OPTIMUM SIZE OF PLOTS IN COCONUT USING MULTIVARIATE TECHNIQUES

BY

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THESIS

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DECLARATION

I hereby declare that the thesis entitled **"Optimum size of plots in coconut using multivariate techniques"** 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, fellowship, associateship or other similar title, of any other university or society.

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We, the undersigned members of the Advisory Committee of **Ms.Kumari Liji, R.S.**, a candidate for the degree of **Master of Science in Agricultural Statistics**, agree that the thesis entitled **"Optimum size of plots in coconut using multivariate techniques"** may be submitted by Ms.Kumari Liji, R.S., in partial fulfilment of the requirement, for the degree.

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KUMARI LIJI, R.S.

To my parents

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Introduction

INTRODUCTION

Field experimentation is the most powerful tool in agricultural research. The prime consideration in planning a field experiment is control of variation among experimental units or reducing experimental error. Size and shape of experimental units influences the heterogeneity among them to a great extent. Therefore attempts to evolve strategies that can determine size and shape of experimental units that are optimum under various considerations have been made by many researchers. But most of these methods have been devised for univariate situations.

Needless to say that, any experiment on a crop is conducted to study its total performance. Any plant or crop is characterised by a multitude of observations and all these taken together characterise it. In other words, when we conduct an experiment in a crop, we are studying very many characters of the crop and hence it is desirable to arrive at the optimum size and shape of plots by considering all or atleast the most important characters rather than a single important character. Therfore it is necessary to arrive at optimum size or shape or both of experimental units by multivariate approach. Procedures to determine optimum size of plots by multivariate consideration have been suggested recently (Sheela and Unnithan, 1992a).

Coconut palm (*Cocos nucifera* L.) popularly known as `Kalpavriksha' or the tree of heaven is the most important plantation crop in Kerala. Moreover it plays a major role in Kerala economy. The origin of coconut cultivation in the state can be traced back to centuries. Coconut is inextricably interwoven with the culture and life of the people of Kerala. Every part of the tree is useful. At present many coconut based industrial establishments are coming up in the country. In short, importance of this crop can not be over emphasised particularly in the Kerala scenario. Therefore, more and more experiments are to be planned on various aspects of the crop to exploit its potential. Therefore, it is imperative to arrive at the otpimum size of plots for experiments in coconut by simultaneous consideration of important characters.

The present investigation was therefore, under taken with the following objectives.

1) To determine optimum size of plots for experiments in coconut with respect to different characters.
2) To determine optimum size of plots for coconut in multivariate case with and without blocking using procedures already evolved.

Review of Literature

2. REVIEW OF LITERATURE

Investigations on the determination of optimum size of experimental units using multivatiate observations have been attempted only very recently and not many work are reported in literature. Therefore review of research work done in univariate case has been given in this chapter in addition to single isolated work in the multivatiate case.

2.1 Univariate case

Smith (1938) proposed the model $V_x = V_{1x}^{-b}$ where V_x is the variance of the mean yield per plot based on plots of x units, `b' an index of soil heterogeneity. Value of `b' nearer to one was interpreted as having no significant correlation among contiguous units, and a value nearer to zero as having strong correlation between adjacent units.

Freeman (1963) modified Smith's model to $V_x = V_1'/x^b + V''/x$ where V_x is the variance per plant of x units, V_1' the variance due to environment of plots of different sizes and V''/x the variance of plants with in plots of x units.

Prabhakaran (1983) proposed three non-linear models for representing the relationship between plot size and coefficient of variation which were found to be more efficient than Smith's model at least for three different crops viz., tapioca, banana and cashew.

The models are

$$Y = a + b / \sqrt{x} + c / x$$

$$Y^{-1} = a + b \log x$$
$$Y^{-1} = a + b \sqrt{x} + cx$$

2.1.1 Methods of estimation of plot size

Method of maximum curvature has been extensively used to determine optimum size of experimental units (Hariharan *et al.*, 1986; Nambiar, 1986; Lizy *et al.*, 1987; Nambiar *et al.*, 1992; Sheela and Unnithan, 1992a; Reji, K., 1995). Federer (1967) criticised this method on two grounds. The first one was that the method does not take the cost involved into consideration. The second was that the point of maximum curvature is not independent of units of measurements.

Hayes (1925) proposed the formula $r = CV^2/(p/100)^2$ for determining the minimum number of replication (r) required to achieve P% SE, where cv is the coefficient of variation. The number of smallest units (on which observations are recorded in the uniformity trial) required to achieve P% error was obtained by multiplying number of replications with corresponding plot size. Gomez and Gomez (1972) defined optimum plot size as that which require minimum experimental material for a given precision.

Kalamkar (1932) defined efficiency of plots of X units as $1/X_{Cx}$ where c_x is the coefficient of variation of plots of x units and the optimum plot size as that having maximum efficiency.

Ray *et al.* (1973) proposed a methodology to determine optimum size and shape of plots from data collected from field experiments by eliminating treatment effects and block effects. They also illustrated the technique using data from field experiments in tomato to determine optimum size of plot.

Sunderaraj (1977) modified the method suggested by Ray *et al.* (1973) to determine optimum plot size utilising data from field trials involving incomplete blocks.

2.1.2 Estimation of plot size for perennial crops

Shrikande (1958) observed that genetic variation between trees was a more potential source of error than environmental variation in coconut. This was based on the assumption that 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 could be expressed as $Y = G + E$, where G is the contribution due to genotype and E that due to environment.

According to Butters (1964) optimum plot size can be estimated by maximising information per unit area and be obtained the optimum plot size as nine tree plots in the case of robusta coffee.

Agarwal *et al.* (1968) conducted uniformity trial on arecanut and reported that Smith's law gave satisfactory fit to the relationship between plot size and coefficient of variation. The magnitude of b ranged from 0.37 to 0.496 and was statistically significant. They also reported that efficiency of plot decreased with increase in size of plot.

Abraham *et al.* (1969) conducted uniformity trial on Black pepper and found that coefficient of variation decreased with increase in plot size in either direction, but decrease was more rapid with increase in length. Smith's law was found to be a satisfactory fit to the relationship between plot size and coefficient of variation. With the given experimental area, the smallest plot was more efficient. They also concluded that a plot size of two standards was optimum with one guard row.

Menon and Tyagi (1971) reported single tree plots to be optimum in the case of mandarin orange which gave maximum relative information per tree.

Agarwal (1973) obtained single tree plot as optimum for Apple using the criterion of minimum experimental area for a given precision.

Bhargave and Sardana (1973) obtained single tree plot as optimum in the case of Apple which gave maximum relative information per unit area. Fair Field Smith's law was found to be satisfactory for describing relationship between plot size and variance of the mean per plot.

George *et al.* (1983) conducted uniformity trial on Cardamom. Four and six rows of three plants were found to be optimum size of plots for smaller and larger blocks respectively using Fair Field Smith's law.

Nair and Prabhakaran (1983) reported that 2 plot blocks were the most efficient for conducting field experiments on cashew. The Smith's equation gave a good fit to the relationship between plot size and coefficient of variation. The high value of b indicated that genotypic variation was more predominant than positional variation.

Nambiar (1986) arrived at an optimum size of experimental units in T x D coconut hybrids as 8 seedlings using Fair Field Smith's law and the graphical method of maximum curvature. For this purpose he used experimental palms at two locations.

Sheela and Unnithan (1989) reported four tree plots to be optimum for cocoa with blocks of different sizes, using maximum curvature method.

Nambiar *et al.* (1992) using Fair Field Smith's law and the method of maximum curvature, arrived at the optimum size of plots for experiments on oil palm to be 8 palms.

2.1.3 Estimation of plot size for annual crops

Wallace and Chapman (1956) conducted uniformity trial on oat and found that long and narrow plots had smaller heterogeneity index. The optimum plot size was found to be 8 feet along single row of oats using Fair Field Smith's law.

Lessman and Atkins (1963) conducted uniformity trial and found that single row with length of 15 to 20 feet was optimum in the case of grain sorghum. They suggested the model, $\log C_x = a/(a+\log x)^b$ where C_x is the coefficient of variation of plots of size x units and opined that their model would be more efficient than that of Smith's.

Weideman and Leininger (1963) reported that plot shape had little effect on plot variance for safflower.

Joshi (1972) conducted uniformity trials on unirrigated Rabi gram and found that plot variance and coefficient of variation decreased with increase in plot size. He also concluded that long and narrow plots reduced error more rapidly. A plot having an area of 16.2 m^2 and length, breadth ratio 6:1 was found to be ideal giving maximum accuracy from statistical point of view.

Gupton (1972) conducted uniformity trial on Tobacco to determine optimum size and shape of plots and found one row plots to be slightly better than 2 row plots.

Utilising uniformity trial data, Sreenath (1973) determined optimum size of plots for sorghum and found that long and narrow east west plots of 6-8 m^2 as optimal.

Prabhakaran and Thomas (1974) conducted uniformity trial on Tapioca and found that the shape of plot did not have a consistent effect on coefficient of variation. Long and narrow plots on the average had less variation than square plots.

Bist *et al.* (1975) conducted uniformity trial on potato and found that the shape of plot had no consistent effect on coefficient of variation. Smith's law was found to be a good fit to the relationship between plot size and coefficient of variation.

Kaushik *et al.*(1977) conducted uniformity trial on mustard and reported that coefficient of variation decreased with increase in plot size, though decrease was rapid along the north-south direction compared to east west direction. They also reported that square blocks were less efficient than long and narrow blocks.

Bhargava *et al.* (1978) conducted uniformity trial on banana and found that coefficient of variation decreased with increase in plot size for with and without blocking. Fair Field Smith's variance law fitted well. It was also observed that unit plot size was optimum for 3 per cent Standard Error of mean.

Prabhakaran *et al.* (1978) conducted uniformity trial on banana and single plant plots were recommended as the most efficient. Smith's law was found to give a good fit.

Ram babu *et al.* (1980) conducted uniformity trial on fodder grass and found that coefficient of variation decreased with increase in plot size up to 8 m^2 . Smith's model was a good fit. Long and narrow plots had lower coefficient of variation.

Sasmal and Katyal (1980) conducted uniformity trial on jute and found that the decline in coefficient of variation was substantial up to 30 basic units and marginal afterwards. Further they reported that blocking reduced variability of plots of a given size to a great extent.

Pahuja and Mehra (1982) conducted field experiments with chickpea and maximum precision was obtained for a plot size 1.8 m x 5 m with four replications.

Handa *et al.* (1982) conducted uniformity trial on fodder oat and found that the coefficient of variation decreased with increase in plot size and that the value of `b' in Smith's model ranged from 0.084 to 0.187.

Nair (1984) conducted uniformity trial on turmeric and found that b was nearer to zero which implied that there was strong correlation between neighbouring plots. The optimum plot size for turmeric was determined to be 3 m^2 using maximum curvature method.

Chetty and Reddy (1987) reported that for experiments with dry land sorghum on a test crop on interceptisols, the optimum dimensions of the plots were 12 m across and 3.5 m along the seed row.

Bajpai and Sikarwar (1992) used Fair Field Smith's law and its modified form to determine optimum plot size for sugarcane. It was observed that coefficient of variation decreased with increase in plot size up to 30 units. A net plot size of 19 to 57 m^2 ,regardless of its shape was recommended as optimum.

2.1.4 Estimation of plot size for seasonal crops

Gopani *et al.* (1970) conducted uniformity trial on groundnut and found that coefficient of variation decreased with increase in plot size. The number of replications required for a given level of precision decreased with increase in plot size. They further reported that block efficiency decreased with increase in plot size.

Gupta and Raghava Rao (1971) conducted uniformity trial on onion bulbs and found that value of b in Smith's model was significant.

Kripasankar *et al.* (1972) conducted uniformity trial on soyabean and found that long and narrow plots were better than square ones. Efficiency of plot decreased with increase in size of plots. They found that a plot of about 9 m^2 with 3 replications as optimal.

Saxena *et al.* (1972) conducted uniformity trial on fodder oat and found that the coefficient of variation decreased with increase in plot size and that it was slightly less for rectangular plots than for square plots. Optimum size of plot varied between 9 m^2 and 2 m^2 depending on the cost per unit area.

Biswas *et al.* (1982) found that a plot having 24 plants arranged in any shape to be optimum for experiments on cabbage.

Hariharan *et al.* (1986) conducted uniformity trial on Brinjal and found that 8.64 m^2 as optimum size of experimental units using maximum curvature method. Long and narrow plots were also reported to be better than square plots.

Patil *et al.* (1987) conducted a uniformity trial on Indian Mustard and found that smaller and narrow plots to be more efficient in controlling soil variation. It required 7 or more replications to achieve 5% precision. The optimum plot size varied between 7.7 m^2 and 23 m^2 depending on cost per unit area. The value of Smith's coefficient of heterogeneity was 0.63.

Lizy *et al.* (1987) obtained the optimum plot size as 3 m^2 in the case of Colocasia using maximum curvature method.

Reji (1995) studied optimum plot size for intercropping experiments with bhindi and cowpea and reported that 2.7 m^2 to be optimum using maximum curvature method.

2.2 Multivariate case

Sheela and Unnithan (1992a) suggested procedures to determine optimum size of experimental units using multivariate observations for any crop. Matrix of relative dispersion was defined and its determinant was used as the measure of variation to determine optimum size of experimental units. Optimum plot size was determined by three methods, namely method of maximum curvature, minimisation of number of experimental units to achieve P% error and efficiency. Sheela and Unnithan (1992b) determined optimum size of experimental units for cocoa (*Theobroma cacao*) using multivariate observations with and without blocking. Optimum plot size was determined as single tree by all the three methods.

Materials and Methods

3. MATERIALS AND METHODS

3.1 Materials

The experimental data required for the present investigation were gathered from two sets of coconut trees. The first set consisted of seventy nine palms belonging to sixteen cross combinations planted in 1973 at Regional Agricultural Research Station, Pilicode. It is located at 13°N latitude, 70°E longitude and at an altitude of 15 m above mean sea level. The soil of the experimental site is laterite. These trees started yielding in 1978 and data during 1990 and 1991 were collected from them. The second set consisted of one hundred and five West Cost Tall coconut palm planted in 1963 at Coconut Research Station, Balaramapuram for a 3^3 partially confounded factorial experiment involving nitrogen, phosphorus and potassium each at three levels. The station lies at 8° 28'N latitude and 76°57'E longitude and 64 m above the mean sea level. The soil of the experimental area is deep red, well drained, and moderately acidic sandy loam. These trees started yielding in 1974 and data during 1975 and 1976 were collected from them. Observations on four characters namely yield, female flower production, number of functional leaves and percentage of buttons set were utilised in this investigation.

3.2 Methods

Data collected from uniformity trials are usually used for arriving at optimum plot size. In the case of perennial crops data on trees planted in bulk are usually utilised for the purpose. Smallest unit that can be considered for formation of plots to determine optimum size of plots in the case of perennial crops is an individual plant.

The data utilised in this investigation were from different field trials in two locations and systematic effects were present in them. Hence the systematic effects had to be eliminated. For this purpose, consider the model,

$$X_{ijkl} = \mu + S_i + t_{ij} + b_{ik} + e_{ijkl}$$

where X_{ijkl} is the observation on the l^{th} palm belonging to k^{th} block, j^{th} treatment and i^{th} set,

μ - the overall mean effect

S_i - the effect of i^{th} set

t_{ij} - effect of jth treatment in i^{th} set

b_{ik} - effect of kth block in i^{th} set

e_{ijkl} - residual term for the l^{th} palm belonging to k^{th} block, j^{th} treatment and i^{th} set

i - 1, 2

j - 1, 2, ... t_i where $t_1 = 16$, $t_2 = 27$

k - 1, 2, ... b_i, $b_1 = 0$, $b_2 = 6$

l - 1, 2, ... n_{ijk}, where n_{ijk} is the number of trees belongs to i^{th} set, j^{th} treatment and k^{th} block. After eliminating treatment and block effects as well as the effect of the two sets the residual observations could be represented as

$$X_{ijkl} = \mu + e_{ijkl} = X_{ijkl} - S_i - t_{ij} - b_{ik} \quad \rightarrow (3.1)$$

These quantities are devoid of any known systematic effect. Thus they can be treated as observations from a uniformity trial and hence were used to determine optimum size of plots for various sizes of blocks.

Measure of variation in multivariate case

Relative dispersion matrix (Unnithan and Sheela, 1992a) for P characters, each observed on N itmes could be represented by $S = (S_{ij})_{PxP}$, where

$$S_{ij} = \frac{\sum_{k=1}^{N} Y_{ik}Y_{jk} - N\,\bar{Y}_i\,\bar{Y}_j}{N\,\bar{Y}_i\,\bar{Y}_j} \rightarrow (3.2) \qquad i, j = 1, 2 \ldots\ldots P$$

and its determinant was used as the measure of variation analogous to coefficient of variation in univariate case (Sheela and Unnithan, 1992a) where,

Y_{ik} is the observation on i^{th} character on k^{th} tree

$\bar{Y}_i$ is the mean of i^{th} character

$i = 1, 2 \ldots\ldots P$

$k = 1, 2 \ldots\ldots N$ and N is the total number of units

3.2.1 Methods of plot formation

All the 184 trees were arranged in the ascending order of magnitude of the number of functional leaves of first year. Experimental units of sizes ranging from single tree to ten trees by combining near by trees in the list were formed and the measure of variation, Viz., cv in the univariate case and determinant of relative dispersion matrix in the multivariate case were worked out without forming blocks.

Measure of with in block variation were also worked out after combining near by plots in to blocks of five plots, seven plots and ten plots for various plot size.

3.2.2 Determination of optimum plot size

Optimum size of plots was determined by three different criteria for no blocking as well as for blocks of different sizes.

3.2.2.1 Minimum number of trees to achieve P% error

Optimum plot size by this criterion was defined as that which requires minimum number of trees to achieve a specified precision. The minimum number of replications required to achieve P% standard error in the univariate case is given by

$$r = (cv)^2/(P/100)^2 \quad \rightarrow (3.3)$$

where

r = number of replications

cv = coefficient of variation

P = Percentage standard error of mean (required precision)

The number of trees required to achieve P% error was obtained by multiplying number of replications with corresponding plot size.

3.2.2.1a Multivariate case

Let $\bar{Y}' = (\bar{Y}_1, \bar{Y}_2 \ldots\ldots\ldots \bar{Y}_p)$ be the mean vector of the p dimensional vector variable $\bar{Y}'$ from 'r' plots. The relative dispersion matrix for $\bar{Y}$ is given by $D(\bar{Y}) = (S_{ij}/r)$

Determinant of relative dispersion matrix is given by $|D(\bar{Y})| = |S|/r^P$

Analogous to fixing cv at P% level in univariate case, for P% error in multivariate case

$$|S| / r^p = (P/100)^{2p}$$

$$r = |S|^{1/p} / (P/100)^2 \quad \rightarrow (3.4)$$

This provides the number of replications required to achieve P% error. In other words the number of replication 'r' required to achieve P% error has to be atleast $|S|^{1/p}/(P/100)^2$. The number of trees required to achieve P% error may be obtained by multiplying number of replications with corresponding plot size.

3.2.2.2 Plot size having maximum efficiency

Efficiency of a plots of X units was defined as 1/XCV in the univariate case and $1/x\sqrt[p]{|S|}$ in multivariate case. The plot size which gave maximum value for efficiency was adjudged optimum by this criterian.

3.2.2.3 Method of maximum curvature

It consists in representing the relationship between plot size and cv graphically by a smooth curve taking plot size along X axis and cv along Y axis. Optimum plot size is the abscissa of the point just beyond the point of maximum curvature.

The following four models were fitted to cv in the univariate case and |S| in the multivariate case against plot size.

$$Y = ax^{-b} \quad \rightarrow (3.5)$$

$$Y = a + b/\sqrt{x} + c/x \quad \rightarrow (3.6)$$

$$Y^{-1} = a + b \log x \qquad \rightarrow (3.7)$$

$$Y^{-1} = a + b\sqrt{x} + cx \qquad \rightarrow (3.8)$$

where Y is the cv in univariate case and |S| in multivariate case and x plot size.

Among the four estimated models one having the best fit was selected to determine the point of maximum curvature graphically.

Results

4. RESULTS

Applying model (3.1) to the two sets of data described in chapter III, the residual terms which are devoid of effects of treatments, blocks, locations or temporal sources have been worked out for yield, female flower production, number of functional leaves and percentage of buttons set for each tree for two consecutive years. These observations could be treated as equivalent to these from a uniformity trial. They were used for arriving at optimum sizes of plot under various consideration.

4.1 Univariate case

All the trees were arranged in increasing order of magnitude of the number of functional leaves. Plots of various sizes were formed by combining trees which are adjecent in the list of arranged trees. Similarly blocks of sizes, 5, 7 and 10, were formed by grouping homogeneous trees (with respect to the character by which the trees were arranged).

4.1.1 Yield

Coefficients of variation (cv) of yield were calculated for plots of sizes ranging from single tree to ten trees. The number of replications and corresponding number of trees required to achieve 5 per cent error, and efficiencies for plots of different sizes were also worked out. In addition to these calculations in the case of no blocking, they were also determined for blocks of sizes five, seven and ten and are given in Tables 1 and 2 respectively for the first and second years.

An examination of Table 1 reveals that cv in the first year decreased from 0.372 for single tree plots to 0.153 for ten tree plots when blocking was not adopted. The minimum number of trees required to achieve 5 per cent error was for single tree plots. Maximum efficiency was also for single tree plots. The four models estimated for coefficient of variation against plot sizes are given in Table 10. All the four models were good fit with R^2 value of 99 per cent or 98 per cent. Optimum size of plot by the method of maximum curvature was arrived at for model (3.6) (Fig.1). Four tree plots was optimum.

When block size was five, cv decreased from 0.361 for single tree plots to 0.160 for ten tree plots. Minimum number of trees required to achieve 5 per cent error as well as maximum efficiency was for single tree plots. R^2 was highest (98%) for model (3.6) and four tree plots was found optimum by the method of maximum curvature (Fig.1).

When block size was seven cv decreased from 0.363 for single tree plots to 0.167 for six tree plots and fluctuated for further increase in plot size. Minimum number of trees required to achieve 5 per cent error was for single tree plots. Maximum efficiency was also for single tree plots. R^2 was highest (98%) for model (3.6) and four tree plot was optimum by method of maximum curvature (Fig.1).

When block size was ten, cv decreased from 0.360 for single tree plot to 0.136 for nine tree plots. Minimum number of trees required to achieve 5 per cent error as well as maximum efficiency was for single tree plots. R^2 was highest (96%) for model (3.6) and four tree plot was optimum by the method of maximum curvature (Fig.1).

Table 2 revealed that cv of yield in second year decreased from 0.391 for single tree plot to 0.172 for ten tree plots when blocking was not adopted. Minimum number of trees required to achieve 5 per cent error was for two tree plots which was almost same as that of single tree plots. Maximum efficiency was for single tree plots. The models estimated for cv against plot size are given in Table 11. R^2 was highest (99%) for model (3.62) and four tree plot was optimum by the method of maximum curvature (Fig.2).

When block size was five, cv decreased from 0.373 for single tree plots to 0.148 for eight tree plots and increased slightly for nine and ten tree plots. Minimum number of trees required to achieve 5 per cent error was for two tree plots. Maximum efficiency was for single tree plots. R^2 was highest (99%) for model (3.6) and four tree plot was optimum by the method of maximum curvature (Fig.2).

When the block size was seven, cv decreased from 0.376 for single tree plots is 0.158 for six tree plots and then increased for all plot sizes. Minimum number of trees required to achieve 5 per cent error was for two tree plots. Maximum efficiency was for single tree plots. R^2 was highest (94%) for model (3.6) and four tree plot was optimum by the method of maximum curvature (Fig.2).

When block size was ten, cv decreased from 0.374 for single tree plots to 0.153 for nine tree plots and then increased for ten tree plots. Minimum number of trees required to achieve 5 per cent error was for two tree plots. Maximum efficiency was found for single tree plots R^2 was highest (96%) for model (3.6) and four tree plot was optimum by the method of maximum curvature (Fig.2).

4.1.2 Female flower production

Coefficient of variation of female flower production for the first and second years were calculated for various plot sizes ranging from single tree plots to ten tree plots for blocks of sizes five, seven and ten and also for without blocking. The number of replications and corresponding number of trees required to achieve 5 per cent error and efficiencies for plots of different sizes were also worked out along with the cv and are provided in Tables 3 and 4.

Cv of female flower production in the first year decreased from 0.408 for single tree plots to 0.133 for ten tree plots when blocking was not adopted. Minimum number of trees required to achieve 5 per cent standard error was for two tree plots. Maximum efficiency was found for single tree plots. The models estimated for cv against plot size are given in Table 12. R^2 was highest (97%) for model (3.6) and four tree plot was optimum by the method ofmaximum curvature(Fig.3).

When block size was five, cv decreased from 0.404 for single tree plots to 0.125 for nine tree plots. Minimum number of trees required to achieve 5 per cent error was for two tree plots. Maximum efficiency was found for single tree plots. R^2 was highest (95%) for model (3.6) and four tree plot was optimum by the method of maximum curvature (Fig.3).

When block size was seven, cv decreased from 0.419 for single tree plots to 0.150 for ten tree plots. Minimum number of trees required to achieve 5 per cent standard error was for two tree plots. Maximum efficiency was found for single tree plots. R^2 was highest (95%) for model (3.6) and four tree plot was optimum by the method of maximum curvature (Fig.3).

When block size was ten, cv decreased from 0.412 for single tree plot to 0.137 for nine tree plots. Minimum number of trees required to achieve 5 per cent standard error was for two tree plots. Maximum efficiency was found for single tree plots. R^2 was highest (93%) for model (3.6) and four tree plot was optimum by the method of maximum curvature (Fig.3).

It may be noted from Table 4 that cv of female flowers production in the second year, decreased from 0.430 for single tree plots to 0.151 for ten tree plots when blocking was not adopted. Minimum number of trees required to achieve 5 per cent error was for two tree plots. Maximum efficiency was found for single tree plots. The models estimated for cv against plot sizes are given in Table 13. R^2 was highest (97%) for model (3.6) and four tree plot was optimum by the method of maximum curvature (Fig.4).

When block size was five, cv decreased from 0.417 for single tree plot to 0.125 for ten tree plots. Minimum number of trees required to achieve 5 per cent error was for two tree plots. Maximum efficiency was found for single tree plots. R^2 was highest (97%) for model (3.6) and four tree plot was optimum by the method of maximum curvature (Fig.4).

When block size was seven, cv decreased from 0.431 for single tree plot to 0.157 for seven tree plots and there was slight increase in cv for further increase in plot size. Minimum number of trees required to achieve 5 per cent error was for two tree plots. Maximum efficiency was for single tree plots. R^2 was highest (93%) for model (3.6) and four tree plot was optimum by the method of maximum curvature.

When block size was ten, cv decreased from 0.430 for single tree plot to 0.154 for ten tree plots. Minimum number of trees required to achieve 5 per cent error was for two tree plots. Maximum efficiency was found for single tree plots and R^2 was highest (95%) for model (3.6) and four tree plot was optimum by the method of maximum curvature (Fig.4).

4.2 Multivariate case

4.2.1 Yield for two years

The characters considered for calculating relative dispersion matrix were yield during first and second years.

$|S|$, number of replications and number of trees required to achieve 5 per cent error along with efficiency of plots of various sizes are given in Table 5.

$|S|$ decreased from 0.021627 for single tree plot to 6.94×10^{-4} for ten tree plots when blocking was not adopted. Minimum number of trees required to achieve 5 per cent error as well as maximum efficiency was for single tree plots.

The four models described in chapter III were fit to the relation between determinant of relative dispersion matrix and plot sizes. The estimated models are given in Table 14. The highest R^2 value of 99 per cent was for model (3.6) and four tree plot was optimum by the method of maximum curvature (Fig.5).

When block size was five, |S| decreased from 0.0187 for single tree plots to 4.54×10^{-4} for nine tree plots. Minimum number of trees required to achieve 5 per cent error was for two tree plots. When efficiencies of various plot sizes were considered maximum efficiency was also for two tree plots. Among the four models, model (3.6) gave the best fit with R^2 value of 99 per cent. Optimum size of plot by the method of maximum curvature was determined as four tree plots (Fig.5).

When block size was seven, |S| decreased from 0.0935 for single tree plot so 8.13×10^{-4} for eight tree plots. Minimum number of trees required to achieve 5 per cent error as well as maximum efficiency was for two tree plots. R^2 was highest (99%) for model (3.6) and four tree plot was optimum by the method of maximum curvature.

When block size was ten, |S| decreased from 0.01883 for single tree plots to 4.37×10^{-4} for nine tree plots. Minimum number of trees required to achieve 5 per cent error as well as maximum efficiency was for two tree plots. R^2 was highest (98%) for model (3.6) and four tree plot was optimum by the method of maximum curvature (Fig.5).

4.2.1a Female flower production for two years

The characters considered for calculating relative dispersion matrix were female flowers in the first and second years.

|S|, number of replications and trees required to achieve 5 per cent error and efficiencies for plots of various sizes with different block sizes are given in Table 6.

|S| decreased from 0.0321 for single tree plots to 4.2×10^{-4} for ten tree plots when blocking was not adopted. Minimum number of trees required to achieve 5 per cent error as well as maximum efficiency was for two tree plots. The models estimated

for |S| against plot size are given in Table 15. R^2 was highest (98%) for model (3.6) and three tree plot was optimum by the method of maximum curvature (Fig.6).

When block size was five, |S| decreased from 0.0297 for single tree plot to 3.49×10^{-4} for ten tree plots. Minimum number of trees required to achieve 5 per cent error as well as maximum efficiency was for two tree plots. R^2 was highest (98%) for model (3.6) and four tree plot was optimum by the method of maximum curvature (Fig.6).

When block size was seven, |S| decreased from 0.0346 for single tree plot to 4.61×10^{-4} for eight tree plots. Minimum number of trees required to achieve 5 per cent error as well as maximum efficiency was for two tree plots. Model (3.6) had the highest R^2 value of (97%) and optimum plot size by maximum curvature was found to be three tree plots (Fig.6).

When block size was ten, |S| decreased from 0.0329 for single tree plot to 3.26×10^{-4} for ten tree plots. Minimum number of trees required to achieve 5 per cent error as well as maximum efficiency was for two tree plots. R^2 was highest (97%) for model (3.6) and three tree plot was optimum by the method of maximum curvature (Fig.6).

4.2.2 Yield and female flower production for two years

Relative dispersion matrices (S) of order 4 were obtained with female flower production and yield for the two years.

|S|, number of replication and trees required to achieve 5 per cent error and efficiency for plots of various sizes with different block sizes are given in Table 7.

|S| decreased from 5.818×10^{-4} for single tree plots to 2.7×10^{-7} for ten tree plots when blocking was not adopted. Minimum number of trees required to achieve 5 per cent error as well as maximum efficiency was for two tree plots. The models

estimated for |S| against plot sizes are given in Table 16. R^2 was highest (98%) for model (3.6) and three tree plot was optimum by the method of maximum curvature (Fig.7).

When block size was five, |S| decreased from 4.79 x 10^{-4} for single tree plots to 2.3 x 10^{-7} for ten tree plots. Minimum number of trees required to achieve 5 per cent error as well as maximum efficiency was for two tree plots. R^2 was highest (97%) for model (3.6) and three tree plot was optimum by the method of maximum curvature (Fig.7).

When block size was seven, |S| decreased from 5.826 x 10^{-4} for single tree plots to 0.25 x 10^{-6} for ten tree plots. Minimum number of trees required to achieve 5 per cent error was for two tree plots. Maximum efficiency was also for two tree plots. R^2 was highest (95%) for model (3.6) and three tree plot was optimum by the method of maximum curvautre (Fig.7).

When block size was ten, |S| decreased from 5.375 x 10^{-4} for single tree plots to 2.6 x 10^{-7} for ten tree plots. Minimum number of trees required to achieve 5 per cent standard error was for two tree plots. Maximum efficiency was found for single tree plots. R^2 was highest (96%) for model (3.6) and three tree plot was optimum by the method of maximum curvature (Fig.7).

4.2.3 Yield, female flower production and percentage of buttons set for first year

Characters considered for calculating relative dispersion matrices were yield, female flower production and percentage of buttons set for first year.

|S|, number of replications and trees require to achieve 5 per cent error and efficiency for plots of various sizes with different block sizes are given in Table 8.

|S|, decreased from 8.564×10^{-4} for single tree plot to 8.04×10^{-6} for ten tree plots when blocking was not adopted. Minimum number of trees required to achieve 5 per cent error as well as maximum efficiency was for single tree plots.

Four models described in chapter III were estimated to relationship of determinant of relative dispersion matrix and plot sizes. R^2 was highest (98%) for model (3.6) Table 17 and three tree plot was optimum by the method of maximum curvature (Fig.8).

When block size was five |S| had a decreasing trend with plot size as in the other cases. Minimum number of trees required to achieve 5 per cent error as well as maximum efficiency was for two tree plots. R^2 was highest (97%) for model (3.6) and three tree plot was optimum by the method of maximum curvature (Fig.8).

When block size was seven also, |S| had a decreasing trend with increase in plot size, though there was reverse trend after the size of eight. Minimum number of trees required to achieve 5 per cent error as well as maximum efficiency was for two tree plots. The highest R^2 value of 96 per cent was for model (3.6) and three tree plot was optimum by the method of maximum curvature (Fig.8).

When block size was ten, |S| decreased from 5.149×10^{-4} for single tree plot to 4.81×10^{-6} for nine tree plots. Minimum number of trees required to achieve 5 per cent error as well as maximum efficiency was for two tree plots. R^2 was highest (97%) for model (3.6) and three tree plot was optimum by the method of maximum curvature (Fig.8).

4.2.4 Yield, female flower production and percentage of buttons set for second year

Characters considered for calculating relative dispersion matrix were yield, female flower production and percentage of buttons set for second year.

|S|, number of replication and trees require to achieve 5 per cent error and efficiency for various sizes of plots and blocks are given in Table 9.

|S|, decreased from 0.000738 for single tree plots to 2.98 x 10^{-6} for ten tree plots when blocking was not adopted. Minimum number of trees required to achieve 5 per cent SE as well as maximum efficiency was for single tree plots.

Four models described in Chapter III were estimated to the relationship of the determinant of relative dispersion matrix and plot sizes. R^2 was highest 98 per cent for model (3.6) (Table 18) and three tree plot was optimum by the method of maximum curvature (Fig. 9).

When block size was five |S| decreased from 0.000558 for single tree plots to 1.54 x 10^{-6} for ten tree plots. Minimum number trees required to achieve 5 per cent error as well as maximum efficiency was for two tree plots. R^2 was highest 98 per cent for model (3.6) three tree plot was optimum by the method of maximum curvature (Fig.9).

When block size was seven, |S| decreased from 0.000673 for single tree plot to 3.47 x 10^{-6} for ten tree plots. Minimum number of trees required to achieve 5 per cent SE as well as maximum efficiency was for two tree plots. R^2 was highest (98%) for model (3.6) and three tree plot was optimum by the method of maximum curvature (Fig.9).

When block size was ten, |S| decreased from 0.000673 for single tree plots to 1.98 x 10^{-6} for ten tree plots. Minimum number of trees required to achieve 5 per cent SE as well as maximum efficiency was for two tree plots. R^2 was highest (96%) for model (3.6) and three tree plot was optimum by the method of maximum curvature (Fig.9).

Table 1. cv of first year yield, number of replication and trees required to achieve 5% error and efficiencies corresponding to different sizes of plots and blocks

Plot sizes	Without blocking				5 plot block			
	cv	No. of repli-cation for 5% SE	No. of trees for 5% SE	Efficiency 1/x cv	cv	No. of repli-cation for 5% SE	No. of trees for 5% SE	Efficiency 1/x cv
1	0.372	55	55	2.68	0.361	52	52	2.77
2	0.271	29	58	1.84	0.261	27	54	1.91
3	0.229	21	63	1.45	0.210	18	54	1.58
4	0.204	17	68	1.22	0.184	14	56	1.35
5	0.189	14	70	1.05	0.163	11	55	1.22
6	0.172	12	72	0.96	0.162	10	60	1.02
7	0.165	11	77	0.86	0.154	9	63	0.92
8	0.161	10	80	0.77	0.155	10	80	0.80
9	0.147	9	81	0.75	0.134	7	63	0.82
10	0.153	9	90	0.65	0.160	10	100	0.62

Contd.

Table 1. Continued

Plot sizes	7 plot block				10 plot block			
	cv	No. of replication for 5% SE	No. of trees for 5% SE	Efficiency 1/x cv	cv	No. of replication for 5% SE	No. of trees for 5% SE	Efficiency 1/x cv
1	0.363	52	52	2.75	0.360	51	51	2.77
2	0.259	27	54	1.95	0.258	27	54	1.93
3	0.227	21	63	1.46	0.223	20	60	1.49
4	0.202	16	64	1.23	0.206	17	68	1.21
5	0.180	13	65	1.11	0.201	16	80	0.99
6	0.167	11	66	0.99	0.162	10	60	1.02
7	0.173	12	84	0.82	0.177	13	91	0.80
8	0.146	9	72	0.85	0.153	9	72	0.81
9	0.160	10	90	0.69	0.136	7	63	0.81
10	0.164	10	100	0.60	0.168	11	110	0.59

Table 2. cv of second year yield, number of replications and trees required to achieve 5 per cent error and efficiencies corresponding to different sizes of plots and block

Plot sizes	Without blocking				5 plot block			
	cv	No. of repli-cation for 5% SE	No. of trees for 5% SE	Efficiency 1/x cv	cv	No. of repli-cation for 5% SE	No. of trees for 5% SE	Efficiency 1/x cv
1	0.391	61	61	2.55	0.373	56	56	2.68
2	0.275	30	60	1.81	0.242	23	46	2.06
3	0.235	22	66	1.41	0.197	16	48	1.69
4	0.229	21	84	1.09	0.185	14	56	1.35
5	0.209	17	85	0.95	0.173	12	60	1.15
6	0.204	17	102	0.81	0.168	11	66	0.99
7	0.181	13	91	0.79	0.150	9	63	0.95
8	0.197	16	128	0.63	0.148	9	72	0.84
9	0.188	14	126	0.59	0.158	10	90	0.70
10	0.172	12	120	0.58	0.161	10	100	0.62

Contd.

Table 2. Continued

Plot sizes	7 plot block				10 plot block			
	cv	No. of repli-cation for 5% SE	No. of trees for 5% SE	Efficiency 1/x cv	cv	No. of repli-cation for 5% SE	No. of trees for 5% SE	Efficiency 1/x cv
1	0.376	57	57	2.65	0.374	56	56	2.67
2	0.241	23	46	2.07	0.237	22	44	2.10
3	0.206	17	51	1.61	0.204	17	51	1.63
4	0.200	16	64	1.25	0.194	15	60	1.28
5	0.181	13	65	1.10	0.205	17	85	0.97
6	0.158	10	60	1.05	0.195	15	90	0.85
7	0.177	15	91	1.23	0.161	10	70	0.88
8	0.194	15	120	0.64	0.155	10	80	0.86
9	0.206	17	153	0.53	0.153	9	81	0.72
10	0.145	8	80	0.68	0.175	12	120	0.57

Table 3. cv of first year female flower production, number of replication and trees required to achieve 5 per cent error and efficiencies corresponding to different sizes of plots and blocks

Plot sizes	Without blocking				5 plot block			
	cv	No. of repli-cation for 5% SE	No. of trees for 5% SE	Efficiency 1/x cv	cv	No. of repli-cation for 5% SE	No. of trees for 5% SE	Efficiency 1/x cv
1	0.408	67	67	2.45	0.404	65	65	2.47
2	0.249	25	50	2.00	0.238	23	46	2.10
3	0.223	20	60	1.49	0.216	19	57	1.54
4	0.186	14	56	1.34	0.180	13	52	1.38
5	0.200	16	80	1.00	0.190	14	70	1.05
6	0.189	14	84	0.88	0.178	12	72	0.93
7	0.145	8	56	0.98	0.130	7	49	1.09
8	0.133	7	56	0.93	0.128	7	56	0.97
9	0.133	7	63	0.83	0.125	6	54	0.88
10	0.133	7	70	0.75	0.150	9	90	0.66

Contd.

Table 3. Continued

Plot sizes	7 plot block				10 plot block			
	cv	No. of replication for 5% SE	No. of trees for 5% SE	Efficiency 1/x cv	cv	No. of replication for 5% SE	No. of trees for 5% SE	Efficiency 1/x cv
1	0.419	70	70	2.38	0.412	68	68	2.42
2	0.242	23	46	2.06	0.245	24	48	2.04
3	0.234	22	66	1.42	0.221	20	60	1.50
4	0.186	14	56	1.34	0.192	15	60	1.30
5	0.204	17	85	0.98	0.223	20	100	0.89
6	0.182	13	78	0.91	0.189	14	84	0.88
7	0.146	9	63	0.97	0.148	9	63	0.96
8	0.126	6	48	0.99	0.137	8	64	0.91
9	0.157	10	90	0.70	0.137	8	72	0.81
10	0.150	9	90	0.60	0.157	10	100	0.63

Table 4. cv of second year female flower production, number of replication and trees required to achieve 5 per cent error and efficiences corresponding to different sizes of plots

Plot sizes	Without blocking				5 plot block			
	cv	No. of replication for 5% SE	No. of trees for 5% SE	Efficiency 1/x cv	cv	No. of replication for 5% SE	No. of trees for 5% SE	Efficiency 1/x cv
1	0.430	73	73	2.32	0.417	70	70	2.39
2	0.282	32	64	1.77	0.271	29	58	1.84
3	0.248	25	75	1.34	0.245	24	72	1.85
4	0.225	20	80	1.11	0.204	17	68	1.22
5	0.224	20	100	0.89	0.207	17	85	0.96
6	0.194	15	90	0.85	0.180	13	78	0.92
7	0.166	11	66	0.86	0.155	10	60	0.92
8	0.169	11	77	0.75	0.149	9	72	0.83
9	0.181	13	117	0.61	0.169	11	99	0.65
10	0.151	9	90	0.66	0.125	6	60	0.80

Contd.

Table 4. Continued

Plot sizes	7 plot block				10 plot block			
	cv	No. of replication for 5% SE	No. of trees for 5% SE	Efficiency 1/x cv	cv	No. of replication for 5% SE	No. of trees for 5% SE	Efficiency 1/x cv
1	0.431	74	74	2.32	0.430	73	73	2.32
2	0.272	30	60	1.83	0.265	28	56	1.88
3	0.249	25	75	1.33	0.239	23	69	1.39
4	0.222	20	80	1.12	0.221	20	80	1.13
5	0.218	19	95	0.91	0.224	20	100	0.89
6	0.178	13	78	0.93	0.187	14	84	0.89
7	0.157	10	70	0.90	0.165	11	66	0.86
8	0.170	12	96	0.73	0.147	9	72	0.85
9	0.214	18	162	0.51	0.161	10	90	0.69
10	0.144	8	80	0.69	0.154	9	90	0.64

Table 5. |S| of yield for first and second years, number of replications and trees required to achieve 5 per cent error and efficiencies corresponding to different sizes of plots and blocks

Plot sizes	Without blocking				5 plot block			
	$\lvert S\rvert \times 10^4$	No. of repli-cation for 5% SE	No. of trees for 5% SE	Efficiency $1/x\sqrt[2]{\lvert S\rvert}$	$\lvert S\rvert \times 10^4$	No. of repli-cation for 5% SE	No. of trees for 5% SE	Efficiency $1/x\sqrt[2]{\lvert S\rvert}$
1	216.27	59	59	6.79	187.00	55	55	7.31
2	55.87	30	60	6.68	38.74	25	50	8.03
3	29.01	22	66	6.18	17.48	17.	51	7.97
4	21.78	19	76	5.35	11.74	14	56	7.29
5	15.77	16	80	5.03	8.04	11	55	7.05
6	12.22	14	64	4.75	7.49	11	66	6.08
7	8.96	12	84	4.77	5.38	9	63	6.15
8	10.05	13	104	3.94	5.32	9	72	5.41
9	7.73	11	99	3.99	4.54	9	81	5.21
10	6.94	11	110	3.79	6.73	10	100	3.85

Contd.

Table 5. Continued

Plot sizes	7 plot block				10 plot block			
	$\lvert S \rvert \times 10^4$	No. of repli-cation for 5% SE	No. of trees for 5% SE	Efficiency $1/x \sqrt[x]{\lvert S \rvert}$	$\lvert S \rvert \times 10^4$	No. of repli-cation for 5% SE	No. of trees for 5% SE	Efficiency $1/x \sqrt[x]{\lvert S \rvert}$
1	193.51	56	56	7.18	188.39	55	55	7.28
2	38.11	25	50	8.09	38.02	25	50	8.10
3	22.22	19	57	7.07	20.96	18	54	7.28
4	16.46	16	64	6.16	16.20	16	64	6.21
5	10.87	13	65	6.06	17.25	17	85	4.81
6	7.08	11	66	6.26	10.03	13	78	5.26
7	9.36	12	84	4.66	8.19	11	77	4.99
8	8.13	11	88	4.38	5.71	10	80	5.23
9	11.01	13	117	3.34	4.37	8	72	5.31
10	5.69	10	100	3.19	8.58	12	120	3.41

Table 6. |S| of female flower production for two years, number of replications and trees required to achieve 5 per cent error and efficiencies corresponding to different sizes of plots and blocks

Plot sizes	Without blocking				5 plot block			
	$\|S\| \times 10^4$	No. of repli-cation for 5% SE	No. of trees for 5% SE	Efficiency $1/x \sqrt[x]{\|S\|}$	$\|S\| \times 10^4$	No. of repli-cation for 5% SE	No. of trees for 5% SE	Efficiency $1/x \sqrt[x]{\|S\|}$
1	321.24	72	72	5.57	297.69	69	69	5.79
2	49.77	28	56	7.09	42.15	26	52	7.70
3	30.78	22	66	6.01	28.04	21	63	6.29
4	17.72	17	68	5.94	13.66	15	60	6.77
5	20.29	18	90	4.44	15.75	16	90	5.04
6	6.95	11	66	6.32	4.81	9	54	7.59
7	5.02	9	63	5.57	3.96	8	56	7.17
8	5.85	10	80	4.59	3.69	8	64	6.50
9	4.20	8	72	4.87	4.50	8	72	5.23
10	4.87	9	90	4.53	3.49	8	80	5.27

Contd.

Table 6. Continued

Plot sizes	7 plot block				10 plot block			
	$\|S\| \times 10^4$	No. of repli-cation for 5% SE	No. of trees for 5% SE	Efficiency $1/x \sqrt[2]{\|S\|}$	$\|S\| \times 10^4$	No. of repli-cation for 5% SE	No. of trees for 5% SE	Efficiency $1/x \sqrt[2]{\|S\|}$
1	346.39	74	74	5.37	329.20	73	73	5.51
2	43.64	26	52	7.57	42.40	26	52	7.67
3	34.21	23	69	5.69	27.86	21	63	6.32
4	17.30	16	64	6.01	18.13	17·0	68	5.87
5	20.11	8	90	4.46	25.44	20	100	3.96
6	5.64	9	54	7.01	5.93	10	60	6.84
7	5.29	9	63	6.21	5.98	10	70	5.84
8	4.61	9	72	5.82	4.14	8	64	6.14
9	11.30	13	117	3.30	4.79	7	63	5.07
10	4.72	9	90	4.60	3.26	7	70	5.53

Table 7. |S| of female flower production and yield for two years, number of replications and trees required to achieve 5 per cent error and efficiencies corresponding to different sizes of plots and blocks

Plot sizes	Without blocking				5 plot block			
	$\lvert S\rvert \times 10^6$	No. of repli-cation for 5% SE	No. of trees for 5% SE	Efficiency $1/x\sqrt[4]{\lvert S\rvert}$	$\lvert S\rvert \times 10^6$	No. of repli-cation for 5% SE	No. of trees for 5% SE	Efficiency $1/x\sqrt[4]{\lvert S\rvert}$
1	581.84	62	62	6.43	479.4	59	59	6.75
2	25.27	28	56	7.05	15.4	25	50	7.98
3	8.28	18	63	6.21	4.65	19	57	7.17
4	3.58	17	68	5.74	1.53	14	56	7.10
5	3.03	17	85	4.80	1.22	13	65	6.01
6	0.84	12	72	5.56	0.34	9	54	6.87
7	0.42	10	70	5.59	0.20	9	63	6.71
8	0.42	11	88	4.74	0.18	8	64	5.99
9	0.42	10	90	4.34	0.19	8	72	5.27
10	0.27	9	90	4.35	0.23	9	90	4.55

Contd.

Table 7. Continued

Plot sizes	7 plot block				10 plot block			
	$\lvert S \rvert \times 10^6$	No. of repli-cation for 5% SE	No. of trees for 5% SE	Efficiency $1/x \sqrt[x]{\lvert S \rvert}$	$\lvert S \rvert \times 10^6$	No. of repli-cation for 5% SE	No. of trees for 5% SE	Efficiency $1/x \sqrt[x]{\lvert S \rvert}$
1	582.66	62	62	6.43	537.5	61	61	6.56
2	15.68	25	50	7.94	15.17	25	50	6.27
3	7.22	21	63	6.43	6.89	21	63	6.50
4	2.71	16	64	6.16	2.79	16	64	6.11
5	2.12	15	75	5.24	4.22	18	90	4.41
6	0.38	10	60	6.69	0.56	11	66	6.07
7	0.47	10	70	5.45	0.46	10	70	5.46
8	0.35	10	80	5.11	0.22	9	72	5.72
9	1.17	13	117	3.37	0.20	8	72	5.24
10	0.25	9	90	4.43	0.26	9	90	4.39

Table 8. |S| of female flower production, yield and percentage of buttons set for first year, number of replication and trees required to achieve 5 per cent error and efficiencies corresponding to different sizes of plots and blocks

Plot sizes	Without blocking				5 plot block			
	$\|S\| \times 10^6$	No. of replication for 5% SE	No. of trees for 5% SE	Efficiency $1/x\sqrt[3]{\|S\|}$	$\|S\| \times 10^6$	No. of replication for 5% SE	No. of trees for 5% SE	Efficiency $1/x\sqrt[3]{\|S\|}$
1	856.48	38	38	10.52	494.17	32	32	12.64
2	113.40	20	40	10.32	38.03	14	28	14.86
3	62.33	16	48	8.40	16.56	10	30	13.07
4	30.27	12	48	8.02	10.05	9	36	11.58
5	29.95	12	60	6.44	11.18	9	45	8.94
6	11.23	9	54	7.44	5.54	7	42	9.41
7	9.90	9	63	6.65	5.44	7	49	8.12
8	8.66	8	64	6.08	6.07	7	56	6.85
9	7.34	8	72	5.71	3.57	6	54	7.27
10	8.04	8	80	4.99	9.40	8	80	4.73

Contd.

Table 8. Continued

Plot sizes	7 plot blocks				10 plot block			
	$\lvert S\rvert \times 10^6$	No. of replication for 5% SE	No. of trees for 5% SE	Efficiency $1/x \sqrt[3]{\lvert S\rvert}$	$\lvert S\rvert \times 10^6$	No. of replication for 5% SE	No. of trees for 5% SE	Efficiency $1/x \sqrt[3]{\lvert S\rvert}$
1	555.27	33	33	12.16	514.95	32	32	12.47
2	34.91	13	26	15.29	53.41	15	30	13.27
3	41.41	14	42	9.63	41.67	14	42	9.61
4	21.50	11	44	8.99	26.69	12	48	8.36
5	18.67	11	55	7.53	35.80	13	45	6.06
6	7.65	8	48	8.45	16.20	10	60	6.57
7	11.24	9	63	6.37	13.13	9	63	6.05
8	4.97	7	56	7.32	7.19	8	56	6.47
9	11.89	9	81	4.86	4.81	7	63	6.58
10	10.79	9	90	4.52	18.79	11	110	3.76

Table 9. |S| of female flower production, field and percentage of buttons set for second year, number of replications and trees required to achieve 5 per cent error and efficiencies corresponding to different size of plots and blocks

Plot sizes	Without blocking				5 plot block			
	$\lvert S \rvert \times 10^6$	No. of replication for 5% SE	No. of trees for 5% SE	Efficiency $1/x\sqrt[3]{\lvert S \rvert}$	$\lvert S \rvert \times 10^6$	No. of replication for 5% SE	No. of trees for 5% SE	Efficiency $1/x\sqrt[3]{\lvert S \rvert}$
1	738.91	36	36	11.06	558.80	33	33	12.14
2	103.73	19	38	10.64	66.21	16	32	12.35
3	33.32	13	39	10.36	22.71	11	33	11.77
4	21.17	11	44	9.04	8.97	9	36	12.06
5	18.16	11	55	7.6	9.59	9	45	9.44
6	8.67	8	48	8.13	4.64	7	42	10.02
7	3.82	6	42	9.15	3.45	6	42	11.03
8	4.91	7	56	7.35	2.82	6	48	8.88
9	5.09	7	63	6.49	2.54	5	45	8.18
10	2.98	6	60	7.01	1.54	5	50	8.73

Contd.

Table 9. Continued

Plot sizes	7 plot blocks				10 plot block			
	$\|S\| \times 10^6$	No. of repli-cation for 5% SE	No. of trees for 5% SE	Efficiency $1/x\sqrt[3]{\|S\|}$	$\|S\| \times 10^6$	No. of repli-cation for 5% SE	No. of trees for 5% SE	Efficiency $1/x\sqrt[3]{\|S\|}$
1	673.35	35	35	11.41	633.01	35	35	11.64
2	69.19	16	32	12.17	62.16	16	32	12.63
3	21.06	11	33	10.10	22.08	11	33	11.89
4	12.08	11	44	9.06	11.16	10	40	11.20
5	11.74	9	45	8.80	16.31	10	50	7.88
6	3.38	6	36	10.19	6.48	7	42	8.97
7	2.57	6	42	10.02	2.14	5	35	11.15
8	2.82	6	48	8.84	1.88	5	40	10.12
9	5.62	7	63	6.25	2.06	5	45	8.80
10	3.47	6	60	6.60	1.98	5	50	8.07

Table 10. Models representing relationship between cv (y) and plot sizes (x) for first year yield

	a	b	c	R^2
Without blocking				
$Y = ax^{-b}$	0.360	0.397		0.99
$Y = a + b/\sqrt{x} + c/x$	0.058	0.268	0.045	0.99
$Y^{-1} = a + b \log x$	2.519	4.14		0.98
$Y^{-1} = a + b\sqrt{x} + cx$	-0.256	-0.331	3.25	0.99
5 plot block				
$Y = ax^{-b}$	0.334	0.390		0.93
$Y = a + b/\sqrt{x} + c/x$	0.099	0.083	0.181	0.98
$Y^{-1} = a + b \log x$	2.807	4.23		0.93
$Y^{-1} = a + b\sqrt{x} + cx$	-1.829	-0.814	5.29	0.94
7 plot block				
$Y = ax^{-b}$	0.340	0.364		0.94
$Y = a + b/\sqrt{x} + c/x$	0.098	0.132	0.133	0.98
$Y^{-1} = a + b \log x$	2.769	3.792		0.94
$Y^{-1} = a + b\sqrt{x} + cx$	-1.015	-0.632	4.339	0.95
10 plot block				
$Y = ax^{-b}$	0.346	0.374		0.93
$Y = a + b/\sqrt{x} + c/x$	0.073	0.227	0.058	0.96
$Y^{-1} = a + b \log x$	2.651	3.98		0.88
$Y^{-1} = a + b\sqrt{x} + cx$	-0.134	3.25		0.88

Table 11. Models representing relationship between cv (y) and plot sizes (x) for second year yield

	a	b	c	R^2
Without blocking				
$Y = ax^{-b}$	0.361	0.322		0.95
$Y = a + b/\sqrt{x} + c/x$	0.143	0.060	0.186	0.99
$Y^{-1} = a + b \log x$	2.663	2.988		0.96
$Y^{-1} = a + b \sqrt{x} + cx$	0.032	-0.409	3.04	0.96
5 plot block				
$Y = ax^{-b}$	0.327	0.367		0.91
$Y = a + b/\sqrt{x} + c/x$	0.158	-0.122	0.338	0.99
$Y^{-1} = a + b \log x$	2.977	3.843		0.93
$Y^{-1} = a + b \sqrt{x} + cx$	-2.177	-0.992	5.846	0.97
7 plot block				
$Y = ax^{-b}$	0.319	0.310		0.75
$Y = a + b/\sqrt{x} + c/x$	0.225	-0.288	0.439	0.94
$Y^{-1} = a + b \log x$	3.139	2.937		0.87
$Y^{-1} = a + b \sqrt{x} + cx$	-1.54	5.29		0.88
10 plot block				
$Y = ax^{-b}$	0.329	0.335		0.87
$Y = a + b/\sqrt{x} + c/x$	0.167	-0.103	0.306	0.96
$Y^{-1} = a + b \log x$	2.947	3.414		0.72
$Y^{-1} = a + b \sqrt{x} + cx$	-0.56	-0.597	4.013	0.78

Table 12. Models representing relationship between cv (y) and plot sizes (x) for first year female flower production

	a	b	c	R^2
Without blocking				
$Y = ax^{-b}$	0.383	0.496		0.94
$Y = a + b/\sqrt{x} + c/x$	0.054	0.176	0.173	0.97
$Y^{-1} = a + b \log x$	2.212	5.538		0.91
$Y^{-1} = a + b\sqrt{x} + cx$	-1.605	-0.468	4.63	0.92
5 plot block				
$Y = ax^{-b}$	0.366	0.487		0.88
$Y = a + b/\sqrt{x} + c/x$	0.089	0.035	0.277	0.95
$Y^{-1} = a + b \log x$	2.417	5.536		0.83
$Y^{-1} = a + b\sqrt{x} + cx$	-3.344	-0.980	6.58	0.84
7 plot block				
$Y = ax^{-b}$	0.375	-0.462		0.87
$Y = a + b/\sqrt{x} + c/x$	0.107	0.007	0.299	0.95
$Y^{-1} = a + b \log x$	2.41	4.92		0.81
$Y^{-1} = a + b\sqrt{x} + cx$	-2.735	-0.819	5.87	0.83
10 plot block				
$Y = ax^{-b}$	0.374	0.456		0.86
$Y = a + b/\sqrt{x} + c/x$	0.096	0.059	0.251	0.93
$Y^{-1} = a + b \log x$	2.395	4.902		0.80
$Y^{-1} = a + b\sqrt{x} + cx$	-2.09	-0.707	5.159	0.81

Table 13. Models representing relationship between cv (y) and plot sizes (x) for second year female flower production

	a	b	c	R^2
Without blocking				
$Y = ax^{-b}$	0.405	0.414		0.95
$Y = a + b/\sqrt{x} + c/x$	0.087	0.191	0.147	0.97
$Y^{-1} = a + b \log x$	2.213	3.951		0.93
$Y^{-1} = a + b\sqrt{x} + cx$	0.136	-0.167	2.48	0.94
5 plot block				
$Y = ax^{-b}$	0.402	0.464		0.95
$Y = a + b/\sqrt{x} + c/x$	0.046	0.278	0.088	0.97
$Y^{-1} = a + b \log x$	2.081	4.85		0.88
$Y^{-1} = a + b\sqrt{x} + cx$	0.622	0.083	1.862	0.91
7 plot block				
$Y = ax^{-b}$	0.394	0.403		0.86
$Y = a + b/\sqrt{x} + c/x$	0.125	0.055	0.247	0.93
$Y^{-1} = a + b \log x$	2.315	3.877		0.80
$Y^{-1} = a + b\sqrt{x} + cx$	-0.537	-0.380	3.33	0.80
10 plot block				
$Y = ax^{-b}$	0.418	0.482		0.80
$Y = a + b/\sqrt{x} + c/x$	0.037	0.311	0.73	0.95
$Y^{-1} = a + b \log x$	1.876	5.137		0.81
$Y^{-1} = a + b\sqrt{x} + cx$	2.47	0.649	-0.355	0.80

Table 14. Models representing relationship between |S| (y) and plot sizes (x) for two years yield

	a	b	c	R^2
Without blocking				
$Y = ax^{-b}$	171.00	1.44		0.98
$Y = a + b/\sqrt{x} + c/x$	90.18	-420.5	544	0.99
$Y^{-1} = a + b \log x$	-1.917×10^{-2}	0.1409		0.88
$Y^{-1} = a + b\sqrt{x} + cx$	-9.9×10^{-3}	1.62×10^{-2}	-2.71×10^{-3}	0.98
5 plot block				
$Y = ax^{-b}$	122.46	1.52		0.93
$Y = a + b/\sqrt{x} + c/x$	101.155	-460.8	544.5	0.99
$Y^{-1} = a + b \log x$	-2.19×10^{-2}	0.211		0.86
$Y^{-1} = a + b\sqrt{x} + cx$	-.143	-1.154×10^{-3}	0.144	0.88
7 plot block				
$Y = ax^{-b}$	123.02	1.35		0.90
$Y = a + b/\sqrt{x} + c/x$	107.68	-474.98	558	0.99
$Y^{-1} = a + b \log x$	-1.064×10^{-2}	0.148		0.79
$Y^{-1} = a + b\sqrt{x} + cx$	-7.68×10^{-2}	-3×10^{-3}	0.080	0.31
10 plot block				
$Y = ax^{-b}$	133.96	1.43		0.92
$Y = a + b/\sqrt{x} + c/x$	97.312	-436.31	524.17	0.98
$Y^{-1} = a + b \log x$	-2.43×10^{-2}	0.181		0.69
$Y^{-1} = a + b\sqrt{x} + cx$	-2.9×10^{-2}	1.65×10^{-2}	1.4×10^{-2}	0.75

Table 15. Models representing relationship between |S| (y)and plot sizes (x) for two years female flower production

	a	b	c	R^2
Without blocking				
$Y = ax^{-b}$	252.92	1.86		0.96
$Y = a + b/\sqrt{x} + c/x$	176.68	-815.27	953.45	0.98
$Y^{-1} = a + b \log x$	-5.43×10^{-2}	0.259		0.77
$Y^{-1} = a + b\sqrt{x} + cx$	0.044	0.0517	-4.8×10^{-2}	0.93
5 plot block				
$Y = ax^{-b}$	223.35	1.91		0.95
$Y = a + b/\sqrt{x} + c/x$	171.057	-786.7	907.39	0.98
$Y^{-1} = a + b \log x$	-6.10×10^{-2}	0.311		0.77
$Y^{-1} = a + b\sqrt{x} + cx$	-3.93×10^{-2}	3.66×10^{-2}	-8.5×10^{-3}	0.87
7 plot block				
$Y = ax^{-b}$	228.03	1.74		0.89
$Y = a + b/\sqrt{x} + c/x$	210.394	-949.5	1077	0.97
$Y^{-1} = a + b \log x$	-3.49×10^{-2}	0.212		0.63
$Y^{-1} = a + b\sqrt{x} + cx$	-8×10^{-2}	9.16×10^{-3}	0.059	0.68
10 plot block				
$Y = ax^{-b}$	250.61	1.88		0.84
$Y = a + b/\sqrt{x} + c/x$	193.556	-880.88	1008.7	0.97
$Y^{-1} = a + b \log x$	-6.318×10^{-2}	0.286		0.63
$Y^{-1} = a + b\sqrt{x} + cx$	0.099	0.071	-0.162	0.65

Table 16. Models representing relationship between |S| (y) and plot sizes (x) for yield and female flower production for two years

	a	b	c	R^2
Without blocking				
$Y = ax^{-b}$	365.59	3.23		0.97
$Y = a + b/\sqrt{x} + c/x$	462.823	-2050	2163.2	0.98
$Y^{-1} = a + b \log x$	-0.947	3.351		0.66
$Y^{-1} = a + b\sqrt{x} + cx$	2.046	1.121	-3.099	0.93
5 plot block				
$Y = ax^{-b}$	246.6	3.41		0.96
$Y = a + b/\sqrt{x} + c/x$	392.07	-1737.7	1812.1	0.97
$Y^{-1} = a + b \log x$	-1.599	6.037		0.70
$Y^{-1} = a + b\sqrt{x} + cx$	0.1244	1.079	1.514	0.83
7 plot block				
$Y = ax^{-b}$	255.27	3.08		0.91
$Y = a + b/\sqrt{x} + c/x$	479.057	-2119.3	2206.7	0.95
$Y^{-1} = a + b \log x$	-0.815	3.0303		0.53
$Y^{-1} = a + b\sqrt{x} + cx$	0.396	0.647	-1.16	0.64
10 plot block				
$Y = ax^{-b}$	301.99	3.296		0.90
$Y = a + b/\sqrt{x} + c/x$	440.511	-1949.5	2031.5	0.96
$Y^{-1} = a + b \log x$	-1.417	4.93		0.62
$Y^{-1} = a + b\sqrt{x} + cx$	2.75	1.591	-4.309	0.60

Table 17. Models representing relationship between |S| (y) and plot sizes (x) for yield, female flowers and percentage of buttons set for first year

	a	b	c	R^2
Without blocking				
$Y = ax^{-b}$	625.17	2.05		0.97
$Y = a + b/\sqrt{x} + c/x$	523.907	-2402.9	2718.8	0.98
$Y^{-1} = a + b \log x$	-3.11×10^{-2}	0.147		0.80
$Y^{-1} = a + b \sqrt{x} + cx$	1.5×10^{-3}	2.32×10^{-2}	-2.83×10^{-2}	0.93
5 plot block				
$Y = ax^{-b}$	202.30	1.78		0.84
$Y = a + b/\sqrt{x} + c/x$	374.55	-1655	1763.1	0.97
$Y^{-1} = a + b \log x$	-2.07×10^{-2}	0.213		0.65
$Y^{-1} = a + b \sqrt{x} + cx$	-0.185	-2.23×10^{-2}	0.19	0.67
7 plot block				
$Y = ax^{-b}$	252.92	1.64		0.83
$Y = a + b/\sqrt{x} + c/x$	404.99	-1781.4	1916.3	0.96
$Y^{-1} = a + b \log x$	-1.36×10^{-2}	0.135		0.54
$Y^{-1} = a + b \sqrt{x} + cx$	-0.1103	-1.2×10^{-2}	0.1119	0.55
10 plot block				
$Y = ax^{-b}$	302.69	1.62		0.84
$Y = a + b/\sqrt{x} + c/x$	342.377	-1509.56	1669	0.97
$Y^{-1} = a + b \log x$	-2.4×10^{-2}	0.135		0.46
$Y^{-1} = a + b \sqrt{x} + cx$	-4.19×10^{-3}	-1.87×10^{-2}	-1.51×10^{-2}	0.53

Table 18. Models representing relationship between |S| (y) and plot sizes (x) for yield, female flowers and percentage of buttons set for second year

	a	b	c	R^2
Without blocking				
$Y = ax^{-b}$	577.16	+2.32		0.97
$Y = a + b/\sqrt{x} + c/x$	463.274	-2133	2396.4	0.98
$Y^{-1} = a + b \log x$	-0.074	0.304		0.68
$Y^{-1} = a + b\sqrt{x} + cx$	0.104	7.72x10-2	-0.179	0.88
5 plot block				
$Y = ax^{-b}$	459.19	2.657		0.94
$Y = a + b/\sqrt{x} + c/x$	370.55	-1696	1874.7	0.98
$Y^{-1} = a + b \log x$	-0.2186	0.858		0.57
$Y^{-1} = a + b\sqrt{x} + cx$	0.026	0.151	-0.228	0.56
7 plot block				
$Y = ax^{-b}$	452.89	2.48		0.93
$Y = a + b/\sqrt{x} + c/x$	470.15	-2129.8	2319.5	0.98
$Y^{-1} = a + b \log x$	-0.13926	0.5672		0.47
$Y^{-1} = a + b\sqrt{x} + cx$	0.154	0.133	-0.292	0.59
10 plot block				
$Y = ax^{-b}$	493.17	2.58		0.94
$Y = a + b/\sqrt{x} + c/x$	438.83	-1988.2	2169.1	0.96
$Y^{-1} = a + b \log x$	-0.188	0.717		0.49
$Y^{-1} = a + b\sqrt{x} + cx$	0.153	0.162	-0.339	0.62

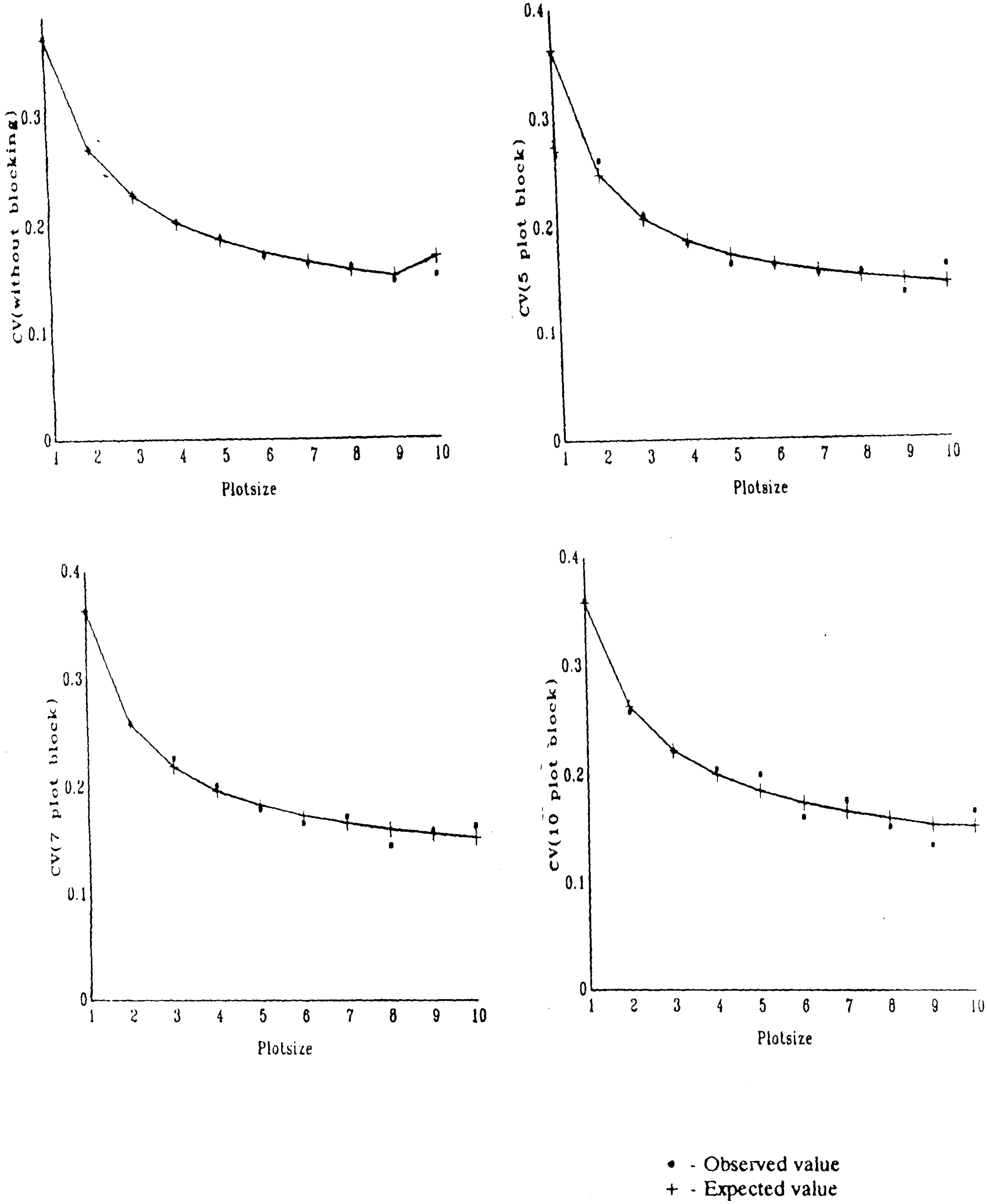


Fig 1. Relation between CV and plotsize for the first year yield

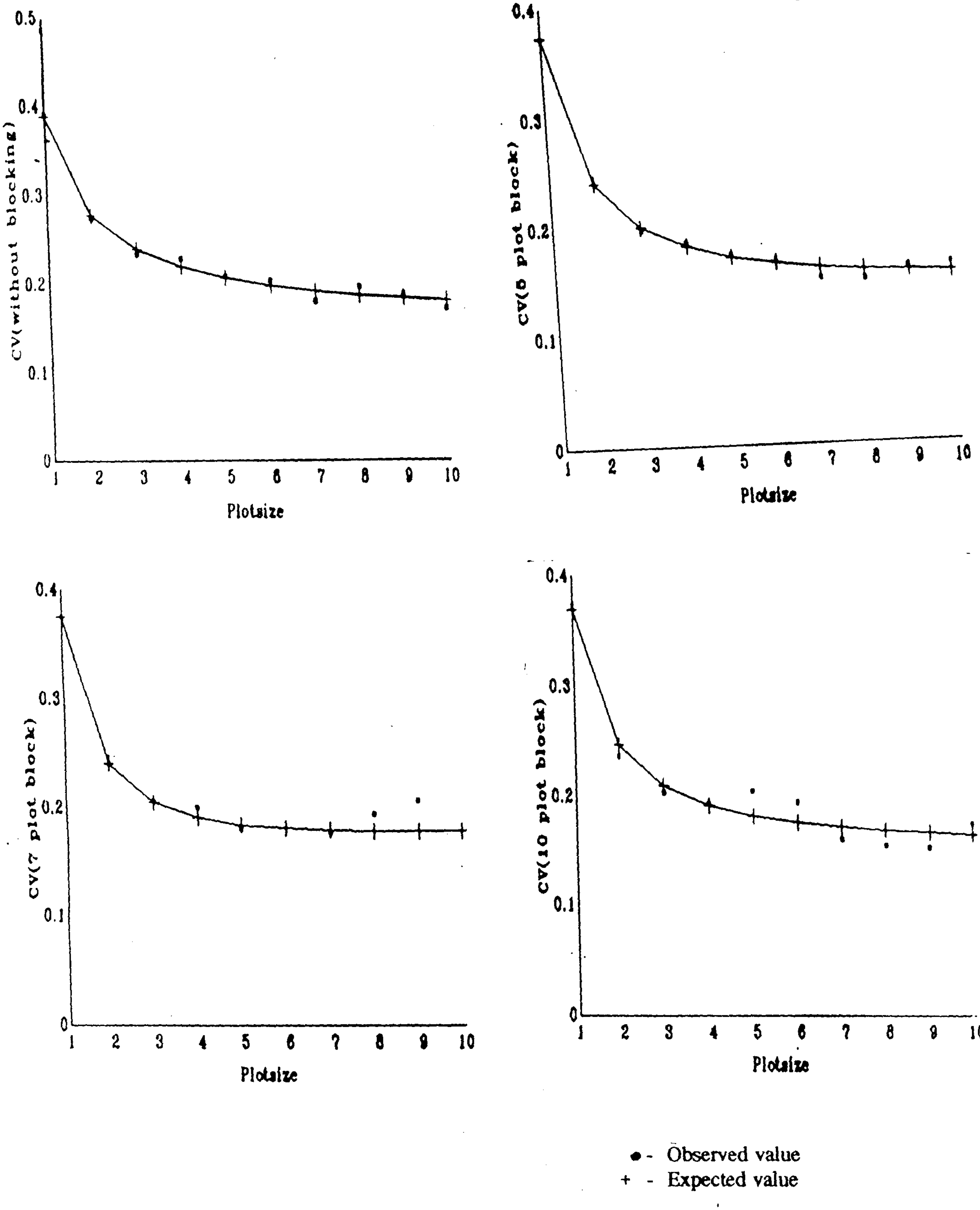


Fig 2. Relation between CV and plotsize for the second year yield

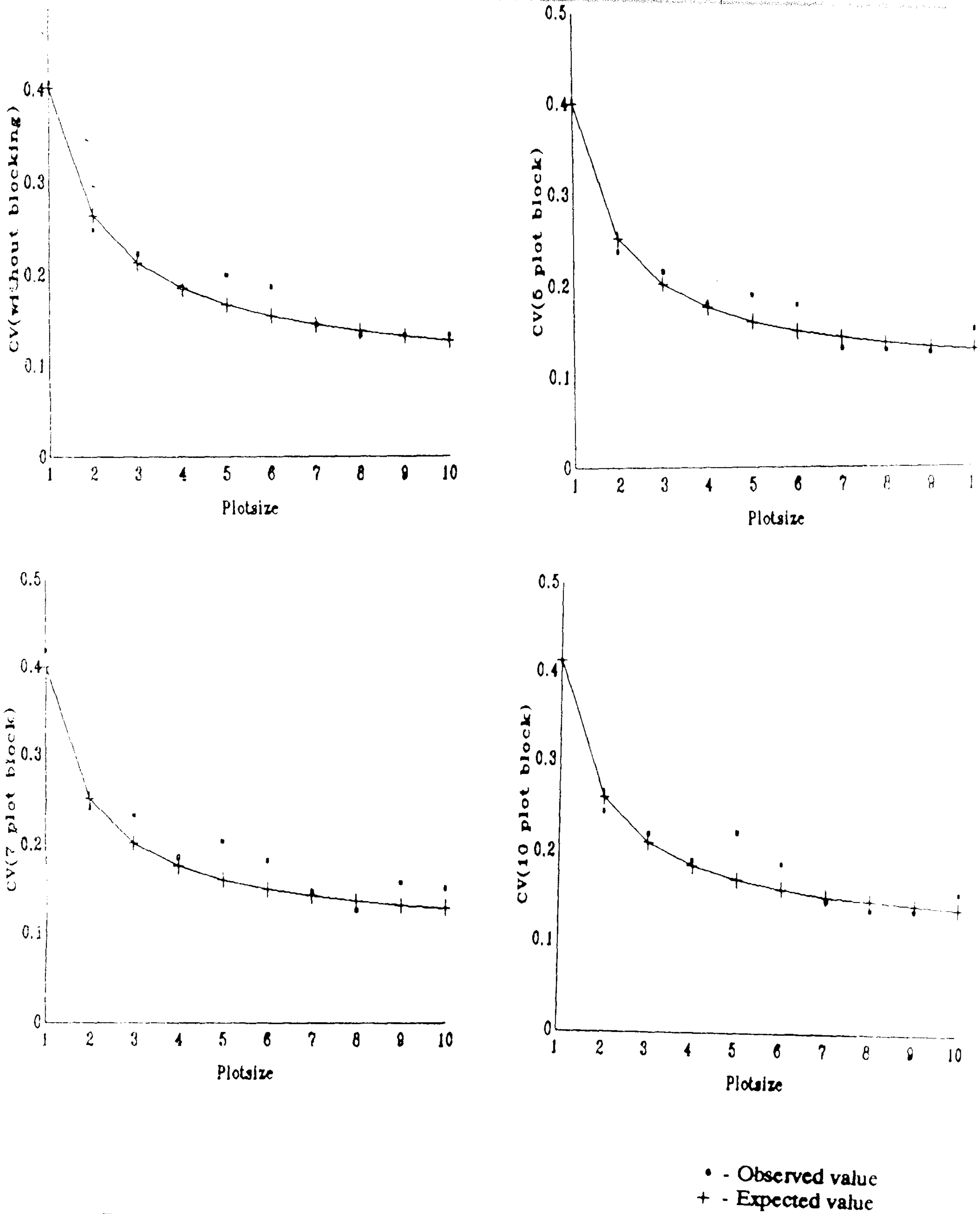


Fig 3. Relation between CV and plotsize for the first year female flower production

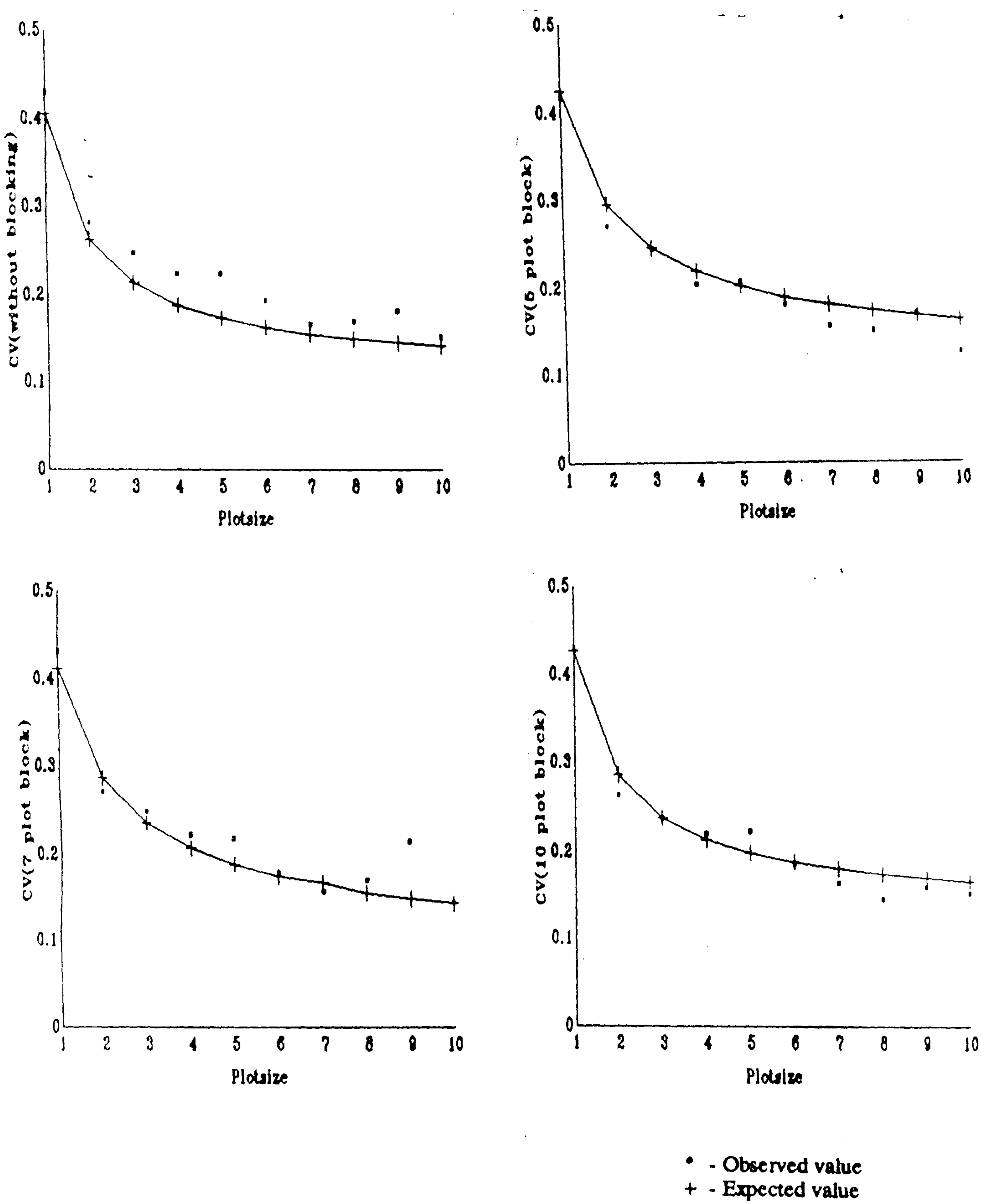
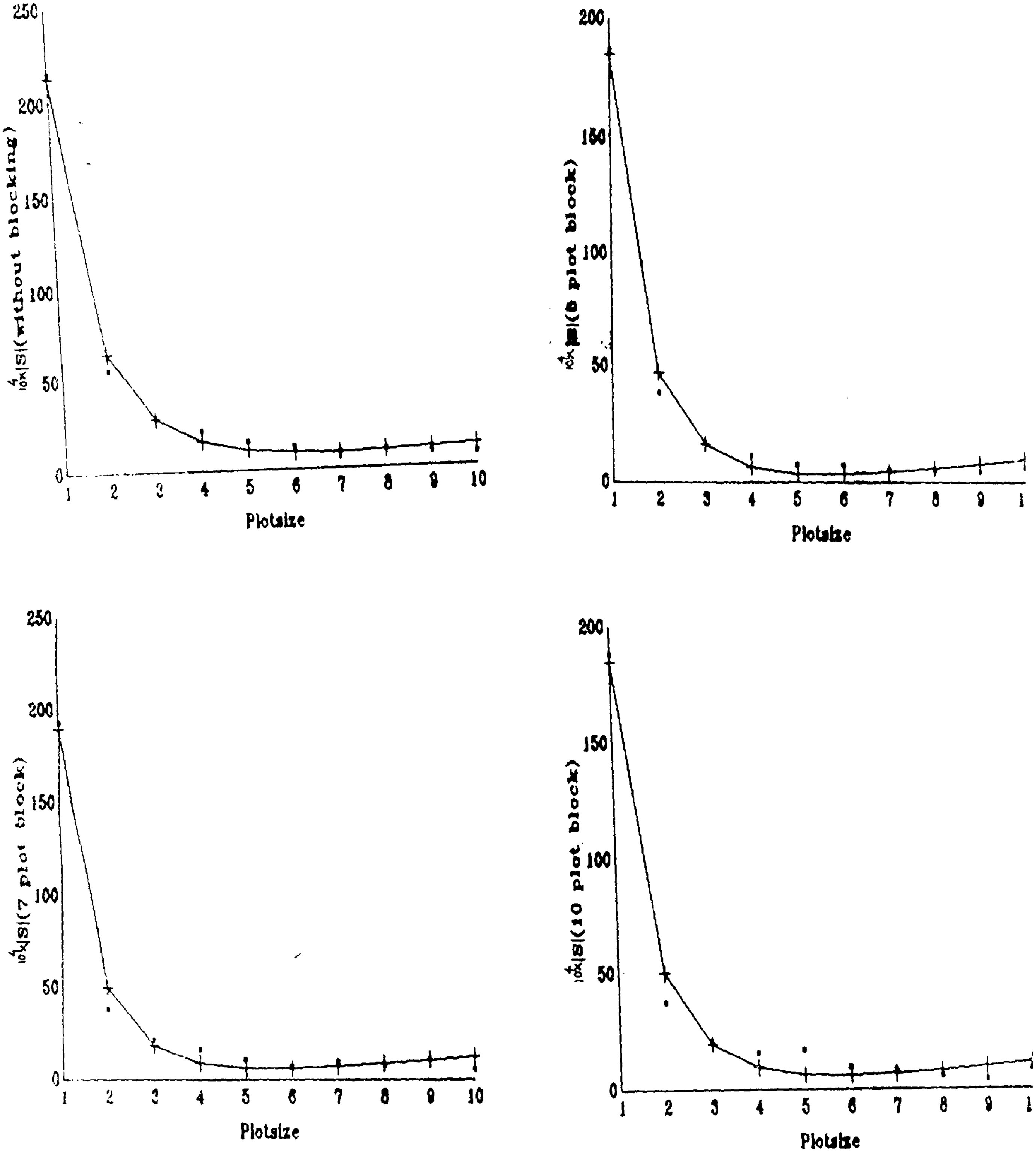


Fig 4. Relation between CV and plotsize for the second year female flower production



• - Observed value
\+ - Expected value

Fig 5. Relation between |S| x 10^4 and plotsize for two years yield

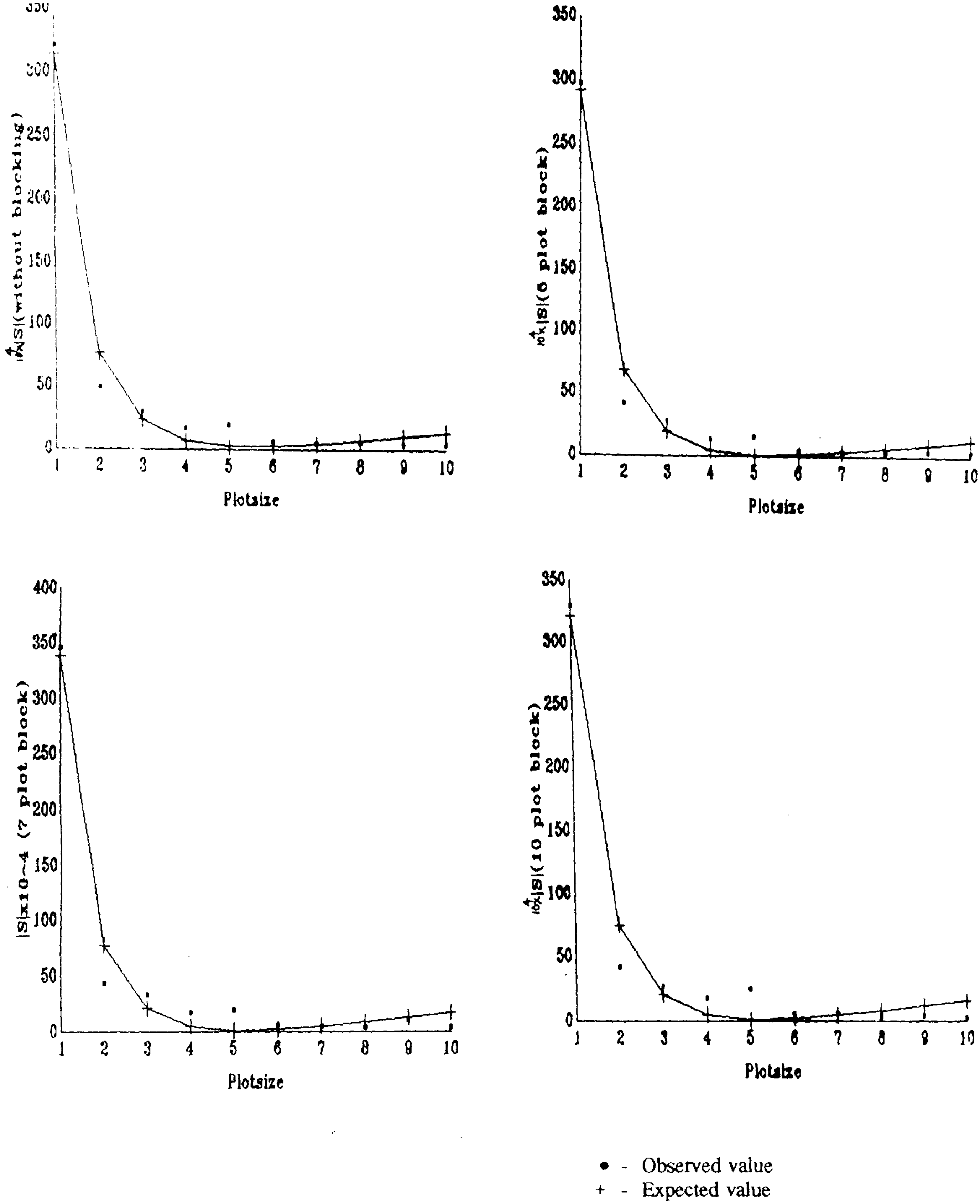
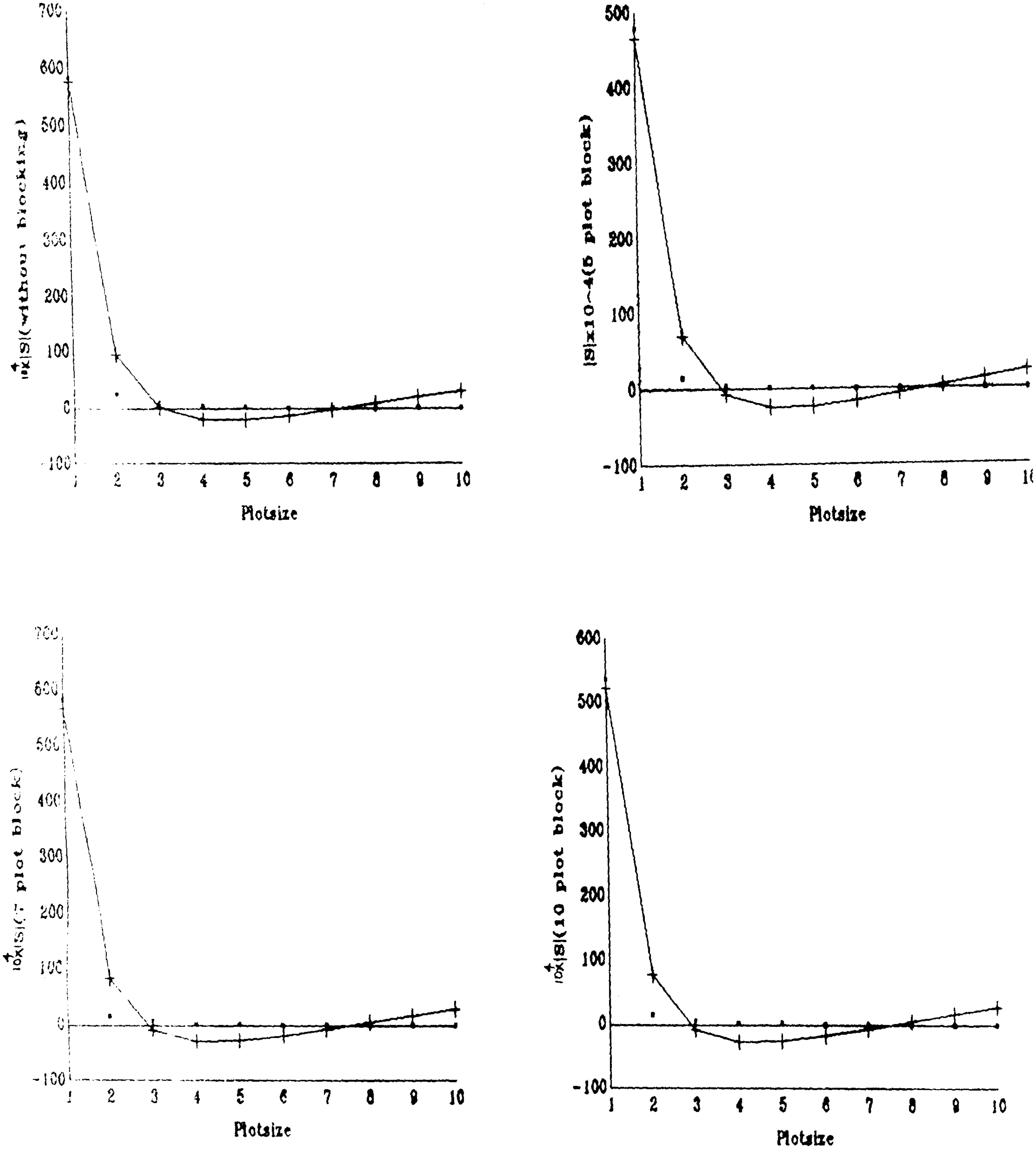


Fig 6. Relation between $|S| \times 10^4$ and plotsize for two years female flower production



● - Observed value
\+ - Expected value

Fig 7. Relation between ¦S¦ x 10 ^{4} and plotsize for two years yield and female flower production

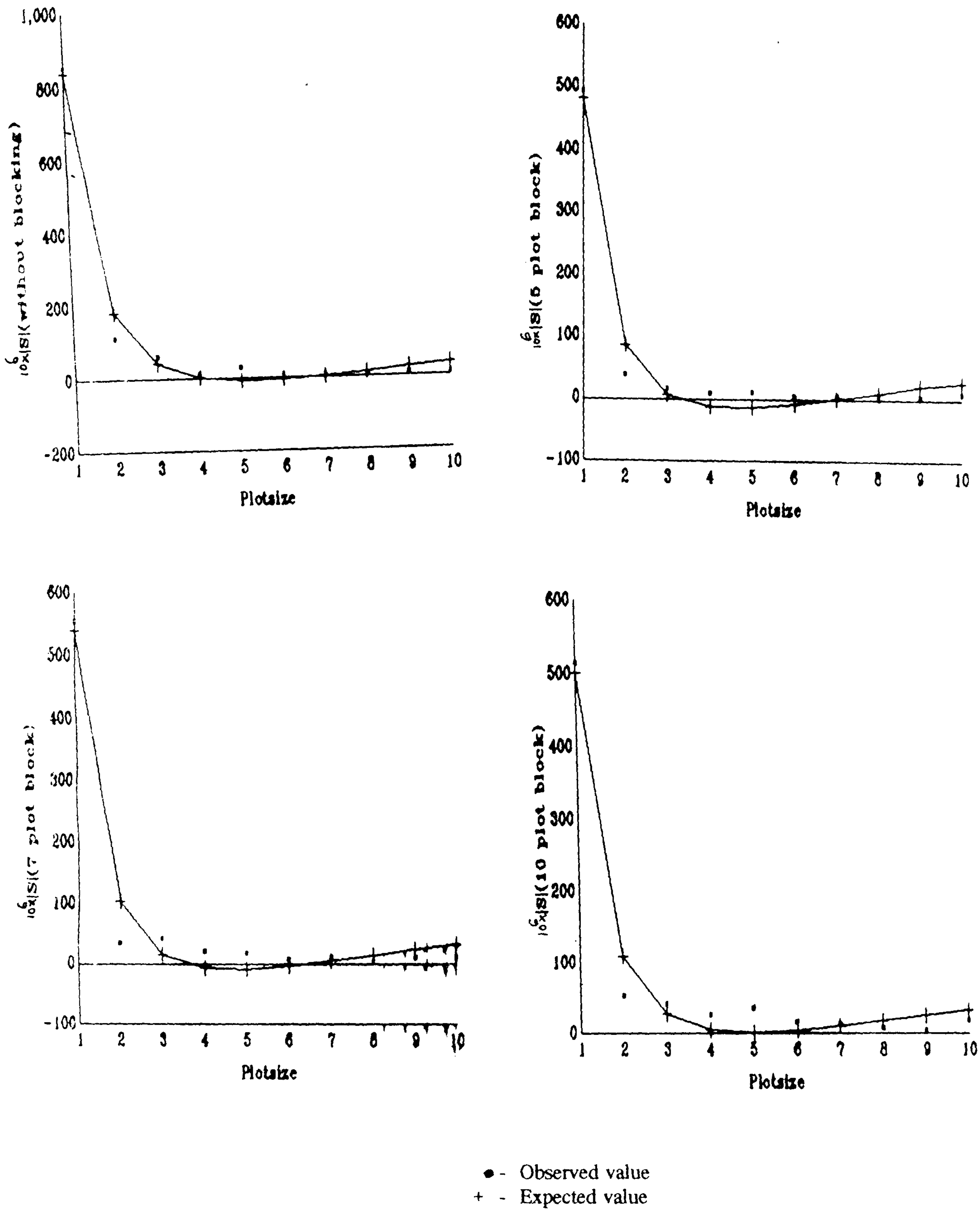
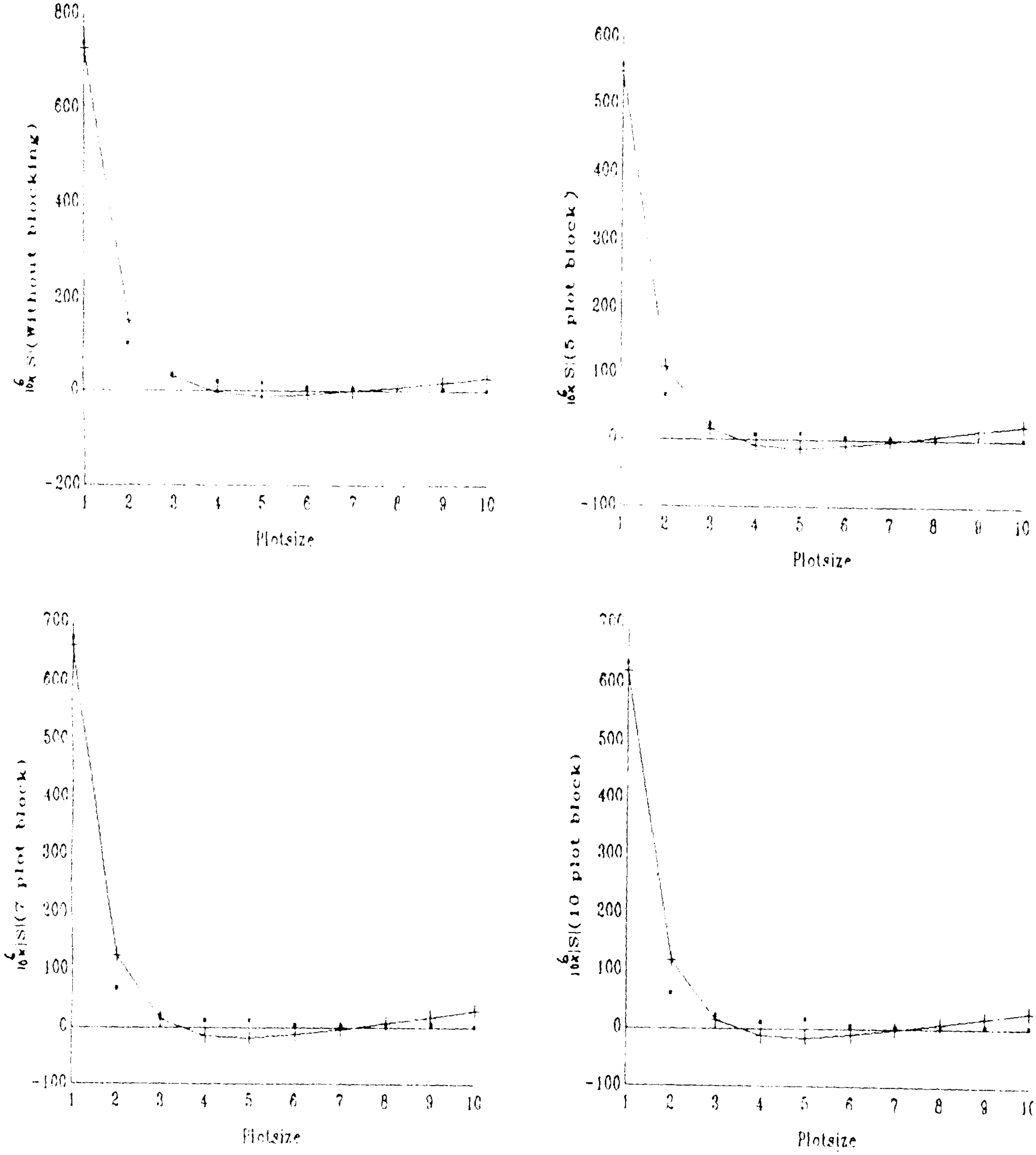


Fig 8. Relation between |S| x 10^6 and plotsize for first year yield, female flower production and percentage of buttons set



• - Observed value
+ - Expected value

Fig 9. Relation between |S| x 10^6 and plotsize for second year yield, female flower production and percentage of buttons set

Discussion

5. DISCUSSION

The results obtained in this investigation are discussed in this chapter.

CV as well as determinant of relative dispersion matrix, in general decreased with increase in plot size, as expected, except in certain stages in some isolated cases. Fair Field Smith's law gave good fit to the relation between plot size and variability, both in the case of coefficient of variation and determinant of relative to dispersion matrix. However, the model $Y = a + b/\sqrt{x} + c/x$ was a better fit in almost all cases as evidenced by the higher R^2 values. This could be because there was a slight increasing trend at higher plot size mainly beyond a plot size of seven in many cases, which is consistent with the trend of this model.

The traditional approach of determining the optimum size of experimental unit by the method of maximum curvature resulted in three or four tree plots. Three tree plots were obtained in cases when the estimated variability values were negative for some plot sizes. This happened in the multivariate cases when the values of $|S|$ was so small that even to represent them, they had to be multiplied by a constant, say 10^6. Therefore we can conclude that, in general, four tree plots are optimum by the method of maximum curvature.

When determination of optimum size of plot by the criterion of having maximum efficiency was considered, single tree plot was optimum in univariate determination and mostly two tree plots in the multivariate determination except two situations. In all the reported works (Agarwal *et al.*, 1968; Gopani *et al.*,1970; Saxena *et al.*, 1972) efficiency of plots decreased with increase in plot size. The investigations in multivariate case also is in agreement with the earlier univariate work. It may be noted that two tree plots had maximum efficiency in most of the multivariate determinations. It is particularly so when more characters were used in the determination. The main thrust of this investigation was in the determination of optimum size of plot by multivariate approach as it is more realistic in the sense of reflecting the crop characters much more than the univariate approach. Therefore two tree plots can be considered optimum in the sense of having more efficiency.

Yet another approach by which optimum size of plots were determined was that which require minimal experimental material to achieve a specified precision. Two tree plots required minimum number of trees to achieve 5 per cent error in most of the situation and in cases where single tree plots required minimum number of trees, there was negligible difference in the number of tree required for single tree and two tree plots. Therefore it could safely be concluded that two tree plots are optimum in the sense of requiring minimal experimental material for a specified precision.

In general, blocking can not said to be very effective, though 5 plot blocks had low variability compared to no blocking or blocks of larger sizes. In other words small blocks were found to be more effective, though the reduction in variation on account of blocking was not substantial particularly for large sized plots. One of the reasons for this could be that the data were devoid of systematic effects. Block effects in the original observations were already eliminated though the eliminated block effects were for blocks formed by near by trees. Whereas blocking attempted in the present investigation was according to the performance of trees in terms of the number of functional leaves. Normally one expects to have a very good effect of blocking.

Another aspect to be noted is that while determining optimum size of plots by any criterion, guard rows were not taken into consideration. If guard rows are to be provided, naturally larger plots would require minimal experimental material. Root distribution study undertaken (Venugopal, V., 1996) revealed that there is no much root competition among coconut trees when the present recommendation of 7.5 m x 7.5 m spacing is adopted. As a consequence it could be inferred that guard rows may not be required for experiments in existing coconut plantation and the optimum size of experimental unit can be recommended to be two trees.

Summary

SUMMARY

Coconut palm (*Cocos nucifera* L.) popularly known as Kalpavriksha is the most important plantation crop in Kerala. It plays a major role in Kerala economy. More over it is emerging as a major crop in other states and many coconut based industries are coming up.

Reduction of experimental error is perhaps the most important aspects of planning an experiment. Size of experimental unit is a major factor that influences error variation. Determination of optimum size of plots for coconut is absolutely necessary to have efficient conduct of experiments in this crop. Since study of any crop is made of the totality of all characters. Size of experimental units is to be determined optimally by simultaneous consideration of all important characters. Therefore the present investigation to determine optimum size of plots in coconut by multivariate approach was taken up.

Data for the present study were gathered from the field records of Regional Agricultural Research Station, Pilicode and Coconut Research Station, Balaramapuram of Kerala Agricultural University. The first set consisted of data on seventy nine coconut palms belonging to sixteen cross combinations and the second set consisted of one hundred and five west cost tall coconut palms belonging to a 3^3 partially confounded fertilizer trial. Observations were recorded on four characters namely number of functional leaves, yield, female flower production and percentage of buttons set for two consecutive years. All the known systematic effects were eliminated from the recorded data using appropriate models.

The characters for which optimum plot size was determined in univariate case were yield and female flower production for the first year and the second year.

Optimum size of plots were determined for the following character combinations in multivariate approach,

1) Yield for first and second year
2) Female flower production for first and second years
3) Yield and female flower production for first and second year
4) Yield, female flower production and percentage of buttons set for the first year
5) Yield female flower production and percentage of bottons set for the second year

The following method of plot formation were used in the present study.

All the trees were arranged in ascending order of magnitude of the number of functional leaves of first year. Experimental units of sizes ranging from single tree to ten trees by combining near by trees in the list were formed and the measure of variation viz., cv in the unvariate case and determinent of relative dispersion matrix in the multivariate case were worked out in the case of no blocking as well as in the case of blocks of five plots, seven plots and ten plots for various plot sizes.

Optimum plot sizes were determined by following three different criteria in the univariate as well as multivariate approaches.

1) Plot size that requires minimum experimental material for a specified preusion
2) Plot size having maximum efficiency, and
3) Optimum plot size by the method of maximum curvature

Plot size that required minimum number of trees for 5 per cent error was two tree plots except in the univariate case of yield in first year and in multivariate case of without blocking for characters sets (4) and (5). But even for these exceptions there was negligible difference in the number of trees required between single tree plots which was optimum and two tree plots.

Efficiency in general decreased with increase in plot size. In all univariate determinations single tree plots had the maximum efficiency and except for characters sets (4) and (5) for no blocking in multivariate case, two tree plots had maximum efficiency.

Four tree plot was optimum by the method of maximum curvature except for characters sets (3), (4) and (5) is multivariate case for which three tree plots were optimum. Though Fairfield Smith's law was a good fit to the relationship between the measure of variation and plot size, $Y = a + b/\sqrt{x} + c/x$ gave better fit in most of the cases.

The first criterion that minimum number of trees for a specified precision is to be given more weightage to arrive at the optimum size of plots as it takes the cost aspect also in to account. Therefore, on the while two tree plots were recommended for experiments in coconut in established gardens.

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OPTIMUM SIZE OF PLOTS IN COCONUT USING MULTIVARIATE TECHNIQUES

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ABSTRACT OFTHETHESIS

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ABSTRACT

This investigation was taken up to determine optimum size of experimental units for coconut using multivariate approach. Observations on yield, female flower production, percentage of buttons set and number of functional leaves from 184 coconut palms for two consecutive years were utilised. These palms belonged to two separate experiments in two locations.

All known systematic effects were eliminated from the observations. The trees were arranged in the ascending order of the number of functional leaves of first year of observations. Experimental units of sizes ranging from single tree to ten trees were formed by combining trees adjacent in the list of ordered trees. Blocks of five plots, seven plots and ten plots were also formed by combining adjacent plots.

Coefficient of variation in univariate case and determinant of relative dispersion matrix in multivariate case were the measures of variation used.

Optimum size of experimental units was determined in univariate case for yield and female flower production in first and second years. Optimum size of plots was determined in multivariate case for the following character combinations.

1) Yield for first and second year
2) Female flower production for first and second years
3) Yield and female flower production for first and second year
4) Yield, female flower production and percentage of buttons set for the first year
5) Yield female flower production and percentage of bottons set for the second year

Optimum size of plot was determined by three different criteria viz., (i) that which requires minimal experimental material for a specified precision (ii) that having maximum efficiency and (iii) that which maximises the curvature of the relationship between measure of variation and plot size.

Plot size that required minimum number of trees for 5 per cent error was two tree plots except in the univariate case of yield in first year and multivariate case of without blocking for characters sets (4) and (5) for which single tree plots were optimum.

In all univariate determinations single tree plots had maximum efficiency. Two tree plots had maximum efficiency in multivariate approach except for characters sets (4) and (5) in the case of no blocking.

Four tree plot was optimum by the method of maximum curvature except for characters sets (3), (4) and (5) is multivariate case for which three tree plots were optimum. Though Fair Field Smith's law was a good fit to the relationship between the measure of variation and plot size, $Y = a + b/\sqrt{x} + c/x$ gave better fit in most of the cases.

Two tree plots were recommended for experiments in established coconut gardens.