (1963) the technique of calibrating variables could be effectively adopted for increasing the precision of estimates in field experiments with perennial crops by applying multiple covariance rather than ordinary covariance ana lysis. Narayanan (1968) observed significant positive correlation between pre-treatment yield and pre-treatment girth in field experiments on rubber. These correlations were found to be dependant on the length of the pre-experimental year. He also suggested that trunk girth could be used as an additional calibrating variable for increasing the precision of experiments with double covariance analysis.

According to Pearce (1955) covariance analysis was more effective in larger plots than in smaller plots in field experiments with grapes and oil palms. He also pointed out the importance of calibration of trees before their experimental use. Pankajakshan (1960) reported that the use of covariance technique with a plot of 8 to 10 trees seemed to be the best alternative for incfeasing the precision. In the case of short term experiments and where the plot size is not to exceed four trees it is always advantages to give importance to genetic compoment to get the desired level of precision.

Menon and Tyagi in field experiments with mandarian orange found the largest gain in precision could be obtained by taking spread as an auxiliary variate. The same precision was also obtained in the case of height of the tree. The gain in precision due to covariance analysis using girth as covarite was not appreciable.

For coconut Shrikhande (1967) has found that genetic and environmental components were in the ratio 2:1 or 3:2 this could be reduced by the method of covariance analysis. Abeywardena (1970) observed 30 to 50 per cent reduction in experimental error by using two years pre-experimental yield as calibrating variate. Recent studies (Anon,1977) revealed that the increase of efficiency due to covariance analysis using two or four years pre-treatment yield was 40 per cent. Longworth and Freeman (1963) recommended trunk girth as a calibrating variate for yield in the case of young trees. Murray (1934) reported from Sumatra that in rubber, when preliminary and experimental years were consecutive there was nearly four fold increase in precision due to covariance analysis. When they were three year apart the error variance of adjusted yield reduced to about a half.

4. Number of pre-experimental periods

Kulkarni and Abraham (1963) observed that in using pre-experimental yield data for covariance adjustments it was important to know a minimum period for which the pre-experimental data should be recorded. This is turn dependent on the pattern of correlation between yields indifferent years. The full advantage of pre-experimental data could be taken only by using multiple covariance analysis on the individual pre-experimental periods. It was found that about 2 years data immediately prior to start of the experiment were sufficient for covariance analysis on field trials with most perennial crops.

Narayanan (1966) showed that the degree of increase in precision due to analysis of covariance gradually decreased with an increase in the time between experimental yield, and pre-experimental yield. On an average the increase precision varied from about 2 in the first year to about 1.5 in the 3rd year. Without the use of pre-treatment the number of replications would perhaps need to be twice as numerous as to achieve the same degree of accuracy.

Agarwal *et al.* (1968) revealed that the maximum reduction could be obtained due to covariance analysis using pre-experimental yeild for a period of 2 years as concomitant variable. In field experiments with mango one pre-experimental period i.e two consecutive years yield was sufficient to control the error to a minimum level (D Singh et al.,1968).

5. Correlation between contiguous units

Constant 'b' in the fair field Smith's equation $V_x = V_1 x^{-b}$ is a measure of correlation between contiguous units (Smith,H.F.,1938). A high value of b indicates that the x units making up a plot are not strongly correlated whereas a low value of 'b' especially in the neighbourhood of zero reveals a strong liner relationship between contiguous units. The value of 'b' for several crops reported by different workers from time to time were reviewed here.

Kripa Shanker et al.(1972) reported that the 'b' value for soyabeen ranged from .31 to .23 indicating a high correlation between contiguous plots.

Prabhakaran et al.(1978) got 'b' values which ranged between 72 to 79, when the plots are arranged in blocks and .904 when the plots are not grouped, in field experiments with banana.

Prabhakaran and Thomas (1974) found that 'b'values for Tapioca lie between .4076 to .2730 indicating a high correlation between contiguous units.

Abraham *et al.* (1969) reported that 'b' value for arecanut fell in the range of .30 to .37.

Gopani *et al.* (1970) found that the values of 'b' varied from .329 to .266 indicated positive correlation between neighbouring plots, in field experiments with groundnut. The value of 'b' decreased with an increase in plot size.

Abraham and Vachani (1964) obtained a 'b' value ranged between .139 to .08 indicating high correlation between contiguous plots in field experiments with rice crop.

Sardana *et al.* (1967) found that in field experiments with potato the 'b' values ranged between .137 to .214.

Menon *et al.* (1971) reported that the 'b' value for mandarian orange was in the range from .138 to .2849.

6. Number of replications

From the results of uniformity trial on fodder Saxena *et al.* (1972) reported that for small plots a fairly large number of replications were to be provided for getting a desired level of accuracy. But as the plot size increased from $2m^2$ to $60m^2$ there was a considerable reduction in the number of replication required to obtain the same level of precision. Prabhakaran et al. (1978) found that the number of replications ranged from 19 to 2 when plots are arranged in blocks and 21 to 5 when they are not arranged in blocks, in field experiments with banana. He also observed that the number of replications required decreased with an increase in plot size inspite of the reduction of experimental plants in enlarged plots.

MATERIALS AND METHODS

MATERIALS AND METHODS

The data required for this study were obtained from the available records of the Cashew Research Station, Madakkathara. The experimental material consisted of a compact block of 625 trees in a 25 x 25 arrangement. A single row of trees on either side of the field was discarded to eliminate border effect. Thus the final stand consisted of 576 trees in 24 x 24 arrangement in the experimental area. Observations on a few missing trees were estimated by a simple averaging process. The seedlings were raised from the same parental stock. All the trees were of the same age group and were subjected to the same cultural and management practices. Both genetic and environmental factors contributed to the large amount of variation observed in the experimental trees. All the trees had reached the stage of yield stability. Secondary data for 5 years from 1976 to 1981 were gathered. Manurial practices were the same for all the trees up to the year 1980, but later changed in accordance with a 3^3 factorial design superimposed on them during the year 1980.

The period 1976-80 for which there was no change in the treatment was considered to be the pre-experimental period and the year following the application of treatment was considered to be the experimental period. Secondary data for the pre-experimental period were treated as if they were generated by conducting a uniformity trial on the same cite for the period under reference. In addition to yield, observations on certain morphological characters related to yield such as height, spread and trunk girth were also gathered during the year 1978-79. The mean yield per tree was calculated for each of the 576 trees on the basis of the pre-experimental data. Plots of different sizes and shapes were formed by combining adjacent trees, a tree representing the basic unit.

Several methods have been suggested from time to time for obtaining the optimum plot size. Among them the well known emperical relationship between plot size and variance of mean per plot developed by Smith (1938) is considered to be the best. Smith's equation is of the form $V_x = V_1/x^b$ where V_x is the variance of yield per unit area among plots of size x units, V_1 is the variance of yield of plots of size unity and b is a measure of correlation among contiguous units. The limiting values of b are 0 and 1, unless inter experimental competition is present (Federer,1955). As the equation is logarithimically linear the best estimates of V_1 and b can be obtained by the principle of least squares. The fitted regression equation provides the expected values of V_x for different values of x.

Smith has also considered the cost function $C=Co+C_{1x}$ where Co is the cost which is independent of plot size and C_1 is the contribution to the cost by a unit increase in plot size. Optimum plot size is the one which minimises the cost per unit of information namely $(Co+C_{1x})\ V_{1x}^{b}$. However for a crop like cashew a tree is the ultimate unit and therefore the entire cost is proportional to the number of trees per plot. Thus it is more logical to define the optimum plot size as the one giving maximum information from the data per unit trees. The optimum plot size was estimated with this objective in view. Optimum plot size can also be defined as the one which requires the minimum experimental material for a given SE of mean.

The number of replications required for estimating the mean yield with P per cent standard error is given by the relation $N = (CV)^2/P^2$ where N is the expected number of replications and CV is the coefficient of variation.

Relative percentage information per tree (RI) for plots of different sizes and for blocks was calculated by using the formula $RI = \frac{V_1}{xV_x}$ where V_1 is the variance for unit plot size and Vx is the expected variance of plot means.

Fair field Smith deduced the following relationship for the variance per unit area between plots of size x units in blocks of m plots $(V_x)_m = \frac{m(1-m^{-b})}{m-1} V_x$ where Vx is the variance in an infinite land, b coefficient of hetrogenity and hence he obtained the relative efficiency of blocks of m plots relative to blocks of n plots to be the same regardless of size of plot and equal to $\frac{(V_x)_n}{(V_x)_m} = \frac{n(m-1)(1-m^{-b})}{m(n-1)(1-n^{-b})}$.

This can be utilised for the study of the efficiency of various block sizes.

Intra class correlation coefficient ρ was calculated by using the formula $\rho = \frac{BSM - WSM}{BSM + (x-1)WSM}$ where x = plot size.

BSM = pooled between sample mean square

WSM = pooled error mean square

As a measure to make allowance for the inherent genetic variation the trees were ranked according to the pre-experimental yield totals and grouped into three blocks of sizes 4, 8 and 12. The relative efficiency of blocking with ranking over blocking without ranking was determined by using the formula.

$$R = \frac{VE_2}{VE_1}$$

where R = relative efficiency of ranking over blocking without ranking.

VE_1 - variance of mean without ranking

VE_2 - variance of mean with ranking

In factorial experiments with large number of factors the number of treatment combination will be too many. In that case confounding of effects could be resorted to reduce the block size. The equation given by (a) could be made use of for finding out the efficiencies of various confounding systems.

The zero order intercorrelation matrix of different characters namely experimental yield (y), girth (x_1), spread (x_2) , height (x_3) and four years pre-experimental yield total (x_4) were calculated. In order to estimate the direct effect of each quantitative character on yield the standardised partial regression coefficients were calculated using the formula $b_i' = b_i \frac{s_i}{s_y}$

b_i' = standardised partial regression coefficient

s_i = standard deviation of the auxiliary variate

s_y = standard deviation of the main variate

b_i = partial regression coefficient of y_i on x_i

Standardised partial regression coefficient is independent of units of measurement. The coefficient of determination was calculated by using the relation

$$R^2 = \frac{\text{sum of squares due to regression}}{\text{total sum of squares}}$$

The significance of the multiple regression equation was tested by using F test with F (4,563) degrees of freedom.

Significance of partial regression coefficient was tested by using student's 't' test given by

$$t = \frac{b_i}{S.E.(b_i)}$$

SE of $(b_i) = \sqrt{c_{ii}s}$

SE(b_i) = standard error of the partial regression coefficient b_i

c_{ii}'s are diagonal elements of the inverted variance covariance matrix.

The fitted regression equation $y = b_0 + b_i x_i$ was used as a selection index for identifying trees of superior nature. An index value was calculated for each tree and the correlation coefficient between the selection index and the yield was found out.

Covariance analysis was performed by using different covariates. In the case of ranked trees the covariates used were girth and spread and in the non-ranked case index score and total yield for four pre-experimental years were used as covariates. Efficiency of covariance analysis was determined as follows:

SS due to yield (y) = A

S.S. due to regression of yield on the covariate x = P

$$\frac{SPXYE^2}{SSXE} = P$$

MSE without adjust $A/df_1 = E_1$

MSE with adjust $A-P/df_2 = E_2$

df_1 = degrees of freedom for error

df_2 = degrees of freedom for error-1

SPxye = sum of product of x on y from the error line

SSxe = sum of squares of x from the error line

Relative efficiency of covariance technique over local control $= \frac{E_1}{E_2} \times 100$

The procedure was also repeated with ranked trees.

RESULTS

RESULT

The yields of adjacent trees were combined together to form plots of 1, 2, 4, 6, 8 and 12 trees. Since a single tree was considered to be the sampling unit there was a serious limitation in varying the shape of the plot to all geometrical configurations. A fixed number k, of contiguous trees of the same row or column or alterations of square or rectangular arrangement of a cluster of k trees constituted a plot of size k. Plot length was defined in east-west direction and breadth in north-south direction. The mean, sum of squares, variance, standard deviation and coefficients of variation for various plot dimensions were worked out. The variability of plots of different sizes and shapes was estimated by using the coefficient of variation and is given in Table 1.

Size and shape of plots

Coefficient of variation was found to decrease consistently with an increase in plot size. CV was found to vary from 46.89 per cent to 116.85 per cent. The CV was highest in the case of single tree plots and lowest in 12 tree plots arranged in 3 rows each consisting of 4 trees. The shape of the plot did not seem to have any consistent effect on variability. For smaller plot sizes shape had some influence on variability. In 4 trees plots, a square arrangement of trees showed a variation of 79 per cent, while 4 trees arranged in row-wise and column wise directions showed only 61 and 67 per cent of variations respectively. But as the plot size increased shape of the plot did not seem to exert any appreciable effect on the precision of the estimate.

Size and shape of blocks

Adjacent plots were grouped to form blocks of different sizes, blocks of five different sizes namely, 2, 4, 6, 8 and 12 plots were formed by combining adjacent plots in various possible ways. Thus a block of size 4 was formed in 3 ways such as in a 1 x 4, 2 x 2 and 4 x 1 arrangements. The total, between and within sum of squares in each case was calculated and the "pooled within sum of squares" was found out for calculating variances and coefficient of variation. The percentage reduction in variability due to blocking was calculated as the ratio of between block sum of squares to total sum of squares. The significance of block variation was tested by using the F-test of significance(Table 2). The coefficient of variation of plots of different dimensions when arranged in blocks of 2, 4, 6, 8 and 12 plots are given in Table 3. The results showed that the CV decreased steadily with an increase in plot size irrespective of the shape of the plot. The minimum CV (36.77) was noticed in 2 plot blocks. Maximum CV (123.5) was also found in 2 plot blocks. As the block size increased the range of variation of CV decreased. In 12 plot blocks it was from 115 to 41. Coefficient of variation seems to be stable for the same plot size in different blocks.

The significance of the between block variation showed that environmental variation was not negligible and local control was effective in seperating and sorting out the components of variation arising from differences between blocks. It could be seen that efficiency of blocking decreased as the block size increased from 2 to 12. The maximum efficiency 65 per cent was observed in 2 plot block, while the minimum 28 per cent was observed in 12 plot blocks (Table 2).

Fair field Smith's variance law

The Fair field Smith's equation was fitted on the basis of observed variances of plot means both in the case when plots are grouped into blocks of various sizes and not grouped into blocks. The observed variances are given in table 4. The observed variances decreased with an increase in block size. The fitted equations were given in Table 5. The values of 'b' ranged from .975 to 0.8224 in the case when plots are arranged in blocks and 0.6843 when plots are not arranged. This indicated a very poor correlation between neighbouring units suggesting that positional variation was not as important as inherent genetic variation between the trees. It could also be seen that 'b' value showed a decreasing tendency as the block size increased. The value of 'b' was statistically significant in all the cases and the multiple correlation coefficients ranged from 0.96 to 0.98 as the block size increased from 2 to 12. It was 0.99 in the case of without blocking.

The intra-class correlation coefficients for plots of different sizes and shapes are given in Table 6. It could be seen that the intra-class correlation coefficient ranged from -0.44 to 0.49. This indicated that the correlation between plots of the same block was not high. It was foun that intra-class correlation decreased with an increase in plot size. It was also found that intra-class correlation coefficient increased with an increase in the block size and found to be maximum(0.49) in 12 plot blocks.

Block efficiency

The relative efficiency of blocks of different sizes as estimated from Fair field Smith's equation was given in Table $7_{(a)}$. Two plot blocks were found to be less efficient than 4 plot and 6 plot blocks, but more efficient than 8 plot and 12 plot blocks. The relative efficiencies of the unconfounded designs with different confounding systems are given in Table $7_{(b)}$ as estimated from the Fair field Smith's equation using an overall coefficient of heterogeneity equal to 0.6843. It can be seen that with 4 factors each at two levels the reduction of block size from 16 to 8 resulted in a gain of about 4.5 per cent and reduction from 16 to 4 resulted in a gain of 11 per cent in the unconfounded effects. In 2^5 factorial experiment a reduction from 32 to 8 resulted in a gain of 8 per cent. The gain in precision due to the use of incomplete blocks of size 9 in 3^3 factorial system is about 6 per cent. This calls for the use of incomplete block designs in planning experiments where large number of treatments are to be tested.

The expected variance of plot means based on plots of different sizes are given in table 8. The expected variances decreased with an increase in plot size. The maximum value (2.196) was found in 2 plot block for single tree plots. As the block size increased the range of variation decreased. In 2 plot blocks it ranged from 2.196 to 0.194, while in 12 plot blocks the reduction was from 1.931 to 0.250. The relative percentage information per tree for plots of different sizes is given in Table 9. As the efficiency of a plot size can be defined in terms of the relative percentage information per tree the optimum plot size is the one providing maximum amount of relative percentage information. It could be seen that the relative percentage information was maximum in single tree plots both in the case of arrangement in blocks and without blocking. The relative percentage information decreased from 100 to 45 when the plot size decreased from 1 to 12 When they are not grouped. When plots are arranged in blocks the relative percentage information decreased with an increase in plot size. The maximum relative percentage information (94) was found in 2 plot blocks with a plot size of 12 trees. The minimum value (64) was observed in 12 trees plots laid out in 12 plot blocks. Minimum relative percentage information was noticed in 12 tree plots in all the cases.

The number of replications required to provide estimates of population mean with 5 per cent standard error were calculated for grouped data and given in table 10. On the basis of the desired number of replications and the plot size the expected number of trees corresponding to various plot sizes have been worked out both in the case of grouped and ungrouped arrangements. The results indicated that single tree plots required the minimum experimental material. Since the best plot size can also be defined as the one which utilises the minimum of the resources for providing estimates with a given level of precision, this result brings to light the importance of single tree plots in conducting field experiments with cashew. With single tree plots which are not grouped into blocks, only 546 trees were required to provide estimates with 5 per cent standard error whereas 12 tree plots in a 4 x 3 arrangement required about 1416 trees for getting estimates with the same precision. The same is the case with grouped trees also. In 2 plot blocks the increase in the number of trees for single tree plots to 12 tree plots was from 610 to 649. The ranges of variation of trees for 4, 6, 8 and 12 plot blocks were 570 to 684, 558 to 685, 535 to 797 and 536 to 834 respectively.

Ranking of trees

The utility of pre-experimental data for efficient arrangement of plots and blocks and in covariance technique, for controlling experimental error was also examined. The plots were formed by calibrating the trees on the basis of the yield of the tree for the first four pre-experimental years immediately prior to the start of the experiment. The pre-experimental plot yield totals were arranged in order of merit and the first k such plots in order considered as constituting the first blocks of size k and the next k plots forming the next block and so on. The efficiency of blocking after ranking was compared with that of ordinary blocking in blocks of 4, 8 and 12 plots taking a single tree as the basic unit. The coefficient of variation of ranked data for plots of different sizes are given in Table 11.

It could be seen that the CV ranged from 78 to 23 as the plot size increased from 2 to 24. For a given plot size CV after ranking the data was lower than that of non-ranked data. For a plot of size 4 trees CV after ranking was found to be 45.5 per cent and that of non-ranked data was found to be 65 per cent. Thus there is a reduction of 20 per cent in variability in 4 plot blocks due to ranking of the trees according to the pre-experimental yields. Blocking was found to be very efficient in the case of ranked data. The block efficiencies for different block sizes for single tree plot blocks were given in Table 12. The block efficiency of 2 plot block was 99.6. The block efficiencies of 4, 6, 8, 12 and 24 plot blocks were 99.4, 98.9, 98.8, 98.3 and 95.4 respectively.

Correlation and regression

The correlation coefficients between experimental yield and different quantitative characters namely girth (x_1), height (x_2), spread (x_3) and four years pre-experimental yield total (x_4) were calculated (Table 13). Maximum correlation 0.4335 was found between four years pre-experimental yield total and experimental year's yield. Correlation coefficient of yield and girth and yield and spread were 0.3497 and 0.3689 respectively. All these correlation coefficients were found to be statistically significant.

The multiple regression equation of experimental year's yield on the above four characters was found to be statistically significant (Table 14). The coefficient of determination was rather low (0.22). Partial regression coefficients were computed and standardised. The standardised partial regression coefficients of girth, height, spread, pre-experimental year's yield on experimental year's yield were 0.2276, -0.1067, 0.0767 and 0.3206 respectively. The regression coefficients were tested for significance and all except the partial regression coefficient of experimental year's yield on spread was significant, as given in Table 15.

In order to identify trees of superior nature a selection index was evolved by substituting the corresponding parametric values in the fitted equation. The correlation between this index and the experimental year's yield was found to be 0.49 which is higher than that with other characters like girth, height, pre-experimental yield and spread.

Covariance analysis was done using different covariates in both ranking and non-ranking cases. The covariates used in the ranking method were spread and girth. In the non-ranked case selection index and pre-experimental year's yield total were the concomitant variates. The results are presented in Table 16 and 17. It was found that the gain in efficiency was 44 per cent in 4 plot block, when pre-experimental year's yield total was used as covariate. The efficiency decreased with an increase in plot size. As the plot size increased from 4 to 8 there was a reduction of 8 per cent in efficiency while when the plot size increased from 8 to 12 the reduction in efficiency was only 1 per cent. The maximum gain in precision in covariance analysis (54 per cent) was found when selection index was used as coveriate. As the plot size increased from 4 to 8 the reduction in efficiency was 6 per cent which was lesser than that for the same by using pre-experimental year's yield as the coveriate. But when the plot size increased from 8 to 12 the reduction was 3 per cent which was greater than that for the same by using pre-experimental year's yield as the covariate. The efficiency due to the analysis of covariance by using girth as covariate in ranked case was only 18 per cent (Table 18). The relative efficiencies decreased to 4 and 0.02 when the plot sise decreased from 4 to 8 and 8 to 12 respectively. The relative efficiencies by using spread as covariate were 108.94, 104.22, and 102.88 for 4, 8 and 12 plot blocks respectively (Table 19).

Number of pre-experimental periods

In order to find out the optimum number of pre-experimental periods the correlation coefficients between pre-experimental and experimental year's yield with a time lag of 1, 2, 3 and 4 years were calculated. The experimental year's yield was again correlated to the total of first 2, total of first 3, and total of first 4, pre-experimental year's yield and the correlation coefficients were given in Table 20. Maximum correlation coefficient was found between experimental years yield and total of 4 pre-experimental year's yield. It might be seen that there was only a subtle difference in correlation coefficient between two pre-experimental year's yield total and four pre-experimental year's yield total. The correlation coefficient between 3 years pre-experimental yield total and experimental year's yield was only 0.2444, while that between experimental yield and previous years yield was only .166. The minimum correlation coefficient(-.014) was noticed between experimental yield and pre-experimental yield with a time lag of 4 years.

Table 1.

Relationship between plot size and variability for ungrouped data.

Plot size	Plot shape	CV	Number of replications	Number of trees
1	1:1	116.85	546	546
2	1:2	88.32	311	622
	2:1	86.11	296	592
4	1:4	60.9	148	592
	4:1	67.59	182	728
	2:2	78.72	248	992
6	3:2	69.5	193	1158
	2:3	61.95	153	918
	1:6	60.83	148	888
	6:1	52.13	108	648
8	1:8	53.23	113	904
	8:1	50.69	102	822
	2:4	51.94	108	863
	4:2	56.42	127	1018
12	12:1	51.52	106	1272
	1:12	51.27	105	1260
	4:3	54.5	118	1416
	3:4	46.9	88	1056
	6:2	50.64	102	1224
	2:6	52.69	110	1320

Table 2.

Percentage reduction in sum of squares due to blocks of different sizes

Block size	Percentage reduction	F
2	65.96	2.981 **
4	54.2	4.012 **
6	40.91	4.331 **
8	36.81	5.662 **
12	28.22	7.319 **

Table 3.

Coefficient of variation of plots of different sizes with arrangement in blocks of varying sizes.

Plot size (Number of trees)	Number of plots per block				
	2	4	6	8	12
1	123.5	119.43	118.2	115.64	115.8
2	88.09	86.58	85.59	86.45	87.08
4	62.83	62.76	62.54	64.61	65.48
6	51.56	51.76	51.92	54.80	55.45
8	44.82	45.49	45.49	48.41	49.24
12	36.77	37.08	37.77	40.75	41.68

Table 4.

Observed variance of plot means based on plots of different sizes

Plot size (Number of trees)	Without blocking	Number of plots per block				
		2	4	6	8	12
1	2.0354	2.9355	2.4764	2.3263	2.2617	2.1815
2	1.1323	.905	.9234	.9119	.9795	.9803
4	.7033	.4452	.5174	.5541	.5133	.5854
6	.5656	.3033	.3682	.3849	.4189	.4358
8	.4414	.3854	.2664	.2573	.3025	.3158
12	.3869	.2339	.2571	.2462	.2972	.2919

Table 5.

Smith's equation fitted to the data

Number of plots per block	Fitted equation	r	r^2
2	$V(x) = 2.1966\ x^{-.9751^{**}}$	.9624	.9262
4	$V(x) = 2.0541\ x^{-.9283^{**}}$	.9820	.9643
6	$V(x) = 2.012\ x^{-.9184^{**}}$	.9864	.9730
8	$V(x) = 1.9257 x^{-.8398^{**}}$	.9808	.9620
12	$V(x) = 1.9311\ x^{-.8224^{**}}$	.9891	.9783
Without blocking	$V(x) = 1.887\ x^{-.68437^{**}}$	.9915	.9831

Table 6.
Relationship between plot size and intra-class correlation coefficient.

Plot size	Without blocking	Number of plots per block 2	4	6	8	12
2	-.4433	.2244	.3138	.4243	.3901	.4918
4	-.2180	.226	.2898	.4041	.3268	.4602
6	-.1202	.2256	.2660	.3611	.3352	.4024
8	-.1119	.0805	.2465	.3013	.2982	.3904
12	-.0736	.0879	.2498	.2986	.1936	.3260

Table 7(a)
Relative efficiencies of blocks of different sizes as estimated from Fair field Smith's equation.

Number of plots per block	Relative efficiency
4 vs2	1.018
6 vs2	1.014
8 vs2	.9805
12 vs2	.96001
6 vs4	.9964
8 vs4	1.023
12 vs4	1.130
8 vs6	1.027
12 vs6	1.019
12 vs8	.9935

Table 7(b)

Relative efficiency of unconfounded effects with different confounding systems

Factorial system	Block size	Relative efficiency
2^4	8	1.045
	4	1.109
2^5	16	1.032
	8	1.079
3^3	9	1.063

Table 8.

Expected variance of plot means computed from Fair field Smith's law

Plot size (Number of trees)	Without blocking	Number of plots per block				
		2	4	6	8	12
1	1.887	2.1967	2.054	2.012	1.9257	1.9311
2	1.174	1.1174	1.079	1.064	1.0761	1.092
4	.7307	.5684	.5671	.5632	.6031	.6175
6	.5536	.3828	.3892	.3981	.4278	.4424
8	.4547	.2892	.2980	.2980	.3360	.3492
12	.3445	.1947	.2048	.2054	.2391	.2502

Table 9.

Relative percentage information per tree for plots and blocks of different sizes

Plot size (Number of trees)	Without blocking	Number of plots per block				
		2	4	6	8	12
1	100	100	100	100	100	100
2	85.35	98.2	95.15	94.5	89.61	88.42
4	64.56	96.61	90.55	89.3	80.05	78.18
6	56.81	95.64	87.96	86.4	75.01	72.75
8	51.88	94.95	86.15	84.39	71.64	69.11
12	45.64	94.01	83.70	81.64	67.12	64.38

Table 10.

Number of replications and number of trees required for providing estimates with 5 per cent standard error when plots are arranged in blocks.

Plot size	Number of plots per block: 2		4		6		8		12	
	No.of replications	No.of trees	No.of replications	No.of treesc	No.of replications	No.of trees	No.of replications	No.of trees	No.of replications	No.of trees
1	610	610	570	570	558	558	535	535	536	536
2	310	620	300	600	296	591	299	598	304	607
4	158	631	158	632	157	625	167	668	172	686
6	107	642	108	649	108	647	120	721	123	738
8	80	643	83	662	83	663	93	747	97	776
12	54	649	57	684	57	685	64	797	69	834

Table 11.
Relationship between plot size and variability for ranked data.

Plot size	V(x)	CV
1	2.06	111.36
2	1.03	78.81
4	.5163	55.79
6	.3435	45.51
8	.2604	39.62
12	.1728	32.27
24	.0878	23.001

Table 12.
Efficiencies of blocks of different sizes for ranked data

Number of plots per block	Percentage reduction due to blocking
2	99.6
4	99.4
6	98.92
8	98.84
12	98.34
24	95.40

Table 13.

Correlation matrix of different plant characters in cashew

	Y	X_1	X_2	X_3	X_4
X_1	.3497**				
X_2	.1871**	.6786**			
X_3	.3699**	.7286**	.5965**		
X_4	.4335**	.4349**	.2935**	.5971**	

Table 14.

Analysis of variance of regression of experimental year's yield on certain quantitative traits in cashew

Source	df	SS	MS	F
Regression	4	2.6098	.6525	41.2975**
Error	563	8.9058	.0158	
Total	567	11.5155		

** Significant at 0.01 per cent level.

Table 15.

Partial regression coefficients and their standard errors

Name of the character	Partial regression coefficients	Standardised partial regression coefficients	Standard errors	t
Girth	.0586	.2276	.0156	3.75**
Height	-.0039	-.1067	.0019	-2.053*
Spread	.0016	.0762	.0013	1.215NS
Pre-experimental years yield total	.1862	.3206	.0270	6.91**

** Significant at 0.01 per cent level

* Significant at 0.05 per cent level

NS Statistically non significant

Table 16.

Analysis of covariance of cashew yield data using pre-experimental yield (x4) as covariate without ranking

No.of plots per block	Unadjusted MSE	Percentage reduction due to covariance	Adjusted MSE	Efficiency	Gain in precision
4	9.0476	30.35	6.30	143.59	44
8	9.5974	26.49	7.0594	135.76	36
12	9.6355	26.14	7.1306	135.13	35

Table 17.

Analysis of covariance of cashew yield data using selection index(S) as covariate in without ranking

No.of plots per block	Unadjusted MSE	Percentage reduction due to covariance	Adjusted MSE	Efficiency	Gain in precision
4	9.0476	35.36	5.8623	154.34	54.34
8	9.5974	32.97	6.4456	148.90	48.9
12	9.6355	31.33	6.9450	145.34	45.34

Table 18.

Analysis of covariance of cashew yield data using girth as a covariate in ranked case

No.of plots per block	Unadjusted MSE	Percentage reduction due to covariance	Adjusted MSE	Efficiency	Gain in preci-sion
4	.2449	16.04	.2061	118.84	18.84
8	.4352	4.22	.4178	104.19	4.19
12	.4939	2.18	.4937	100.02	.02

Table 19.

Analysis of covariance of cashew yield data using spread as covariate in ranked case

No.of plots per block	Unadjusted MSE	Percentage reduction due to covariance	Adjusted MSE	Efficiency	Gain in precision
4	.2449	8.39	.2249	108.9	8.94
8	.4352	4.249	.4176	104.2	4.22
12	.4939	2.703	.4814	102.58	2.58

Table 20.

Correlation coefficients of experimental yield data with pre-experimental yield data for different periods

Pre-experimental period	Correlation coefficient
t_1	.1668**
t_2	.3103**
t_3	.1218**
t_4	-.014^{NS}
t_1+t_2	.4332**
$t_1+t_2+t_3$	.2444**
$t_1+t_2+t_3+t_4$	.4335**

DISCUSSION

DISCUSSION

The importance ofoptimum size and shape of plots and blocks for the efficient planning of field experiments is widely known. The size and shape and of plots depends generally on the variability present in the crop and the environment in which it is grown. Lot of work has been done for standardising the technique of field experimentation of annual crops. But in the case of perennial fruit trees and other plantation crops the work done is meagre. With regard to cashew no attempt has been done so far for standardising the field plot technique. The technique developed for annuals cannot be applied to perennials due to the inherent hetrogenity of the planting material. Large plot sizes or number of replications cannot be adopted due to the high cost of experimentation. The result obtained in fixing the size and shape of plots and blocks, number of replications, calibrating variables, optimum number of pre-experimental periods etc are discussed here.

Size and shape of plots

The analysis of the uniformity trial data on cashew showed that CV decreased with an increase in plot size, coefficients of variation for different plot sizes and shapes varied from 46.89 to 116.85. Thus there existed a considerable amount of variability between the yields of individual trees eventhough they were raised from the same parental stock. In other words, a large amount of variation was due to individual tree differences rather than difference between plots with regard to soil fertility. There was much difference in CV with different shapes of plot for a fixed size of plot. A difference of only 2 per cent was observed in two tree plots while arranging them in row wise and column wise directions. But as the plot size increased it was found that CV had a little effect on the shape of the plot. The above results were in agreement with the findings of Prabhakaran et al. (1972), Sardana et al. (1967), Smith, H.F. (1938), Abraham et al. (1964), Saxeena et al. (1972) and Rambabu et al. (1980) in various crops. In 4 tree plots a square arrangement of trees was found to give a higher CV as compared to rectangular arrangement. In 12 plot blocks an arrangement of trees in three rows and four columns was found to give the lowest CV as compared to other possible arrangements.

It seems that an almost square arrangement of plots is advantagoous for reducing variability with large plots. But when very small plots are used rectangular plots are expected to be more advantageous. In 6 plot and 8 plot blocks not much difference in CV was observed between rectangular and almost square arrangement of plots. In 6 plot and 8 plot blocks CV was found to cluster around 50 to 60 per cent. Therefore if plots of medium size were to be used any arrangement of plots could be adopted. When border rows are to be alloted it is advisable to use square plots because square plots give minimum perimeter for a given plot size. For example a net plot of 4 trees in rectangular arrangement required altogether 18 trees in the gross plot while a square arrangement of 4 trees required only 16 trees in gross plot.

It can be seen that the relative percentage information was maximum for single tree plots both in the case when plots are arranged in blocks and also without arranging them in blocks. Thus single tree plots are the most efficient ones in conducting field trials on cashew. The results were in agreement with the findings of Agarwal et al. (1968), Menon et al. (1971), Prabhakaran et al. (1978), and Narayanan (1966) in certain perennial crops.

Since single tree plots provide maximum information we can safely recommend single tree plots for conducting field experiments with cashew. But one disadvantage of single tree plots is that the experimenter has to sacrifice the entire information from the plot on account of missing a single tree from the plot. As an alternative suggestion, two tree plots can also be recommended because the loss in information due to 2 tree plots as compared to single tree plots was not appreciable. A maximum loss of information of about 12 per cent was noticed in 12 plot blocks as the plot size increased from 1 to 12 trees. Thus with larger blocks increasing plot size did not seem to have any beneficial effect in reducing the variability, but in smaller blocks plots of various sizes might be used without much loss in information. Thus in 2 plot or 4 plot blocks 2 trees or even 4 trees plots could be used without much loss in precision. Larger plots are more convenient to conduct agricultural operations.

Practical convenience often give place to experimental precision. But with larger blocks single tree plots were found to be the most efficient and would be used unless the experimenter fears that some of the trees might be destroyed in the course of the experiment, due to some unforeseen causes, in that case 2 tree plots could also be used as an alternative to single tree plots. For a given number of trees the method of increasing replications per treatment was found to be more advantageous than the method of increasing the plot size. So wherever possible the minimum plot size should be used by providing the maximum number of replications per treatment.

Block efficiency

It was found that size of the block had a very little influence on CV. In smaller plots CV was found to decrease with an increase in block size, but as the plot size increased the trend was just the reverse. The statistical significance of between block variation showed that environmental variation was not negligible and local control was effective in seperating and sorting out the components of variation arising due to differences between blocks. The percentage variation removed by blocks of different sizes was found to decrease with an increase in plot size. But the rate of decrease was rather slow from 2 plot to 4 plot blocks. This indicated the need for employing indirect methods of controlling experimental error such as calibration and covariance, especially when a large number of treatments are to be compared.

Efficiency of confounding

In experiments where a large number of treatments are to be tested the device of confounding is usually adopted for reducing block size and improving the precision of the estimate. It was found that confounded designs were more efficient than the corresponding unconfounded designs in the sense that they gave a lower variance of plot means as compared to complete block designs. The relative efficiency was found to increase with a decrease in block size. The results calls for the use of confounded factorial experiments when the experimenter is confronted with the problem of testing several factors simultaneously at 2 or more levels, especially in manurial trials. In varietal trials the use of incomplete block designs was found to be more advantagous as compared to the use of corresponding complete block designs.

Fair field Smith's variance law

Fair field Smith's equation was fitted on the basis of observed variances of plot means in both cases when plots are arranged in blocks and when they are not arranged. The values of the coefficient 'b' was found to very from .97 to .82 as the plot size increased from 2 to 12 in the case when plots are arranged in blocks. When plots are not arranged the value of b was found to be .68 . These results were similar to those obtained by Prabhakaran __et al.__ (1978) in banana and Menon __et al.__

(1971) in mandarin orange.

Moreover 90 per cent of variation of plot yields could be explained by Fair field Smith's equation in each of the cases of grouped and ungrouped trees. From this high 'b' values it could be infered that the contiguous units were not strongly correlated. Therefore, positional variation was not as predominant as the genotypic variation. If the site is homogeneous then the entire variation of the experimental material is expected to be contributed by the genetic make up of the trees.

Calibration of trees and the control of error

As a means of controlling genetic variation among trees, the trees were ranked according to their past performance and the analysis of ranked data indicated that considerable amount of variation could be removed by the above procedure. It was also found that the above method of ranking was very efficient with plots of smaller size, but its efficiency decreased with larger plots. However the method of ranking was found to be superior to ordinary unordered arrangement. Apart from the direct methods like blocking, local control etc for controlling experimental variation ranking is also found to be a satisfactory measure for reducing the error. It is a rather simple and operationally convenient procedure and can be easily performed by the research worker than the techniques of covariance. It was found that more than 95 per cent of variation could be removed by arranging the trees in order according to their past performance. Hence ranking of trees and grouping into different blocks can be recommended as an effective method of controlling experimental variation involved in field experiments with cashew.

Analysis of covariance with ranked data

As an additional method to reduce the error variance covariance analysis was performed with ranked data and the result indicated that girth can be taken as an efficient covariate. But the efficiency of girth as covariate was found to decrease with an increase in plot size. Spread was found to be a more efficient covariate than girth in large plot blocks. However the use of covariance analysis with larger blocks did not seem to affect a substantial reduction in the experimental error. This result is in agreement with the results obtained by Narayanan (1966) on rubber. Menon and Tyagi (1971) in field experiments with mandarian orange found that the largest gain in precision could be obtained by taking spread as an auxiliary variate. This contradicts with our results. This may be due to the differense in morphological characters of mandarin orange and cashew. He also reported that gain in precision due to covariance analysis by using trunk girth as a covariate was not appreciable. But in field experiments with cashew girth served as better covariate than spread. The efficiency of covariance analysis decreased with an increase in plot size irrespective of the nature of covariates. This was in agreement with the findings of Pankajakshan (1966) who found that covariance technique was used only upto 10 tree plots.

Correlation analysis and selection index

The correlation analysis of yield and its component characters showed that yield was positively correlated with girth, height, spread and pre-experimental yield. Among these characters pre-experimental yield was the most prominent character contributing to variations in yield. All these characters were intercorrelated. Therefore it might happen that correlation between yield and any one of these characters might be caused by the relationship of the particular character with another character which was also correlated with yield. So the standardised partial regression coefficients were calculated to assess the direct effect of each character on yield. The direct effect of height on yield was found to be negative indicating that taller trees on the average are likely to exhibit relatively low yielding potentiality when other characters are kept constant at their mean levels. The other three characters exhibited positive liner relationships with yield.

Among the different characters the most important character contributing to variations in tree yield is past performance of the tree. A 100 per cent increase in pre-experimental yield is expected to provides a 32 per cent variation in the actual experimental years yield. Girth is the next important factor in determining the productivity of a tree. It is about two third as important as the pre-experimental yield. This result brings to light the importance of girth as an additional covariate for analysis of coveriance in cashew. In order to give due weightage to these characters in measuring the inherent yielding potentiality of the trees a selection index was developed.

The index value of each tree was calculated and they were correlated with the experimental yield. The correlation coefficient obtained was higher than that obtained by using pre-experimental yield as the covariate. Covariance analysis with 4 years pre-experimental yield data as the covariate was found to reduce the error variance by 44 per cent. Whereas the use of selection index as the covariate was found to reduce the error variance by 54 per cent. This is in agreement with the findings of Abeywardena (1970) in coconut. This suggests a more powerful calibrating variable for covariance analysis. Instead of using pre-experimental yield as the covariate the index values for each tree obtained from this selection index can be more effectively used for reducing experimental error.

Optimum number of pre-experimental periods

One pre-experimental period, that is two consecutive years immediately prior to start of the experiment was found to be sufficient to control the error through covariance technique. A single year's yield immediately prior to start of the experiment was not strongly correlated with experimental yield. This may be due to biennial tendency of the crop. Past data for four consecutive years could also be used effectively for calibration.

But such procedure if adopted, would result in unnecessary time lag wherever such data are not available and the ultimate gain in precision over the use of two years data might be quite negligible. Thus for all practical purposes data for two pre-experimental period immediately prior to start of the experiment may be collected and utilised for the control of genetic variation through the techniques of calibration and covariance. This result is in agreement with the findings of Kulkarni and Abraham (1963) on arecanut.

SUMMARY

SUMMARY

Investigations on different aspects of field experimentation on cashew with reference to size and shape of plots were undertaken using the data collected from available records of Cashew Research Station, Madakathara for a period of five years starting from 1976 and the results obtained are summarised below.

Considerable variability was observed in the yields of trees even though they were raised from the same parental stock. The coefficient of variability ranged from 46.89 to 116.85 in the case of ungrouped data.

Shape of the plot did not seem to have a consistent effect on CV especially in large plot blocks.

The relative percentage information was found to be maximum in single tree plots both in the case when the plots are arranged in blocks and when they are not arranged. Therefore single tree plots could be recommended for conducting field experiments on cashew. In order to avoid the enhanced chance of loss in information with single tree plots as an alternative suggestion two tree plots could also be used for conducting field experiments on cashew.

It was observed that two plot blocks were the most efficient for conducting field experiments on cashew.

The efficiency of blockingdecreased with an increase in plot size. The significance of block variation revealed that environmental variation was not negligible and local control was effective in controlling experimental variation.

The Fair field Smith's equation gave a good fit to the data both in the cases when the plots are arranged in blocks and not arranged. The coefficient of determination was found to be more than 90 per cent in both the above cases. It could also be seen that value of the heterogeneity coefficient 'b' showed a decreasing tendency as the block size increased. The relatively high value of the parameter 'b' indicated that genotypic variation was more predominant than positional variation.

It could be seen that experimental error could be considerably reduced by the use of incomplete block designs. in 2^4 experiment a reduction of block size from 6 to 8 resulted a gain in precision of 4.5 per cent while a reduction from 16 to 4 enhanced the precision to 11 per cent. In 3^3 system a reduction of block size to 9 by the device of confounding resulted a 6 per cent gain in precision.

The number of replications required to provide estimates with a given level of precision decreased with an increase in plot size. But for a given experimental material an increase in number of replications rather than plot size was found to provide more precise information.

As a means of controlling the inherent genotypic variation of the trees, the trees were ranked according to their past performance and the analysis of the ranked data showed that the method of ranking could be used as an effective tool in reducing the experimental error in field trials with cashew. The efficiency of local control was found to be significant with ranked data and it decreased uniformly with an increase in number of plots per block. The coefficient of variation of the ranked data was found to be lesser than that of non-ranked data in all plot sizes.

Correlation studies on different characters revealed that pre-experimental year's yield total was the most contributing character to variations in yield. Among the different morphological characters, trunk girth of the tree was found to be the major factor contributing to variations in yield even though mean spread of the tree was also found to be strongly correlated with yield regression analysis of the data revealed that influence of this character on yield was not direct but through other characters.

A selection index evolved from the fitted regression equation was found to be strongly correlated with the experim ntal yield. The correlation coefficient observed was higher than that for other yield contributing characters. This showed that selection index could be used as a more efficient calibrating variate than trunk girth and pre-experimental yield.

Analysis of covariance performed on the non-ranked data using the pre-experimental yield and selection index as covariates showed that selection index was a better covariate than pre-experimental yield for reducing variations in experimental yield. In both the cases analysis of covariance resulted in a considerable gain in precision and its efficiency decreased with an increase in plot size. Analysis of covariance performed with ranked data using girth and spread as covariates revealed that girth could be served as an efficient covariate especially in small plot blocks. If a large number of treatments are to be tested and consequently blocks of larger sizes are to be used, then ranking and grouping of trees into blocks according to pre-experimental yield is sufficient as the additional gain in precision owing to the use of analysis of covariance is only negligible.

Total of the pre-experimental yield data for two years immediately prior to the start of the experiment was found to be sufficient for controlling experimental error variance by the use of analysis of covariance. Four year's pre-experimental yield total can also be used as an effective calibrating variate with a slight advantage over the former. But a single year's yield data immediately prior to start of the experiment was not found to serve as an efficient covariate. This may be due to the biennial tendency of the crop.

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DETERMINATION OF THE SIZE AND SHAPE OF PLOTS FOR TRIALS ON CASHEW

BY
REMESH B. NAIR

ABSTRACT OF A THESIS

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ABSTRACT

The present study whose objective is to evaluate the problems concerned with field experimentation on cashew was undertaken using the yield records of 625 uniformly treated cashew trees collected from cashew research station, Madakathara for a period of five years starting from 1976. A single row of trees was discarded on either side of the experimental field to eliminate border effect. Thus the experimental material consisted of 576 trees raised from same parental stock in a 24 x 24 compact block arrangement. The period 1976 to 1980 for which there was no change in treatment was considered to be the pre-experimental period and the year following the application of treatment was considered to be the experimental period. Observations on certain yield contributing characters pertaining to the year 1978 to 1979, such as height, spread and trunk girth were also gathered.

Plots of different sizes and shapes were formed by combining yields of adjoining trees in various possible ways, a single tree being considered as the ultimate unit. The plots were grouped into blocks of different sizes and CV was worked out for plots of different dimensions

when plots were arranged in blocks and not arranged.

The trees were found to be highly heterogenous even though they were raised from the same parental stock. Single tree plots were found to be the most efficient when viewed from the point of view of maximum relative percentage information and consequently could be recommended for conducting field experiments on cashew. Two tree plots could also be recommended due to certain practical considerations. Shape of plot did not seem to have a consistent effect on variability.

Fair field Smith's equation gave a good fit to the data and the parameter 'b' was found to be high in both the cases when trees are arranged in blocks and when they are not arranged. It was observed that 2 plot blocks were the most efficient for conducting field experiments on cashew. The efficiency of blocking decreased with an increase in plot size.

The result showed that experimental error could be considerably reduced by the use of incomplete block designs. As an effective method of controlling tree to tree variation, the method of ranking based on their past performance can be adopted. Efficiency of local control was considerably increased by ranking of trees as compared to mere grouping of trees with respect to their geographical contiguity. Pre-experimental year's yield was found to be the most important yield contributing character. Trunk girth of tree was also found to have significant influence on the inherent yielding ability of the trees.

A selection index evolved was found to be strongly correlated with experimental yield. The correlation coefficient observed for this variate was higher than that for other yield contributing characters. Maximum efficiency in analysis of covariance was noted by using selection index as covariate. Efficiency of covariance analysis decreased with an increase in plot size. The optimum pre-experimental period for calibration and covariance analysis was found to be two year's immediately prior to the start of the experiment.