STANDARDIZATION OF FIELD PLOT TECHNIQUE FOR CASHEW

BY

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DECLARATION

I hereby declare that this thesis entitled "STANDARDIZATION OF FIELD PLOT TECHNIQUE FOR 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.

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Certified that this thesis, entitled "STANDARDIZATION OF FIELD PLOT TECHNIQUE FOR CASHEW" is a record of research work done independently by Kumari LUCYAMMA MATHEW under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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INTRODUCTION

CHAPTER 1

INTRODUCTION

Perennial and semiperennial plants such as orchard and plantation crops, sugarcane, bananas, tropical fodder grasses, etc. present to the field experimentalist, additional problems not encountered in dealing with ordinary annual field crops. The extreme type of these perennials is found in the fruit orchard where the yield data come from a limited number of relatively large trees. The trees themselves are generally far from uniform in their genetical composition and, consequently, in their yield potential. In orchards there will generally be several age groups. Even if all the trees are of the same age, it is usual that some bear early and may reach their maximum early while others may be late in bearing but continue to yield heavily for a much longer period. The trees are widely spaced, and a relatively small number can be included in a single plot as apart from the question of acreage available, if plots are made too large, the major soil fertility differences within the blocks will counteract the advantage gained by increasing the number of trees per plot. Even where the number of trees is reduced to a minimum the plot size at an average spacing of 7.0 m will be in the neighbourhood of 700 to 1000 m^2 and the effects of soil differences within the plots will be considerable.

The root spread per plant is extensive and makes the inclusion of non-experimental border trees essential to avoid edge interference. The crop is perennial, and the differential response of individual plants to the varying weather conditions from year to year introduces a further source of variation. The yield data alone do not necessarily measure the whole effect of any particular treatment. The quality of the produce is often as important as the quantity. The rate of growth, root-spread, susceptibility to pests and diseases, etc. may be greatly improved without any immediate effect being reflected on the yield data.

In designing experiments on perennial crops, size of plot, layout, uniformity of plants, recording of data, all require careful consideration. Efficient planning of field experiments also depends on the knowledge of inherent variability present in the experimental material. Since much of the variation in a plantation may be from sources other than environmental, the study of size and shape of plots is not as important as that of annual crops, but even so it should not be neglected. In perennials individual trees assume more importance. So the method of arrangement of individual trees to reduce experimental error to the maximum is of prime concern.

Cashew (Anacardium occidentale L.) being a perennial tree is far different from annuals, needs special statistical considerations in planning experiments with them. The fact that it lives longer and is thus more susceptable to mishaps needs greater caution to be bestowed in designing experiments with them. Due to the fairly large size of the tree and by virtue of its individuality the influence of genetic variation is more pronounced than positional variation. So in field experiments on perennials we should give more emphasize on the variability present in the crop than with environmental factors. The vegetative method of propagation is likely to produce trees true to type and the planting material should be derived from the same parent stock. Where the experiment Is to be superimposed on established plantations, a locality in which the trees are all of same age group shall be selected.

It is highly desirable that the plant material used for any field experimentation should be as homogeneous as possible with respect to yield is concerned. Cashew being a highly cross-pollinated (uncontrolled method of pollination) crop the possibility of varied vigour due to varied behaviour of parental combination is common. Such a varied vigour of plants brings in an error due to genetic variation. In agronomic experiment the variability can be reduced by including a large number of plants in a plot.

Because of the heterogeneous nature of perennial plants, a design which take into account the maximum benefit from heterogeneity is most important. Having decided on an optimum plot size, orientation of plots in blocks is known to have profound influence on experimental error. This necessitates the choice of an efficient design.

In deciding upon the type of design it should be remembered that statistical considerations, though very important are never paramount. The design used must be need based and situation specific. The true aim of the design of experiment is to reduce experimental error as far as possible and to obtain desired information as precise as possible with ease.

One special problem associated with perennial crops is that of their biennial or other cyclic fruit bearing tendency. In one year the tree yields heavily, in the next year its activity confines chiefly in growth, in a third year it returns to cropping and so on. In such cases where there is a tendency to yield heavily every alternate year, statistical analysis applied to the combined yield of plots for two consecutive harvests has obvious advantage.

To sum up, perennial plants have their own problems in field experimentation. They are usually larger and need more to be regarded as individuals rather than a group. Not least, by their longevity they raise questions about the source of variation, which may well receive differing answers as the trees develop and some sources wax where others wane.

The general method of laying out experiments by taking compact blocks does not seem feasible in experiments with adult trees because of the high genic variability in the individual trees. The present practice is to form blocks with trees having uniform yield, the real aim being to reduce the variation within blocks. We can think of methods which reduce the within block variation by increasing the within plot variation, following the methods applied in selecting samples by cluster sampling technique. It has shown that cluster sampling will be more efficient if the clusters are formed with heterogeneous elements (Sukhatme et al. 1984). So, whatever be the influence of environment and previous nutrition on the tree, the within block variation will be reduced by increasing the within plot variation. Thus the present method of forming plots by increasing the within plot variation is aimed with the following objectives.

1. To solve the difficulty of getting homogeneous experimental trees with respect to character yield in forming blocks.

2. To make the maximum use of trees with heterogeneous yield from a plantation or an area, by adopting the principle of cluster sampling with negative correlation, with the aim of reducing the between plot variation within a block.

3. To fix the optimum number of plants per plot and the number of plots per block.

REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

Perennial plants and fruit trees are, in general far different from annual crops. Eventhough much work has been done in evaluating the optimum size and shape of plots in annual crops, only very little work has been done on perennials. The wide variability present with the experimental material makes it virtually impossible for the experimenter to transfer the results of studies from one place to another. In annual crops the contribution of biological variation is less as compared to perennials because of the large plant population involved. In the present study of 'Standardization of field plot technique for cashew', maximum consideration is given for the inherent variability present in the experimental material. In perennial crops the data are collected for a number of years from the same tree, so error due to environmental differences will build up with time and small differences in growth rate can be important.

2.1 Plant-to-plant variation

The earliest work to discover the relative importance of various sources of error was that of Smith (1938). He pointed out that if variation comes from the plants and if they have been allocated to their position at random, the variance of mean per tree as determined from a plot of 'x' trees should be that of the individual plants divided by x.

$$\text{i.e. } V_x = \frac{V_1}{x}$$

But infact it more usually follows the law

$V_x = \frac{V_1}{x^b}$ where b takes some value between zero and one.

The argument was later taken further by Pearce (1955). If the variation is infact made up of two parts, one due to environment as given by Fairfield Smith's law and the other due to plant themselves.

$$\text{i.e. } V_x = \frac{V_1}{x^b} + \frac{V_2}{x}$$

where V_1 - the inherent variability to be assessed.

V_2 - the variation between individual trees, due to position corresponds to genetic and environmental component of the total variation.

V_x - variation per unit area between plot size 'x'.

If the second term dominates there will be no correlation between performance of neighbours.

Shrikande (1958) from his investigations on the relative contribution of genetic and environmental factors to the total variation in yield between trees of coconut (Cocos nucifera), observed that the genetic variation between trees is a more potential source of error than environmental variation. This investigation was based on the main assumption that the genetic and environmental effects on the phenotype are additive and independent and that the average yield 'y' of a tree over an even number of consecutive years can be expressed as

$Y = G + E$ where

G - contribution due to genotype

E - the contribution due to environment.

Bavappa (1959) showed that arecanut being a highly cross-fertilised crop the possibility of seednut gathered from open pollinated nuts breeding true to their mother palm is rather remote. Certain parental combinations can possibly produce seedlings with better vigour than certain others. Such varied behaviour of parental combination brings in an error due to genetic variation.

Pankajakshan (1960) found that the earlier report of Shrikande (1958) that the genetic variation between trees is a more potential source of error than environmental variation, does not seem to hold good in all cases considered. It was seen that genetic and environmental component of the total variation between trees are in the ratio 3:2 for averages based on two years and 1:1 for four years. For six and eight year period the ratio changes to 2:3 and it shifts to 1:2 for the ten year period, thus indicating that environmental component is more important for periods higher than four years.

Pearce and Moore (1962) studied the variability of apple trees using a statistical method and it appears that variation of trees at planting does not persist for more than a few years, but that sources of variation of continuing effectiveness can build up large differences between trees. It was also found that variability builds up more in poor conditions than in good.

The empirical relationship given by Smith (1938) was modified by Freeman (1963) to take account of plant variation. If V_x is the total variance per plant of a plot of x plants them $V_x = \frac{V_1^1}{x^b} + \frac{V^{11}}{x}$ where

V^{11} - variance of a single plant

If $V_1^1 = V_1 \alpha$ and

$V^{11} = V_1 (1 - \alpha)$, α being the proportion due to environment of the variance of a unit plot can be re-written as $V_x = \frac{V_1 \alpha}{x^b} + \frac{V_1 (1 - \alpha)}{x}$

A previous study on variability of apple trees, has been extended to a study of variation in oranges, peaches, cocoa, cherries and peans by Moore (1968). Study revealed that variation at planting does not persist and is eliminated by the time the trees have increased their girth fourfold.

Abraham et al. (1969) in their study with uniformly treated blackpepper at two pepper gardens in different regions having different climate, soils etc., the optimum size obtained at these places indicated that, the optimum size of plot is invariant under different climatic soil and other conditions. Inspite of this invariance, the actual number of standards required for a given precision was vastly different in the two gardens because it depends on the specific variability. This latter inherent specific variability needs to be determined for application of these results in individual garden.

Singh et al. (1975) discussed the genetical contribution while analysing the results relating to perennial crops like arecanut, mango, coconut, blackpepper, orange, apple and banana.

Nair (1983) observed considerable variability in the yields of cashew despite the fact that all trees raised from same parental stock.

2.2 Biennial bearing tendency

One special problem associated with perennial crops is its alternate bearing tendency. In the 'on' year the tree crops heavily, in the off year its activity lies chiefly in growth and in the third year it returns to cropping and so on. Most perennial crops are in some extend biennial in cropping and growth and consequently periods containing an odd number of years are rarely comparable one with another. So if the time taken by the experiment is to be divided into periods, it is best for them to be equal in length and for each to cover an even number of seasons (Pearce 1976).

Haldane (1958) commented on repeated biennial tendency on coconut and felt that it is important to know if this is a sharply defined character, and whether this is an inherited character or whether it can be overcome by the use of fertilisers.

Shrikande (1958) and Pankajakshan (1960) have made passing references about the biennial tendency in coconut.

Singh (1961a) studied the biennial bearing in mango, concluded that biennial habit of mango cannot be prevented by resorting to manuring, irrigation, pruning and control of pest, nor it is affected by vigour of varieties or the major climatic factor, rainfall and temperatures. It was also evident from the findings that exact cause of biennial bearing is not yet known and till it is fully discovered. Thus the first attempt towards the control of phenomenon will be to determine the exact cause of fruit bud differentiation.

During the course of study of biennial bearing studies in mango, Singh (1961b) found that biennial bearing is governed by the timely production of new vegetative shoots.

Method of estimating biennial bearing tendency in cashew through correlation studies has been established by Northwood (1967). The low correlation coefficient between years suggest a tendency towards alternate bearing.

Various methods for the measurement of irregular and biennial phenomena in apple trees were considered by Pearce and Urbanc (1967).

An attempt has been made by Saraswathi (1983) to derive appropriate test of significance to detect bienniality and time trend in coconut. The study established the fact that bienniality is a significant feature of coconut palms. The presence of bienniality was also tested by a non-parametric approach. This method also revealed the effect of bienniality but over estimated its presence.

2.3 Optimum size of plot

Experimental plot refers to the unit on which random assignment of treatment is made. Size of plot in perennials refers to the number of plants in a plot.

An important consideration in determining plot size must always be the kind of record that it is proposed to make (Pearce 1976). Plot size must also be considered in the light of possible losses of trees. In the analysis of data completely missing plots are manageable provided these are not too many of them, at the other extreme, no irreparable harm is done if one or two plants die in a plot of say, twelve or more. Difficulty is however caused by a tree being lost from a medium sized plot.

Gadd (1922) working on the experimental errors of field trials with Hevea (Rubber) found that 16 tree plots gave low probable error expressed as a percentage of mean and that the increase in size of plot above 16 gave in comparison only a small reduction of probable error. The same author while reviewing the uniformity of probable errors stated that there is a large diversity with reference to probable error as given by different workers showing thereby that the value will probably vary with parentage of trees, then age and conditions under which they are grown.

On account of the wide spacing required by most orchard crops, plots of larger size than those recommended for annual crops will usually be necessary. Each plot should contain 10 or more trees, with an average orchard spacing, this will give a plot size of approximately 1/6 acre (Patterson 1939).

Pearce and Thom (1950) studied the optimum plot size for apple experiments with no guard rows. One tree plot gave most information per tree and it was taken as optimum plot size.

Sharpe and Blackmon (1950) recommended single tree plots with pecan yield data.

Pearce and Thom (1951) found with cacao that plots should be as small as possible.

Pearce (1953) while cataloguing the uniformity trials conducted by different workers with reference to various perennial crops stated that the choice of the plot size would depend entirely on circumstances. He also stated that in any experiment the source of each plant should be known and if it is not practicable to use plants from only one source either each block should be made up in this way or a Pseudovariate used to eliminate possible differences.

Conagin and Fraga (1955) working on coffee with two plot sizes of nine and four found that smaller plots were efficient in eliminating differences in soil fertility.

Shrikande (1958) formed plots of uniform yield. This usually presents difficulty in getting homogeneous experimental material. Also it necessitates the yield of pre-experimental data.

Bavappa (1959) in his studies with arecanut, 24 seedling plot was found to be optimum plot size for nursery experiment. While selecting nuts for experiments care may be taken to select nuts of the most commonly occurring ecotype from middle aged or older palms and from the same order of bunch so as to reduce the error variance.

Working on tea Dutta and Heath (1960) found plots of size 30-45 bushes were optimum because smaller ones would cause difficulties of weighing.

Butters (1964) studied the variation in yields of robusta coffee found that the optimum plot size varies slightly with spacing, but practical circumstances permitting a nine tree plot (3 x 3) appears to be most suitable.

Narayanan (1965) recommended plots of medium size for rubber.

Agarwal et al. (1968) worked out the optimum plot size for arecanut. For arecanut with a single guard row, a plot of size 6 trees was found to be optimum.

Abraham et al. (1969) in their study with uniformly treated blackpepper found that with a given experimental area, the smallest plot with a single standard was more efficient. They also observed that taking guard rows into consideration a plot size of two standard was optimum with one guard row, while plot size between 6 to 8 were optimum with double guard rows.

By analysis of pattern of variability in the yield of mandarin orange Menon and Tyagi (1971) studied the relative efficiencies of various sizes and shapes of plots and single tree plots were found to be optimum size. Agarwal (1973) studied the optimum size of plot in apple and it was found that 10 trees per cluster as optimum.

Bhargava and Sardana (1975) working with apple crop found that single tree plots was most efficient. It was also found that for 20 percentage SE (standard error) of the mean, the number of replications decreases with increase in the size of the plot for all block sizes, however the total experimental material required was minimum when a single tree experimental unit was adopted.

Bhargava et al. (1978) studied the optimum size and shape of plot on banana and it was found that for 3 percentage SE of the mean unit plot size was the optimum plot size.

Prabhakaran et al. (1978) analysed a uniformity trial on banana for finding the optimum plot size and the result showed that single plant plots were most efficient. However as banana plants are liable for disease incidence three plant plots were suggested for experiment.

Nair (1983) studied the optimum size of plot for cashew and found that one tree plot as optimum since relative percentage of information was maximal in single tree plot irrespective whether the plots were arranged in blocks or not and single tree plots were considered optimum for field experiments. Plots of differrent sizes and shapes were formed by combining adjacent trees, a tree representing the basic unit. The plots were also grouped into blocks of different sizes and shapes.

An attempt has been made by George et al. (1983) to work out the optimum size and shape of plots and blocks for cardamom experimentation at different price situations. Four and six rows of three plants each were found to be optimum plots for smaller and larger blocks respectively. Brar et al. (1983) studied optimum plot size for experiments on sweet orange and it was found that a plot size of 4 trees appeared to be sufficient.

Because of the high variability present with the perennial crops like cashew the usual method of forming plots suggested by Shrikande (1958) is difficult. For conducting experiments on existing orchards naturally there will be difficulty in getting homogeneous experimental material. So forming plots with heterogeneous yield by creating a negative intra-class correlation among units in a plot was worked out by Saraswathi (1983). This method gave beneficial effect in plot formation and hence the reduction in experimental error.

Optimum size and shape of plots were also studied by Siao (1935), Keller (1949), Wiedemann and Leininger (1963), Sardana et al. (1967), Agarwal and Deshpande (1967), Brown and Morris (1967), Iyer and Agarwal (1970), Saxena et al. (1972), Shanker et al. (1972), Prabhakaran and Thomas (1974), Sreenath and Marwaha (1977), Kushik et al. (1977), Sasmal and Katyal (1980), Biswas et al. (1982), Jayaraman (1979) and Hariharan (1983) on annual crops like cotton, hops, safflower, potato, dibbled paddy, sorghum, sugarcane, oats, soybean, tapioca, cowpea, mustard, tossa jute, cabbage, sunflower and brinjal.

2.4 Effect of plot size on coefficient of variation

Coefficient of variation (CV) with different plot sizes and shapes were studied by different workers in perennial crops like coconut (Shrikande 1958), arecanut (Agarwal et al. 1968). All these workers found that coefficient of variation found to decrease as plot size increases.

Chapas (1961) based his results on two uniformity trials of oil palm, using data for twelve years from one and for five years from other, the quantities studied being the number and the total weight of bunches. He did not find plot shape to be of much importance, but the CV did depend upon age, falling as trees got older and crops increased. Also with increasing age, for one trial, values of Fairfield Smith's b rose, indicating less association between neighbouring trees, not as might have been expected, more as environmental effects built up. When crops were grouped into two year periods the CV fell markedly indicating that the individual variation of trees was now relatively less.

A study of CV associated with plots of different sizes on some important annual crops like paddy, wheat, jowar, cotton, oilseeds, sugarcane, Tyagi et al. (1973) showed that the decrease in CV with increase in plot size is marked for oilseeds and sugarcane than for other crops.

In the case of paddy the crop is grown under very uniform condition which might explains partly for these smaller change in the CV with increase in plot size.

Nair (1983) found with cashew that when plot size increases CV decreases.

The usual practice of selecting plants within a plot is by maintaining high positive intraclass correlation. There are situations where it can also be negative. By creating a negative intraclass correlation Saraswathi (1983) reported a sufficient reduction in CV in the case of experiment with coconut palms.

2.5 Blocksize

Blocking is a non statistical method to reduce experimental error mainly due to difference in soil heterogeneity. Blocking also helps the experimenter to reduce the experiment to convenient administrative units. But the variation in a plantation may be coming from sources that are genetical, the study of size and shape of blocks is not as important as with annual crops. But even so it should not be neglected.

By forming plots of trees with uniform yield Shrikande (1958) showed that blocking is most efficient with this method for elimination of error.

Agarwal et al. (1968) found that formation of blocks is not helpful in reducing variation.

Study of size and shape of plots and blocks with blackpepper Abraham et al. (1969) showed that CV increased with an increase in the number of plots per block but the increase was small with small sized plot.

Saraswathi (1983) found that blocking has not much effect on the reduction of CV when plots are formed with negative intraclass correlation. So there is no need to go into designs like RBD, LSD etc. CRD will be sufficient.

2.6 Efficiency of designs

Relative efficiency of one design over another is the ratio of amount of information supplied by the two. Fisher (1960) has shown that the amount of information supplied by an experiment is $\frac{(V+1)}{(V+3)} \frac{1}{S^2}$ where

S^2 - an estimate of σ^2

V - degrees of freedom for S^2

If a design has an estimated error variance S_1^2 with V_1 d.f and if a second design has an estimated error variance with V_2 d.f. Then the relative efficiency of first design R_1 to the second design R_2 is given by

$$RE \quad (R_1/R_2) = \frac{(V_1 + 1)\ (V_2 + 3)\ S_2^2}{(V_2 + 1)\ (V_1 + 3)\ S_1^2}$$

S_1^2 - error variance of first design R_1

S_2^2 - error variance of second design R_2

V_1 - d.f of S_1^2

V_2 - d.f of S_2^2

2.7 Number of replications

Replication serves two purposes (1) it makes possible an estimate of residual variability of the experiment by providing error degrees of freedom and (2) it enhances the estimate of treatment effects which otherwise would be based on single plots. Although increased replication does lead to better determination of treatment means, it is not wise to base precision on that alone. For one thing, it is often disappointing in its result. Because replication has to increased fourfold to halve the standard error. Again standardisation of experimental material and calibration are usually more effective.

Investigations on the number of replications one should keep in mind the possibility as suggested by Salmon (1923) that an added replication results in an increase in the size of the field and a consequent likely increase in the soil variability.

Taking efficiency of smallest plot as unity Agarwal et al. (1968) found in arecanut that relative efficiency decreases as plot size increases. Thus it recommends the fact that as far as possible we should try to decrease the size of plot by proportionately increasing the number of replications.

2.8 Calibration

Numerous writers have reported successful application of method of calibration and a summary is presented below.

Blocking is the one which controls environmental variation and calibration controls the biological variation of the plant material. The calibrating measurements has been made, the analysis of covariance usually provide the best means of using them. In essence the method of covariance provide two bodies of data. Dependent variate and independent variate. Dependent variate is the character under study and independent variate represents some other character that is suspected of disturbing the results of the experiment and which arises from sources irrelevant to its purpose. The method allows the dependent variate to be adjusted by the independent, using a formula derived from data themselves. Hence if the independent variate is not infact causing any disturbance, no adjustment will be made.

Chandler (1921) and Vidyanathan (1934) says that calibration has widespread application.

Sharpe and Blackmon (1950) worked with pecan found that the crop over the past five years to be better than either trunk circumference or crossectional area.

Pearce and Thom (1951) working with cocoa found a correlation between crops over successive periods of two or four years but concluded that calibration should not go on too long.

Shrikande (1958) recommended calibration but argues that two year periods are needed when there is a biennial tendency. Where there are biennial effects neither the on year nor the off year crop alone shows much relation to yield in neighbouring years, but two year periods are much better.

Pearce and Brown (1960) found a suggestion that trunk records are of greatest use after a calibrating period of poor crops but good growth, whereas previous crops are of greater value after trees have been yielded well. They further recommended as a general procedure that apple crops should be calibrated by double covariance on both past crops and initial trunk circumferences.

Chapas (1961) working with oil palm found from the empirical data that about two years experimental data collected immediately preceding the experiment are sufficient to obtain maximum efficiency from covariance analysis.

Longworth and Freeman (1963) studied the use of trunk girth as a calibrating variate for field experiments on cocoa trees. It has been found that, with increasing age of the trees, correlations of yield with trunk girth tend to decrease, but correlations between yields in successive periods do not. Girth is recommended as a calibrating variate for yield in the following circumstances : on young trees, as a supplement to pre-treatment yield on mature trees and where it is essential to begin a trial immediately on previously unrecorded trees.

Sen (1963) pointed out that calibration is most effective when blocking system is poor. He found with crops of tea that there was little to choose between calibration and blocking as a means of allowing for known past differences.

Abraham and Kulkarni (1963) studied for coconut the optimum number of pre-experimental period required to collect the data before start of the experiment so as to use them for reduction in experimental error by covariance. It was found that about two years experimental period data immediately prior to the experimental period are sufficient for covariance analysis.

Vernon and Morris (1964) make the useful point that when biennial cropping occurs it is better to use periods containing an even number of years. They found a single year crop to be a valuable calibrator, but they recommended two, provided that does not cause delay.

Butters (1964) working with robusta coffee found that stem diameter, measured at the first internode on bearing stems, appears to be of limited use as a calibrating variate.

Narayanan (1966) studied the relationship between trunk circumferences and yield of rubber at different times and later Narayanan (1968) concluded that yield was well calibrated by trunk circumference, but for longer experimental periods it was better to use record of previous yield and to use double covariance.

For arecanut Agarwal et al. (1968) found it possible to calibrate one year's crop by that of two preceding years.

Menon and Tyagi (1971) studied with mandarin orange the relative merits of various growth characteristics of trees as auxillary variate for analysis of covariance and it was found that spread and height of the tree as most suitable. The largest gain in precision of about

40 percentage was in the spread of the tree as an auxillary variate. More or less the same magnitude of gain in precision was seen when height of the tree was auxillary variate. Measurements like length of the trunk, though much simpler to record have not indicated a reasonable gain in precision due to weak correlation.

An analysis of covariance was performed (Nair 1983) on cashew with pre-experimental yield, trunk girth and selection index (identification of superior trees) as concommitant variables, and relative efficiency of covariance analysis over ordinary analysis of variance was estimated. Among the three calibrating variables selection index served as a better covariate than four years average annual pre-experimental yield or trunk girth.

By taking two years pre-experimental data immediately preceding the experimental year (Saraswathi 1983) found with coconut that covariance analysis has not much effect on the reduction of co-efficient of variation when plots are formed with negative intraclass correlation coefficient.

MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

Statistical analysis and interpretation of a set of experimental data depend upon the way in which the experiment is planned. The results obtained from an experiment are affected by treatments and also by a variety of causes of variation. The minimisation of these causes of variation can be achieved by adopting suitable experimental techniques. However, still there will be the effect of many uncontrolled causes of variation which has to be taken into account while drawing inferences about the treatment effects. These uncontrolled causes of variation is termed as experimental error. Statistical test of significance are the tools used for drawing inferences from treatmental effects. The inferences drawn from these tests are valid only if appropriate randomisation is adopted.

The main sources of experimental errors are (i) the inherent variability present in the experimental material and (ii) the lack of uniformity in the conduct of the experiment.

In experiments with perennial crops the first source of variation assumes more importance. The first source of error can be reduced by increasing the size of the experiment with addition of more replications while the second source of error can be reduced by improved experimental techniques. But there is a limitation for increasing the size of an experiment as it will lead to an increase in cost. Hence methods of increasing accuracy of the experiment without increasing the size of the experiment assume importance. One way of increasing the accuracy of the experiment is by proper choice of experimental design. As the first source of error assumes more importance in perennial crops, our aim is to investigate on layout plans which will help to draw reliable conclusions by taking into account the inherent variability present among the plant materials.

The present study 'standardization of field plot technique for cashew' by making use of trees with heterogeneous yield per plot is based on an important principle of cluster sampling that, the clusters formed with negative intraclass correlation i.e with units within the same cluster as heterogeneous, are relatively more efficient (Sukhatme et al. 1984).

3.1 Materials for the study

The data for the present investigation were collected from Cashew Research Station, Kerala Agricultural University, Madakkathara. The plantation consists of 1044 trees planted in 1973 of which 405 trees are subjected to a NPK trial. The remaining 639 trees were treated uniformly from which a sample of 294 trees was utilised for the present study by discarding trees which were not yielding continuously for four consecutive years. The yield records for eight consecutive years ranging from 1976-77 to 1983-84 were collected. Since the trees exhibited remarkable biennial tendency the yields of two successive years were combined in all calculations to eliminate the effect of biennial tendency. Thus the data for 8 years divided into four groups of two years each were utilised for the empirical study. The yield of each tree was recorded separately which formed the basis of study of variation in plot sizes and arrangement of plots in blocks of different sizes.

3.2 Calibration of trees

'Calibration' is the use of past records in forecasting the future performance of experimental units (Pearce and Taylor, 1950). The calibration of trees has had widespread application. Calibration provides some control over plant variation which has not been eliminated by initial selection. Blocking and calibration are not to be seen as having unrelated uses, the former controlling environmental variation or positional variation while the latter controlling biological variation. To calibrate to the best advantage the trees should be planted and left for some time without differential treatments, and measurements of the plants will be taken. Pre-experimental yield of each tree for anyear was taken as the calibrating variate by using the principle of maximum correlation. The optimum number of pre-experimental period was determined by observing the correlation coefficient between years separated by one period, two period, three period etc. The period having maximum average correlation coefficient is taken as the optimum pre-experimental period for calibration.

3.3 Methods of plot formation

Since experiments on perennial crops are conducted over a long period, maximum care should be taken in the planning and conduct of the experiment. As the material is costly, economy in the layout reduces the total cost of experiment. In experiments with perennials concentration is on individual plants rather than a group of plants and hence the size and shape of plots are not so important as that of annuals. In experiments with perennial crops an experimental unit can be an individual plant or group of plants. Generally, there is a practical difficulty in getting trees with homogeneous yield in designing experiments with perennials. A method to overcome this difficulty is to choose trees with homogeneous yield to form blocks (Shrikande 1958). This procedure results in a significant positive correlation between plants within a plot, but by minimising the within plot variation, the homogeneity within a block is lost. The present method is based on the creation of a negative correlation among trees within a plot with the aim of reducing the plot to plot variation within a block to a minimum.

The clusters formed with negative intraclass correlation are tend to be relatively most efficient in sample surveys. The upper limit of this intraclass correlation coefficient was given as $-\frac{1}{nm-1}$ (Sukhatme et al.

1984) where

n - number of clusters

m - size of the cluster

In general intraclass correlation coefficient will be positive within a cluster. There are situations where it can be negative or can be made negative. The efficiency of cluster sampling can best be elucidated with the help of intraclass correlation coefficient between the elements of a cluster. If there are 'n' clusters each having 'm' elements, the relative efficiency of cluster sampling with regard to single element is given by

$$\text{Relative Efficiency (RE)} = \frac{m\,(n-1)}{nm-1}\left[\frac{1}{1+(m-1)\rho}\right] \qquad (3.3.1)$$

where

ρ is the intraclass correlation coefficient

For sufficiently large n,

$$RE = \frac{1}{1+(m-1)\rho}$$

For $m = 1$ the relative efficiency is unity and hence both will behave in the same manner. If $m>1$, $(m-1)\rho$ will measure the relative change in sampling variance brought about by sampling clusters instead of elements and ρ is estimated as

$$\rho = \frac{\text{(Mean square between clusters - Mean square within clusters)}}{\text{(Meansquare between clusters + (m-1) meansquare within clusters)}} \qquad (3.3.2)$$

A negative value of ρ was found to increase the efficiency of cluster sampling (Sukhatme et al. 1984).

Efficiency of cluster sampling is given by

$$E = \frac{S^2}{mS_b^2} \qquad (3.3.3)$$

where

S^2 = the total meansquare

m = the cluster size

S_b^2 - meansquare between cluster means.

From 3.3.3 it can be seen that efficiency of cluster sampling increases as meansquare between clusters decreases. This suggests that for cluster sampling to be efficient the clusters should be so formed that the variation between cluster means is as small as possible while variation within clusters is as large as possible. A field plot technique based on the above results is suggested in the present study.

3.3.a Method I

The trees are ranked according to their yield performance (descending or ascending order). Then the trees were grouped into two - trees having yield less than the median yield and greater than the median yield. One tree from each group is taken at random to form plots of size 2. The same data were divided into four groups based on quartiles. Those having yield less than the first quartile formed group I, between first quartile and the median as group II, between median and third quartile as group III and above the third quartile as group IV. A plant from each group is selected at random to form a plot of size 4. So a group of heterogeneous plants constitute a plot. To form plots of sizes 3, 5, 6, 7 or 8 the ordered trees are divided into 3, 5, 6, 7 and 8 groups of equal size and one tree from each group is taken to form plots of appropriate size. So in each case, the plants within each plot will be heterogeneous in yield for the calibrating period.

Intraclass correlation coefficient and efficiency were worked out for the above method using the formula given in 3.3.2 and 3.3.3 respectively. The above mentioned method of plot formation resulted in a negative intraclass correlation within plots and thereby helped to reduce the between plot variation.

3.3.b Method II (Shrikande's method)

Shrikande (1958) working with coconut formed plots of trees having homogeneous yield for the calibrating period. This method aims at reducing the variation between plots within blocks. In this method the trees are arranged in descending order of yield performance over an even number of consecutive years. If there are v treatments to be tried in K - tree plots, the ordered trees are divided into groups of KV trees even group being called as a block, where the block is no more a compact piece of land but a group of relatively homogeneous genotypes with respect to the character 'yield'. In this block of ordered trees the V treatments are applied at random to the first V trees, then to the next V trees and so on, till all the trees in that block are exhausted. In this block, the K trees to which the first treatment is applied form a plot, all the K trees to which the second treatment is applied form another plot and so on. Thus there are V plots in this block. Similarly the other blocks are dealt with. This method will help to reduce the within block variation.

Intraclass correlation coefficient and efficiency were worked out using the formula given in 3.3.2 and 3.3.3. The above mentioned method of plot formation resulted in a positive intraclass correlation within plots.

3.3.c Method III (Random method)

The plots of different sizes are formed by selecting trees at random from the entire area.

Using the formula given in 3.3.2 and 3.3.3, the intraclass correlation coefficient and efficiency were worked out for this method.

In all the above methods the trees are dispersed over the entire plantation. Plot mean, plot variance and coefficient of variation were calculated for each method for various sizes of plots.

3.4 Relation between plot size and coefficient of variation.

Coefficient of variation determined for each method was plotted against the respective plot sizes. A curve of the form $y = ax^b$ (3.4.1)

where

y - coefficient of variation

x - plot size, a and b are constants was used to define the relationship between plot size and coefficient of variation. Constants of the function were estimated by transforming it into the linear form

$$\log y = \log a + b \log x \quad (3.4.2)$$

or $Y = A + b X$ where

$Y = \log y$

$A = \log a$ and

$X = \log x$

The method of least squares was used to solve for a and b.

The solutions of a and b are given by

$$\hat{b} = \frac{\Sigma XY - n\ (\Sigma X)\ (\Sigma Y)}{\Sigma X^2 - n\ (\Sigma X)^2} \quad (3.4.3)$$

$$\hat{a} = \text{Antilog}\ (\Sigma Y - \hat{b}\Sigma X)\ /n) = \text{Antilog}\ (\bar{Y} - \hat{b}\ \bar{X}) \quad (3.4.4)$$

Thus y is estimated as

$$\hat{y} = \hat{a}\ x^{\hat{b}} \quad (3.4.5)$$

3.5 Optimum plot size - Maximum curvature method.

The curvature k of a curve y = f(x) at any point P on it, is the rate of change in direction (i.e the angle of inclination α of the tangent line at P) per unit of arc length s (Granville et al. 1965).

Thus $$k = \frac{d\alpha}{ds} = \lim_{\Delta S \to 0} \frac{\Delta\alpha}{\Delta S} = \frac{\frac{d^2y}{dx^2}}{\left[1 + \left(\frac{dy}{dx}\right)^2\right]^{3/2}} \qquad (3.5.1)$$

where $\frac{dy}{dx}$ and $\frac{d^2y}{dx^2}$ are the first and second derivative respectively of the function y = f (x). Curvature is maximum where the derivative of k with respect to x is zero for the function y = f (x). Thus the point of maximum curvature, X_c for the function $y = ax^b$ is given at

$$X_c = \left[\frac{b - 2}{a^2b^2(2b-1)}\right]^{\frac{1}{2b-1}} \qquad (3.5.2)$$

The optimum plot size was determined as X_c given by 3.5.2 which is the point where the curve has got maximum curvature. The maximum curvature method tries to identify a plot size beyond which the rate of reduction in coefficient of variation is minimal. The optimum plot size is the one just beyond the point of maximum curvature (Federer 1967).

3.6 Blocksize

Block size is the number of plots included in a block. Blocks of different sizes were formed using plots of different sizes. The coefficients of variation for different block sizes was determined as

$$CV = \frac{\sqrt{\text{Error meansquare}}}{\text{Grandmean}} \times 100 \qquad (3.6.1)$$

3.7 Efficiency of designs

The relative efficiency of one design D_1 to a second design D_2 is the ratio of amount of information supplied by these two designs (Federer 1967). The amount of information is measured as the inverse of the variance. Thus the relative efficiency of D_1 to D_2 is given by

$$RE\ (D_1/D_2) = \frac{1}{\sigma_1^2} \Big/ \frac{1}{\sigma_2^2} \qquad (3.7.1)$$

where

σ_1^2 is the expected value of error variance in D_1 and σ_2^2 is the expected value of error variance in D_2. σ_1^2 and σ_2^2 are estimated by S_1^2 and S_2^2, the error mean squares for D_1 and D_2.

Then $\hat{RE}\ (D_1/D_2) = \frac{1}{S_1^2} / \frac{1}{S_2^2} = \frac{S_2^2}{S_1^2}$ (3.7.2)

Fisher (1960) has suggested in general a need for correction term $\frac{V+1}{V+3}$ to be applied to $\frac{1}{S^2}$ as a factor of weightage depending upon the degrees of freedom available for estimating S_1^2, the error mean square. Then $\hat{RE}\ (D_1/D_2)$

$$= \frac{\frac{(V_1+1)}{(V_1+3)} \times \frac{1}{S_1^2}}{\frac{(V_2+1)}{(V_2+3)} \times \frac{1}{S_2^2}} \times 100 \qquad (3.7.3)$$

where

V_1 and V_2 are the degrees of freedom to estimate S_1^2 and S_2^2 respectively from D_1 and D_2.

On simplification

$$\hat{RE}\ (D_1/D_2) = \frac{(V_1+1)\ (V_2+3)\ S_2^2}{(V_2+1)\ (V_1+3)\ S_1^2} \times 100 \qquad (3.7.4)$$

3.8 Efficiency of RBD over CRD

Using the general formula (3.7.4) the estimate of relative efficiency of RBD over CRD can be written as

$$\hat{RE}\ (RBD/CRD) = \frac{(V_1+1)\ (V_2+3)\ MSE_1}{(V_2+1)\ (V_1+3)\ MSE_2} \times 100 \qquad (3.8.1)$$

where

V_1 is the d.f for error in RBD

V_2 is the d.f for error in CRD

MSE_1 is the estimated error meansquare for CRD

MSE_2 is the error meansquare for RBD

MSE_1 was estimated using the formula given ochran and Cox (1962).

$$MSE_1 = \frac{V_b\ MSB\ (V_t+V_e)\ MSE_2}{(V_b+V_t+V_e)} \qquad (3.8.2)$$

V_b - d.f for blocks for RBD

V_t - d.f for treatment in RBD

V_e - d.f for error in RBD

MSB - block mean sum of square for RBD

MSE_2 - error meansquare for RBD

Efficiency of RBD over CRD was estimated by (3.8.1) for blocks of different sizes.

3.9 Number of replications

Since variability is almost universal, replication should be practiced in all experimental work. Randomisation and replication are the two necessary conditions to obtain a valid estimate of the experimental error (Fisher, 1960). Hence replication is an important feature of any experimental work.

The number of replications required for 5% standard error of the mean was given by

$$r = \frac{(CV)^2}{p^2} \qquad (3.9.1)$$

where p is the percentage standard error.

3.10 Analysis of covariance

The possibility of improving the results by analysis of covariance has been investigated. Pre-experimental yield was taken as the independent variate in this analysis. The optimum number of pre-experimental period needed for covariance analysis was determined by maximum correlation method. The average correlation coefficients were worked out for separating periods ranging from one to five years. The separating period having maximum average correlation was taken as the optimum pre-experimental period. By taking optimum pre-experimental period as independent variate coefficient of variation (adjusted) was calculated for selected plot sizes.

It was also tried to obtain a relationship of the form

$$y = \alpha + \beta \rho^{x} \qquad (3.10.1)$$

between average correlation coefficient (y) and separating period (x) where

α is the assymptotic value of y, β measures the rate of change in y for unit change in x and ρ is a factor which measures the deviation in y from its assymptotic value at given values of x. The coefficients (α, β and ρ) of the function were estimated by the method of selected points (Yamena, 1964).

RESULTS

CHAPTER 4

RESULTS

The methods discussed in Chapter 3 were illustrated with yield data on cashew for eight years collected from Cashew Research Station, Madakkathara, Kerala. Cashew being a perennial crop is subjected to biennial fruit bearing tendency and hence the yields of two successive years have been added to eliminate biennial tendency and the two year totals were utilised to illustrate the methods under study. Thus the plot formation was based on the yield data for successive year-pairs 1976-77 and 1977-78, 1978-79 and 1979-80, 1980-81 and 1981-82, 1982-83 and 1983-84. The average yields(kg) per tree for the above periods were 3.42, 8.41, 8.46 and 13.15 with standard deviations(kg) 2.98, 6.30, 5.71 and 8.25. The corresponding coefficients of variations (CV) were 87.13 percentage, 74.91 percentage, 67.49 percentage, 62.74 percentage.

4.1 Plot formation based on ordered arrangement.

Plots of various sizes were formed using the method I described in section 3.3.a. The median yield (kg/tree) were 2.74, 7.01, 7.05 and 11.60 respectively for each year-pair. The number of plots available to form plots of different sizes for different year-pairs is given in Appendix I. For the first year-pair, the range of values the plots can take to form different plot sizes is given in Appendix II along with the range of values of yield in other year-pairs. To form plots of size two, the trees were divided into two groups, those having yield (kg/tree) greater than 2.741 and those less than or equal to 2.741 and one tree from each group was selected at random. The data were grouped into three as follows - those less than or equal to 1.480, greater than 1.480 and less than or equal to 3.775, greater than 3.775 and less than or equal to 16.712. Plots of size three were formed by a random selection of one tree each from these groups. Plots of size four was formed by a random selection of one tree each from the following yield groups - those trees having yield, less than or equal to 0.995, greater than 0.995 and less than or equal to 2.741, greater than 2.741 and less than or equal to 4.940, greater than 4.940 and less than or equal to 16.712. For plot size five, the trees constituting the different groups were, those less than or equal to per tree yield(kg) 0.82, greater than 0.82 and less than or equal to 1.90, greater than 1.90 and less than or equal to 3.364, greater than 3.364 and less than or equal to 5.160, greater than 5.160 and less than or equal to 16.712. With a plot size of six, the respective range of values of yield(kg) in each groups were less than or equal to 0.70, greater than 0.70 and less than or equal to 1.48, greater than 1.48 and less than or equal to 2.741, greater than 2.741 and less than or equal to 3.819, greater than 3.819 and less than or equal to 6.10, greater than 6.10. Trees were selected randomely from each of the yield group - those less than or equal to 0.645, those greater than 0.645 and less than or equal to 1.280, greater than 1.280 and less than or equal to 2.150, greater than 2.150 and less than or equal to 3.197, greater than 3.197 and less than or equal to 4.380, greater than 4.380 and less than or equal to 6.902, greater than 6.902 to form plots of size seven. To form plots of size eight, the entire trees in the plantation were grouped into eight classes those trees having yield less than or equal to 0.597, greater than 0.597 and less than or equal to 0.995, greater than 0.995 and less than or equal to 1.720, greater than

1.720 and less than or equal to 2.741, greater than 2.741 and less than or equal to 3.515, greater than 3.515 and less than or equal to 4.842, greater than 4.842 and less than or equal to 7.074, greater than 7.074. The respective yield groups for other year-pairs along with these results are given in Appendix II.

The average per plot yield(kg) for the above plot sizes were 6.87, 9.90, 13.66, 16.28, 20.23, 23.52 and 26.42 with a standard deviation of 2.396, 1.332, 1.397, 0.845, 0.821, 0.750 and 0.618 in the first year-pair. These values along with the values for other year-pairs are given in Table 1. The CV worked out for various plot sizes are given in Table 4. The CV (%) decreased from 34.88 to 2.34 when plot size increased from two to eight for the first year-pair. The corresponding reduction in CV were 23.60 to 1.68, 23.59 to 1.53, 19.78 to 1.30 respectively for the second, third and fourth year-pairs. The CV obtained was the highest for plot size two compared to all other plot sizes. It was found to decrease with an increase in plot size.

4.21 Intraclass correlation coefficient (ρ) and efficiency.

Arrangement of trees by the above method for

Table 1. Plot mean and SD of yield.

Plot size	Mean (kg)				SD (kg)			
	1976-77 to 1977-78	1978-79 to 1979-80	1980-81 to 1981-82	1982-83 to 1983-84	1976-77 to 1977-78	1978-79 to 1979-80	1980-81 to 1981-82	1982-83 to 1983-84
2	6.87	16.81	16.91	25.95	2.396	3.966	3.989	5.134
3	9.90	24.47	25.38	38.90	1.332	2.595	3.143	3.830
4	13.66	33.61	33.71	51.89	1.397	2.640	2.345	2.837
5	16.28	41.48	41.63	63.48	0.845	1.916	2.074	2.817
6	20.23	49.21	50.74	77.87	0.821	1.474	1.951	2.370
7	23.52	56.19	54.79	88.71	0.750	1.096	1.069	1.535
8	26.42	64.34	62.62	99.12	0.618	1.081	0.958	1.289

various plot sizes in the first year-pair is given in Appendix II. It is seen that maximum heterogeneity within plots is maintained with respect to the character yield. The extent of heterogeneity as a measure of intraclass correlation coefficient can be viewed from Table 7 to Table 10. The intraclass correlation coefficients (ρ) were less than the upper limits provided for each ρ. Its value ranged from -0.350 to -0.135, -0.603 to -0.138, -0.510 to -0.137, -0.586 to -0.138 for the first, second third and fourth year-pair. It can be seen that the magnitude of ρ decreased with an increase in plot size. The efficiency worked out for different plot sizes and for different year-pairs are given in Table 7 to Table 10. Efficiency increased from 154.14 to 1942.73, 252.42 to 2797.94, 204.61 to 2399.18, 242.55 to 3094.08 as plot size increased from two to eight in the first, second, third and fourth year-pairs respectively. As the size of the cluster increased efficiency was found to increase. However not much difference in efficiency was noticed with plot size three and four in the first two year-pairs because of the small increase in meansquare between clusters (Sb^2).

4.3 Plot formation based on method II.

Plots of size 2, 3, 4, 5, 6, 7 and 8 were formed by the method described in section 3.3.b. The number of plots available from the whole area with various plot sizes for different year-pairs are given in Appendix I. The average per plot yield(kg) and plot SD(kg) are presented in Table 2.

The values of the CV (%) are given in Table 5. The CV ranged from 33.96 to 61.55, 29.81 to 53.08, 27.96 to 48.13, 25.41 to 43.53 for different year-pairs in various plot sizes. The CV was highest for a plot size of two compared to all other plot sizes in each year-pair. It was found to decrease with an increase in plot size.

4.3.1 Intraclass correlation coefficient (ρ) and efficiency.

The arrangement of trees by the above method for various plot sizes for the first year-pair are given in Appendix II. It can be seen that maximum homogeneity was maintained within plots. The extend of homogeneity as a measure of intraclass correlation coefficient can be seen from Table 7 to Table 10. The intraclass correlation

Table 2. Plot mean and SD of yield.

Plot size	Mean (kg)				SD (kg)			
	1976-77 to 1977-78	1978-79 to 1979-80	1980-81 to 1981-82	1982-83 to 1983-84	1976-77 to 1977-78	1977-78 to 1978-79	1979-80 to 1980-81	1980-81 to 1981-82
2	6.84	16.81	16.98	25.95	4.210	8.923	8.172	11.297
3	9.90	24.61	25.52	38.92	4.739	10.324	10.147	13.875
4	13.21	33.67	32.96	51.94	5.476	12.676	10.823	16.116
5	16.28	41.51	40.14	64.11	5.961	13.762	11.338	17.549
6	19.81	49.22	51.09	77.80	6.726	14.672	14.283	19.771
7	23.50	55.81	54.79	88.71	7.550	15.037	12.612	20.324
8	26.41	64.34	62.62	99.12	7.762	16.280	13.536	20.780

coefficients were positive for all plot sizes and nearly equal to one. However a slight decrease in was observed when plot size increased from two to eight. The efficiency was found to decrease with an increase in plot size (vide Table 7 to Table 10). Efficiency ranged from 49.83 to 12.24, 49.87 to 12.28, 49.74 to 12.07, 49.71 to 11.99 in the first, second, third and fourth year-pairs.

4.4 Plot formation based on random method.

As described in section 3.3.c plots of different sizes were formed. The number of plots available for different year-pairs with different plot sizes is given in Appendix I. The average per plot year(kg) and SD of yield(kg) are given in Table 3.

The values of the CV (%) for various plot sizes are given in Table 6. The CV (%) was decreased from 43.74 to 15.01, 36.82 to 12.18, 31.67 to 11.15, 30.41 to 10.89 as plot size increased from two to eight. The range of variation in CV was 87.39 to 62.73 with single tree plots for the four year-pairs.

4.4.1 Intraclass correlation coefficient (ρ) and efficiency.

In random method ρ may be expected to be either

Table 3. Plot mean and SD of yield.

Plot size	Mean (kg)				SD (kg)			
	1976-77 to 1977-78	1978-79 to 1979-80	1980-81 to 1981-82	1982-83 to 1983-84	1976-77 to 1977-78	1978-79 to 1979-80	1980-81 to 1981-82	1982-83 to 1983-84
2	6.84	16.81	16.91	26.32	2.989	6.187	5.356	8.004
3	10.32	25.18	25.37	39.48	2.991	6.081	5.066	8.716
4	13.77	33.61	33.67	52.64	3.341	5.877	5.257	8.986
5	17.27	42.10	41.61	65.93	3.256	6.820	4.768	8.153
6	20.66	50.37	50.74	78.96	3.101	6.135	5.658	8.597
7	24.02	58.97	58.45	92.44	3.505	7.226	4.771	8.863
8	27.55	67.26	66.80	106.24	3.468	6.629	5.346	9.733

Table 4. Method I. CV for different plot sizes.

Plot size (X)	Year-pair			
	1976-77 to 1977-78	1978-79 to 1979-80	1980-81 to 1981-82	1982-83 to 1983-84
2	34.88	23.60	23.59	19.78
3	13.46	10.61	12.38	9.85
4	10.23	7.85	6.96	5.47
5	5.19	4.62	4.98	4.44
6	4.06	3.00	3.85	3.04
7	3.19	1.95	1.95	1.73
8	2.34	1.68	1.53	1.30
Single tree plots	87.39	74.91	67.49	62.73

Table 5. Method II. CV for different plot sizes.

Plot size	Year-pair			
	1976-77 to 1977-78	1978-79 to 1979-80	1980-81 to 1981-82	1982-83 to 1983-84
2	61.55	53.08	48.13	43.53
3	47.87	41.95	39.76	35.65
4	41.45	37.65	32.83	31.03
5	36.62	33.15	28.25	27.37
6	33.96	29.81	27.96	25.41
7	32.14	26.94	23.02	22.91
8	29.39	25.30	21.62	20.96

Table 6. Method III. CV for different plot sizes.

Plot size	Year-pair			
	1976-77 to 1977-78	1978-79 to 1979-80	1980-81 to 1981-82	1982-83 to 1983-84
2	43.74	36.82	31.67	30.41
3	28.99	24.15	19.97	22.08
4	24.25	17.48	15.62	17.07
5	18.86	16.20	11.46	12.37
6	15.01	12.18	11.15	10.89
7	14.60	12.25	8.16	9.59
8	12.59	9.86	8.00	9.40

positive or negative. ρ ranged from ±0.004 to ±0.087, -0.011 to -0.055, -0.003 to -0.118 and -0.008 to +0.060 respectively in the four year-pairs. The intraclass correlation coefficients were very low in magnitude. No remarkable change in efficiency was noticed with an increase in plot size. It ranged from 79.19 to 99.20, 85.58 to 114.96, 101.71 to 135.99, 84.76 to 106.82 percentage respectively for each year-pair.

4.5 Relationship between plot size (X) and coefficient of variation (Y).

The relationship between plot size (X) and CV among plots (y) were defined by the experimental model

$$y = ax^b, \ b \leq 0$$

where 'a' and 'b' are constants.

This model was fitted for each year-pair and the results are presented in Table 12. The curve $y = a\,x^b$ gave a good fit to the data and the expected and observed values of CV are given in Table 11. The coefficients of determination (r^2) for the fitted function showed that 97 to 99 percentage variation in CV was explained by the fitted functions. The values of the fitted constants 'a' and 'b' ranged from 90.64 to 124.81 and -1.91 to -1.95 during the

Table 7. Intraclass correlation coefficient (ρ), upper limit of ρ and Efficiency (E) of different plot sizes. (Year-pair: 1976-77 to 1977-78).

Plot size	ρ			E (%)		
	Method I	Method II	Method III	Method I	Method II	Method III
2	-0.350	0.998	0.012	154.14	49.83	98.83
3	-0.300	0.998	0.004	418.55	33.08	99.20
4	-0.260	0.994	0.087	455.90	24.77	79.19
5	-0.224	0.993	0.049	982.76	19.74	83.57
6	-0.183	0.990	0.018	1192.69	16.42	91.89
7	-0.155	0.981	0.065	1431.14	14.12	71.87
8	-0.135	0.986	0.051	1942.73	12.24	73.76

Upper limit of ρ = -0.005

Table 8. Intraclass correlation coefficient (ρ), Upper limit of ρ and Efficiency (E) of different plot sizes (Year-pair: 1978-79 to 1979-80).

Plot size	ρ			E (%)		
	Method I	Method II	Method III	Method I	Method II	Method III
2	-0.603	0.997	-0.036	252.42	49.87	103.72
3	-0.406	0.996	-0.055	536.30	33.14	107.55
4	-0.275	0.993	-0.043	569.73	24.81	114.96
5	-0.226	0.991	-0.042	1024.43	19.81	85.58
6	-0.188	0.993	-0.011	1627.53	16.40	105.78
7	-0.160	0.997	0.050	2679.72	13.95	76.78
8	-0.138	0.986	0.014	2797.94	12.28	90.94

Upper limit of ρ = -0.004

Table 9. Intraclass correlation coefficient (ρ), Upper limit of ρ and Efficiency (E) of different plot sizes (Year-pair: 1980-81 to 1981-82)

Plot size	ρ			E (%)		
	Method I	Method II	Method III	Method I	Method II	Method III
2	-0.510	0.999	-0.118	204.61	49.74	113.50
3	-0.347	0.997	-0.105	329.01	33.01	126.87
4	-0.272	0.997	-0.046	544.18	24.62	116.02
5	-0.212	0.991	-0.066	663.43	19.68	135.99
6	-0.177	0.995	-0.003	855.23	16.25	101.71
7	-0.158	0.989	-0.044	1936.29	13.91	136.11
8	-0.137	0.991	-0.011	2399.18	12.07	108.38

Upper limit of ρ = -0.006.

Table 10. Intraclass correlation coefficient (ρ), Upper limit of ρ and Efficiency (E) of different plot sizes (Year-pair: 1982-83 to 1983-84).

Plot size	ρ			E (%)		
	Method I	Method II	Method III	Method I	Method II	Method III
2	-0.586	0.999	-0.064	242.55	49.71	106.82
3	-0.385	0.998	0.055	437.40	32.96	90.10
4	-0.291	0.997	0.060	794.74	24.57	84.76
5	-0.219	0.993	-0.008	807.70	19.59	103.46
6	-0.182	0.992	0.016	1138.36	16.24	92.60
7	-0.160	0.990	0.023	2430.57	13.85	88.05
8	-0.138	0.994	0.051	3094.08	11.99	73.46

Upper limit of ρ = -0.006.

Table 11. Observed and expected values of the exponential function $y = ax^b$

Plot size	Year-pair							
	1976-77 to 1977-78		1978-79 to 1979-80		1980-81 to 1981-82		1982-83 to 1983-84	
	O	E	O	E	O	E	O	E
2	34.88	33.22	23.60	25.01	23.59	26.34	19.78	23.69
3	13.46	15.32	10.61	11.40	12.38	11.93	9.85	10.81
4	10.23	8.84	7.85	6.53	6.96	6.80	5.47	6.19
5	5.19	5.77	4.62	4.24	4.98	4.40	4.44	4.02
6	4.06	4.08	3.00	2.98	3.85	3.08	3.04	2.83
7	3.19	3.04	1.95	2.21	1.95	2.28	1.73	2.09
8	2.34	2.35	1.68	1.71	1.53	1.76	1.30	1.62
χ^2 5[illegible]	0.600		0.466		0.652		0.999	

year-pairs.

4.6 Optimum plot size - Maximum curvature method.

The method of maximum curvature explained in section 3.5 was used to estimate the optimum plot size. The maximum curvature was observed at 6.80, 6.14, 6.23, 6.03 respectively for each year-pair.

4.7 Block size and number of replications.

The possibility of using heterogeneous genotype in Randomised Block Design was examined. Here again a plot means a group of heterogeneous genotypes - heterogeneity in the sense of measurable character 'yield'. Six and ten dummy treatments were tried in randomised blocks. The CV (%) obtained for six and ten plot block was almost equal. So an increase in block size did not result in a reduction of experimental error (vide Table 13 to Table 16). CV was found to decrease with an increase in plot size. The CV obtained with the same number of treatments using completely Randomised design was also given in Tables 13 to 16. The CV was almost equal for both the designs.

The minimum number of replications required at

Table 12. Relationship between plot size (x) and CV (y).

Year-pair	Fitted function	r^2	X opt
1976-77 to 1977-78	$y = 124.81\ x^{-1.910}$	0.99	6.80
1978-79 to 1979-80	$y = 95.73\ x^{-1.94}$	0.99	6.14
1980-81 to 1981-82	$y = 101.99\ x^{-1.95}$	0.98	6.23
1982-83 to 1983-84	$y = 90.64\ x^{-1.94}$	0.97	6.03

5% standard error of the mean is given in Table 13 to Table 16. A substantial reduction in number of replications was observed when plot size increased from three. With plots of size six and above the minimum number of replications was found to vary from two to four.

4.8 Efficiency of Randomised Block Design (RBD) over completely Randomised Block Design (CRD).

The relative efficiency of RBD over CRD was examined using the formula given in section 3.8 and the results are given in Table 17. From the table it can be seen that block efficiency was approximately equal to one. If plots are formed with negative intraclass correlation coefficient, CRD and RBD were found to be equally efficient.

4.9 Analysis of covariance.

The correlation between years with respect to the character yield is given in Appendix I. From this, the average correlation coefficient separated by different periods obtained. The relationship between average correlation coefficients and separating periods was explained by

$$y = 0.1349 + 0.2394 \times 0.4605^{x}$$

Table 13. CV and minimum number of replications (r)
(Year-pair: 1976-77 to 1977-78)

Plot size	CRD				RBD			
	6 treatments		10 treatments		6 treatments		10 treatments	
	CV	r	CV	r	CV	r	CV	r
2	48.89	96	47.44	90	48.70	95	44.58	80
3	23.60	22	22.22	20	23.91	23	21.53	19
4	20.41	17	22.01	19	20.16	16	22.67	21
5	11.67	5	11.01	5	11.75	6	11.38	5
6	9.75	4	9.33	3	9.92	4	9.34	3
7	8.54	3	9.32	3	9.15	3	9.61	4
8	7.49	2	6.80	2	7.93	3	7.14	2

Table 14. CV and minimum number of replications (r)
(Year-pair: 1978-79 to 1979-80)

Plot size	CRD				RBD			
	6 treatments		10 treatments		6 treatments		10 treatments	
	CV	r	CV	r	CV	r	CV	r
2	33.05	44	32.12	41	32.13	41	30.59	37
3	18.28	13	18.28	13	17.61	12	17.30	12
4	14.87	9	15.85	10	13.43	7	16.16	10
5	9.42	4	9.92	4	9.22	3	9.61	4
6	6.80	2	7.15	2	7.10	2	6.76	2
7	5.09	1	6.06	1	5.36	1	6.37	2
8	4.21	1	3.39	1	4.57	1	3.57	1

Table 15. CV and minimum number of replications (r)
(Year-pair: 1980-81 to 1981-82)

Plot size	CRD				RBD			
	6 treatments		10 treatments		6 treatments		10 treatments	
	CV	r	CV	r	CV	r	CV	r
2	33.68	45	34.12	47	32.68	43	34.59	48
3	19.12	15	20.39	17	19.44	15	20.02	16
4	13.55	7	13.88	8	14.36	8	14.59	9
5	11.37	5	11.76	6	11.10	5	12.24	6
6	9.16	3	8.58	4	8.35	3	7.60	2
7	5.02	1	3.32	1	5.16	1	3.49	1
8	4.57	1	4.48	1	4.97	1	4.44	1

Table 16. CV and minimum number of replications (r)
(Year-pair: 1982-83 to 1983-84)

Plot size	CRD				RBD			
	6 treatments		10 treatments		6 treatments		10 treatments	
	CV	r	CV	r	CV	r	CV	r
2	28.29	32	27.83	31	29.70	35	28.89	33
3	16.65	11	16.35	11	16.34	11	16.98	12
4	10.67	5	12.51	6	10.30	4	12.37	6
5	10.32	4	9.66	4	11.01	5	10.05	4
6	5.61	1	6.61	2	5.66	1	6.95	2
7	4.54	1	4.40	1	3.41	1	4.23	1
8	4.02	1	--	--	4.15	1	--	--

Table 17. Block efficiency

Plot size	1976-77 to 1977-78		1978-79 to 1979-80		1980-81 to 1981-82		1982-83 to 1983-84	
	6 plot block	10 plot block	6 plot block	10 plot block	6 plot block	10 plot block	6 plot block	10 plot block
2	1.002	1.129	1.055	1.101	1.057	0.970	0.903	0.924
3	0.968	1.100	1.071	1.113	0.959	1.032	1.029	0.923
4	1.017	0.937	1.218	0.957	0.883	0.899	1.060	1.018
5	1.046	0.931	1.036	1.058	1.034	0.915	0.865	0.915
6	0.954	0.988	0.907	1.103	1.181	1.111	0.933	0.890
7	0.881	0.950	0.807	0.926	0.944	0.936	1.106	1.013
8	0.899	0.936	0.866	0.935	0.869	1.100	0.933	--

A good agreement was obtained between observed and expected values of average correlation coefficient (Table 18). The average correlation coefficient decreased from 0.3743 to 0.1457 when the separating period increased from one to five. The same range was observed for the estimated correlation coefficient. The maximum average correlation was obtained for periods separating by one year. So one-year period was taken as the optimum pre-experimental period for covariance analysis. This one year is the year just preceding the experimental period.

The optimum plot size was determined as six to seven. Covariance analysis was performed with these plot sizes and the results are presented in Table 19. The coefficients of variation adjusted for the pre-experimental period of one year did not show any reduction as compared to unadjusted coefficients of variation with these plot sizes.

Table 18. Average coefficient of correlation between yield separated by different periods.

Number of separating periods (x)	Coefficient of correlation (y)	
	Observed	Expected
1	0.3743	0.3743
2	0.2238	0.2451
3	0.1857	0.1857
4	0.1562	0.1583
5	0.1457	0.1457

Table 19. CV for plot yields with and without covariance adjustment.

Plot size	Year-pair		
	1978-79 to 1979-80	1980-81 to 1981-82	1982-83 to 1983-84
6	5.70 (3.00)	3.84 (3.84)	4.01 (3.04)
7	4.93 (1.95)	3.21 (1.95)	3.64 (1.73)

The figures given in paranthesis corresponds to the CV without covariance adjustment.

DISCUSSION

CHAPTER 5

DISCUSSION

The design is very important in conducting any field experiment and to draw meaningful inferences from them. The usual method of forming blocks is on the basis of geographical contiguity of trees. But this method was not found to be efficient with plantation crops. It is important that the biological variation among individual trees should be taken into account in designing experiments with them. Because of the biological variation present among the experimental trees calibration techniques are preferred in forming plots and blocks with perennials, the blocks so formed may indeed allow for past sources of variation. But the trees of a plot thus formed will be scattered over the experimental area instead of lying side by side. Uniformity of pre-experimental yields over an even number of years is always preferred for calibration so as to eliminate biennial periodicity. But in the present study with Cashew, the yield of each tree for an year is taken as the best calibrating variate. This calibrating variate has been decided upon by taking the maximum average correlation on different number of separating periods (years).

In the present investigation three methods of plot formation are tried. The first method is based on creating maximum heterogeneity within plots in selecting experimental units thereby decreasing the between plot variation within a block to a minimum. In the second method maximum homogeneity is created among units in a plot and in the third method a random collection of units constitute a plot. In all these methods the trees are spread over the entire area. The first two methods are based on calibration techniques while the third method does not require any knowledge of past performance of trees. The yield record of one year immediately preceding the experimental period is found to be sufficient for calibration.

Though it is better to have uniform experimental trees with respect to an important measurable character like 'yield', it is generally found to be impracticable with perennials because of the high genetical variation present among the trees. The first method will solve the problem of getting uniform experimental trees and will lead to successful experimentation with adult trees.

In the first method plots are formed with trees having marked yield differences. With a plot size two median may be used as the criteria for selection of trees. When median is used as the criteria, 60 to 68 percentage reduction in CV is observed when compared to single tree plots. With a plot size of three, if the selection of trees is based on the ordered arrangement of trees 82 to 86 percentage reduction in CV is effected in comparison with single tree plots. For all other plot sizes ordered arrangement of tree are used as selection criteria in plot formation. To form plots of size four trees are selected on the basis of quartiles. This selection resulted in a reduction of 88 to 90 percentage in CV compared to single tree plots. With plot size five, six, seven and eight, 88 to 98 percentage reduction in CV is obtained and this reduction is almost similar in magnitude over all the year-pairs.

In all the above methods the intraclass correlation coefficients (ρ) are negative and below the specified upper limit defined theoritically for ρ. With an increase in plot size the magnitude of intraclass correlation coefficient is found to decrease. This will certainly help to improve the efficiency of the design of experiment.

A comparison of CV for various plot sizes with ordered arrangement of trees (Method I) with Method II a substantial reduction in CV is observed. This reduction is 43 to 55 percentage, 70 to 75 percentage, 75 to 82 percentage, 82 to 86 percentage, 86 to 90 percentage, 90 to 93 percentage, 92 to 94 percentage respectively for plot sizes two, three, four, five, six, seven and eight in the four year-pairs. This indicates that method I is better than method II in plot formation.

A comparison of CV for various plot sizes in method I and method III again shows that the former is superior to the latter. The CV reduced by 20 to 36 percentage, 38 to 56 percentage, 55 to 68 percentage, 56 to 72 percentage, 65 to 75 percentage, 76 to 84 percentage, 81 to 86 percentage respectively for plot sizes two, three, four, five, six, seven and eight in the four year-pairs.

In method I, a high negative intraclass correlation (ρ) within a plot while in method II a high positive intraclass correlation (ρ) within a plot. The high negative ρ explains the heterogeneity of experimental unit within a plot whereas high positive intraclass correlation explains the homogeneity of trees within a plot. In method III a very low intraclass correlation coefficient (either positive or negative) in magnitude is observed.

Efficiency of cluster sampling increases as the meansquare within clusters increases and meansquare between clusters decreases. In method I clusters (cluster means a plot) are formed by grouping heterogeneous genotype thereby reducing between cluster variation to a minimum. The between cluster meansquare decreases and within cluster meansquare increases as plot size increases. Hence efficiency increases as plot size increases. In the present method the variation between clusters is as small as possible while the variation within clusters is as large as possible and hence the present method is more efficient than all other methods. This method is in accordance with the following principle in cluster sampling. For cluster sampling to be efficient the clusters should be so formed that the variation between cluster means is as small as possible while the variation within clusters is as large as possible (Sukhatme et al. 1984).

The maximum curvature observed at 6.8, 6.14, 6.23, 6.03 respectively in each year-pair. Since the point of maximum curvature ranges from 6 to 6.8 in the studied year-pairs 7 can be recommended as optimum plot size for experiments with cashew. With the optimum plot size seven method I is about 101 to 192 times as efficient as compared to method II. Whereas this range is about 14 to 35 times when compared to method III in different year-pairs. Thus we can conclude that method I is the best method in designing experiments with cashew followed by method III and method II. Efficiency of Randomised block design (RBD) over completely Randomised Block design (CRD) is found to be equal to one approximately. The efficiency nearly equals to one indicates that both CRD and RBD are equally efficient. This leads to a conclusion that if heterogeneous genotype are taken from distant areas to form a plot even a CRD can be used instead of a RBD for field experimentation with cashew.

The use of covariance technique do not reveal any substantial reduction in CV. Since the plots are formed with pre-recorded yield again using the same yield as covariate assumes no importance.

The above results obtained are in agreement with the results in experimentation with coconut (Saraswathi 1983). Based on all the above results it may be concluded that method I is the best to design experiments with Cashew.

SUMMARY

CHAPTER 6

SUMMARY

Designing is very important in conducting field experiment and to draw reliable conclusions from them. The design specifies the nature of control over the operations in the experiment. Proper designing will increase the accuracy and sensitivity of the results. It is therefore necessary that the data are collected by adopting proper designs so that they can be validly interpretable.

The usual method of forming blocks on the basis of geographical contiguity of tree is often not found to be efficient in plantation crops. The high biological variation among the individual trees should be taken into consideration to design experiments with them. It is always better to have uniform experimental trees, uniformity in the sense of measurable characteristic of the tree (eg. yield) both within and between plots in a block.

But there are practical constraints in achieving this homogeneity. The high variation from plant to plant

necessitates a search for other field plot technique.

The method of forming plots by grouping trees having marked yield differences is examined. This method (method I) is based on the introduction of negative intraclass correlation among the trees within a plot and found to reduce the within block variation by increasing the within plot variation and thereby increasing the accuracy of the experiment.

This method is illustrated with an empirical yield data of 294 trees collected from Cashew Research Station, Kerala Agricultural University, Madakkathara for a period of eight years ranging from 1976-77 to 1983-84. Cashew being a perennial which is often subjected to biennial periodicity. So the yield data were pooled over an even number of consecutive years to eliminate the bienniality. Even this pooling will not help to get uniform experimental trees to layout experiments on them. The four pairs of yield data were used to design experiments with various plot sizes. The same data were also utilised to design experiments by applying Shrikande's method where maximum homogeneity is maintained both between and within plots. The plots are also formed with a random selection of trees from the whole plantation under consideration. This method is named as random method. All these methods were tried in for plot sizes ranging from two to eight. However the first method was found to be superior to other two methods. The efficiency of RBD over CRD was found to be one approximately with method I.

The relationship between CV and plot sizes was described by an exponential model $y = ax^b$ and using the method of maximum curvature seven was found to be optimum for field experimentation with cashew.

The correlation coefficients separated by different periods were worked out and the principle of maximum correlation was adopted to decide upon the optimum pre-experimental period for calibration purpose. As such yield data of one year prior to the start of the experiment was found to be sufficient for calibration. The possibility of increasing accuracy of the experiment by covariance analysis with ancillary variate as the calibrating variate is examined and found that covariance is not necessary with method I.

Based on the above results it can be concluded that method I is the best field plot technique to design experiments with cashew.

REFERENCES

REFERENCES

Abraham, T.P., Khosla, R.K. and Agarwal, K.N. (1969). Uniformity trials on black pepper; piper nigrum L. Indian J. agric. Sci; 39(8): 790-806.

Abraham, T.P. and Kulkarni, G.A. (1963). Investigations on the optimum pre-experimental period in field experimentation on perennial crops. J. Indian Soc. agric. Statist; 15(1): 175-184.

Agarwal, K.N. (1973). Uniformity trial of apple. Indian J. Hort; 30: 525-528.

Agarwal, K.N., Bavappa, K.V.A. and Khosla, R.K. (1968). Study of size and shape of plots and blocks and optimum number of pre-experimental periods on arecanut. Indian J. agric. Sci; 38: 444-60.

Agarwal, K.N. and Deshpande, M.R. (1967). Size and shape of plots and blocks in field experiments with dibbled paddy. Indian J. agric. Sci; 37(6): 445-55.

Bavappa, K.V.A. (1959). Field experimentation in arecanut - Part I. Arecanut J., 10(3): 116-122.

Bhargava, P.N. and Sardana, M.G. (1975). Size and shape of plots in field trials with apple. Indian J. Hort; 32(1): 50-57.

Bhargava, P.N., Saxena, A. and Baika, P.K. (1978). Size and shape of plots in field trials with Banana. Indian J. Hort; 35(1): 68-73.

Biswas, S.R., Ramachander, P.R. and Gupta, A. (1982). Size and shape of experimental plots in cabbage experiments. Indian J. Agric. Sci; 52(2): 139-41.

Brar, W.S., Chahal, B.S. and Gill, D.S. (1983). Optimum plot size for experiments on sweet orange (Citrus Sinensis Osbee). CV. Jaffa. South Indian Hort; 31: 99-100.

Brown, A.R. and Morris, H.D. (1967). Estimation of optimum plot size for grain Sorghum yield trials. Agron. J; 59(6): 576-77.

Butters, B. (1964). Some practical considerations in the conduct of field trials with robusta coffee. J. Hort. Sci; 39: 24-33.

*Chapas, L.C. (1961). Plot size and reduction of variability in oil-palm experiments. Emp. J. exp. Agric; 29: 212-24.

Chandler, W.H. (1921). The trend of research in pomology. Proc. Amer. Soc. Hort. Sci; 18: 233-40.

Cochran, W.G. and Cox, G.M. (1962). Experimental Designs. 2nd Ed. John Wiley and Sons, Inc., New York.

*Conagin, A. and Fraga, Jr. C.C. (1955). Design and analysis of coffee experiments. International symposium of Biometry.

*Dutta, S.K. and Heath, E.D. (1960). Size, shape and number of plots for field experiments with tea. Emp. J. exp. Agric; 28: 121-32.

Federer, W.T. (1967). Experimental Design. Oxford and IBH Publishing Company, Calcutta, Ind. Ed. p.59-85.

Fisher, R.A. (1960). The design of experiments. 7th Ed., Hafner Press, Macmillan Publishing Co. Inc., New York.

Freeman, G.H. (1963). The combined effect of environmental and plant variation. Biometrics; 19(2): 273-277.

*Gadd, C.H. (1922). Experimental errors of field trials with Hevea - Bull No. 66. Department of agriculture, Ceylon.

George, M.V., Pattan Shetty, M.V., Narasimhayya, G., Nambiar, M.C. and Sathe, K.V. (1983). Optimum size and shape of plots in blocks for cardamom experimentation. J. Plantation Crops; 11(1): 50-54.

Granville, W.H., Smith, P.F. and Longley, W.R. (1965). Elements of the differential and integral calculus. Oxford and IBH Publishing Co., Calcutta. pp 149-152.

Haldane, J.B.S. (1958). Suggestions for research on coconut. Indian Coco. J; 12: 1-9.

Hariharan, V. (1983). Optimum plot size for field experiments on Brinjal. Unpublished M.Sc.(Ag. Stat.) thesis, Kerala Agricultural University.

Iyer, S.S. and Agarwal, K.C. (1970). Optimum size and shape of plots for sugarcane. Indian J. agric. Sci; 40(2): 124-132.

Jayaraman, K. (1979). Optimum size and shape of plots and blocks and relative efficiency of designs for field experiments in sunflower (Helianthus annuus Linn.). M.Sc. thesis. University of Agricultural Sciences, Bangalore.

Keller, K.R. (1949). Uniformity trials on Hops, Humus Lupus L. for increasing the precision of field experiments. Agron. J; 41(8): 389-91.

Kushik, L.S., Singh, R.P. and Yadava, T.P. (1977). A uniformity trial with mustard. Indian J. agric. Sci; 47(10): 515-8.

Longworth, J.F. and Freeman, G.H. (1963). The use of trunk girth as a calibrating variate for field experiments on Cocoa trees. J. Hort. Sci; 38: 61-67.

Menon, T.C.M. and Tyagi, B.N. (1971). Optimum size and shape of plots in experiments with mandarin orange (Citrus reticulata Blanco). Indian J. agric. Sci; 41(10): 857-861.

Moore, C.S. (1968). The course of variation in fruit tree experiment. J. Hort. Sci; 43(2): 121-31.

Nair, R.B. (1983). Optimum plot size for field experiments on cashew. Unpublished M.Sc. (Ag. Stat) thesis, Kerala Agricultural University.

*Narayanan, R. (1965). Some considerations in deciding the optimum number of recorded trees in a plot for experiments on immature Hevea brasiliensis. J. Rubb. Res. Inst. Malaya; 19: 120-31.

*Narayanan, R. (1966). Value of covariance analysis in manurial experiments on rubber. J. Rubb. Res. Inst. Malaya; 19: 176-88.

*Narayanan, R. (1968). Girth as a calibrating variate for improving field experiments on Hevea brasiliensis. J. Rubb. Res. Inst. Malaya; 20: 130-5.

*Northwood, P.J. (1967). The variation in cashew yields in southern Tanzania. E. Afr. agric. For. J; 32: 237-9.

Pankajakshan, A.S. (1960). A note on the relative contribution of genetic and environmental factors on the yield of uniformly treated coconut trees. Indian Coco. J; 14(1): 37-43.

Patterson, D.D. (1939). Statistical technique in agricultural research. First Edn. McGraw - Hill Book Company, New York and London.

*Pearce, S.C. (1953). Field experimentation with fruit trees and other perennial plants. Common Wealth Bur. Hort. Plantation crops. Tech. Comn; 23.

Pearce, S.C. (1955). Some considerations in deciding plot size in field trials with trees and bushes. J. Indian Soc. Agric. Statist; 7: 23-26.

Pearce, S.C. (1976). Field experimentation with fruit trees and other perennial plants. Common Wealth Agricultural Bureaux. pp 106.

Pearce, S.C. and Brown, A.H.F. (1960). Improving fruit tree experiments by a preliminary study of the trees. J. Hort. Sci; 35: 56-65.

Pearce, S.C. and Moore, C.S. (1962). A study of sources of variation in apple tree experiments. J. Hort. Sci; 37: 175-89.

Pearce, S.C. and Taylor, J. (1950). The purpose and design of calibration trials. A.R.E. Malling Res. Stat. 1949, 83-90.

Pearce, S.C. and Thom, J.M.S. (1951). A study of plot size with Nigerian estate cacao. J. Hort. Sci; 26: 261-7.

Pearce, S.C. and Urbanc, S.D. (1967). The measurement of irregularity in growth and cropping. J. Hort. Sci; 42(3): 295-305.

Prabhakaran, P.V., Balakrishnan, S. and Mary George (1978). Optimum plot size for field trials with banana. Agric. Res. J. Kerala; 16(1): 33-38.

Prabhakaran, P.V. and Thomas, E.J. (1974). Optimum plot size for field experiments with tapioca. Agric Res. J. Kerala; 12(1): 19-23.

Salmon, S.C. (1923). Some limitations in the application of the method of least squares to field experiments. J. Amer. Soc. Agron; 15(5): 225-238.

Saraswathi, P. (1983). Methodological studies in designing experiments on coconut - Unpublished. Ph.D. Thesis, IARI, New Delhi.

Sardana, M.G., Sreenatha, P.R. and Malhotra, V.P. (1967). Size and shape of plots and blocks in field trials with potato. Indian J. agric. Sci; 37(4): 338-355.

Sasmal, B.C. and Katyal, V. (1980). Note on the size and shape of plots and blocks in field experiments with tossa Jute. Indian J. agric. Sci; 50(10): 791-794.

Saxena, P.N., Kavitkar, A.G. and Monga, M.K. (1972). Optimum plot size for oat grown for fodder. Indian J. agric. Sci; 42(1): 63-9.

*Sen, A.R. (1963). Use of pretreatment data in designing experiments on tea. Emp. J. exp. Agric; 31: 41-9.

Shanker, K., Lal, M.S. and Goswamy, U. (1972). Size and shape of plots and blocks in yield trials of soybean. Indian J. agric. Sci; 42(10): 901-908.

Sharpe, R.H. and Blackmon, G.H. (1950). A study of plot size and experimental design with pecan yield data. Proc. Amer. Soc. Hort. Sci; 56: 236-41.

Shrikande, V.J. (1958). Some considerations in designing experiments on coconut trees. Indian Coco. J; 11(4): 140-157.

Siao, S. (1935). Uniformity trials with cotton. J. Amer. Soc. Agron; 27(12): 974-79.

Singh, L.B. (1961a). Biennial bearing in mango as affected by cultural operations, weather conditions and tree vigour. Hort. adv; 5: 17-23.

Singh, L.B. (1961b). Biennial bearing studies in mango - effect of Gibberllic acid and Maleic Hydrazide. Hort. adv; 5: 97-103.

Singh, D., Bhargava, P.N., Khosla, R.K. and Saxena, A. (1975). Monograph on study of size and shape of plots for field experiments on vegetable and perennial crops. IASRI (ICAR), New Delhi.

Smith, H.F. (1938). An empirical law describing heterogeneity in the yields of agricultural crops. J. agric. Sci; 28: 1-23.

Sreenath, P.R. and Marwaha, S.P. (1977). Preliminary study on size and shape of plots and blocks in field trials with cowpea. Indian J. agric. Sci; 47(1): 52-57.

Sukhatme, P.V., Sukhatme, B.V., Sukhatme, S. and Asok, C. (1984). Sampling theory of surveys with applications. Third Edition, Indian Society of Agricultural Statistics, New Delhi, pp. 270-284.

Tyagi, B.N., Kathuria, O.P., Sahni, M.L. and Kulkarni, G.A. (1973). A study of co-efficient of variation associated with plots and blocks of different sizes for some important field crops. J. Indian Soc. agric. Statist; 25(2): 38-48.

Vaidhyanathan, M. (1934). The method of "covariance" applicable to the utilization of the previous crop records for judging the improved precision of experiments. Indian J. agric. Sci; 4: 327-41.

Vernon, A.J. and Morris, M.G. (1964). Variability in West African peasant cocoa farm; time studies on Agodi cocoa yields. J. Hort. Sci; 39: 241-53.

Wiedemann, A.M. and Leininger, L.N. (1963). Estimation of optimum plot size and shape for safflower yield trials. Agron. J; 55(3): 222-5.

Yamane, T. (1964). Statistics, An introductory analysis. Harper & Row publishers, Inc., New York. pp. 706-708.

*Originals not seen.

APPENDIX I

Available number of plots as per various methods.

Plot size	Year-pair			
	1976-77 to 1977-78	1978-79 to 1979-80	1980-81 to 1981-82	1982-83 to 1983-84
2	109	118	87	78
3	72	78	58	52
4	54	59	43	39
5	43	47	34	31
6	36	39	29	26
7	31	33	24	22
8	27	29	21	19

Correlation matrix

Year							
1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83	1983-84
1.000	0.3376337	0.3699507	0.4158717	0.1713564	0.0542954	0.3037638	0.2644446
	1.00	0.4585172	0.3807676	0.03558044	-0.07331436	0.1263181	0.3189225
		1.00	0.3945086	0.08852131	-0.06539645	0.2230366	0.2566183
			1.000	0.3052713	0.0005019	0.3199022	0.3036955
				1.00	0.4237777	0.4274108	0.2225693
					1.00	0.2148946	0.07539744
						1.00	0.4857411
							1.000

APPENDIX II

Range of values in yield

Plot size	Year-pair: 1976-77 to 1977-78
2	≤2.741, >2.741
3	≤1.480, >1.480 and ≤3.775, >3.775
4	≤0.995, >0.995 and ≤2.741, >2.741 and ≤4.940, >4.940
5	≤0.820, >0.820 and ≤1.90, >1.90 and ≤3.364, >3.364 and ≤5.160, >5.160
6	≤0.700, >0.700 and ≤1.480, >1.48 and ≤2.741, >2.741 and ≤3.819, >3.819 and ≤6.100, >6.100
7	≤0.645, >0.645 and ≤1.280, >1.280 and ≤2.150, >2.150 and ≤3.197, >3.197 and ≤4.380, >4.380 and ≤6.902, >6.902
8	≤0.597, >0.597 and ≤0.995, >0.995 and ≤1.720, >1.720 and ≤2.741, >2.741 and ≤3.515, >3.515 and ≤4.842, >4.842 and ≤7.074, >7.074

Range of values in yield

Plot size	Year-pair: 1978-79 to 1979-80
2	≤ 7.005, >7.005
3	≤ 4.300, >4.30 and ≤ 10.253, >10.253
4	≤ 3.300, >3.300 and ≤ 7.005, >7.005 and ≤ 12.350, >12.350
5	≤ 2.50, >2.50 and ≤ 5.27, >5.27 and ≤ 8.925, >8.925 and ≤ 13.300, >13.300
6	≤ 2.000, >2.000 and ≤ 4.300, >4.300 and ≤ 7.005, >7.005 and ≤ 10.253, >10.253 and ≤ 14.500, >14.500
7	≤ 1.750, >1.750 and ≤ 3.600, >3.600 and ≤ 5.750, >5.75 and ≤ 8.53, >8.53 and ≤ 11.025, >11.025 and ≤ 14.635, >14.635
8	≤ 1.550, >1.550 and ≤ 3.300, >3.300 and ≤ 4.900, >4.90 and ≤ 7.005, >7.005 and ≤ 9.481, >9.481 and ≤ 11.965, >11.965 and ≤ 15.20, >15.20

Range of values in yield

Plot size	Year-pair: 1980-81 to 1981-82
2	≤7.05, >7.05
3	≤5.43, >5.43 and ≤9.00, >9.00
4	≤4.75, >4.75 and ≤7.05, >7.05 and ≤10.35, >10.35
5	≤4.10, >4.10 and ≤6.00, >6.00 and ≤8.10, >8.10 and ≤11.80, >11.80
6	≤3.35, >3.35 and ≤5.43, >5.430 and ≤7.05, >7.05 and ≤9.00, >9.00 and ≤14.18, >14.18
7	≤3.10, >3.10 and ≤4.95, >4.95 and ≤6.05, >6.05 and ≤7.70, >7.70 and ≤9.20, >9.20 and ≤14.00, >14.00
8	≤2.85, >2.85 and ≤4.40, >4.40 and ≤5.58, >5.58 and ≤7.05, >7.05 and ≤8.15, >8.15 and ≤10.00, >10.00 and ≤14.65, >14.65

Range of values in yield

Plot size	Year-pair: 1982-83 to 1983-84
2	≤11.60, >11.60
3	≤7.80, >7.80 and ≤15.25, >15.25
4	≤6.54, >6.54 and ≤11.60, >11.60 and ≤17.70, >17.70
5	≤5.70 >5.70 and ≤ 8.85, >8.85 and ≤13.40 >13.40 and ≤19.65, >19.65
6	≤5.45, >5.45 and ≤7.80, >7.80 and ≤11.60, >11.60 and ≤15.25, >15.25 and ≤20.82, >20.85
7	≤4.90, >4.90 and ≤ 6.80, >6.80 and ≤9.60, >9.60 and ≤12.50, >12.50 and ≤15.95, >15.95 and ≤ 21.30, >21.30
8	≤4.70, >4.70 and ≤ 6.45, >6.45 and ≤8.15, >8.15 and ≤11.60, >11.60 and ≤13.65, >13.65 and ≤ 17.20, >17.20 and ≤21.80, >21.80

Arrangement of trees as per method I (Two trees per plot)

Plot Number	Tree Number	Plot Number	Tree Number	Plot Number	Tree Number	Plot Number	Tree Number	Plot Number	Tree Number	Plot Number	Tree Number
1	185 (4.380) 234 (0.845)	2	86 (8.658) 164 (2.235)	3	109 (4.535) 202 (0.930)	4	133 (3.190) 63 (0.440)	5	223 (10.075) 40 (2.485)	6	163 (6.683) 246 (1.575)
7	13 (5.210) 217 (1.405)	8	158 (5.167) 33 (1.340)	9	104 (6.425) 221 (1.525)	10	143 (3.605) 269 (0.645)	11	11 (5.180) 200 (1.344)	12	232 (9.940) 179 (2.475)
13	41 (3.362) 47 (0.505)	14	276 (2.800) 18 (0.130)	15	191 (7.591) 119 (2.060)	16	231 (8.199) 123 (2.180)	17	212 (8.054) 57 (2.165)	18	174 (16.712) 38 (2.715)
19	270 (15.238) 152 (2.697)	20	150 (5.083) 242 (1.260)	21	144 (3.965) 266 (0.790)	22	126 (3.590) 58 (0.637)	23	169 (4.256) 281 (0.820)	24	97 (6.242) 110 (1.525)
25	43 (2.767) 140 (0.100)	26	151 (3.199) 229 (0.466)	27	134 (3.392) 250 (0.520)	28	149 (5.222) 170 (1.420)	29	176 (7.040) 15 (1.590)	30	208 (3.150) 147 (0.330)
31	98 (4.330) 262 (0.840)	32	17 (3.197) 51 (0.457)	33	222 (5.160) 181 (1.300)	34	201 (3.688) 70 (0.647)	35	136 (4.940) 46 (0.995)	36	211 (7.545) 244 (2.010)
37	240 (9.184) 291 (2.270)	38	194 (11.210) 271 (2.565)	39	203 (7.710) 90 (2.137)	40	171 (3.364) 228 (0.510)	41	142 (5.057) 184 (1.258)	42	85 (6.100) 24 (1.466)
43	45 (5.485) 226 (1.440)	44	77 (5.135) 256 (1.280)	45	3 (3.428) 36 (0.549)	46	193 (7.045) 177 (1.690)	47	87 (5.300) 78 (1.435)	48	112 (3.515) 172 (0.550)
49	107 (3.489) 69 (0.550)	50	42 (3.528) 161 (0.597)	51	209 (2.860) 23 (0.188)	52	180 (7.440) 5 (1.720)	53	127 (3.405) 190 (0.530)	54	294 (2.970) 81 (0.213)
55	135 (9.596) 59 (2.359)	56	233 (9.095) 15 (1.590)	57	10 (3.142) 79 (0.330)	58	160 (6.220) 16 (1.492)	59	118 (4.740) 53 (0.965)	60	25 (4.067) 258 (0.810)
61	192 (3.550) 125 (0.600)	62	241 (7.074) 34 (1.700)	63	207 (7.825) 8 (2.139)	64	183 (3.747) 141 (0.665)	65	93 (8.545) 156 (2.187)	66	84 (3.775) 237 (0.694)
67	220 (7.492) 159 (1.735)	68	195 (13.100) 124 (2.670)	69	44 (3.052) 272 (0.245)	70	225 (3.425) 102 (0.530)	71	52 (2.782) 264 (0.129)	72	139 (6.902) 218 (1.580)
73	7 (3.695) 273 (0.665)	74	157 (6.100) 138 (1.480)	75	178 (8.005) 290 (2.150)	76	243 (2.830) 100 (0.140)	77	175 (5.000) 66 (1.100)	78	12 (4.943) 145 (1.000)
79	239 (3.562) 186 (0.605)	80	106 (7.515) 196 (1.900)	81	114 (4.395) 292 (0.850)	82	115 (3.310) 122 (0.490)	83	166 (3.063) 48 (0.285)	84	154 (5.015) 56 (1.232)
85	132 (3.190) 33 (0.395)	86	205 (3.190) 117 (0.770)	87	215 (7.512) 2 (1.815)	88	216 (4.955) 214 (1.032)	89	49 (3.819) 285 (0.700)	90	224 (4.020) 116 (0.800)
91	111 (4.527) 105 (0.910)	92	204 (9.292) 139 (2.300)	93	129 (3.234) 173 (0.485)	94	206 (4.067) 281 (0.820)	95	155 (4.842) 248 (0.993)	96	137 (6.100) 198 (1.480)
97	80 (4.389) 91 (0.850)	98	162 (3.085) 72 (0.320)	99	92 (4.540) 6 (0.965)	100	197 (5.090) 252 (1,260)	101	188 (5.894) 247 (1.450)	102	128 (12.852) 213 (2.662)
03	108 (7.520) 138 (2.000)	104	14 (7.507) 165 (1.802)	105	121 (3.880) 55 (0.715)	106	96 (7.443) 50 (1.728)	107	284 (7.520) 253 (1.910)	108	230 (10.044) 130 (2.480)
09	167 (2.810) 255 (0.410)										

Figures given in brackets represents yield.

Arrangement of trees as per method I (Three trees per plot)

Plot Number	Tree Number	Plot Number	Tree Number	Plot Number	Tree Number	Plot Number	Tree Number	Plot Number	Tree Number	Plot Number	Tree Number
1	58 (0.637) 134 (3.392) 106 (7.515)	2	262 (0.840) 10 (3.142) 85 (6.100)	3	125 (0.600) 5 (1.720) 160 (6.220)	4	184 (1.258) 179 (2.475) 87 (5.300)	5	145 (1.000) 50 (1.728) 176 (7.040)	6	202 (0.930) 162 (3.085) 232 (9.940)
7	285 (0.700) 136 (4.940) 149 (5.222)	8	63 (0.440) 271 (2.565) 216 (4.955)	9	88 (1.340) 165 (1.802) 233 (9.095)	10	234 (0.845) 112 (3.515) 139 (6.902)	11	24 (1.466) 43 (2.767) 182 (4.109)	12	47 (0.505) 123 (2.180) 231 (8.199)
13	105 (0.910) 291 (2.270) 180 (7.440)	14	36 (0.549) 124 (2.670) 195 (13.100)	15	55 (0.715) 159 (1.735) 92 (4.540)	16	272 (0.245) 129 (3.234) 175 (5.000)	17	247 (1.450) 110 (1.525) 80 (4.389)	18	273 (0.665) 133 (3.190) 205 (3.910)
19	91 (0.850) 40 (2.485) 185 (4.380)	20	242 (1.260) 44 (3.052) 163 (6.683)	21	116 (0.800) 213 (2.662) 142 (5.057)	22	66 (1.100) 42 (3.528) 12 (4.943)	23	266 (0.790) 94 (1.700) 284 (7.520)	24	181 (1.300) 192 (3.550) 104 (6.425)
25	6 (0.965) 171 (3.364) 121 (3.880)	26	173 (0.485) 57 (2.165) 77 (5.135)	27	264 (0.129) 16 (1.492) 222 (5.160)	28	69 (0.550) 221 (1.525) 193 (7.045)	29	78 (1.435) 132 (3.190) 240 (9.184)	30	100 (0.140) 225 (3.425) 212 (8.054)
31	141 (0.665) 156 (2.187) 96 (7.443)	32	186 (0.605) 15 (1.590) 154 (5.015)	33	226 (1.440) 151 (3.199) 241 (7.074)	34	51 (0.457) 164 (2.235) 128 (12.852)	35	81 (0.213) 239 (3.562) 108 (7.520)	36	198 (1.480) 127 (3.405) 45 (5.485)
37	217 (1.405) 107 (3.489) 203 (7.710)	38	190 (0.530) 38 (2.715) 25 (4.067)	39	172 (0.550) 158 (2.250) 93 (8.545)	40	33 (0.395) 243 (2.830) 206 (4.067)	41	46 (0.995) 8 (2.139) 150 (5.083)	42	161 (0.597) 294 (2.970) 97 (6.242)
43	23 (0.188) 84 (3.775) 109 (4.535)	44	72 (0.320) 253 (1.910) 230 (10.044)	45	200 (1.344) 138 (2.700) 203 (7.710)	46	256 (1.280) 143 (3.605) 118 (4.740)	47	252 (1.260) 59 (2.359) 224 (4.020)	48	70 (0.647) 3 (3.428) 230 (10.044)
49	269 (0.645) 244 (2.010) 111 (4.527)	50	229 (0.466) 41 (3.362) 13 (5.210)	51	250 (0.520) 177 (1.690) 49 (3.819)	52	53 (0.965) 119 (2.060) 215 (7.512)	53	79 (0.330) 90 (2.137) 207 (7.825)	54	248 (0.993) 290 (2.150) 130 (6.100)
55	117 (0.770) 201 (3.688) 168 (5.167)	56	122 (0.490) 167 (2.810) 191 (7.591)	57	140 (0.100) 218 (1.580) 98 (4.330)	58	17 (3.197) 255 (0.140) 169 (4.256)	59	113 (0.820) 7 (2.662) 144 (3.965)	60	281 (0.820) 189 (2.300) 197 (5.090)
61	214 (1.032) 126 (3.590) 178 (8.005)	62	170 (1.420) 2 (1.815) 155 (4.842)	63	237 (0.694) 208 (3.150) 188 (5.894)	64	258 (0.810) 115 (3.310) 194 (11.210)	65	147 (0.333) 52 (2.782) 204 (9.292)	66	292 (0.850) 276 (2.800) 136 (4.940)
67	102 (0.530) 246 (1.575) 14 (7.507)	68	56 (1.232) 166 (3.063) 211 (7.545)	69	18 (0.130) 152 (2.697) 220 (7.492)	70	28 (0.820) 209 (2.860) 135 (9.596)	71	48 (0.285) 196 (1.900) 114 (4.395)	72	228 (0.510) 183 (3.747) 11 (5.180)

The Figures given in brackets represents yield.

Arrangement of trees as per method I (Four trees per plot)

Plot Number	Tree Number	Plot Number	Tree Number	Plot Number	Tree Number	Plot Number	Tree Number	Plot Number	Tree Number	Plot Number	Tree Number
1	58 (0.637)	2	262 (0.840)	3	125 (0.600)	4	202 (0.930)	5	285 (0.700)	6	63 (0.440)
	5 (1.720)		179 (2.475)		50 (1.728)		184 (1.258)		130 (2.480)		271 (2.565)
	134 (3.392)		10 (3.142)		162 (3.085)		112 (3.515)		43 (2.767)		182 (4.109)
	106 (7.515)		85 (6.100)		160 (6.220)		87 (5.300)		176 (7.040)		232 (9.940)
7	234 (0.845)	8	47 (0.505)	9	105 (0.910)	10	36 (0.549)	11	55 (0.715)	12	272 (0.245)
	145 (1.000)		165 (1.802)		123 (2.180)		291 (2.270)		88 (1.340)		124 (2.670)
	129 (3.234)		133 (3.190)		44 (3.052)		42 (3.528)		92 (4.540)		192 (3.550)
	149 (5.222)		216 (4.955)		233 (9.095)		139 (6.902)		231 (8.199)		180 (7.440)
13	273 (0.665)	14	91 (0.850)	15	116 (0.800)	16	266 (0.790)	17	6 (0.965)	18	173 (0.485)
	159 (1.735)		24 (1.466)		110 (1.525)		247 (1.450)		40 (2.485)		213 (2.662)
	80 (4.389)		205 (3.910)		185 (4.380)		171 (3.364)		171 (3.364)		132 (3.190)
	270 (15.238)		195 (13.100)		175 (5.000)		163 (6.683)		142 (5.057)		12 (4.943)
19	264 (0.129)	20	69 (0.550)	21	100 (0.140)	22	141 (0.665)	23	186 (0.605)	24	51 (0.457)
	242 (1.260)		66 (1.100)		94 (1.700)		181 (1.300)		57 (2.165)		78 (1.435)
	225 (3.425)		151 (3.199)		239 (3.562)		127 (3.405)		107 (3.489)		243 (2.830)
	284 (7.520)		104 (6.425)		77 (5.135)		222 (5.160)		193 (7.045)		240 (9.184)
25	81 (0.213)	26	190 (0.530)	27	172 (0.550)	28	33 (0.395)	29	46 (0.995)	30	161 (0.597)
	16 (1.492)		221 (1.525)		226 (1.440)		156 (2.187)		15 (1.590)		164 (2.235)
	294 (2.970)		84 (3.775)		25 (4.067)		206 (4.067)		143 (3.605)		3 (3.428)
	212 (8.054)		96 (7.443)		154 (5.015)		241 (7.074)		128 (12.852)		108 (7.520)
31	23 (0.188)	32	72 (0.320)	33	70 (0.647)	34	269 (0.645)	35	229 (0.466)	36	250 (0.520)
	198 (1.480)		217 (1.405)		38 (2.715)		158 (2.250)		8 (2.139)		253 (1.910)
	41 (3.362)		109 (4.535)		118 (4.740)		224 (4.020)		201 (3.688)		167 (2.810)
	45 (5.485)		203 (7.710)		93 (8.545)		150 (5.083)		97 (6.242)		223 (10.075)
37	53 (0.965)	38	79 (0.330)	39	248 (0.993)	40	117 (0.770)	41	122 (0.490)	42	140 (0.100)
	138 (2.000)		200 (1.344)		256 (1.280)		252 (1.260)		59 (2.359)		244 (2.010)
	111 (4.527)		17 (3.197)		49 (3.819)		7 (3.695)		126 (3.590)		208 (3.150)
	86 (8.658)		230 (10.044)		13 (5.210)		215 (7.512)		174 (16.712)		207 (7.825)
43	255 (0.140)	44	113 (0.820)	45	281 (0.820)	46	237 (0.694)	47	258 (0.810)	48	147 (0.333)
	177 (1.690)		119 (2.060)		90 (2.137)		290 (2.150)		214 (1.032)		218 (1.580)
	98 (4.330)		115 (3.310)		52 (2.782)		276 (2.800)		169 (4.256)		144 (3.965)
	137 (6.100)		168 (5.167)		191 (7.591)		197 (5.090)		178 (8.005)		188 (5.894)
49	292 (0.850)	50	102 (0.530)	51	18 (0.130)	52	28 (0.820)	53	48 (0.285)	54	228 (0.510)
	189 (2.300)		170 (1.420)		2 (1.815)		246 (1.575)		56 (1.232)		152 (2.697)
	155 (4.842)		166 (3.063)		136 (4.940)		209 (2.860)		114 (4.395)		183 (3.747)
	194 (11.210)		204 (9.292)		14 (7.507)		211 (7.545)		220 (7.492)		135 (9.596)

Figures given in brackets represents yield.

Arrangement of trees as per method I (five trees per plot)

Plot No.	Tree Number	Plot No.	Tree Number	Plot No.	Tree Number	Plot No.	Tree Number	Plot No.	Tree Number	Plot No.	Tree Number	Plot No.	Tree Numbe
1	58 (0.637) 5 (1.720) 10 (3.142) 134 (3.392) 106 (7.515)	2	125 (0.600) 262 (0.840) 179 (2.475) 216 (4.955) 85 (6.100)	3	285 (0.700) 50 (1.728) 162 (3.085) 112 (3.515) 160 (6.220)	4	63 (0.440) 184 (1.258) 130 (2.480) 182 (4.109) 87 (5.300)	5	47 (0.505) 145 (1.000) 27 (2.565) 42 (3.528) 176 (7.040)	6	36 (0.549) 165 (1.802) 43 (2.767) 92 (4.540) 232 (9.940)	7	55 (0.715 202 (0.930 123 (2.180 175 (5.000 149 (5.222
8	272 (0.245) 88 (1.340) 291 (2.270) 192 (3.550) 233 (9.095)	9	273 (0.665) 159 (1.735) 124 (2.670) 80 (4.389) 139 (6.902)	10	116 (0.800) 234 (0.845) 129 (3.234) 205 (3.910) 231 (8.199)	11	266 (0.790) 24 (1.460) 133 (3.190) 185 (4.380) 180 (7.440)	12	173 (0.485) 105 (0.910) 40 (2.485) 142 (5.057) 163 (6.683)	13	264 (0.129) 110 (1.525) 44 (3.052) 12 (4.943) 284 (7.520)	14	69 (0.550) 247 (1.450) 213 (2.662) 121 (3.880) 104 (6.425)
15	100 (0.140) 91 (0.850) 171 (3.364) 77 (5.135) 193 (7.045)	16	141 (0.665) 242 (1.260) 57 (2.165) 222 (5.160) 240 (9.184)	17	186 (0.605) 66 (1.100) 132 (3.190) 225 (3.425) 212 (8.054)	18	51 (0.457) 94 (1.700) 156 (2.187) 239 (3.562) 96 (7.443)	19	81 (0.213) 181 (1.300) 151 (3.199) 127 (3.405) 241 (7.074)	20	190 (0.530) 6 (0.965) 164 (2.235) 107 (3.489) 128(12.852)	21	172 (0.550) 78 (1.435) 38 (2.715) 154 (5.015) 108 (7.520)
22	33 (0.395) 16 (1.492) 158 (2.250) 84 (3.775) 45 (5.485)	23	161 (0.597) 221 (1.525) 243 (2.830) 25 (4.067) 203 (7.710)	24	23 (0.188) 226 (1.440) 8 (2.139) 206 (4.067) 93 (8.545)	25	72 (0.320) 15 (1.590) 294 (2.970) 143 (3.605) 97 (6.242)	26	70 (0.647) 198 (1.480) 253 (1.910) 150 (5.083) 223(10.075)	27	269 (0.645) 217 (1.405) 138 (2.000) 3 (3.428) 86 (8.658)	28	229 (0.466) 46 (0.995) 59 (2.359) 109 (4.535) 230(10.044)
29	250 (0.520) 200 (1.344) 244 (2.010) 118 (4.740) 13 (5.210)	30	79 (0.330) 256 (1.280) 41 (3.362) 224 (4.020) 215 (7.512)	31	117 (0.770) 252 (1.260) 119 (2.060) 201 (3.688) 207 (7.825)	32	122 (0.490) 53 (0.965) 90 (2.137) 111 (4.527) 137 (6.100)	33	140 (0.100) 248 (0.993) 290 (2.150) 49 (3.819) 168 (5.167)	34	255 (0.140) 177 (1.690) 167 (2.810) 7 (3.695) 191 (7.591)	35	113 (0.820) 281 (0.820) 17 (3.197) 126 (3.590) 178 (8.005)
36	237 (0.694) 214 (1.032) 189 (2.300) 98 (4.330) 188 (5.894)	37	258 (0.810) 218 (1.580) 208 (3.150) 169 (4.256) 194(11.210)	38	147 (0.338) 170 (1.420) 115 (3.310) 144 (3.965) 204 (9.292)	39	102 (0.530) 2 (1.815) 52 (2.782) 197 (5.090) 14 (7.507)	40	18 (0.130) 292 (0.850) 276 (2.800) 155 (4.842) 211 (7.545)	41	28 (0.820) 246 (1.575) 166 (3.063) 136 (4.940) 220 (7.492)	42	48 (0.285) 56 (1.232) 152 (2.697) 114 (4.395) 135 (9.596)
43	228 (0.510) 196 (1.900) 209 (2.860) 183 (3.747) 11 (5.180).												

Arrangement of trees as per method I (six trees per plot)

Plot No.	Tree Number	Plot No.	Tree Number	Plot No.	Tree Number	Plot No.	Tree Number	Plot No.	Tree Number	Plot No.	Tree Number	Plot No.	Tree Number
1	58 (0.637)	2	125 (0.600)	3	285 (0.700)	4	63 (0.440)	5	47 (0.505)	6	36 (0.549)	7	272 (0.245)
	262 (0.840)		184 (1.258)		145 (1.000)		202 (0.930)		88 (1.340)		234 (0.845)		24 (1.466)
	5 (1.720)		179 (2.475)		50 (1.728)		130 (2.480)		271 (2.565)		165 (1.802)		123 (2.180)
	134 (3.392)		10 (3.142)		162 (3.085)		112 (3.515)		43 (2.767)		129 (3.234)		133 (3.190)
	85 (6.100)		87 (5.300)		149 (5.222)		216 (4.955)		182 (4.109)		92 (4.540)		175 (5.000)
	106 (7.515)		160 (6.220)		176 (7.040)		232 (9.940)		233 (9.095)		139 (6.902)		231 (8.199)
8	273 (0.665)	9	173 (0.485)	10	264 (0.129)	11	69 (0.550)	12	100 (0.1400)	13	141 (0.665)	14	186 (0.605)
	105 (0.910)		55 (0.715)		247 (1.450)		91 (0.850)		242 (1.260)		116 (0.800)		66 (1.100)
	291 (2.270)		124 (2.670)		159 (1.735)		110 (1.525)		40 (2.485)		213 (2.662)		94 (1.700)
	44 (3.052)		42 (3.528)		192 (3.550)		171 (3.364)		132 (3.190)		225 (3.425)		151 (3.199)
	80 (4.389)		205 (3.910)		185 (4.380)		142 (5.057)		12 (4.943)		121 (3.880)		77 (5.135)
	180 (7.440)		270(15.238)		195 (13.100)		163 (6.683)		284 (7.520)		104 (6.425)		193 (7.045)
15	51 (0.457)	16	81 (0.213)	17	190 (0.530)	18	172 (0.550)	19	33 (0.395)	20	161 (0.597)	21	23 (0.188)
	266 (0.790)		181 (1.300)		6 (0.965)		78 (1.435)		226 (1.440)		198 (1.480)		217 (1.405)
	57 (2.165)		16 (1.492)		221 (1.525)		156 (2.187)		15 (1.590)		164 (2.235)		38 (2.715)
	239 (3.562)		127 (3.405)		107 (3.489)		243 (2.830)		294 (2.970)		84 (3.775)		143 (3.605)
	222 (5.160)		154 (5.015)		45 (5.485)		25 (4.067)		206 (4.067)		150 (5.083)		109 (4.535)
	240 (9.184)		212 (8.054)		96 (7.443)		241 (7.074)		128 (12.852)		108 (7.520)		203 (7.710)
22	72 (0.320)	23	70 (0.647)	24	269 (0.645)	25	229 (0.466)	26	250 (0.520)	27	79 (0.330)	28	122 (0.490)
	46 (0.995)		200 (1.344)		256 (1.280)		252 (1.260)		53 (0.965)		248 (0.993)		117 (0.770)
	158 (2.250)		8 (2.139)		253 (1.910)		138 (2.000)		59 (2.359)		244 (2.010)		177 (1.690)
	3 (3.428)		41 (3.362)		201 (3.688)		167 (2.810)		17 (3.197)		49 (3.819)		7 (3.695)
	118 (4.740)		224 (4.020)		111 (4.527)		13 (5.210)		137 (6.100)		168 (5.167)		98 (4.330)
	93 (8.545)		97 (6.242)		223(10.075)		86 (8.658)		230(10.044)		215 (7.512)		135 (9.596)
29	196 (1.900)	30	255 (0.140)	31	237 (0.694)	32	147 (0.333)	33	102 (0.530)	34	18 (0.130)	35	48 (0.285)
	113 (0.820)		281 (0.820)		214 (1.032)		170 (1.420)		258 (0.810)		292 (0.850)		56 (1.232)
	119 (2.060)		90 (2.137)		290 (2.150)		218 (1.580)		189 (2.300)		2 (1.815)		246 (1.575)
	126 (3.590)		208 (3.150)		115 (3.310)		52 (2.782)		276 (2.800)		166 (3.063)		209 (2.860)
	169 (4.256)		144 (3.965)		197 (5.090)		155 (4.842)		188 (5.894)		136 (4.940)		114 (4.395)
	207 (7.825)		191 (7.591)		178 (8.005)		194 (11.210)		204 (9.292)		14 (7.507)		211 (7.545)
36	228 (0.694)												
	28 (0.820)												
	152 (2.697)												
	183 (3.747)												
	11 (5.180)												
	220 (7.492).												

Arrangement of trees as per method I (Seven trees per plot)

Plot Number	Tree Number	Plot Number	Tree Number	Plot Number	Tree Number	Plot Number	Tree Number	Plot Number	Tree Number	Plot Number	Tree Number
1	58 (0.637)	2	125 (0.600)	3	63 (0.440)	4	47 (0.505)	5	36 (0.549)	6	272 (0.245)
	262 (0.840)		184 (1.258)		145 (1.000)		202 (0.930)		285 (0.700)		234 (0.845)
	5 (1.720)		50 (1.728)		165 (1.802)		88 (1.340)		159 (1.735)		24 (1.466)
	10 (3.142)		179 (2.475)		162 (3.085)		130 (2.480)		271 (2.565)		43 (2.767)
	134 (3.392)		112 (3.515)		182 (4.109)		129 (3.234)		42 (3.528)		192 (3.550)
	85 (6.100)		160 (6.220)		87 (5.300)		149 (5.222)		216 (4.955)		139 (6.912)
	106 (7.515)		175 (7.040)		232 (9.940)		233 (9.095)		231 (8.199)		180 (7.440)
7	173 (0.465)	8	264 (0.129)	9	69 (0.550)	10	100 (0.140)	11	186 (0.605)	12	51 (0.457)
	105 (0.910)		55 (0.715)		273 (0.665)		91 (0.850)		242 (1.260)		116 (0.800)
	110 (1.525)		247 (1.456)		94 (1.700)		181 (1.300)		78 (1.435)		16 (1.492)
	123 (2.180)		291 (2.270)		124 (2.670)		133 (3.190)		40 (2.485)		44 (3.052)
	205 (3.910)		185 (4.380)		171 (3.364)		121 (3.880)		225 (3.425)		151 (3.199)
	92 (4.540)		175 (5.000)		80 (4.389)		163 (6.683)		142 (5.057)		12 (4.943)
	270 (15.238)		195 (13.100)		284 (7.520)		193 (7.045)		240 (9.184)		212 (8.054)
13	81 (0.213)	14	190 (0.530)	15	172 (0.550)	16	33 (0.395)	17	161 (0.597)	18	23 (0.188)
	66 (1.100)		265 (0.790)		6 (0.965)		141 (0.665)		46 (0.995)		256 (1.280)
	221 (1.525)		226 (1.440)		15 (1.590)		198 (1.480)		217 (1.405)		8 (2.139)
	213 (2.662)		57 (2.165)		132 (3.190)		156 (2.187)		164 (2.235)		38 (2.715)
	239 (3.562)		127 (3.405)		107 (3.489)		84 (3.775)		25 (4.067)		206 (4.067)
	104 (6.425)		77 (5.135)		222 (5.160)		154 (5.015)		45 (5.485)		150 (5.083)
	96 (7.443)		241 (7.074)		128 (12.852)		108 (7.520)		203 (7.710)		93 (8.545)
19	72 (0.320)	20	269 (0.645)	21	229 (0.466)	22	250 (0.520)	23	79 (0.330)	24	122 (0.490)
	252 (1.260)		273 (0.665)		53 (0.965)		248 (0.993)		117 (0.770)		113 (0.820)
	253 (1.910)		153 (2.000)		200 (1.344)		244 (2.010)		177 (1.690)		119 (2.060)
	158 (2.250)		243 (2.830)		294 (2.970)		59 (2.359)		167 (2.810)		17 (3.197)
	143 (3.605)		3 (3.428)		41 (3.362)		224 (4.020)		201 (3.688)		49 (3.819)
	97 (6.242)		109 (4.535)		118 (4.740)		111 (4.527)		13 (5.210)		137 (6.100)
	223 (10.075)		86 (8.658)		230 (10.044)		215 (7.512)		207 (7.825)		191 (7.591)
25	140 (0.100)	26	255 (0.140)	27	147 (0.333)	28	102 (0.530)	29	55 (0.715)	30	48 (0.285)
	281 (0.820)		214 (1.032)		237 (0.694)		258 (0.810)		292 (0.850)		56 (1.232)
	90 (2.137)		290 (2.150)		218 (1.580)		170 (1.420)		2 (1.815)		246 (1.575)
	189 (2.300)		208 (3.150)		52 (2.782)		276 (2.800)		166 (3.063)		152 (2.697)
	7 (3.695)		126 (3.590)		98 (4.330)		115 (3.310)		169 (4.256)		144 (3.965)
	168 (5.167)		197 (5.090)		155 (4.842)		188 (5.894)		136 (4.940)		114 (4.395)
	178 (8.005)		194 (11.210)		204 (9.292)		14 (7.507)		211 (7.545)		220 (7.492)
31	228 (0.510)										
	28 (0.820)										
	196 (1.900)										
	209 (2.860)										
	183 (3.747)										
	11 (5.180)										
	135 (9.596)										

Arrangement of trees as per method I (eight trees per plot)

Plot No.	Tree Number	Plot No.	Tree Number	Plot No.	Tree Number	Plot No.	Tree Number	Plot No.	Tree Number	Plot No.	Tree Number	Plot No.	Tree Number
1	63 (0.440)	2	47 (0.505)	3	36 (0.549)	4	272 (0.245)	5	173 (0.485)	6	264 (0.129)	7	69 (0.550)
	58 (0.637)		262 (0.840)		125 (0.600)		202 (0.930)		285 (0.700)		234 (0.845)		105 (0.910)
	5 (1.720)		184 (1.258)		145 (1.000)		88 (1.340)		24 (1.466)		110 (1.525)		247 (1.450)
	179 (2.475)		50 (1.728)		130 (2.480)		271 (2.565)		165 (1.802)		123 (2.180)		291 (2.270)
	134 (3.392)		10 (3.142)		162 (3.084)		112 (3.515)		43 (2.767)		129 (3.234)		133 (3.190)
	182 (4.109)		42 (3.528)		92 (4.540)		192 (3.550)		80 (4.389)		205 (3.910)		185 (4.380)
	85 (6.100)		160 (6.220)		87 (5.300)		176 (7.040)		149 (5.222)		216 (4.955)		139 (6.902)
	106 (7.515)		232 (9.940)		233 (9.095)		231 (8.199)		180 (7.440)		195 (13.100)		284 (7.520)
8	100 (0.140)	9	51 (0.457)	10	81 (0.213)	11	190 (0.530)	12	172 (0.550)	13	33 (0.395)	14	161 (0.597)
	55 (0.715)		273 (0.665)		91 (0.850)		116 (0.800)		266 (0.790)		6 (0.965)		141 (0.665)
	242 (1.260)		66 (1.100)		94 (1.700)		181 (1.300)		78 (1.435)		16 (1.492)		221 (1.525)
	124 (2.670)		159 (1.735)		40 (2.485)		213 (2.662)		57 (2.165)		156 (2.187)		164 (2.235)
	44 (3.052)		171 (3.364)		132 (3.190)		225 (3.425)		151 (3.199)		127 (3.405)		107 (3.489)
	121 (3.880)		239 (3.562)		84 (3.775)		25 (4.067)		206 (4.067)		143 (3.605)		109 (4.535)
	175 (5.000)		163 (6.683)		142 (5.057)		12 (4.943)		104 (6.425)		77 (5.135)		222 (5.160)
	240 (9.184)		212 (8.054)		96 (7.443)		128 (12.852)		108 (7.520)		203 (7.710)		93 (8.545)
15	23 (0.188)	16	72 (0.320)	17	229 (0.466)	18	250 (0.520)	19	79 (0.330)	20	122 (0.4900)	21	140 (0.100)
	186 (0.605)		46 (0.995)		70 (0.647)		269 (0.645)		53 (0.965)		248 (0.993)		117 (0.770)
	226 (1.440)		15 (1.590)		198 (1.480)		217 (1.405)		200 (1.344)		256 (1.280)		252 (1.260)
	158 (2.250)		8 (2.139)		253 (1.910)		138 (2.000)		59 (2.359)		244 (2.010)		119 (2.060)
	38 (2.715)		243 (2.830)		294 (2.970)		3 (3.428)		41 (3.362)		167 (2.810)		17 (3.197)
	118 (4.740)		224 (4.020)		201 (3.688)		111 (4.527)		49 (3.819)		7 (3.695)		126 (3.590)
	193 (7.045)		154 (5.015)		241 (7.074)		45 (5.485)		150 (5.083)		97 (6.242)		13 (5.210)
	223 (10.075)		86 (8.658)		230 (10.044)		215 (7.512)		207 (7.825)		191 (7.591)		178 (8.005)
22	255 (0.140)	23	147 (0.333)	24	102 (0.530)	25	18 (0.130)	26	48 (0.285)	27	228 (0.510)		
	113 (0.820)		281 (0.820)		237 (0.694)		258 (0.810)		292 (0.850)		28 (0.820)		
	177 (1.690)		214 (1.032)		218 (1.580)		170 (1.420)		246 (1.575)		56 (1.232)		
	90 (2.137)		290 (2.150)		189 (2.300)		276 (2.800)		152 (2.697)		196 (1.900)		
	208 (3.150)		115 (3.310)		52 (2.782)		155 (4.842)		166 (3.063)		209 (2.860)		
	98 (4.330)		169 (4.256)		144 (3.965)		188 (5.894)		114 (4.395)		183 (3.747)		
	137 (6.100)		168 (5.167)		197 (5.090)		211 (7.545)		136 (4.940)		11 (5.180)		
	194 (11.210)		204 (9.292)		14 (7.507)		2 (1.815)		220 (7.492)		135 (9.596)		

Arrangement of trees as per method II (two trees per plot)

Plot number	Tree number	Plot number	Tree number	Plot number	Tree number	Plot number	Tree number	Plot number	Tree number	Plot number	Tree number
1	140 (0.100) 264 (0.129)	2	18 (0.130) 255 (0.140)	3	100 (0.140) 23 (0.188)	4	81 (0.213) 272 (0.245)	5	48 (0.285) 72 (0.320)	6	79 (0.330) 147 (0.333)
7	33 (0.395) 63 (0.440)	8	51 (0.457) 229 (0.466)	9	173 (0.485) 122 (0.490)	10	47 (0.505) 228 (0.510)	11	250 (0.520) 190 (0.530)	12	102 (0.530) 36 (0.549)
13	69 (0.550) 172 (0.550)	14	161 (0.597) 125 (0.600)	15	186 (0.605) 58 (0.637)	16	269 (0.645) 70 (0.647)	17	273 (0.665) 141 (0.665)	18	237 (0.694) 285 (0.700)
19	55 (0.715) 117 (0.770)	20	266 (0.790) 116 (0.800)	21	258 (0.810) 28 (0.820)	22	113 (0.820) 281 (0.820)	23	262 (0.840) 234 (0.845)	24	91 (0.850) 292 (0.850)
25	105 (0.910) 202 (0.930)	26	6 (0.965) 53 (0.965)	27	248 (0.993) 46 (0.995)	28	145 (1.000) 214 (1.032)	29	66 (1.100) 56 (1.232)	30	184 (1.258) 242 (1.260)
31	252 (1.260) 256 (1.280)	32	181 (1.300) 88 (1.340)	33	200 (1.344) 217 (1.405)	34	170 (1.420) 78 (1.435)	35	226 (1.440) 247 (1.450)	36	24 (1.466) 198 (1.480)
37	16 (1.492) 110 (1.525)	38	221 (1.525) 246 (1.575)	39	218 (1.580) 15 (1.590)	40	177 (1.690) 94 (1.700)	41	5 (1.720) 50 (1.728)	42	159 (1.735) 165 (1.802)
43	2 (1.815) 196 (1.900)	44	253 (1.910) 138 (2.000)	45	244 (2.010) 119 (2.060)	46	90 (2.137) 8 (2.139)	47	290 (2.150) 57 (2.165)	48	123 (2.180) 156 (2.187)
49	164 (2.235) 158 (2.250)	50	291 (2.270) 189 (2.300)	51	51 (2.359) 179 (2.475)	52	130 (2.480) 40 (2.485)	53	271 (2.565) 213 (2.662)	54	124 (2.670) 152 (2.697)
55	38 (2.715) 43 (2.767)	56	52 (2.782) 276 (2.800)	57	167 (2.810) 243 (2.830)	58	209 (2.860) 294 (2.970)	59	44 (3.052) 166 (3.063)	60	162 (3.085) 10 (3.142)
61	208 (3.150) 132 (3.190)	62	133 (3.190) 17 (3.197)	63	151 (3.199) 129 (3.234)	64	115 (3.310) 41 (3.362)	65	171 (3.364) 134 (3.392)	66	127 (3.405) 225 (3.425)
67	3 (3.428) 107 (3.489)	68	112 (3.515) 42 (3.528)	69	192 (3.550) 239 (3.562)	70	126 (3.590) 143 (3.605)	71	201 (3.688) 7 (3.695)	72	183 (3.747) 84 (3.775)
73	49 (3.819) 121 (3.880)	74	205 (3.910) 144 (3.965)	75	224 (4.020) 25 (4.067)	76	206 (4.067) 182 (4.109)	77	169 (4.256) 98 (4.330)	78	185 (4.380) 80 (4.389)
79	114 (4.395) 111 (4.527)	80	109 (4.535) 92 (4.540)	81	118 (4.740) 155 (4.842)	82	136 (4.940) 12 (4.943)	83	216 (4.955) 175 (5.000)	84	154 (5.0150) 142 (5.057)
85	150 (5.083) 197 (5.090)	86	77 (5.135) 222 (5.160)	87	168 (5.167) 11 (5.180)	88	13 (5.210) 149 (5.222)	89	87 (5.300) 45 (5.485)	90	188 (5.894) 85 (6.100)
91	137 (6.100) 160 (6.200)	92	97 (6.242) 104 (6.425)	93	163 (6.683) 139 (6.902)	94	176 (7.040) 193 (7.045)	95	241 (7.074) 180 (7.440)	96	96 (7.443) 220 (7.492)
97	14 (7.507) 215 (7.512)	98	106 (7.515) 284 (7.520)	99	108 (7.520) 211 (7.545)	100	191 (7.591) 203 (7.710)	101	207 (7.825) 178 (8.005)	102	212 (8.054) 231 (8.199)
103	93 (8.545) 86 (8.658)	104	233 (9.095) 240 (9.184)	105	204 (9.292) 135 (9.596)	106	232 (9.949) 230 (10.044)	107	223 (10.075) 194 (11.210)	108	128 (12.852) 195 (13.100)
109	270 (15.238) 174 (16.712)										

Arrangement of trees as per method II (three trees per plot)

Plot number	Tree number	Plot number	Tree number	Plot number	Tree number	Plot number	Tree number	Plot number	Tree number	Plot number	Tree number
1	140 (0.100) 264 (0.129) 18 (0.130)	2	255 (0.140) 100 (0.140) 23 (0.188)	3	81 (0.213) 272 (0.245) 48 (0.285)	4	72 (0.320) 79 (0.330) 147 (0.333)	5	33 (0.395) 63 (0.440) 51 (0.457)	6	229 (0.466) 173 (0.485) 122 (0.490)
7	47 (0.505) 228 (0.510) 250 (0.520)	8	190 (0.530) 102 (0.530) 36 (0.549)	9	69 (0.550) 172 (0.550) 161 (0.597)	10	125 (0.600) 186 (0.605) 58 (0.637)	11	269 (0.645) 70 (0.647) 273 (0.665)	12	141 (0.665) 237 (0.694) 285 (0.700)
13	55 (0.715) 117 (0.770) 266 (0.790)	14	116 (0.800) 258 (0.810) 28 (0.820)	15	113 (0.820) 281 (0.820) 262 (0.840)	16	234 (0.845) 91 (0.850) 292 (0.850)	17	105 (0.910) 202 (0.930) 6 (0.965)	18	53 (0.965) 248 (0.993) 46 (0.995)
19	145 (1.000) 214 (1.032) 66 (1.100)	20	56 (1.232) 184 (1.258) 242 (1.260)	21	252 (1.260) 256 (1.280) 181 (1.300)	22	88 (1.340) 200 (1.344) 217 (1.405)	23	170 (1.420) 78 (1.435) 226 (1.440)	24	247 (1.450) 24 (1.466) 198 (1.480)
25	16 (1.492) 110 (1.525) 221 (1.525)	26	246 (1.575) 218 (1.580) 15 (1.590)	27	177 (1.690) 94 (1.700) 5 (1.720)	28	50 (1.728) 159 (1.735) 165 (1.802)	29	2 (1.815) 196 (1.900) 253 (1.910)	30	138 (2.000) 244 (2.010) 119 (2.060)
31	90 (2.137) 8 (2.139) 290 (2.150)	32	57 (2.165) 123 (2.180) 156 (2.187)	33	164 (2.235) 158 (2.250) 291 (2.270)	34	189 (2.300 59 (2.359) 179 (2.475)	35	130 (2.480) 40 (2.485) 271 (2.565)	36	213 (2.662) 124 (2.670) 152 (2.697)
37	38 (2.715) 43 (2.767) 52 (2.782)	38	276 (2.800) 167 (2.810) 243 (2.830)	39	209 (2.860) 294 (2.970) 44 (3.052)	40	166 (3.063) 162 (3.085) 10 (3.142)	41	208 (3.150) 132 (3.190) 133 (3.190)	42	17 (3.197) 151 (3.199) 129 (3.234)
43	115 (3.310) 41 (3.362) 171 (3.364)	44	134 (3.392) 127 (3.405) 225 (3.425)	45	3 (3.428) 107 (3.489) 112 (3.515)	46	42 (3.528) 192 (3.550) 239 (3.562)	47	126 (3.590) 143 (3.605) 201 (3.688)	48	7 (3.695) 183 (3.747) 84 (3.775)
49	49 (3.819) 121 (3.880) 205 (3.910)	50	144 (3.965) 224 (4.020) 25 (4.067)	51	206 (4.067) 182 (4.109) 169 (4.256)	52	98 (4.330) 185 (4.380) 80 (4.389)	53	114 (4.395) 111 (4.527) 109 (4.535)	54	92 (4.540) 118 (4.740) 155 (4.842)
55	136 (4.940) 12 (4.943) 216 (4.955)	56	175 (5.000) 154 (5.015) 142 (5.057)	57	150 (5.083) 197 (5.090) 77 (5.135)	58	222 (5.160) 168 (5.167) 11 (5.180)	59	13 (5.210) 149 (5.220) 87 (5.300)	60	45 (5.485) 188 (5.894) 85 (6.100)
61	137 (6.100) 160 (6.220) 97 (6.242)	62	104 (6.425) 163 (6.683) 139 (6.902)	63	176 (7.040) 193 (7.045) 241 (7.074)	64	180 (7.440) 96 (7.443) 220 (7.492)	65	14 (7.507) 215 (7.512) 106 (7.515)	66	284 (7.520) 108 (7.520) 211 (7.545)
67	191 (7.591) 203 (7.710) 207 (7.825)	68	178 (8.005) 217 (8.054) 231 (8.199)	69	93 (8.545) 86 (8.658) 233 (9.095)	70	240 (9.184) 204 (9.292) 135 (9.596)	71	232 (9.940) 230 (10.044) 223 (10.075)	72	194 (11.210) 128 (12.852) 195 (13.100)

Figures given in brackets represents yield.

Arrangement of trees as per method II (four trees per plot)

Plot number	Tree number	Plot number	Tree number	Plot number	Tree number	Plot number	Tree number	Plot number	Tree number	Plot number	Tree number
1	140 (0.100) 264 (0.129) 18 (0.130) 255 (0.140)	2	100 (0.140) 23 (0.188) 81 (0.213) 272 (0.245)	3	48 (0.285) 72 (0.320) 79 (0.330) 147 (0.330)	4	33 (0.395) 63 (0.440) 51 (0.457) 229 (0.466)	5	173 (0.485) 122 (0.490) 47 (0.505) 228 (0.510)	6	250 (0.520) 190 (0.530) 102 (0.530) 36 (0.549)
7	69 (0.550) 172 (0.550) 161 (0.597) 125 (0.600)	8	186 (0.605) 58 (0.637) 269 (0.645) 70 (0.647)	9	273 (0.665) 141 (0.665) 237 (0.694) 285 (0.700)	10	55 (0.715) 117 (0.770) 266 (0.790) 116 (0.800)	11	258 (0.810) 28 (0.820) 113 (0.820) 281 (0.820)	12	262 (0.840) 234 (0.845) 91 (0.850) 292 (0.850)
13	105 (0.910) 202 (0.930) 6 (0.965) 53 (0.965)	14	248 (0.993) 46 (0.995) 145 (1.000) 214 (1.032)	15	66 (1.100) 56 (1.232) 184 (1.258) 242 (1.260)	16	252 (1.260) 256 (1.280) 181 (1.300) 88 (1.340)	17	200 (1.344) 217 (1.405) 170 (1.420) 78 (1.435)	18	226 (1.440) 247 (1.450) 24 (1.466) 198 (1.480)
19	16 (1.492) 110 (1.525) 221 (1.525) 246 (1.575)	20	218 (1.580) 15 (1.590) 177 (1.690) 94 (1.700)	21	5 (1.720) 50 (1.728) 159 (1.735) 165 (1.802)	22	2 (1.815) 196 (1.900) 253 (1.910) 138 (2.000)	23	244 (2.010) 119 (2.060) 90 (2.137) 8 (2.139)	24	290 (2.150) 57 (2.165) 123 (2.180) 156 (2.187)
25	164 (2.235) 158 (2.250) 291 (2.270) 189 (2.300)	26	59 (2.359) 179 (2.475) 130 (2.480) 40 (2.485)	27	271 (2.565) 213 (2.662) 124 (2.670) 152 (2.697)	28	38 (2.715) 43 (2.767) 52 (2.782) 276 (2.800)	29	167 (2.810) 243 (2.830) 209 (2.860) 294 (2.970)	30	44 (3.052) 166 (3.063) 162 (3.085) 10 (3.142)
31	208 (3.150) 132 (3.190) 133 (3.190) 17 (3.197)	32	151 (3.199) 129 (3.234) 115 (3.310) 41 (3.362)	33	171 (3.364) 134 (3.392) 127 (3.405) 225 (3.425)	34	3 (3.428) 107 (3.489) 112 (3.515) 42 (3.528)	35	192 (3.550) 239 (3.562) 126 (3.590) 143 (3.605)	36	201 (3.688) 7 (3.695) 183 (3.747) 84 (3.775)
37	49 (3.819) 121 (3.880) 205 (3.910) 144 (3.965)	38	224 (4.020) 25 (4.067) 206 (4.067) 182 (4.109)	39	169 (4.256) 98 (4.330) 185 (4.380) 80 (4.389)	40	114 (4.395) 111 (4.527) 109 (4.535) 92 (4.540)	41	118 (4.740) 155 (4.842) 136 (4.940) 12 (4.943)	42	216 (4.955) 175 (5.000) 154 (5.015) 142 (5.057)
43	150 (5.083) 197 (5.090) 77 (5.135) 222 (5.160)	44	168 (5.167) 11 (5.180) 13 (5.210) 149 (5.222)	45	87 (5.300) 45 (5.485) 188 (5.894) 85 (6.100)	46	137 (6.100) 160 (6.200) 97 (6.242) 104 (6.425)	47	163 (6.683) 139 (6.902) 176 (7.040) 193 (7.045)	48	241 (7.074) 180 (7.440) 96 (7.443) 220 (7.492)
49	14 (7.507) 215 (7.512) 106 (7.515) 284 (7.520)	50	108 (7.520) 211 (7.545) 191 (7.591) 203 (7.710)	51	207 (7.825) 178 (8.005) 212 (8.054) 231 (8.199)	52	93 (8.545) 86 (8.658) 233 (9.095) 240 (9.184)	53	204 (9.292) 135 (9.596) 232 (9.940) 230 (10.044)	54	223 (10.075) 194 (11.210) 128 (12.852) 195 (13.100)

Figures given in brackets represents yield.

Arrangement of trees as per method II (five trees per plot)

Plot number	Tree number	Plot number	Tree number	Plot number	Tree number	Plot number	Tree number	Plot number	Tree number	Plot number	Tree number
1	140 (0.100) 264 (0.129) 18 (0.130) 255 (0.140) 100 (0.140)	2	23 (0.188) 81 (0.213) 272 (0.245) 48 (0.285) 72 (0.320)	3	79 (0.330) 147 (0.333) 33 (0.395) 63 (0.440) 51 (0.457)	4	229 (0.466) 173 (0.485) 122 (0.490) 47 (0.505) 228 (0.510)	5	250 (0.520) 190 (0.530) 102 (0.530) 36 (0.549) 69 (0.550)	6	172 (0.550) 161 (0.597) 125 (0.6000) 186 (0.605) 58 (0.637)
7	269 (0.645) 70 (0.647) 273 (0.665) 141 (0.665) 237 (0.694)	8	285 (0.700) 55 (0.715) 117 (0.770) 266 (0.790) 116 (0.800)	9	258 (0.810) 28 (0.820) 113 (0.820) 281 (0.820) 262 (0.840)	10	234 (0.845) 91 (0.850) 292 (0.850) 105 (0.910) 202 (0.930)	11	6 (0.965) 53 (0.965) 248 (0.993) 46 (0.995) 145 (1.000)	12	214 (1.032) 66 (1.100) 56 (1.232) 184 (1.258) 242 (1.260)
13	252 (1.260) 256 (1.280) 181 (1.300) 88 (1.340) 200 (1.344)	14	217 (1.405) 170 (1.420) 78 (1.435) 226 (1.440) 247 (1.450)	15	24 (1.466) 198 (1.480) 16 (1.492) 110 (1.525) 221 (1.525)	16	246 (1.575) 218 (1.580) 15 (1.590) 177 (1.690) 94 (1.700)	17	5 (1.720) 50 (1.728) 159 (1.735) 165 (1.802) 2 (1.815)	18	196 (1.900) 253 (1.910) 138 (2.000) 244 (2.010) 119 (2.060)
19	90 (2.137) 8 (2.139) 290 (2.150) 57 (2.165) 123 (2.180)	20	156 (2.187) 164 (2.235) 158 (2.250) 291 (2.270) 189 (2.300)	21	59 (2.359) 179 (2.475) 130 (2.480) 40 (2.485) 271 (2.565)	22	213 (2.662) 124 (2.670) 152 (2.697) 38 (2.715) 43 (2.767)	23	52 (2.782) 276 (2.800) 167 (2.810) 243 (2.830) 209 (2.860)	24	294 (2.970) 44 (3.052) 166 (3.063) 162 (3.085) 10 (3.142)
25	208 (3.150) 132 (3.190) 133 (3.190) 17 (3.197) 151 (3.199)	26	129 (3.234) 117 (3.310) 41 (3.362) 171 (3.364) 134 (3.392)	27	127 (3.405) 225 (3.425) 3 (3.428) 107 (3.489) 112 (3.515)	28	42 (3.528) 192 (3.550) 239 (3.562) 126 (3.590) 143 (3.605)	29	201 (3.688) 7 (3.695) 183 (3.747) 84 (3.775) 49 (3.819)	30	121 (3.880) 205 (3.910) 144 (3.965) 224 (4.020) 25 (4.067)
31	206 (4.067) 182 (4.109) 169 (4.256) 98 (4.330) 185 (4.380)	32	80 (4.389) 114 (4.395) 111 (4.527) 109 (4.535) 92 (4.540)	33	118 (4.740) 155 (4.842) 136 (4.940) 12 (4.943) 216 (4.955)	34	175 (5.000) 154 (5.015) 142 (5.057) 150 (5.083) 197 (5.090)	35	77 (5.135) 222 (5.160) 168 (5.167) 11 (5.180) 13 (5.210)	36	149 (5.222) 87 (5.300) 45 (5.485) 188 (5.894) 85 (6.100)
37	137 (6.100) 160 (6.220) 97 (6.242) 104 (6.425) 163 (6.683)	38	139 (6.902) 176 (7.040) 193 (7.045) 241 (7.074) 180 (7.440)	39	96 (7.443) 220 (7.492) 14 (7.507) 215 (7.512) 106 (7.515)	40	284 (7.520) 108 (7.520) 211 (7.545) 191 (7.591) 203 (7.710)	41	207 (7.825) 178 (8.005) 212 (8.054) 231 (8.199) 93 (8.545)	42	86 (8.658) 233 (9.095) 240 (9.184) 204 (9.292) 135 (9.596)
43	232 (9.940) 230 (10.044) 223 (10.075) 194 (11.210) 128 (12.852)										

Arrangement of trees as per method II (six trees per plot)

Plot number	Tree number	Plot number	Tree number	Plot number	Tree number	Plot number	Tree number	Plot number	Tree number	Plot number	Tree number
1	140 (0.100)	2	81 (0.213)	3	33 (0.395)	4	47 (0.505)	5	69 (0.550)	6	269 (0.645)
	264 (0.129)		272 (0.245)		63 (0.440)		228 (0.510)		172 (0.550)		70 (0.647)
	18 (0.130)		48 (0.285)		51 (0.457)		250 (0.520)		161 (0.597)		273 (0.665)
	255 (0.140)		72 (0.320)		229 (0.466)		190 (0.530)		125 (0.600)		141 (0.665)
	100 (0.140)		79 (0.330)		173 (0.485)		102 (0.530)		186 (0.605)		237 (0.694)
	23 (0.188)		147 (0.333)		122 (0.490)		36 (0.549)		58 (0.637)		285 (0.700)
7	55 (0.715)	8	113 (0.820)	9	105 (0.910)	10	145 (1.000)	11	252 (1.260)	12	170 (1.420)
	117 (0.770)		281 (0.820)		202 (0.930)		214 (1.032)		256 (1.280)		78 (1.435)
	266 (0.790)		262 (0.840)		6 (0.965)		66 (1.100)		181 (1.300)		226 (1.440)
	116 (0.800)		234 (0.845)		53 (0.965)		56 (1.232)		88 (1.340)		247 (1.450)
	258 (0.810)		91 (0.850)		248 (0.993)		184 (1.258)		200 (1.344)		24 (1.466)
	28 (0.820)		292 (0.850)		46 (0.995)		242 (1.260)		217 (1.405)		198 (1.480)
13	16 (1.492)	14	177 (1.690)	15	2 (1.815)	16	90 (2.137)	17	164 (2.235)	18	130 (2.480)
	110 (1.525)		94 (1.700)		196 (1.900)		8 (2.139)		158 (2.250)		40 (2.485)
	221 (1.525)		5 (1.720)		253 (1.910)		290 (2.150)		291 (2.270)		271 (2.565)
	246 (1.575)		50 (1.728)		138 (2.000)		57 (2.165)		189 (2.300)		213 (2.662)
	218 (1.580)		159 (1.735)		244 (2.010)		123 (2.180)		59 (2.359)		124 (2.670)
	15 (1.590)		165 (1.802)		119 (2.060)		156 (2.187)		179 (2.475)		152 (2.697)
19	38 (2.715)	20	209 (2.860)	21	208 (3.150)	22	115 (3.310)	23	3 (3.428)	24	126 (3.590)
	43 (2.767)		294 (2.970)		132 (3.190)		41 (3.362)		107 (3.489)		143 (3.605)
	52 (2.782)		44 (3.052)		133 (3.190)		171 (3.364)		112 (3.515)		201 (3.688)
	276 (2.800)		166 (3.063)		17 (3.197)		134 (3.392)		42 (3.528)		7 (3.695)
	167 (2.810)		162 (3.085)		151 (3.199)		127 (3.405)		192 (3.550)		183 (3.747)
	243 (2.830)		10 (3.142)		129 (3.234)		225 (3.425)		239 (3.562)		84 (3.775)
25	49 (3.819)	26	206 (4.067)	27	114 (4.395)	28	136 (4.940)	29	150 (5.083)	30	13 (5.210)
	121 (3.880)		182 (4.109)		111 (4.527)		12 (4.943)		197 (5.090)		149 (5.222)
	205 (3.910)		169 (4.256)		109 (4.535)		216 (4.955)		77 (5.135)		87 (5.300)
	144 (3.965)		98 (4.330)		92 (4.540)		175 (5.000)		222 (5.160)		45 (5.485)
	224 (4.020)		185 (4.380)		118 (4.740)		154 (5.015)		168 (5.167)		188 (5.894)
	25 (4.067)		80 (4.389)		155 (4.842)		142 (5.057)		11 (5.180)		85 (6.100)
31	137 (6.100)	32	176 (7.040)	33	14 (7.507)	34	191 (7.591)	35	93 (8.545)	36	232 (9.940)
	160 (6.220)		193 (7.045)		215 (7.512)		203 (7.710)		86 (8.658)		230 (10.044)
	97 (6.242)		241 (7.074)		106 (7.515)		207 (7.825)		233 (9.095)		223 (10.075)
	104 (6.425)		180 (7.440)		284 (7.520)		178 (8.005)		240 (9.184)		194 (11.210)
	163 (6.683)		96 (7.443)		108 (7.520)		212 (8.054)		204 (9.292)		128 (12.852)
	139 (6.902)		220 (7.492)		211 (7.545)		231 (8.199)		135 (9.596)		195 (13.100)

Figures given in brackets represents yield.

Arrangement of trees as per method II (Seven trees per plot)

Plot No.	Tree Number	Plot No.	Tree Number	Plot No.	Tree Number	Plot No.	Tree Number	Plot No.	Tree Number	Plot No.	Tree Number	Plot No.	Tree Number
1	140 (0.100)	2	272 (0.245)	3	51 (0.457)	4	190 (0.530)	5	186 (0.605)	6	285 (0.700)	7	113 (0.820)
	264 (0.129)		48 (0.285)		229 (0.466)		102 (0.530)		58 (0.637)		55 (0.715)		281 (0.820)
	18 (0.130)		72 (0.320)		173 (0.485)		36 (0.549)		269 (0.645)		117 (0.770)		262 (0.840)
	255 (0.140)		79 (0.330)		122 (0.49)		69 (0.550)		70 (0.647)		266 (0.790)		234 (0.845)
	100 (0.140)		147 (0.333)		47 (0.505)		172 (0.550)		273 (0.665)		116 (0.800)		91 (0.850)
	23 (0.188)		33 (0.395)		228 (0.510)		161 (0.597)		141 (0.665)		258 (0.810)		292 (0.850)
	81 (0.213)		63 (0.440)		250 (0.520)		125 (0.600)		237 (0.694)		28 (0.820)		105 (0.910)
8	202 (0.930)	9	66 (1.100)	10	88 (1.340)	11	24 (1.466)	12	15 (1.590)	13	2 (1.815)	14	8 (2.139)
	6 (0.965)		56 (1.232)		200 (1.344)		198 (1.480)		177 (1.690)		196 (1.900)		290 (2.150)
	53 (0.965)		184 (1.258)		217 (1.405)		16 (1.492)		94 (1.700)		253 (1.910)		57 (2.165)
	248 (0.993)		242 (1.260)		170 (1.420)		110 (1.525)		5 (1.720)		138 (2.000)		123 (2.180)
	46 (0.995)		252 (1.260)		78 (1.435)		221 (1.525)		50 (1.728)		244 (2.010)		156 (2.187)
	145 (1.000)		256 (1.280)		226 (1.440)		246 (1.575)		159 (1.735)		119 (2.060)		164 (2.235)
	214 (1.032)		181 (1.300)		247 (1.450)		218 (1.580)		165 (1.802)		90 (2.137)		158 (2.250)
15	291 (2.270)	16	213 (2.662)	17	167 (2.810)	18	10 (3.142)	19	115 (3.310)	20	107 (3.489)	21	201 (3.688)
	189 (2.300)		124 (2.670)		243 (2.830)		208 (3.150)		41 (3.362)		112 (3.515)		7 (3.695)
	59 (2.359)		152 (2.697)		209 (2.860)		132 (3.190)		171 (3.364)		42 (3.528)		183 (3.747)
	179 (2.475)		38 (2.715)		294 (2.970)		133 (3.190)		134 (3.392)		192 (3.550)		84 (3.775)
	130 (2.480)		43 (2.767)		44 (3.052)		17 (3.197)		127 (3.405)		239 (3.562)		49 (3.819)
	40 (2.485)		52 (2.782)		166 (3.063)		151 (3.199)		225 (3.425)		126 (3.590)		121 (3.880)
	271 (2.565)		276 (2.805)		162 (3.085)		129 (3.234)		3 (3.428)		143 (3.605)		205 (3.910)
22	144 (3.965)	23	185 (4.380)	24	155 (4.842)	25	150 (5.083)	26	149 (5.222)	27	97 (6.242)	28	180 (7.440)
	224 (4.020)		80 (4.389)		136 (4.940)		197 (5.090)		87 (5.300)		104 (6.425)		96 (7.443)
	25 (4.067)		114 (4.395)		12 (4.943)		77 (5.135)		45 (5.485)		163 (6.683)		220 (7.492)
	206 (4.067)		111 (4.527)		216 (4.995)		222 (5.160)		188 (5.894)		139 (6.902)		14 (7.507)
	182 (4.109)		109 (4.535)		175 (5.000)		168 (5.167)		85 (6.100)		176 (7.040)		215 (7.512)
	169 (4.256)		92 (4.540)		154 (5.015)		11 (5.180)		137 (6.100)		193 (7.045)		106 (7.515)
	98 (4.330)		118 (4.740)		142 (5.057)		13 (5.210)		160 (6.200)		241 (7.074)		284 (7.520)
29	108 (7.520)	30	231 (8.199)	31	232 (9.940)								
	211 (7.545)		93 (8.545)		230 (10.044)								
	191 (7.591)		86 (8.658)		223 (10.075)								
	203 (7.710)		233 (9.095)		194 (11.210)								
	207 (7.825)		240 (9.184)		128 (12.852)								
	178 (8.005)		204 (9.292)		195 (13.100)								
	212 (8.054)		135 (0.596)		270 (15.238).								

Figures given in brackets represents yield.

Arrangement of trees as per method II (Eight trees per plot)

Plot No.	Tree Number	Plot No.	Tree Number	Plot No.	Tree Number	Plot No.	Tree Number	Plot No.	Tree Number	Plot No.	Tree Number	Plot No.	Tree Number
1	140 (0.100)	2	48 (0.285)	3	173 (0.485)	4	69 (0.550)	5	273 (0.665)	6	258 (0.810)	7	105 (0.910)
	264 (0.129)		72 (0.320)		122 (0.490)		172 (0.550)		141 (0.665)		28 (0.820)		202 (0.930)
	18 (0.130)		79 (0.330)		47 (0.505)		161 (0.597)		237 (0.694)		113 (0.820)		6 (0.965)
	255 (0.140)		147 (0.330)		228 (0.510)		125 (0.600)		285 (0.700)		281 (0.820)		53 (0.965)
	100 (0.140)		33 (0.395)		250 (0.520)		186 (0.605)		55 (0.715)		262 (0.840)		248 (0.993)
	23 (0.188)		63 (0.440)		190 (0.530)		58 (0.637)		117 (0.770)		234 (0.845)		46 (0.995)
	81 (0.213)		51 (0.457)		102 (0.530)		269 (0.645)		266 (0.790)		91 (0.850)		145 (1.000)
	272 (0.245)		229 (0.466)		36 (0.549)		70 (0.647)		116 (0.800)		292 (0.850)		214 (1.032)
8	66 (1.100)	9	200 (1.344)	10	16 (1.492)	11	5 (1.720)	12	244 (2.010)	13	164 (2.235)	14	271 (2.565)
	56 (1.232)		217 (1.405)		110 (1.525)		50 (1.728)		119 (2.060)		158 (2.250)		213 (2.662)
	184 (1.258)		170 (1.420)		221 (1.525)		159 (1.735)		90 (2.137)		291 (2.270)		124 (2.670)
	242 (1.260)		78 (1.435)		246 (1.575)		165 (1.802)		8 (2.139)		189 (2.300)		152 (2.697)
	256 (1.280)		226 (1.440)		218 (1.580)		2 (1.815)		290 (2.150)		59 (2.359)		38 (2.715)
	181 (1.300)		247 (1.450)		15 (1.590)		196 (1.900)		57 (2.165)		179 (2.475)		43 (2.767)
	88 (1.340)		24 (1.466)		177 (1.690)		253 (1.910)		123 (2.180)		130 (2.480)		52 (2.782)
	252 (1.260)		198 (1.480)		94 (1.700)		138 (2.000)		156 (2.187)		40 (2.485)		276 (2.805)
15	167 (2.810)	16	208 (3.150)	17	171 (3.364)	18	192 (3.550)	19	49 (3.819)	20	169 (4.256)	21	118 (4.740)
	243 (2.830)		132 (3.190)		134 (3.392)		239 (3.562)		121 (3.880)		98 (4.330)		155 (4.842)
	209 (2.860)		133 (3.190)		127 (3.405)		126 (3.590)		205 (3.910)		185 (4.380)		136 (4.940)
	294 (2.870)		17 (3.197)		225 (3.425)		143 (3.605)		144 (3.965)		80 (4.389)		12 (4.943)
	44 (3.052)		151 (3.199)		3 (3.428)		201 (3.688)		224 (4.020)		114 (4.395)		216 (4.955)
	166 (3.063)		129 (3.234)		107 (3.489)		7 (3.695)		25 (4.067)		111 (4.527)		175 (5.000)
	162 (3.085)		115 (3.310)		112 (3.515)		183 (3.747)		206 (4.067)		109 (4.535)		154 (5.015)
	10 (3.142)		41 (3.362)		42 (3.528)		84 (3.775)		182 (4.109)		92 (4.540)		142 (5.057)
22	150 (5.083)	23	87 (5.300)	24	163 (6.683)	25	14 (7.507)	26	207 (7.825)	27	204 (9.292)		
	197 (5.090)		45 (5.485)		139 (6.902)		215 (7.512)		178 (8.005)		135 (9.596)		
	77 (5.135)		188 (5.894)		176 (7.040)		106 (7.515)		212 (8.054)		232 (9.940)		
	222 (5.160)		85 (6.100)		193 (7.045)		284 (7.520)		231 (8.199)		230 (10.044)		
	168 (5.167)		137 (6.100)		241 (7.074)		108 (7.520)		93 (8.545)		223 (10.075)		
	11 (5.180)		160 (6.220)		180 (7.440)		211 (7.545)		86 (8.658)		194 (11.210)		
	13 (5.210)		97 (6.242)		96 (7.443)		191 (7.591)		233 (9.095)		128 (12.852)		
	149 (5.222)		104 (6.425)		220 (7.492)		203 (7.710)		240 (9.184)		195 (13.100).		

Figures given in brackets represents yield.

Arrangement of trees as per method III (two trees per plot)

Plot number	Tree number	Plot number	Tree number	Plot number	Tree number	Plot number	Tree number	Plot number	Tree number	Plot number	Tree number
1	247 (1.450) 228 (0.510)	2	173 (0.485) 163 (6.683)	3	48 (0.285) 119 (2.060)	4	72 (0.320) 142 (5.057)	5	121 (3.880) 162 (3.085)	6	46 (0.995) 230 (10.044)
7	224 (4.020) 93 (8.545)	8	237 (0.694) 276 (2.800)	9	223 (10.075) 211 (7.545)	10	143 (3.605) 270 (15.238)	11	145 (1.000) 88 (1.340)	12	123 (2.180) 178 (8.005)
13	151 (3.199) 81 (0.213)	14	55 (0.715) 234 (0.845)	15	17 (3.197) 135 (9.596)	16	196 (1.900) 264 (0.129)	17	139 (6.902) 100 (0.140)	18	148 (0.850) 122 (0.490)
19	77 (5.135) 241 (7.074)	20	109 (4.535) 33 (0.395)	21	80 (4.389) 42 (3.528)	22	56 (1.232) 11 (5.180)	23	169 (4.256) 112 (3.515)	24	108 (7.520) 51 (0.457)
25	292 (0.850) 166 (3.063)	26	144 (3.965) 291 (2.270)	27	160 (6.220) 147 (0.333)	28	78 (1.435) 94 (1.700)	29	179 (2.475) 59 (2.359)	30	91 (0.850) 205 (3.910)
31	118 (4.700) 58 (0.637)	32	212 (8.054) 180 (7.440)	33	201 (3.688) 191 (7.591)	34	200 (1.344) 233 (9.095)	35	214 (1.032) 172 (0.550)	36	98 (4.330) 209 (2.860)
37	248 (0.993) 84 (3.775)	38	24 (1.466) 3 (3.428)	39	134 (3.392) 232 (9.940)	40	43 (2.767) 106 (7.515)	41	111 (4.527) 7 (3.695)	42	190 (0.530) 52 (2.782)
43	217 (1.405) 218 (1.580)	44	113 (0.920) 47 (0.505)	45	107 (3.489) 239 (3.562)	46	165 (1.802) 175 (5.000)	47	18 (0.130) 136 (4.940)	48	116 (0.800) 168 (5.167)
49	137 (6.100) 10 (3.142)	50	271 (2.565) 110 (1.525)	51	262 (0.840) 181 (1.300)	52	242 (1.260) 104 (6.425)	53	174 (16.712) 40 (2.435)	54	177 (1.690) 150 (5.083)
55	44 (3.052) 16 (1.492)	56	213 (2.662) 240 (9.184)	57	290 (2.150) 138 (2.000)	58	250 (0.520) 156 (2.187)	59	132 (3.190) 87 (5.300)	60	159 (1.735) 188 (5.294)
61	45 (5.485) 8 (2.139)	62	126 (3.590) 225 (3.425)	63	255 (0.140) 127 (3.405)	64	13 (5.210) 102 (0.530)	65	97 (6.242) 194 (11.210)	66	96 (7.443) 266 (0.790)
67	195 (13.100) 50 (1.728)	68	49 (3.819) 183 (3.747)	69	23 (0.188) 215 (7.512)	70	141 (0.665) 38 (2.715)	71	85 (6.100) 176 (7.040)	72	128 (12.852) 171 (3.364)
73	14 (7.507) 86 (8.658)	74	57 (2.165) 117 (0.770)	75	25 (4.067) 231 (8.199)	76	204 (9.292) 2 (1.815)	77	284 (7.520) 269 (0.645)	78	206 (4.067) 129 (3.234)
79	130 (2.480) 133 (3.190)	80	193 (7.045) 6 (0.965)	81	184 (1.258) 69 (0.550)	82	155 (4.842) 70 (0.647)	83	281 (0.820) 90 (2.137)	84	115 (3.310) 203 (7.710)
85	167 (2.810) 222 (5.160)	86	189 (2.300) 185 (4.380)	87	246 (1.575) 294 (2.970)	88	256 (1.280) 140 (0.100)	89	105 (0.910) 182 (4.109)	90	53 (0.965) 229 (0.466)
91	220 (7.492) 124 (2.670)	92	63 (0.440) 253 (1.910)	93	15 (1.590) 164 (2.235)	94	198 (1.480) 170 (1.420)	95	152 (2.697) 154 (5.015)	96	79 (0.330) 197 (5.090)
97	192 (3.550) 216 (4.955)	98	258 (0.810) 207 (7.825)	99	41 (3.362) 114 (4.395)	100	226 (1.440) 92 (4.540)	101	285 (0.700) 272 (0.245)	102	161 (0.597) 208 (3.150)
103	244 (2.010) 252 (1.260)	104	243 (2.830) 149 (5.222)	105	158 (2.250) 125 (0.600)	106	5 (1.720) 66 (1.100)	107	12 (4.943) 273 (0.665)	108	202 (0.930) 221 (1.525)
109	186 (0.605) 36 (0.549)										

Figures given in brackets represents yield.

Arrangement of trees as per method III (three trees per plot)

Plot number	Tree number	Plot number	Tree number	Plot number	Tree number	Plot number	Tree number	Plot number	Tree number	Plot number	Tree number
1	247 (1.450) 228 (0.510) 173 (0.485)	2	163 (6.683) 48 (0.285) 119 (2.060)	3	72 (0.320) 142 (5.057) 121 (3.880)	4	162 (3.085) 46 (0.995) 230 (10.044)	5	224 (4.020) 93 (8.545) 237 (0.694)	6	276 (2.800) 223 (10.075) 211 (7.545)
7	143 (3.605) 270 (15.238) 145 (1.000)	8	88 (1.340) 123 (2.180) 178 (8.005)	9	151 (3.199) 81 (0.213) 55 (0.715)	10	234 (0.845) 17 (3.197) 135 (9.596)	11	196 (1.900) 264 (0.129) 139 (6.902)	12	100 (0.140) 148 (0.850) 122 (0.490)
13	77 (5.135) 241 (7.074) 109 (4.535)	14	33 (0.395) 80 (4.389) 42 (3.528)	15	56 (1.232) 11 (5.180) 169 (4.256)	16	112 (3.515) 108 (7.520) 51 (0.457)	17	292 (0.850) 166 (3.063) 144 (3.965)	18	291 (2.270) 160 (6.220) 147 (0.333)
19	78 (1.435) 94 (1.700) 179 (2.475)	20	59 (2.359) 91 (0.850) 205 (3.910)	21	118 (4.700) 58 (0.637) 212 (8.054)	22	180 (7.440) 201 (3.688) 191 (7.591)	23	200 (1.344) 233 (9.095) 214 (1.032)	24	172 (0.550) 98 (4.330) 209 (2.860)
25	248 (0.993) 84 (3.775) 24 (1.466)	26	3 (3.428) 134 (3.392) 232 (9.940)	27	43 (2.767) 106 (7-515) 111 (4.527)	28	7 (3.695) 190 (0.530) 52 (2.782)	29	217 (1.405) 218 (1.580) 113 (0.820)	30	47 (0.505) 107 (3.489) 239 (3.562)
31	165 (1.802) 175 (5.000) 18 (0.1300)	32	136 (4.940) 116 (0.800) 168 (5.167)	33	137 (6.100) 10 (3.142) 271 (2.565)	34	110 (1.525) 262 (0.840) 181 (1.300)	35	242 (1.260) 104 (6.425) 174 (16.712)	36	40 (2.485) 177 (1.690) 150 (5.083)
37	44 (3.052) 16 (1.492) 213 (2.662)	38	240 (9.184) 290 (2.150) 138 (2.000)	39	250 (0.520) 156 (2.187) 132 (3.190)	40	87 (5.300) 159 (1.735) 188 (5.894)	41	45 (5.485) 8 (2.139) 126 (3.590)	42	225 (3.425) 255 (0.140) 127 (3.405)
43	13 (5.210) 102 (0.530) 97 (6.242)	44	194 (11.210) 96 (7.443) 266 (0.790)	45	195 (13.100) 50 (1.728) 49 (3.819)	46	183 (3.747) 23 (0.188) 215 (7.512)	47	141 (0.665) 38 (2.715) 85 (6.100)	48	176 (7.040) 128 (12.852) 171 (3.364)
49	14 (7.507) 86 (8.658) 57 (2.165)	50	117 (0.770) 25 (4.067) 231 (8.199)	51	204 (9.292) 2 (1.815) 284 (7.520)	52	269 (0.645) 206 (4.067) 129 (3.234)	53	130 (2.480) 133 (3.190) 193 (7.045)	54	6 (0.965) 184 (1.258) 69 (0.550)
55	155 (4.842) 70 (0.647) 281 (0.820)	56	90 (2.137) 115 (3.310) 203 (7.710)	57	167 (2.810) 222 (5.160) 189 (2.300)	58	185 (4.380) 246 (1.575) 294 (2.970)	59	256 (1.280) 140 (0.100) 105 (0.910)	60	182 (4.109) 53 (0.965) 229 (0.466)
61	220 (7.492) 124 (2.670) 63 (0.440)	62	253 (1.910) 15 (1.590) 164 (2.235)	63	198 (1.480) 170 (1.420) 152 (2.697)	64	154 (5.015) 79 (0.330) 197 (5.090)	65	192 (3.550) 216 (4.955) 258 (0.810)	66	207 (7.825) 41 (3.362) 114 (4.395)
67	226 (1.440) 92 (4.540) 285 (0.700)	68	272 (0.245) 161 (0.597) 208 (3.150)	69	244 (2.010) 252 (1.260) 243 (2.830)	70	149 (5.222) 158 (2.250) 125 (0.600)	71	5 (1.720) 66 (1.100) 12 (4.943)	72	273 (0.665) 202 (0.930) 221 (1.525)

Figures given in brackets represents yield.

Arrangement of trees as per method III (four trees per plot)

Plot number	Tree number	Plot number	Tree number	Plot number	Tree number	Plot number	Tree number	Plot number	Tree number	Plot number	Tree number
1	247 (1.450) 228 (0.5[illegible]0) 173 (0.[illegible]85) 163 (6.[illegible])	2	48 (0.285) 119 (2.060) 72 (0.320) 142 (5.057)	3	121 (3.880) 162 (3.095) 46 (0.995) 230 (10.044)	4	224 (4.020) 93 (8.545) 237 (0.694) 276 (2.800)	5	223 (10.075) 211 (7.545) 143 (3.605) 270 (15.235)	6	145 (1.000) 85 (1.340) 123 (2.180) 178 (8.005)
7	151 (3.199) 81 (0.213) 55 (0.715) 234 (0.845)	8	17 (3.197) 135 (9.596) 196 (1.900) 264 (0.129)	9	139 (6.902) 100 (0.140) 148 (0.850) 122 (0.490)	10	77 (5.135) 241 (7.074) 109 (4.535) 33 (0.395)	11	80 (4.389) 42 (3.528) 56 (1.232) 11 (5.180)	12	169 (4.256) 112 (3.515) 108 (7.520) 51 (0.457)
13	292 (0.350) 165 (3.065) 144 (3.965) 291 (2.270)	14	160 (6.220) 147 (0.333) 78 (1.435) 94 (1.700)	15	179 (2.475) 59 (2.359) 91 (0.850) 205 (3.910)	16	118 (4.700) 58 (0.637) 212 (8.054) 180 (7.440)	17	201 (3.688) 191 (7.591) 200 (1.344) 233 (9.095)	18	214 (1.032) 172 (0.550) 98 (4.330) 209 (2.860)
19	248 (0.993) 84 (3.775) 24 (1.455) 3 (2.423)	20	134 (3.392) 232 (9.940) 43 (2.767) 106 (7.515)	21	111 (4.527) 7 (3.695) 190 (0.530) 52 (2.782)	22	217 (1.405) 218 (1.580) 113 (0.820) 47 (0.505)	23	107 (3.489) 239 (3.562) 165 (1.802) 175 (5.000)	24	18 (0.130) 136 (4.940) 116 (0.800) 168 (5.167)
25	137 (6.100) 10 (3.142) 271 (2.565) 110 (1.525)	26	262 (0.840) 181 (1.300) 242 (1.260) 104 (6.425)	27	174 (16.712) 40 (2.485) 177 (1.690) 150 (5.083)	28	44 (3.052) 16 (1.492) 213 (2.662) 240 (9.184)	29	290 (2.150) 138 (2.000) 250 (0.520) 156 (2.187)	30	132 (3.190) 87 (5.300) 159 (1.735) 188 (5.894)
31	45 (5.485) 8 (2.139) 126 (3.590) 225 (3.425)	32	255 (0.140) 127 (3.405) 13 (5.210) 102 (0.530)	33	97 (6.242) 194 (11.210) 96 (7.443) 256 (0.790)	34	195 (13.100) 50 (1.728) 49 (3.819) 183 (3.747)	35	23 (0.188) 215 (7.512) 141 (0.665) 38 (2.715)	36	85 (6.100) 176 (7.040) 128 (12.852) 171 (3.364)
37	14 (7.507) 86 (8.658) 57 (2.165) 117 (0.770)	38	25 (4.067) 231 (8.199) 204 (9.292) 2 (1.815)	39	284 (7.520) 259 (0.645) 206 (4.067) 129 (3.234)	40	130 (2.480) 133 (3.190) 193 (7.045) 6 (0.965)	41	184 (1.258) 69 (0.550) 155 (4.842) 70 (0.647)	42	281 (0.820) 90 (2.137) 115 (3.310) 203 (7.710)
43	167 (2.810) 222 (5.160) 189 (2.300) 185 (4.380)	44	246 (1.575) 294 (2.970) 256 (1.280) 140 (0.100)	45	105 (0.910) 182 (4.109) 53 (0.965) 229 (0.466)	46	220 (7.492) 124 (2.670) 63 (0.440) 253 (1.910)	47	15 (1.590) 164 (2.235) 198 (1.480) 170 (1.420)	48	152 (2.697) 154 (5.015) 79 (0.330) 197 (5.090)
49	192 (3.550) 216 (4.955) 258 (0.810) 207 (7.225)	50	41 (3.362) 114 (4.395) 226 (1.440) 92 (4.540)	51	285 (0.700) 272 (0.245) 161 (0.597) 208 (3.150)	52	244 (2.010) 252 (1.260) 243 (2.830) 149 (5.222)	53	158 (2.250) 125 (0.600) 5 (1.720) 66 (1.100)	54	12 (4.943) 273 (0.665) 202 (0.930) 221 (1.525)

Figures given in brackets represents yield.

Arrangement of trees as per method III (five trees per plot)

Plot number	Tree number	Plot number	Tree number	Plot number	Tree number	Plot number	Tree number	Plot number	Tree number	Plot number	Tree number
1	247 (1.450) 228 (0.510) 173 (0.485) 163 (6.683) 48 (0.285)	2	119 (2.060) 72 (0.320) 142 (5.057) 121 (3.880) 162 (3.085)	3	46 (0.995) 230 (10.044) 224 (4.020) 93 (8.545) 237 (0.694)	4	276 (2.800) 223 (10.075) 211 (7.545) 143 (3.605) 270 (15.238)	5	145 (1.000) 88 (1.340) 123 (2.180) 178 (8.005) 151 (3.199)	6	81 (0.213) 55 (0.715) 234 (0.845) 17 (3.197) 135 (9.596)
7	196 (1.900) 264 (0.129) 139 (6.902) 100 (0.140) 148 (0.850)	8	122 (0.490) 77 (5.135) 241 (7.074) 109 (4.535) 33 (0.395)	9	80 (4.389) 42 (3.528) 56 (1.232) 11 (5.180) 169 (4.256)	10	112 (3.515) 108 (7.520) 51 (0.457) 292 (0.850) 166 (3.063)	11	144 (3.965) 291 (2.270) 160 (6.220) 147 (0.330) 78 (1.435)	12	94 (1.700) 179 (2.475) 59 (2.359) 91 (0.850) 205 (3.910)
13	118 (4.700) 58 (0.637) 212 (8.054) 180 (7.440) 201 (3.688)	14	191 (7.591) 200 (1.344) 233 (9.095) 214 (1.032) 172 (0.550)	15	98 (4.330) 209 (2.860) 248 (0.993) 84 (3.775) 24 (1.466)	16	3 (3.428) 134 (3.392) 232 (9.940) 43 (2.767) 106 (7.515)	17	111 (4.527) 7 (3.695) 190 (0.530) 52 (2.782) 217 (1.405)	18	218 (1.580) 113 (0.820) 47 (0.505) 107 (3.489) 239 (3.562)
19	165 (1.802) 175 (5.000) 18 (0.130) 136 (4.940) 116 (0.800)	20	168 (5.167) 137 (6.100) 10 (3.142) 271 (2.565) 110 (1.525)	21	262 (0.840) 181 (1.300) 242 (1.260) 104 (6.425) 174 (16.712)	22	40 (2.485) 177 (1.690) 150 (5.083) 44 (3.052) 16 (1.492)	23	213 (2.662) 240 (9.184) 290 (2.150) 138 (2.000) 250 (0.520)	24	156 (2.187) 132 (3.190) 87 (5.300) 159 (1.735) 188 (5.894)
25	45 (5.485) 8 (2.139) 126 (3.590) 225 (3.425) 255 (0.140)	26	127 (3.405) 13 (5.210) 102 (0.530) 97 (6.242) 194 (11.210)	27	96 (7.443) 266 (0.790) 195 (13.100) 50 (1.728) 49 (3.819)	28	183 (3.747) 23 (0.188) 215 (7.512) 141 (0.665) 38 (2.715)	29	85 (6.100) 176 (7.040) 128 (12.852) 171 (3.364) 14 (7.507)	30	86 (8.658) 57 (2.165) 117 (0.770) 25 (4.067) 231 (8.199)
31	204 (9.292) 2 (1.815) 284 (7.520) 269 (0.645) 206 (4.067)	32	129 (3.234) 130 (2.480) 133 (3.190) 193 (7.045) 6 (0.965)	33	184 (1.258) 69 (0.550) 155 (4.842) 70 (0.647) 281 (0.820)	34	90 (2.137) 115 (3.310) 203 (7.710) 167 (2.810) 222 (5.160)	35	189 (2.300) 185 (4.380) 246 (1.575) 294 (2.970) 256 (1.280)	36	140 (0.100) 105 (0.910) 182 (4.109) 53 (0.965) 229 (0.466)
37	220 (7.492) 124 (2.670) 63 (0.440) 253 (1.910) 15 (1.590)	38	164 (2.235) 198 (1.480) 170 (1.420) 152 (2.697) 154 (5.015)	39	79 (0.330) 197 (5.090) 192 (3.550) 216 (4.955) 258 (0.810)	40	207 (7.825) 41 (3.362) 114 (4.395) 226 (1.440) 92 (4.540)	41	285 (0.700) 272 (0.245) 161 (0.597) 208 (3.150) 244 (2.010)	42	252 (1.260) 243 (2.830) 149 (5.222) 158 (2.250) 125 (0.600)
43	5 (1.720) 66 (1.100) 12 (4.943) 273 (0.665) 202 (0.930)										

Figures given in brackets represents yield.

Arrangement of trees as per method III (six trees per plot)

Plot number	Tree number	Plot number	Tree number	Plot number	Tree number	Plot number	Tree number	Plot number	Tree number	Plot number	Tree number
1	247 (1.450) 228 (0.510) 173 (0.485) 163 (6.683) 48 (0.285) 119 (2.060)	2	72 (0.320) 142 (5.057) 121 (3.880) 162 (3.085) 46 (0.995) 230 (10.044)	3	224 (4.020) 93 (8.545) 237 (0.694) 276 (2.8000) 223 (10.075) 211 (7.545)	4	143 (3.605) 270 (15.238) 145 (1.000) 88 (1.340) 123 (2.180) 178 (8.005)	5	151 (3.199) 81 (0.213) 55 (0.715) 234 (0.845) 17 (3.197) 135 (9.596)	6	196 (1.900) 264 (0.129) 139 (6.902) 100 (0.140) 148 (0.850) 122 (0.490)
7	77 (5.135) 241 (7.074) 109 (4.535) 33 (0.395) 80 (4.389) 42 (3.528)	8	56 (1.232) 11 (5.180) 169 (4.256) 112 (3.515) 108 (7.520) 51 (0.457)	9	292 (0.850) 166 (3.063) 144 (3.965) 291 (2.270) 160 (6.220) 147 (0.330)	10	78 (1.435) 94 (1.700) 179 (2.475) 59 (2.359) 91 (0.850) 205 (3.910)	11	118 (4.700) 58 (0.637) 212 (8.054) 180 (7.440) 201 (3.688) 191 (7.591)	12	200 (1.344) 233 (9.095) 214 (1.032) 172 (0.550) 98 (4.330) 209 (2.860)
13	248 (0.993) 84 (3.775) 24 (1.466) 3 (3.428) 134 (3.392) 232 (9.940)	14	43 (2.767) 106 (7.515) 111 (4.527) 7 (3.695) 190 (0.530) 52 (2.782)	15	217 (1.405) 218 (1.580) 113 (0.820) 47 (0.505) 107 (3.489) 239 (3.562)	16	165 (1.802) 175 (5.000) 18 (0.130) 136 (4.940) 116 (0.800) 168 (5.167)	17	137 (6.100) 10 (3.142) 271 (2.565) 110 (1.525) 262 (0.840) 181 (1.300)	18	242 (1.260) 104 (6.425) 174 (16.712) 40 (2.485) 177 (1.690) 150 (5.083)
19	44 (3.052) 16 (1.492) 213 (2.662) 240 (9.184) 290 (2.150) 138 (2.000)	20	250 (0.520) 156 (2.187) 132 (3.190) 87 (5.300) 159 (1.735) 188 (5.894)	21	45 (5.485) 8 (2.139) 126 (3.590) 225 (3.425) 255 (0.140)	22	127 (3.405) 13 (5.210) 102 (0.530) 97 (6.242) 194 (11.210) 96 (7.443) 266 (0.790)	23	195 (13.100) 50 (1.728) 49 (3.819) 183 (3.747) 23 (0.188) 215 (7.512)	24	141 (0.665) 38 (2.715) 85 (6.100) 176 (7.040) 128 (12.852) 171 (3.364)
25	14 (7.507) 86 (8.658) 57 (2.165) 117 (0.770) 25 (4.067) 231 (8.199)	26	204 (9.292) 2 (1.815) 284 (7.520) 269 (0.645) 206 (4.067) 129 (3.234)	27	130 (2.480) 133 (3.190) 193 (7.045) 6 (0.965) 184 (1.258) 69 (0.550)	28	155 (4.842) 70 (0.647) 281 (0.820) 90 (2.137) 115 (3.310) 203 (7.710)	29	167 (2.810) 222 (5.160) 189 (2.300) 185 (4.380) 246 (1.575) 294 (2.970)	30	256 (1.280) 140 (0.100) 105 (0.910) 182 (4.109) 53 (0.965) 229 (0.466)
31	220 (7.492) 124 (2.670) 63 (0.440) 253 (1.910) 15 (1.590) 164 (2.235)	32	198 (1.480) 170 (1.420) 152 (2.697) 154 (5.015) 79 (0.330) 197 (5.090)	33	192 (3.550) 216 (4.955) 258 (0.810) 207 (7.825) 41 (3.362) 114 (4.395)	34	226 (1.440) 92 (4.540) 285 (0.700) 272 (0.245) 161 (0.597) 208 (3.150)	35	244 (2.010) 252 (1.260) 243 (2.830) 149 (5.222) 158 (2.250) 125 (0.600)	36	5 (1.720) 66 (1.100) 12 (4.943) 273 (0.665) 202 (0.930) 221 (1.525)

Figures given in brackets represents yield.

Arrangement of trees as per method III (Seven trees per plot)

Plot No.	Tree Number	Plot No.	Tree Number	Plot No.	Tree Number	Plot No.	Tree Number	Plot No.	Tree Number	Plot No.	Tree Number	Plot No.	Tree Number
1	247 (1.450)	2	142 (5.057)	3	237 (0.694)	4	88 (1.340)	5	17 (3.197)	6	122 (0.490)	7	56 (1.232)
	228 (0.510)		121 (3.880)		276 (2.800)		123 (2.180)		135 (9.596)		77 (5.135)		11 (5.180)
	173 (0.485)		162 (3.085)		223 (10.075)		178 (8.005)		196 (1.900)		241 (7.074)		169 (4.256)
	163 (6.683)		46 (0.995)		211 (7.545)		151 (3.199)		264 (0.129)		109 (4.535)		112 (3.515)
	48 (0.285)		230 (10.044)		143 (3.605)		81 (0.213)		139 (6.902)		33 (0.395)		108 (7.520)
	119 (2.060)		224 (4.020)		270 (15.238)		55 (0.715)		100 (0.1400)		80 (4.389)		51 (0.457)
	72 (0.320)		93 (8.545)		145 (1.00)		234 (0.845)		148 (0.850)		42 (3.528)		292 (0.850)
8	166 (3.063)	9	179 (2.475)	10	180 (7.440)	11	98 (4.330)	12	232 (9.940)	13	217 (1.405)	14	10 (3.142)
	144 (3.965)		59 (2.359)		201 (3.688)		209 (2.860)		43 (2.767)		218 (1.580)		175 (5.000)
	291 (2.270)		91 (0.850)		191 (7.591)		248 (0.993)		106 (7.515)		113 (0.820)		18 (0.1300)
	160 (6.220)		205 (3.910)		200 (1.344)		84 (3.775)		111 (4.527)		47 (0.505)		136 (4.940)
	147 (0.330)		118 (4.700)		233 (9.095)		24 (1.466)		7 (3.695)		107 (3.489)		116 (0.800)
	78 (1.435)		58 (0.637)		214 (1.032)		3 (3.428)		190 (0.530)		239 (3.562)		168 (5.167)
	94 (1.700)		212 (8.054)		172 (0.550)		134 (3.392)		52 (2.782)		165 (1.802)		137 (6.100)
15	174 (16.712)	16	40 (2.485)	17	290 (2.150)	18	188 (5.894)	19	13 (5.210)	20	50 (1.728)	21	85 (6.100)
	271 (2.565)		177 (1.690)		138 (2.000)		45 (5.485)		102 (0.530)		49 (3.819)		176 (7.040)
	110 (1.525)		150 (5.083)		250 (0.520)		8 (2.139)		97 (6.242)		183 (3.747)		128 (12.852)
	262 (0.840)		44 (3.052)		156 (2.187)		126 (3.590)		194 (11.210)		23 (0.188)		171 (3.364)
	181 (1.300)		16 (1.492)		132 (3.190)		225 (3.425)		96 (7.443)		215 (7.512)		14 (7.507)
	242 (1.260)		213 (2.662)		87 (5.300)		255 (0.140)		266 (0.790)		141 (0.665)		86 (8.658)
	104 (6.425)		240 (9.184)		159 (1.735)		127 (3.405)		195 (13.100)		38 (2.715)		57 (2.165)
22	117 (0.770)	23	206 (4.067)	24	69 (0.550)	25	167 (2.810)	26	140 (0.100)	27	63 (0.440)	28	154 (5.015)
	25 (4.067)		129 (3.234)		155 (4.842)		222 (5.160)		105 (0.910)		253 (1.910)		79 (0.330)
	231 (8.199)		130 (2.480)		70 (0.647)		189 (2.300)		182 (4.109)		15 (1.590)		197 (5.090)
	204 (9.292)		133 (3.190)		281 (0.820)		185 (4.380)		53 (0.965)		164 (2.235)		192 (3.550)
	2 (1.815)		193 (7.045)		90 (2.137)		246 (1.575)		229 (0.466)		198 (1.480)		216 (4.955)
	284 (7.520)		6 (0.965)		115 (3.310)		294 (2.970)		220 (7.492)		170 (1.420)		258 (0.810)
	269 (0.645)		184 (1.250)		203 (7.710)		256 (1.280)		124 (2.670)		152 (2.697)		207 (7.825)
29	41 (3.362)	30	208 (3.150)	31	5 (1.720)								
	114 (4.395)		244 (2.010)		66 (1.100)								
	226 (1.440)		252 (1.260)		12 (4.943)								
	92 (4.540)		243 (2.830)		273 (0.665)								
	285 (0.700)		149 (5.222)		202 (0.930)								
	272 (0.245)		158 (2.250)		221 (1.525)								
	161 (0.597)		125 (0.600)		186 (0.605).								

Figures given in brackets represents yield.

Arrangement of trees as per method III (Eight trees per plot)

Plot Number	Tree Number	Plot Number	Tree Number	Plot Number	Tree Number	Plot Number	Tree Number	Plot Number	Tree Number	Plot Number	Tree Number
1	247 (1.450) 228 (0.510) 173 (0.485) 163 (6.683) 48 (0.285) 119 (2.060) 72 (0.320) 142 (5.057)	2	121 (3.880) 162 (3.085) 46 (0.995) 230 (10.044) 224 (4.020) 93 (8.545) 237 (0.694) 276 (2.800)	3	223 (10.075) 211 (7.545) 143 (3.605) 270 (15.238) 145 (1.000) 88 (1.340) 123 (2.180) 178 (8.005)	4	151 (3.199) 81 (0.213) 55 (0.715) 234 (0.845) 17 (3.197) 135 (9.596) 196 (1.900) 264 (0.129)	5	139 (6.902) 100 (0.1400) 148 (0.8500) 122 (0.4900) 77 (5.135) 241 (7.074) 109 (4.535) 33 (0.395)	6	80 (4.389) 42 (3.528) 56 (1.232) 11 (5.180) 169 (4.256) 112 (3.515) 108 (7.520) 51 (0.457)
7	282 (0.850) 166 (3.063) 144 (3.965) 291 (2.270) 160 (6.220) 147 (0.330) 78 (1.435) 94 (1.700)	8	179 (2.475) 59 (2.359) 91 (0.850) 205 (3.910) 118 (4.700) 58 (0.637) 212 (8.054) 180 (7.440)	9	201 (3.688) 191 (7.591) 200 (1.344) 233 (9.095) 214 (1.032) 172 (0.550) 98 (4.330) 209 (2.860)	10	248 (0.993) 84 (3.775) 24 (1.466) 3 (3.428) 134 (3.392) 232 (9.940) 43 (2.767) 106 (7.515)	11	111 (4.527) 7 (3.695) 190 (0.530) 52 (2.782) 217 (1.405) 218 (1.580) 113 (0.820) 47 (0.505)	12	107 (3.489) 239 (3.562) 165 (1.802) 10 (3.142) 175 (5.000) 18 (0.130) 136 (4.940) 116 (0.800)
13	168 (5.167) 137 (6.100) 174 (16.712) 271 (2.565) 110 (1.525) 262 (0.840) 181 (1.300) 242 (1.260)	14	104 (6.425) 40 (2.485) 177 (1.690) 150 (5.083) 44 (3.052) 16 (1.492) 213 (2.662) 240 (9.184)	15	290 (2.150) 138 (2.000) 250 (0.520) 156 (2.187) 132 (3.190) 87 (5.300) 159 (1.735) 188 (5.894)	16	45 (5.485) 8 (2.139) 126 (3.590) 225 (3.425) 255 (0.140) 127 (3.405) 13 (5.210) 102 (0.530)	17	97 (6.242) 194 (11.210) 96 (7.443) 266 (0.790) 195 (13.100) 50 (1.728) 49 (3.819) 183 (3.747)	18	23 (0.188) 215 (7.512) 141 (0.665) 38 (2.715) 85 (6.100) 176 (7.040) 128 (12.852) 171 (3.364)
19	14 (7.507) 86 (8.658) 57 (2.165) 117 (0.770) 25 (4.067) 231 (8.199) 204 (9.292) 2 (1.815)	20	284 (7.520) 269 (0.645) 206 (4.067) 129 (3.234) 130 (2.480) 133 (3.190) 193 (7.045) 6 (0.965)	21	184 (1.258) 69 (0.550) 155 (4.842) 70 (0.647) 281 (0.820) 90 (2.137) 115 (3.310) 203 (7,710)	22	167 (2.810) 222 (5.160) 189 (2.300) 185 (4.380) 246 (1.575) 294 (2.970) 256 (1.280) 140 (0.100)	23	105 (0.910) 182 (4.109) 53 (0.965) 229 (0.466) 220 (7.492) 124 (2.670) 63 (0.440) 253 (1.910)	24	15 (1.590) 164 (2.235) 198 (1.480) 170 (1.420) 152 (2.697) 154 (5.015) 79 (0.330) 197 (5.090)
25	192 (3.550) 216 (4.955) 258 (0.810) 207 (7.825) 41 (3.362) 114 (4.395) 226 (1.440) 92 (4.540)	26	285 (0.700) 272 (0.245) 161 (0.597) 208 (3.150) 244 (2.010) 252 (1.260) 243 (2.830) 149 (5.222)	27	158 (2.250) 125 (0.600) 5 (1.720) 66 (1.100) 12 (4.943) 273 (0.665) 202 (0.930) 221 (1.525)						

Figures given in brackets represents yield.

STANDARDIZATION OF FIELD PLOT TECHNIQUE FOR CASHEW

BY

LUCYAMMA MATHEW

ABSTRACT OF A THESIS
submitted in partial fulfilment of the requirements
for the degree
MASTER OF SCIENCE IN AGRICULTURAL STATISTICS
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ABSTRACT

The present study deals with a plot technique for conducting field experiments on a biologically heterogeneous tree crop 'cashew' by applying a well known result in sampling theory that the clusters formed with negative intraclass correlation are relatively more efficient. Cashew being a perennial crop are sensitive to variation in fertility status of soil in which they grow, susceptable to mishaps, long gestation period etc. Because of their large size and long life they are considerably different from annuals or field crops as to need special considerations in designing experiments with them.

The experimenter is always faced with the difficulty of getting uniform experimental trees on account of the biological variation present among the individual trees. The difficulty in getting experimental trees with uniform yield or some other measurable characteristic of the tree and some considerations in overcoming this problem is discussed. Achieving greater homogeneity between plots within a block by creating greater heterogeneity within plots is found to be a better field

plot technique for experiments with adult trees on cashew. Similar techniques are also applicable to other plantation crops which are subjected to high biological variation.

Two other methods - Shrikande's method and Random method were also tried and the superiority of the present design approach over the others were evaluated. The optimum plot size estimated seven for the present design approach. Completely Randomised Design and Randomised Block Design were found to be equally efficient with this plot technique. The usefulness of the covariance analysis is investigated and found that no covariance adjustment is necessary with this approach.