OPTIMUM PLOT SIZE FOR FIELD EXPERIMENTS ON BRINJAL

BY
V. HARIHARAN

THESIS

Submitted in partial fulfilment of the
requirements for the degree of

Master of Science (Agricultural Statistics)

Faculty of Agriculture
Kerala Agricultural University

Department of Statistics

COLLEGE OF VETERINARY & ANIMAL SCIENCES

Mannuthy, Trichur.

1981

DECLARATION

I hereby declare that this thesis entitled "optimum plot size for field experiments on brinjal" is a bona fide record of research work done by me during the course of research and that the thesis has not been previously formed the basis for the award to me for any degree, diploma, associateship, fellowship or other similar title of any other university or society.

Mannuthy,
31-7-1981.

(HARIHARAN, V.)

CERTIFICATE

Certified that this thesis, entitled "Optimum plot size for field experiments on brinjal" is a record of research work done independently by Shri. V. HARIHARAN, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

K. C. George

Dr. K.C. GEORGE

Chairman
Advisory Committee
Associate Professor of the
Department of Agricultural
Statistics

Mannuthy,

31-7-1981.

ACKNOWLEDGEMENT

I am deeply indebted to Dr. K.C. George, Associate Professor of the Department of Agricultural Statistics and the chairman of the Advisory Committee, for the keen interest and unflagging enthusiasm shown in guiding me towards the completion of the post-graduate programme and preparation of this thesis.

I am extremely grateful to Dr. K.V. Peter, professor of Horticulture and Special Officer (vegetable breeding) and Shri. P.V. Prabhakaran, Associate professor of the Department of Agricultural Statistics for critically going through the entire manuscript and suggesting modifications.

My thanks are also due to Dr. P.U. Surendran, Professor and Head of the Department of Statistics and Shri. V.K. Gopinathan Unnithan, Assistant professor in the Department of Agricultural Statistics who had been helpful, at various stages, in the preparation of this thesis.

My gratitude is also extended to Sri. C.Parameswaran, who had read the manuscript partly and made useful and pertinent suggestions.

I express my sincere gratitude to the staff of the Department of Olericulture, College of Horticulture, Vellanikkara for the help rendered during the field trials.

I have great pleasure to acknowledge the assistance of my fellow-students in taking the biometrical observations.

Lastly, I am thankful to Kerala Agricultural University for the fellowship made available to me.

(HARIHARAN, V.)

CONTENTS

LIST OF TABLES AND APPENDICES

APPENDIX

o:o:o:o:

LIST OF ILLUSTRATIONS

o:o:o:o:

INTRODUCTION

INTRODUCTION

The application of statistical techniques has practically revolutionised the field of experimentation. These techniques are frequently used in two diverse areas of agricultural research namely agronomic and plant breeding trials. On the agronomic side, complete experiments enabling the experimenter to test the simultaneous effect of two or more treatments have become common, while with the growing appreciation that statistical methods are as necessary and appropriate in plant breeing, as in agronomic research, breeders have started to undertake properly laid out varietal trials containing an increased number of varieties.

Variability is inherent in any experimental material. Due to this inherent variability it has become difficult to compare the relative worth of treatments. Even if a treatment is found to be promising, we cannot decide whether the effect can be attributed to the treatment or to the inherent variation in soil fertility. Soil fertility varies not only from place to place but even from pocket to pocket in the same field. This variation in soil fertility cannot be eliminated by any statistical technique. There are numerous other factors such as climate, type of soil, disease incidence, attack of insects etc which contribute to plot to plot variation in yield. Thus even if the same treatment is applied to a set of plots their yields are found to differ. This plot to plot variation due to the effect of uncontrollable factors is called experimental error. Statistical techniques, aimed at reducing the experimental error and getting an estimate of experimental error for conducting valid tests, are of greater significance.

In agriculture a research worker is required to experiment mainly in the field. Whether it is new varieties, cultivation practices or methods of seed treatment, he has to try them out in the field before he can assess their value. These objects of comparison in his trials may be termed treatments. When conducting an experiment the experimenter has to ensure the repeatability of his experimental results. This has got bearing on the number of times each treatment is to be repeated. Further the plots available for the experiment may not be uniform. When heterogeneous materials are used, appropriate methods are to be employed to make the treatment comparisons effective, efficient and purposeful. There may also arise situations in which different types of treatments have to be combined into a single experiment. To have the comparison of treatments more efficient an experiment should ensure (a) randomisation (b) replication and (c) local control (blocking).

Randomisation is impartial application of treatment to the experimental plots so that every treatment has the same chance of being applied to each plot. It is of an insurance against unforeseen causes.

Replication of a treatment is the number of times it occurs in an experiment. If only every treatment is replicated more than once, the experimental error can be estimated.

Local control is a device through which we can control all known sources of variation entering treatment comparisons.

In agricultural experiments the experimenter is interested to ascertain the relative worth of a set of treatments with reasonable confidence. To achieve this objective, the efficiency of experimental design is improved by adopting the principles of randomisation, replication and local control. Besides these, the accuracy of the estimates also depends on the size and shape of the experimental plots adopted.

To determine the suitable size and shape of the plot and the number of plots in a block, an experiment called Uniformity trial is conducted.

A uniformity trial consists in growing in a piece of land a particular cro with a uniform treatment, dividing the field into small units and harvesting and recordi g the produce from each of these units separately.

Results from a uniformity trial experiment can be utilised for getting an estimate of experimental error and also to determine the suitable size and shape of plots and blocks and proper orientation of plots within the blocks. Fertility contour map can be drawn from the results of such trials which gives us some idea regarding the uniformity of the land. As the magnitude of experimental error depends upon soil heterogeneity the choice of optimum size and shape of plots should be based upon soil heterogeneity, the choice of optimum size and shape of plots should be based upon the estimate of experimental error.

From the coefficient of variation of plot yields (which is obtained for different sizes and shapes by combining the neighbouring units accordingly); we can estimate the variation due to uncontrolled factors. The coefficient of variation, if it is high, indicates that the variation in the soil fertility is high, if it is low then it is otherwise. But the inherent variation of the soil has a different magnitude for different sizes and shapes of plots and blocks adopted. Generally we find the suitable size and shape of the plot and block for which this variation is minimum.

On annual crops like paddy, wheat, jowar, maize and sugarcane and perennial crops like arecanut, mango, coconut, black pepper, orange and apple a large number of studies have been made in India and abroad. But regarding the suitable size and shape of plot and block on vegetables comparatively lesser work has been done in the country. The heterogeneous nature of the various types of vegetable crops makes it virtually impossible to transfer results of plot studies from one crop to another. The diversity of vegetable crops particularly with reference to number of harvests presents the greatest problem. Vegetable crops such as potato, cabbage, sweet potato and onions which normally are single harvest crops, give much more precise experimental data in terms of the coefficient of variability per experimental unit as compared to multiple harvest crops such as brinjal, bhindi and tomato. Keeping these points in view the experiment is conducted in brinjal, one of the most used vegetable in kerala.

Vegetables play a key role in the human diet, supplying the 'gaps' which other food materials cannot fill up. They are important in reducing the intestine acidity produced during the process of digestion. They are valuable sources of vitamins and mineral elements needed by the body.

Brinjal is a native of India and has been in cultivation for a long time. It belongs to the Solanaceae or nightsade family and known under the botanical name Solanum melongena.

The present investigation is aimed wit the folloing objectives.

(i) To study the nature and magnitude of soil heterogeneity of the vegetable fields of the Main Campus at Vellanikkara.

(ii) To estimate the optimum plot size and shape for efficient evaluation of brinjal variety(s).

(iii) To determine the optimum block size and number of plots which can be accommodated in a block without confounding, having prior knowledge on soil heterogeneity.

(iv) To determine the direction of the blocks to increase the efficiency of the experiments on brinjal.

crops, reflects the considerable importance that has now been attached to it in vegetable agronomic programmes.

II. 2. Plot size, shape and orientation

Experimental plot refers to the unit on which random assignment of treatments is made. The size of the plot, therefore, refers not only to the harvest area but to the whole unit receiving the treatment. Gomez (1972) further gave an idea of shape and orientation of plots. The shape of the plot refers to the ratio of its length to its width. The orientation of plots, on the other hand, refers to the choice of direction along which the lengths of the plots will be placed.

Although many studies of plot size and shape have been made with a number of crops, it was not until 1931 that the first theoretical consideration of plot shape was made by Christids (1931). Even before this Harris (1915, 1920) proposed using the intra-class correlation coefficient of yields from adjacent areas as a coefficient of heterogeneity but although numerous workers have taken the trouble to evaluate such coefficients for their data it does not appear to serve any other purpose than to demonstrate that the fertilities of adjacent areas are correlated.

With regard to shape of plots as an independent factor affecting the variability, the most extensive discussion has been given by Christids (1931). Making the assumption of a linear fertility gradient, he derived a formula for the effect of plot shape on variation. He concluded that long and narrow plots are always less variable than square ones. He considered the competition also. Christids (1931) continued this study and reported in 1939 on the effect of plots as influencing the optimum shape of plot.

Smith (1938) proposed the first theoretical formula for assessing the effect of plot size on variation. He demonstrated a linear relationship between logarithms of variance and plot size with the regression coefficient describing the degree of correlation between adjacent areas of land. He ignored the shape of plot in this consideration but admitted that it might have some effect.

Cochran (1940) also considered the problem of the shape of plots for various types of fields. He discussed the cases for small and large values of the fertility gradient. When the value of the fertility gradient is small, the selected plot shape is largely a matter of preference. For large values of fertility gradient long and narrow plots should be selected, since the additional variance due to plots with other than optimum shape will need to be compensated by additional replication. He concluded that it may prove impractical to use long and narrow plots because of the nature of the crop and it may be less costly to increase plot size than the number of replicates to obtain the desired degree of precision, as in such cases long and narrow plots may not be desirable.

Investigations on the shape of plots by Wood and Strattom (1909) have suggested that long and narrow plots may not be more variable than square ones depending upon their orientation. Nevertheless, it does appear that long and narrow plots tend to be on the average less variable than square plots, a finding which agrees with the observation that adjacent areas tend to be more closely correlated than distant areas.

Panse (1941) studied the effect of size and shape of block and arrangement of plots on variation. He developed a concept of block efficiency and experimental error. He concluded, however, that plot size and shape are of greater importance in error variation than is block efficiency.

The work of Christids (loc. cit) and Smith (loc. cit) on the effects of variation in plot shape and size had been extended by Taylor (1948). He developed an equation, using a simple discontinuous correlation function for estimating experimental error for any size and shape of lot. He points out that even though his equation seemed to have results more nearly approaching those obtained experimentally than Smith's, a less simplified or more realistic approach should lead to more realistic results.

Koch and Rigney (1951) presented a method of estimating optimum plot size from experimental data. By using certain assumptions they were able to calculate smith's regression coefficient from data other than uniformity trials. Koch and Rigney (1951) demonstrated that the regression coefficient of the logarithm of variance on the regression of plot size could be estimated from the experimental data in which treatment effects are present, as well as from the data of uniformity trials. They noted that Smith (1938) had recommended that, in estimating the regression coefficient 'b' the variances of the different sizes plot should be weighted by their respective degrees of freedom. In fact, since the variance estimates, for different size of the plot, both in uniformity trials and experimental data were built up from common components, they are frequently highly correlated. They had illustrated the use of experimental data from split-plot and lattice design in determining the optimum plot size.

Experimental plot shape may be square or rectangular. In experiments where edge or border effects are of differential importance in variety response, square plots are desirable because they have a minimum perimeter for a given plot area. But rectangular plots are more convenient for mechanized operations.

There are conflicting opinions about the relation of plot shape to experimental error. Some early worker concluded that shape was of little consequence but the majority believed that it had some influence on experimental error (Hayes and Immer, 1942; Leclerg _et al._, 1962).

Mercer and Hall (1911), working with mangoes, found no superiority of long and narrow plots over square ones. Similar conclusions were reached by Smith (1958) in beans; Batchelor and Reed (1918) in oranges; Stephens and Vinall (1928) in sorghum and Lyon (1911) and Kiesselback (1923) in wheat.

Others agreed with this conclusion, but only if the length of the plot was oriented in the direction of soil fertility gradient, otherwise square plots were more effective in reducing variability (Siao, 1935 in cotton; and Smith, 1938, Day, 1920 and Iyer, 1942 in wheat).

Most evidence, however, indicated that rectangular plots are much more effective than square ones in controlling variability due to soil heterogeneity, for example, by Smith (1907-09), McClelland (1926b) and Bryan (1931, 1933) in corn; McDonald et al. (1938) in cotton; Holle and Pierce (1960) in lima beans; Kiesselbach (1923) in oats; Westover (1924), Justesen (1932) and Kalamkar (1932a) in potatoes; Swanson (1930) and Kulkarni and Bose (1936) in sorghum; Vagholkar et al. (1940) in sugarcane; and Bose (1935) in wheat. Taylor (1907-09), who summarised contemporary field experiments, found that rectangular plots are more desirable and convenient for experimentation with field crops.

Dendrinos (1931), from theoretical considerations, stated that variability would be smaller with rectangular plots than with square ones, if soil heterogeneity was patcy.

Numerous studies have been made with horticultural crops to determine the sources of variation and their magnitude, to establish both general ideas as to influence of these size and shape factors on error and to specify for each crop and location optimum combination of size and shape. The recent researches which establish long and narrow plots are those of Bargava and Sardhana (1975) in apple; George *et al.*(1979) in turmeric; Jayaraman (1979)in sunflower; Menon and Tyagi (1971) in mandarin orange.

Field plot technique data with vegetable is more voluminous in potatoes. In potato, it was found that a long and narrow plot was the most desirable. Krants (1923) and Currence and Krants (1936) suggested a plot of one row by 494 cm. They also emphasized the practical factor that workers customarily adjusted the sizes of plot to what they cared for under their particular conditions. Results obtained by Justeson (1932) and Kalamkar (1932) as also Sardhana *et al.*(1967) agreed quite well with the above suggestion on size of the plot.

Hodnett (1955) in groundnut; Weber and Horner (1959); Joshi *et al.*(1972) and Kripashankar *et al.*(1972) in soyabean; Saxena *et al.*(1972) in oat fodder; Sreenath (1973) in fodder sorghum; Prabhakaran and Thomas (1974) in tapioca; George *et al.*(1979) in cardamom; and Rambabu *et al.*(1980) in grasses obtained more efficiency with long and narrow plots than with square plots.

2. 4. Relation of replication to experimental error

The number of times that a complete set of varieties or strains is repeated in an experiment is called the number of replications. The number of replications needed in a field experiment depends primarily on (a) the degree of soil heterogeneity in the experimental site and (b) the genetic variability of the plant material under test. Experimental precision improves with an increased number of replications but after a certain point, the improvement is not commensurate to the additional input costs. However, for a given land area greater experimental precision is attained by using many replications of small-sized plots rather than a few replications of large plot. Such studies have bee a made by Roemer (1925), Kalamkar (1932a), Justesen (1932) and Livermore (1927) in potatoes; Sommerby (1923) in oats and wheat; Immer and Raleigh (1933) in sugarbeets; Beattie and Boswell (1936) in onions and carrots; Siao (1935), Hutchinson and Panse (1935), Panse (1941) in cotton; Joshi et al.(1972), Kripashankar et al.(1972), Weber and Horner (1959) in soyabean; Prabhakaran and Thomas (1974) in tapioca; Prabhakaran et al.(1978) in banana; Saxena et al.(op. cit) in oat fodder; Sreenath (op. cit) in sorghum and Pahuja and Mehra (1981) in chickpea.

When land is limiting, but labour and trained field assistants are available, Currence and Krantz(1936) advised using small plots with more replications, but Currence (1947) cautioned that small plots complicated record taking and resulted in more competition between plants.

Replication is required in an experiment to provide a measure of experimental error. More over, one of the simplest means of increasing precision is increasing the number of replications. Beyond a certain number of replications, however, the improvement in precision is too small to be of worth the additional cost, when such a point is reached and the required precision is still not attained, other means besides increasing the number of replications must be used(Gomez, 1972).

Gomez (1972) suggested further that the magnitude of the experimental error that is to be obtained in an experiment and the requirement of the degree of precision are the main factors that determines the number of replications.

There is no rule about a desired replication number but generally, there should be enough to provide a minimum of 10 to 15 degrees of freedom for error. With fewer than 10 to 15 degrees of freedom, the value of [redacted] F required rises rapidly (Fisher and Yates, 1963).

2. 5. Plot-to-plot variability

It was customary to illustrate the plot-to-plot variability with the help of a fertility contour map. This is constructed by taking the moving averages of the yields of the unit plots and demarcating the regions of same soil fertility by considering those areas which have yields of same magnitude. This approach of describing the variation in fertility has been adapted by a large number of workers in India and abroad (singh et al., 1975).

Unfortunately the pattern of fertility gradients established with a certain crop in one season may not be characteristic of the same field in succeeding seasons with the same or different crops.

Smith (1938) pointed out that fertility contour maps constructed from long and narrow plots are misleading since they do not provide adequate points to show where the contour lines should be connected. Consequently, they suggest greater variability across than along the plots. Fertility contour maps were published for bajari by Kadam and Patel (1937); for barley, wheat and lentils by Bose (1935); for carrots by Currence (1936); for cotton by Crowther and Bartlett (1938), Hutchinson and Panse (1935a) and MacDonald et al. (1938); for groundnuts Hodnett (1953); for oats by Johnson and Murphy (1943) and for sugarcane by Iyer (1970).

All studies show that plot-to-plot variability reduces as plot size increases, but the reduction is not proportionate to the increase in plot size.

Uniformity trials are used also to calculate inter-annual correlations of yields from the same plot. From studies of many uniformity trials, Cochran (1937) concluded that the crop yields from the same plot in successive years were positively correlated, but the degree of correlation varied considerably.

Forester (1937) found that the inter-annual correlation of plot yields decreased as the number of intervening years increased. From a ten-year barley uniformity test grown under unirrigated conditions, Baker et al.(1952) showed that the plots did not maintain the same rank throughout the experiments. The inter-annual correlation varied over a wide range of values and the yield data from one or a few years were not an accurate index of the natural soil variation of an experimental site.

2. 6. Plant-to-plant variability

Another source of variability in field experiments is the inherent variation among individual plants. Inherent variability in productive ability of individual plants is particularly important in many horticultural crop trials because a plot may contain only a few plants or trees. In most agronomic experiments, the number of plants per plot is usually so large that plant-to-plant variation is not of major importance. Since plant-to-plant variation is due largely to differences in the genetic constitution of the plants, some crops are more subject to this variation source than others (LeClerg, 1977). With crops which utilize single genotype varieties, a genetic contribution to plant-to-plant variation should not exist. Theoretically, the inherent variability of plants propagated from seed should be more pronounced than that of plants propagated vegetatively. Some factors of environment can also cause plant-to-plant variability if they affect only one or few of the plants in a plot (LeClerg, 1977).

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

Pearce (1955) modified Smith's equation as

$$Y = V_1/X + V_2 X^{-b}$$

Where V_1 is the variance between individual trees and V_2 is the variance between single trees, due to position correspond to the genetic and environmental components of the total variation and y is the variance per unit area between plots of x trees.

2. 7. Size of plot

Because small differences in yielding ability among genotypes must be detected in a crop-improvement programme, the plot size we use must give accurate yield estimates. Now, optimum plot size for a given crop depends upon the extend of soil heterogeneity, the cost of the experimental operations and degree of inter-varietal heterogeneity (Smith, 1938).

2. 8. Importance of soil heterogeneity

There are two principal sources of variation in field experiments. (a) That due to the heterogeneity of the soil or position of plots on the experimental site, and (b) that due to the inherent variability within the crop species. (Rigney, 1948; Kempthorne, 1974; and Garber and Hoover, 1930).

Since the medium for field experimentation is primarily the soil, the degree of soil uniformity in the site obviously influences the precision and accuracy of results. Not only do soils vary from one part of the world to another, but, in any field or orchard, marked variations occur within a single soil type. These variations cause appreciable experimental error in field experiments. In fact, the greatest source of error is due to the non-uniformity of soil. It introduces a degree of uncertainty into inferences made from yield data of crops (Gomez, 1972; Forester, 1937; and Garber et al., 1926).

Soil heterogeneity refers to the non-uniformity of soil from part of the field to another (Gomez, 1972). Even within a small area, soil can vary greatly in texture, drainage, moisture and available nutrients. This variability is generally present even in a field that seems uniform.

Soil heterogeneity is a major contributor to error in field experiments. It introduces a degree of uncertainity into inferences made from yield data of crops (Garber et al., 1926)

While little can be done to eliminate or reduce soil heterogoneity itself, proper experimental techniques can considerably reduce the effects of soil heterogeneity on experimental results.(Fisher, 1951; Panse and Sukhatme, 1954; Federer, 1955; Cochran and Cox, 1957 and Kempthorne, 1951).

Harris and Scofield (1920, 1928) concluded that the fertility characteristics of field plots may persist for many years. They showed a preponderance of positive correlations between the yields of a series of plots in consecutive years. Such relationships clearly indicate a relatively high permanence of the differences in the plots of an experimental site.

Bose (1935), using Harris's soil fertility index upon yields from uniformity trials of barley, lentils and wheat grown for three consecutive years at a site in Pusa, found that an experimental site which was reasonably uniform for one crop in one season was not necessarily uniform for another crop in another season. He concluded that the analysis of variance was more useful than Harris's index because it provided a measure of soil heterogeneity and permitted the identification of fertility gradients.

Hayes and Garber (1927) showed that correlation between yields of adjacent 16½ feet rows of oats, spring wheat, and winter wheat where higher than those between the same 16½ feet rows separated by one or more plots.

Smith (1938) proposed a method for determining optimum plot size from uniformity trial data. His empirical results obtained for a finite field were generalised to apply to an infinite field. Using the yield data from uniformity trials with 18 crops, conducted by various workers, he calculated indices of soil heterogeneity designated by 'b'.

Generally 'b' varies from zero to unity. A value of 1.0 indicates a non-correlation between adjacent basic units, whereas a value near zero indicates a high correlation between adjacent basic units. Also with self-fertilized crops the value of 'b' is largely a function of the effect of soil heterogeneity, but with cross-fertilized crops the plant-to-plant genetic variation can contribute to the value of 'b'.

2. 9. The cost function

The costs of field experimentation must also be reflected in optimum plot size. Where costs are included, Smith (1938) suggested that the optimum plot size for unguarded plots is computed from the following relationship.

(1) $$X = b K_1 / (1-b) K_2$$

Where

X - the number of basic units per plot,

K_1 - the cost associated with the number of plots

and K_2 - the cost associated with unit area.

The optimum size of the plot where border rows were also considered is given by Smith (1938) as

(2) $$X = b(K_1 + K_b A)/(1-b)\ (K_2 + K_b B)$$

Where

K_1 - the cost per plot,

K_2 - the cost per basic unit,

K_b - the cost per unit area of plot for handling the border rows,

A - the guard area at the end of the guarded plot, B - is given by (W-w)/w, where

W - the width of the entire area (test area plus guard area),

and w - the width of the experimental area.

Examples of various cost involved in conducting a uniformity trial are given for tobacco by Crews, Hones and Mason (1963) and Pointer and Koch (1961); for soyabeans by Brim and Mason (1959); for tapioca by Prabhakaran and Thomas (1974) and for fodder sorghum by Sreenath (1973).

Considering the equation 1, Federer (1955) had made the following observation.

"The value of 'b' in the range 0.3 to 0.7 does not greatly affect the increase in cost or in variance when plots of size one fourth to four times the optimum plot size are used. On the basis of these results, plot size of one-half to twice the optimum size can be taken without any loss of efficiency. However, for plot sizes one fourth or four times the optimum size a loss in efficiency of twenty per cent results because of the increased variance".

In yield tests, with some crops, guard rows and ends of experimental rows are discarded prior to harvest. Smith (1938) found that the average variances of guarded and unguarded rows plotted against the test area gave similar curves. Also Hodnett (1953) considered this relationship, "....if P guarded plots of a given size excluding guards occupy the same total area as P' unguarded plots of the same size, then the variance within blocks of P guarded plots will be equal to that of the P' unguarded plots". He showed that the adverse effect of guard areas is greater with small, than with large plots because the experimental area is a smaller proportion of the total area.

2. 10. <u>Misuse of Smith's cost concept</u>

Smith (<u>loc. cit</u>) did not specifically define the basis for calcualting the cost factors, K_1 and K_2. He computed K_1 on a per plot basis and K_2 on a square foot basis, but Robinson <u>et al</u>.(1948) and Rigney (1948), who applied the method to uniformity data, assumed the total cost to be proportional to the total area. The concept of the latter researches was followed in work on optimum plot size with spring wheat by Elliot <u>et al</u>. (1952); in brome grass by Wasson and Kalton (1953); in tobacco by pointer and Koch (<u>op. cit</u>); in lima beans by Holle and Pierce (1960); in alfalfa-bromegrass mixtures by Torrie <u>et al</u>.(1963).

The differences in the two concepts are
(a) According to Smith (<u>loc. cit</u>):

$K_1 + K_2(x) =$ the cost per plot, where

K_1 - the total cost per plot of those costs which depend only on the number of plots,

and $K_2(x)$ - THE Total cost per plot of those costs which depend only on the number of basic units of area.

Thus K_2 is the cost per unit area of those costs proportional to area.

(b) According to Robinson et al.(1948) and others:

$K_1 + K_2 =$ the cost per plot, where

K_1 - That part of the total cost per plot which is proportional to the number of plots and

K_2 - The total cost per plot of those costs which depend only on the number of basic units per area.

Marani (1963) pointed out that the cost ratios calcualted by Robinson et al.(1948), Elliot et al.(1952), Pointer and Koch (1961) and Miller and Koch (1962) were for $K_1/K_2(x)$ and not for K_1/K_2. The ratio of $K_1/K_2(x)$ is dependent on the size of the plot (x) and cannot be used in Equation 1. Since the value of Smith's 'b' is independent of the size of the basic units, only K_2 in the Equation 1 is expressed on a per unit basis.

Marani (loc. cit) proposed that both K_2 and K_1 in the above equations, be estimated on a per unit of area basis.

The correct definitions of K_1 and K_2 were used by Hodnett (1953) in an optimum plot size study in groundnut; Wallace and Chapman (1956) in oatforage; by Rampton and Peterson (1962) in orchard grass; by Weber and Horner (1957) and Brim and Mason (1959) in soyabeans; by Sen (1963b) in tea; by Crews et al.(1963) in tobacco; by Sardhana et al.(1967) in potato, by Sreenath (1973) in fodder sorghum and by George et al. (1979) in turmeric.

Table 1. CV for different plot sizes and shapes

Yield		Number of units along N-S direction							
		1	2	3	4	6	8	12	24
Number of units along E-W direction	1	66.11	50.66	44.38	39,49	29.64	23.58	22.64	21.20
	2	48.56	38.25	32.90	30.86	25.90	22.19	15.19	12.46
	3	42.98	33.76	28.63	22.75	22.25	17.72	13.77	11.89
	4	31.75	29.06	22.26	24.09	21.93	17.22	12.75	9.54
	6	30.38	26.22	23.51	20.92	20.02	13.90	12.50	8.93
	8	32.37	24.78	22.48	20.60	20.14	14.03	10.98	7.83
	12	21.94	15.35	14.62	12.32	13.68	7.36	6.37	5.57
	24	20.30	14.55	14.29	11.56	12.82	4.70	3.51	-

MATERIALS AND METHODS

MATERIALS AND METHODS

Plot sizes and shapes for field experiments vary with crops soil types and treatments. The technique of uniformity trial is generally adopted to find the best size and shape of plots for different crops. Thus a uniformity trial was conducted at the main campus, Vellanikkara during the third crop season, 1980. The variety of brinjal planted was SM - 6. Crop was planted in North-South rows with a row to row spacing of 60 cm and plant-to-plant distance of 45 cm. The trial consisted of 68 rows each comprising of 64 plants. Harvesting of the crop was done in small units of 4 plants with two lines each having two plants, the size of the unit being 1.2 m x 0.9 m. Thus the units are arranged in 34 rows each consisting of 32 units. The number and weight of fruits for each unit were recorded separately in each harvest. For the purpose of study, total weight of brinjal fruits of each unit were considered. Two rows on both sides and one unit on either sides of each row were left as non-experimental area before harvest, thereby leaving 32 rows of 30 units each for statistical examination.

3. 1. Biometrical observations

Biometrical observations were made for the following traits at the time of harvest, from all the plants.

3. 1. 1. Yield

The total weight of brinjal fruits of each unit was recorded in kilograms. The yields of each basic unit was recorded separately, which formed the basis of the study of variation in plot sizes and shapes and arrangement of plots in blocks of different sizes. The data were analysed statistically for a study of variation among plots of different sizes and shapes, variation among blocks of different sizes and the estimation of optimum plot size.

3. 1. 2. Number of fruits

Total number of fruits from each unit was counted and recorded.

3. 1. 3. Height of the plant

The height of the individual plant was measured in centimeters and added on a per unit basis.

3. 1. 4. Number of Primary branches

The number of primary branches was counted and the total number of primary branches per unit was worked out.

3. 2. Size and shape of plots

From Uniformity trial yield data we can determine optimum size and shape of plots for field experiments by two methods. (i) Maximum curvature methods: and (iii) Heterogeneity Index method.

3. 2. 1. Maximum curvature method

With the maximum curvature method, yield data from basic units of a uniformity trial are combined into plots of different sizes which are compared for degree of variability. An index of variability, either coefficient of variation ($= \frac{\text{Standard Deviation}}{\text{Mean}} \times 100$) or standard error, and plot (block) sizes are plotted on the Y and X axes, respectively. A free hand curve is drawn through resulting co-ordinates and the optimum plot (block) size is read as the point on thecurve where the rate of change for the variability index per increment of plot (block) size is the greatest.

Thus the optimum plot or block size is one just beyond the point of maximum curvature. All of the early estimates of optimum plot size used this method. But the argument that the plot or block in the region of maximum curvature will be optimum is fallacious since this optimum size entirely depends on the scale of the co-ordinates against which the observations have been plotted. Secondly this method does not take into account the relative cost of various plot or block sizes (Singh et al., 1975).

3. 2. 2. Fertility contour map

One of the methods to describe the heterogeneity of land is to construct the fertility contour map. This is constructed by taking the moving averages of the yields of unit plots and demarcating the regions of the same soil fertility by considering those areas which have yields of same magnitude. This approach of describing the variation in fertility has been adopted by large number of workers in India and abroad.

Some of the workers who have made use of this method was, for barley, wheat and lentils by Bose (1935); for carrots by Currence (1936); for bajara by Kadam and Patel (1937); for cotton by Hutchinson and Panse (1935a); for groundnuts by Hodnett (1953); for oats by Johnson and Murphy (1943); for potatoes by Kalamkar (1932a); and for sugarcane by Iyer and Agarwal (1970).

Every one has observed that this procedure does not provide any quantitative estimate of the soil fertility variation. Also, if the soil is patchy it becomes difficult to lay out the experiment and to find the plot or block of suitable size and shape. Apart from this, if the contour map is constructed from the yields of rectangular plots oriented in both thedirections along the field, it has been found that the contour lines would run predominently in the direction of the length of the plot whatever this direction might be. The appearence of greater variability across the plots than along them may mislead the experimenters (singh *et al.*, 1975 and Smith, 1938).

3. 2. 3. Heterogeneity Index method

Smith (1938) proposed a method, which will be referred to as the Heterogeneity Index method, for determining the optimum plot size from uniformity trial data. His empirical results obtained for a finite field were generalised to apply to an infinite field. By harvesting a crop in very small units, he found that the variance per unit area for plots of area x units was given approximately by

(1) $$V_x = V_1 / x^b$$

Where

x is the number of basic units in a plot,

V_x is the variance (calculated on a per unit basis) of the yield per unit area among plots of x units in size,

V_1 is the variance among plots of one unit in size and

b is the characteristic of the soil and a measure of the correlation among contiguous units.

For example, if b = 1,

(2) $$V_x = V_1 / x.$$

and the units making up the plot of units are not correlated at all. If, on the other hand, the x units are perfectly correlated, when 'b' is zero and

(3) $$V_x = V_1$$

so that there is no gain due to the use of larger size of plot. In general 'b' will be between zero and unity, so that larger plots give more information with the same number of plots.

Transforming equation 1 to logarithms, the expression has linear regression relationship.

(4) $$\text{Log}(V_x) = \text{Log}(V_1) - b \log(x)$$

The index of soil heterogeneity 'b', is the regression of the logarithm of the plot variance (on a per unit basis) on the logarithm of the number of basic units per plot. In equation 4, 'b' is computed by the method of least squares.

3. 3. Smith's equation in the modified form

Smith (1938) gave an empirical relation between variance and the size of the plot. He defined the variance law as follows

(5) $$Y = a X^{-b}$$

Where

Y is the variance of yield per unit area based on plots of X units,

a is the variance per plot of unit area and

b is the characteristic of soil and a measure of correlation among contiguous units.

The value of 'b', as mentioned, generally lies between 0 and 1.

From equation 5, $Y = a X^{-b}$,

(6) $$\log(Y) = \log(a) - b \log(X)$$

which is the regression of log(Y) on log(X) and 'b' is the regression coefficient.

The value of 'b' can be obtained by solving the following normal equations.

(7) $\sum \log y_i = \sum \log a - b \sum \log x_i$

and

(8) $\sum \log x_i \log y_i = \log a \sum \log x_i - b \sum (\log x_i)^2$

The value of 'b' given by these equations is

(9) $$b = \frac{\sum \log x_i \log y_i - \sum \log y_i \sum \log x_i}{\sum (\log x_i)^2 - (\sum (\log x_i))^2}$$

Since y_i's are the individual sample variances on a per unit basis, Smith (1938) and Federer (1955) pointed out that it has a variable number of degrees of freedom and consequently, have different variances. Therefore, the following formula gives a weighted 'b' (Federer, 1955)

(10) $$b = \frac{\sum W_i \log y_i \log x_i - \sum W_i \log y_i \sum W_i \log x_i / \sum W_i}{\sum W_i (\log x_i)^2 - \sum W_i (\log x_i)^2 / \sum W_i}$$

Where

W_i the degrees of freedom associated with a given variance.

(The weights are proportional to the reciprocal of the variances. Since variance of $\log y_i$ to a first approximation is $2/W_i$)

3. 4. Relative efficiency of plot sizes

The ultimate units were combined to form blocks of different sizes. The coefficient of variation for different block sizes are made use of for calculating the relative efficiencies of various plot sizes.

If V_1 and V_2 are the variances of two plot sizes (Agarwal et al., 1968), a_1 and a_2 expressed on a per unit basis and r_1 and r_2 are the number of replications possible, the relative efficiency of plot size a_2 compared with a_1 is given by

(11) $V_1 r_2 / V_2 r_1$.

But coefficient of variation is proportional to V/2.

Therefore V_1/V_2 can be replaced by $\frac{(a_1/a_2)}{(cv_2/cv_1)}$.

Again total area of the field is fixed; therefore

(12) $a_1 r_1 = a_2 r_2$

Finally $(V_1 r_2)/(V_2 r_1)$ can be replaced by

(13) $(a_1/a_2)^2 \times (cv_1/cv_2)^2$

Where

cv_1 - the coefficient of variation for plot size a_1 and

cv_2 - The coefficient of variation for plot size a_2.

3. 5. Block efficiency

The advantage of using blocks in reducing experimental error by removing a portion of variability due to them is called 'block efficiency'.

This can be measured by the ratio of error variance that would have been obtained after eliminating difference due to block. The advantage due to blocks may be considered negligible when the ratio is in the neighbourhood of unity. (Agarwal *et al.*, 1968; Kulkarni *et al.*, 1936 and Singh *et al.*, 1975).

3. 6. Number of replications and area required

The number of replications and area required for 5% standard error of the mean was worked out for different sizes of plots and blocks by using the formula,

(14) $$r = (cv)^2/p^2$$

where

cv - the average coefficient of variation and

p - the 5% standard error of the mean.

The total area required for experimentation was obtained by multiplying the plot size (m^2) with the number of replications at 5% SE of the mean for different sizes of the blocks and plots.

3. 7. <u>Cost function</u>

Suppose the cost function is of the following linear form

(15) $c_t = x\ c_s + c_p$

where

- c_s - is the cost of individual item within the experimental unit,
- c_p - is the overall cost of experimental unit which is independent of the size and
- c_t - is the total cost of the experimental unit of size x

Then C, the total cost per unit of information is given by Cochran (1940) as

(16) $C = (x\ c_s + c_p)/(1/y)$, or

(17) $C = a\ (x\ c_s + c_p)/x^b$

The value of 'x' which minimise the cost is given by the equation

(18) $\frac{dC}{dx} = 0.$

Solving this equation we get

(19) $x = b(cp)/(1-b)cs$

which is the optimum plot size.

RESULTS

RESULTS

A uniformity trial on brinjal was conducted at the main campus of the Keral agricultural University, Vellanikkara. Harvesting of the crop was done in small units of 4 plants with two lines each having two plants, the size of the unit being 1.2 m x 0.9 m. For the purpose of study, total weight of brinjal fruits of each unit was considered.

At the time of harvest, biometrical observations were made for the traits, yield, fruits per plant, height of the plant and number of primary branches per plant from all the plants. The data were then examined statistically for a study of variations among plots of different sizes and shapes, orientation among blocks of different sizes and for the estimation of optimum plot size.

4. 1. Effect of plot shape on variability

From the data of yields (Appendix I), different tables were worked out by pooling the adjacent 1,2,3,4, 6,8 and 12 plots. The basic units were combined both in East-west and North-South direction to form plots of different sizes and shapes. The coefficient of variation for each of these tables were worked out as given in Table 1.

From Table 1, it can be seen that an increase in the plot size in either direction decreases the coefficient of variation. The CV decreased from 66.11 to 3.51.

In the same manner the data on other biometrical characters Viz., number of fruits per plant, primary branches per plant and height of the plants were also pooled in both the directions by combining adjacent 1,2, 3,4,6,8, and 12 units. The respective tables are given in appendices II, III and IV.

The coefficient of variation for each of these tables were worked out. The corresponding tables representing the plot sizes and CV are given in Table 2, Table 3 and Table 4 respectively for number of fruits per plant primary branches per plant and height of the plant.

In all cases the CV decreased as the size of the plot was increased in either directions.

In the case of the number of fruits per plant the CV decreased from 67.26 to 1.04, where as for number of primary branches per plant the CV decreased from 53.42 to 6.67 and for the height of the plant the CV showed a decrease from 62.66 to 9.90.

4. 2. Plot shape

The CV was averaged out over different shapes of blocks for a fixed size and shape of plots. The shape of the plot does not seem to have a consistent effect on the coefficient of variation. However for a given plot size, long and narrow plots generally yielded lower CV than approximately square plots (Table 5). With the smaller plot sizes, the effect of size is more predominant so that larger plots are more efficient than smaller ones irrespective of their shape. As the size of the plot increases, shape also is important, so that broad plots are often less efficient than longer plots of a smaller size. Defining the efficiency of a plot by 1/x (CV), where x is the number of basic units constituting the bigger plot and CV is the coefficient of variation, the efficiency decreased as the size of the plot was increased from 0.0265 to 0.0022 as given in Table 6.

4. 3. Effect of plot size on variability

A free hand curve has been drawn (Fig. 1) in which the plot size is plotted against the average coefficient of variation. It can be seen that the coefficient of variation decreased rapidly, when the size of the plot increased upto 8 m^2 and thereafter the decrease is rather slow. Thus by the method of maximum curvature the best plot size is about 8.64 m^2.

4. 4. Relative efficiency

Taking the efficiency of the smallest plot as unity, the relative efficiencies of various plot sizes are given in Table 7.

From the Table 7, we observe that the relative efficiency decreased from 1.0 to 0.048 as the size of the plot was increased from 2.16 m^2 to 25.92 m^2. Thus as far as possible we should try to decrease the size of the plot by proportionally increasing the number of replications.

4. 5. Fairfield Smith's variance law

The well known Fairfield Smith's variance law,

$$Y = a x^{-b}$$

where

Y - the average CV irrespective of the shape of plots and

x - the plot size,

was fitted for varying block sizes as given in Table 8. The coefficient of heterogeneity 'b' was found to vary between 0.1264 to 0.1866, for the yield data. As the values of 'b' in various block sizes are nearer to zero ($b < 0.2$), we can reasonably assume that there exists a high positive correlation between the neighbouring plots. Hence the position of the plot is important in controlling the error variation. The sum of squares due to fitted equation lies between 93.19% to 99.40%. Hence the fits were seem to be good in all the cases. The value of 'a' in the fitted equation lies between 19.2742 and 26.7659 for different block sizes and was 29.5678 without arrangement in blocks.

For the data on number of fruits per plant, primary branches per plant and height of the plant similar equations were fitted as given in Tables 8(a), 8(b) and 8(c) respectively. In all cases 'b' was found to range between 0.1 and 0.2, thereby confirming the correlation between neighbouring plots.

4. 6. Number of replications

The minimum number of replications per treatment for standard error of 5 per cent and minimum area required per treatment are given in Table 9. From this table it could be seen that the minimum number of replications and the minimum area required for 5 per cent SE of the mean is the 12-plot blocks followed by 8-plot blocks and 6-plot blocks. Thus the formation of large blocks in the case of vegetable crops was found to be advantageous as compared to other crops.

4. 7. Size and shape of block and block efficiency

As in experimental design, the plots are generally arranged within blocks. Therefore, for efficient planning the information on the efficiency of different block sizes is also of great importance. For working out the relative efficiency of various block sizes, the ratio of the error variance of a particular block arrangement was worked out. This ratio was expressed as percentage and was taken as the efficiency of that block arrangement.

The block efficiency in percentage for block sizes 2,4,6,8 and 12 were worked out as in Table 10. For the yield data in the case of 2-plot blocks the most efficient plot size is 12 followed by plot size 8. In the case of 4-plot blocks, the most efficient plot size is 8 closely followed by 4 and in the case of 6-plot blocks the most efficient plot size is 8 closely followed by 12. In the case of 8-plot blocks the most efficient plot size is 8 closely followed by 12 and in the case of 12-plot blocks the most efficient block size is 12 closely followed by 6 and 8. In general we could conclude that for all types of blocks, plots of size 8 and 12 are found to be most efficient.

Similarly from Table 11, we have the block efficiencies for data on number of fruits per plant in different blocks of sizes 2, 4, 6, 8 and 12. In the case of 2, 4, 6 and 8 plot blocks the most efficient plot size is 8. The plot size that closely follows this plot size varies from blocks to blocks. In the case of 2-plot blocks, a plot size 12 closely follows plot size 8 whereas in 4-plot blocks it is plot size 4 and plot size 6 in the case of 6-plot blocks and plot size 12 in the case of 8-plot blocks. But in the case of 12-plot blocks a plot size 4 was most efficient closely followed by a plot size 12.

The efficiency of different block arrangement for the data on the number of primary branches per plant is given in Table 12. In the case of 2-plot blocks a plot size 4 was found to be most efficient closely followed by plot sizes 2 and 6. But for 4-plot blocks a plot size 8 was most efficient closely followed by plot size4. In the case of 6-plot, 8-plot and 12-plot blocks the plot size 8 was most efficient closely follwed by plot size 6.

The data on height of the plant for having the efficiencies of different block arrangement is given in Table 13. For 2, 4, 6, 8 and 12-plot blocks the plots size 8 was found to be most efficient closely followed by the plot size 12.

4. 8. Cost function

Taking the cost function for field experiment as

$$C = C_1 + C_2 x$$

where

C_1 is the cost proportional to the number of replications and

C_2 is the cost proportional to the area required with the basic plot of x m^2

and assuming that the variance is governed by Smith's law, it can be shown that for a fixed cost, the optimum plot size (X_{opt}) is given by the equation,

$$X_{opt} = b\ C_1 / (1-b)\ C_2$$

As it is difficult to get actual values for C_1 and C_2, the optimum plot size was computed by assuming arbitrary values for the ratio $C_1 : C_2$ and taking an average value of 'b' to be equal to 0.1388. The optimum plot size calculated against different values of C_1 and C_2 are given in Table 14. Further assuming that C_1 will not exceed 50 C_2 the optimum plot size is about 8.64 m^2. This is in quite agreement with the result obtained by the method of maximum curvature dicussed earlier.

4. 9. <u>Fertility contour map</u>

From the yield data obtained in the uniformity trials a contour map showing the fertility gradient have been prepared by pooling the plot yield which are homogeneous in nature. This fertility contour map of the plot is depicted in Figure 2.

From the figure it is seen that the soil fertility of this plot do not show any uniform trend. moreover it is showing a very irregular pattern. Hence we can conclude that this soil is not homogeneous in nature. As this plot is only a random sample of the entire Vellanikkara campus of Kerala Agricultural University, this trend may be generalised to the area of the entire campus.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

In agriculture a research worker is required to conduct a good number of field experiments. New varieties, newer cultivation practices or methods of seed treatment etc have to be assessed in the field before recommendation. These objects of comparison in different trials may be termed as treatments. Experimental plot refers to the unit on which random assignment of treatment is made. Efficient planning of field trials depends on adoption of suitable size and shape of plots. It depends on the variability present on the experimental material and with the crops. The idea of magnitude of variability can be obtained from the data on uniformity trials conducted on the crop (Federer, 1955; Fisher, 1951; Panse and Sukhatme, 1954).

For the valid inference and accuracy in probability, randomisation and replication are necessary, but a local control is equally important for increasing the precision of field experiments. The local control mainly deals with the size and shape of individual plots, the division of blocks and their position in the experimental fields which chiefly depend on the distribution of fertility gradients in the experimental area and the number and nature of crop under test.

To investigate these problems, uniformity trials were undertaken by different workers on all important crops. A review of the works that had been done so far in various

Table 2. CV for different plot sizes and shapes

Fruits per plant		Number of units along N-S direction							
		1	2	3	4	6	8	12	24
Number of units along E-W direction	1	67.26	48.22	42.27	35.93	33.51	27.87	22.90	17.20
	2	48.11	34.75	30.49	26.18	24.30	21.73	17.84	12.89
	3	40.06	29.28	24.94	21.45	20.64	17.51	14.75	11.96
	4	33.98	25.88	23.62	20.56	19.41	17.09	13.74	7.97
	6	29.56	22.12	18.93	15.44	15.63	10.69	7.27	4.05
	8	25.82	20.73	19.[illegible]5	15.83	16.00	11.67	8.09	2.34
	12	20.27	15.21	14.36	11.95	9.92	6.59	1.89	1.87
	24	17.34	13.82	17.84	15.46	11.80	6.02	1.04	-

Table 3. CV for different plot sizes and shapes

Primary branches/plant		Number of units along N-S direction							
		1	2	3	4	6	8	12	24
Number of units along E-W direction	1	53.42	36.69	30.74	29.78	24.08	24.41	19.69	16.13
	2	34.47	25.82	22.56	21.54	16.35	18.46	15.74	13.47
	3	29.13	22.71	21.67	18.62	15.99	17.96	15.27	12.33
	4	25.12	19.90	17.52	17.57	14.29	15.87	13.71	12.00
	6	21.35	16.73	15.35	14.55	12.14	13.98	13.55	11.45
	8	18.19	13.92	12.78	12.24	10.07	10.78	10.21	7.93
	12	14.61	12.17	10.48	10.92	9.61	10.08	10.01	7.19
	24	10.17	8.06	7.74	7.51	6.60	6.38	6.67	-

Table 4. CV for different plot sizes and shapes

Height		Number of units along N-S direction							
		1	2	3	4	6	8	12	24
Number of units along E-W direction	1	62.66	50.11	42.58	40.13	34.83	29.28	25.02	19.15
	2	43.12	34.36	30.51	27.22	35.57	21.04	17.63	12.44
	3	35.71	31.48	27.22	23.03	22.81	18.09	15.81	10.75
	4	30.33	25.82	23.37	20.17	25.13	15.17	13.32	8.68
	6	24.78	20.56	18.74	16.24	15.93	12.27	12.00	8.34
	8	22.36	19.52	18.03	15.62	16.13	11.81	10.99	6.73
	12	15.65	[illegible]	12.39	10.65	10.58	7.01	8.16	5.56
	24	12.36	11.34	11.61	9.17	10.59	7.67	9.90	-

Table 5.

Coefficient of variation for plots and blocks of different sizes and shapes

Block size	Plot Size	Plot Shape L : B	Block shape L' : B'	CV
2	2	2 : 1	1 : 2	38.25
	2	2 : 1	2 : 1	31.75
	2	1 : 2	1 : 2	39.49
	2	1 : 2	2 : 1	38.25
				36.94
	3	3 : 1	1 : 2	33.76
	3	3 : 1	2 : 1	30.38
	3	1 : 3	1 : 2	33.12
	3	1 : 3	2 : 1	32.90
	4	1 : 4	1 : 2	29.04
	4	1 :4	2 : 1	30.86
	4	4 : 1	1 : 2	29.06
	4	4 : 1	2: 1	32.37
	4	2 : 2	1 : 2	30.36
	4	2 : 2	2 : 1	29.06
	6	1 : 6	1 : 2	23.58
	6	1 : 6	2 :1	25.90
	6	6 : 1	1 : 2	26.22
	6	6 : 1	2 : 1	21.94
	6	3 : 2	1 : 2	22.75

Contd....

Table 5(contd.....)

Block Size	Plot Size	Plot Shape L:B	Block shape L':B'	CV
2	6	3:2	2:1	26.22
	6	2:3	1:2	25.90
	6	2:3	2:1	22.26
	8	1:8	2:1	22.19
	8	8:1	1:2	24.78
	8	4:2	2:1	24.78
	8	4:2	1:2	24.09
	8	2:4	1:2	22.19
	8	2:4	2:1	24.09
	12	1:12	1:2	19.2[illegible]
	12	1:12	2:1	15.19
	12	12:1	1:2	15.38
	12	12:1	2:1	20.30
	12	6:2	1:2	20.92
	12	6:2	2:1	15.35
	12	2:6	1:2	15.19
	12	2:6	2:1	21.93
	12	4:3	1:2	21.93
	12	3:4	2:1	20.92
	24	1:24	2:1	12.46
	24	24:1	1:2	14.55
	24	2:12	2:1	12.75
	24	2:12	1:2	12.46
	24	12:2	1:2	12.32
	[illegible]	[illegible]	[illegible]	[illegible]

Table 5 (contd.....)

Block size	Plot Size	Plot Shape L:B	Block shape L':B'	CV
2	24	3:8	2:1	13.90
	24	8:3	1:2	20.14
	24	4:6	1:2	12.75
	24	6:4	2:1	20.60
4	2	2:1	4:1	32.37
	2	2:1	2:2	29.06
	2	2:1	1:4	30.86
	2	1:2	1:4	29.64
	2	1:2	2:2	30.86
	2	1:2	4:1	29.06
	3	3:1	1:4	22.75
	3	3:1	2:2	26.22
	3	3:1	4:1	21.94
	3	1:3	1:4	23.58
	3	1:3	2:2	25.90
	3	1:3	4:1	22.26
	4	2:2	1:4	22.19
	4	2:2	2:2	24.09
	4	2:2	4:1	24.78
	4	1:4	4:1	24.09
	4	1:4	2:2	22.19
	4	4:1	1:4	24.09
	4	4:1	2:2	24.78
4	6	1:6	1:4	19.20
	6	1:6	2:2	15.19
	6	1:6	4:1	21.93
	6	6:1	1:4	20.92
	6	6:1	2:2	15.35
	6	6:1	4:1	20.30
	6	3:2	1:4	17.72
	6	3:2	2:2	20.92
	6	3:2	4:1	15.35
	6	2:3	1:4	15.19
	6	2:3	2:2	21.93
	6	2:3	4:1	22.43
	8	2:4	2:2	17.22
	8	2:4	4:1	20.60
	8	1:8	4:1	17.22
	8	4:2	1:4	17.22
	8	4:2	2:2	20.60
	8	8:1	1:4	20.60
	12	2:6	1:4	12.46
	12	2:6	4:1	20.14
	12	2:6	2:2	12.75
	12	4:3	1:4	12.75
	12	4:3	2:2	20.14

Table 5. (contd....)

Block size	Plot Size	Plot Shape L:B	Block shape L':B'	CV	Block size	Plot size	Plot Shape L:B	Block shape L':B'	CV
4	12	6:2	1:4	13.90	6	3	3:1	2:3	23.51
	12	6:2	4:1	14.55		4	1:4	3:2	17.72
	12	12:1	1:4	12.32		4	1:4	6:1	20.92
	12	12:1	2:2	14.55		4	2:2	2:3	21.93
	12	1:12	4:1	12.75		4	2:2	3:2	20.92
	12	1:12	2:2	12.46		4	4:1	2:3	22.48
	24	6:4	2:2	7.36		4	4:1	3:2	15.35
	24	6:4	4:1	11.56		4	4:1	1:6	21.93
	24	4:6	2:2	10.98		6	2:3	3:2	20.02
	24	4:6	1:4	9.54		6	6:1	1:6	20.02
	24	8:3	1:4	10.98		8	4:2	2:3	20.14
	24	3:8	4:1	7.36		12	2:6	3:2	12.50
	24	1:24	4:1	9.54		12	2:6	6:1	13.68
	24	24:1	1:4	11.56		12	12:1	1:6	13.68
	24	2:12	2:2	9.54		24	6:4	2:3	6.37
	24	2:12	4:1	10.98		24	8:3	3:2	12.82
	24	12:2	1:4	7.36		24	12:2	1:6	6.37
	24	12:2	2:2	11.56		24	12:2	2:3	12.82
6	2	2:1	1:6	25.90	8	2	2:1	1:8	22.19
	2	2:1	2:3	22.26		2	2:1	2:4	24.09
	2	2:1	3:2	26.22		3	3:1	1:8	17.72
	2	2:1	6:1	21.94		3	3:1	2:4	20.92
	3	3:1	1:6	22.25		3	3:1	4:2	15.35

contd....

Table 5. (contd...)

Block size	Plot Size	Plot Shape L:B	Block shape L':B'	CV	Block size	Plot size	Plot Shape L:B	Block shape L':B'	CV
8	4	1:4	4:2	17.22	12	2	1:2	1:12	19.20
	4	1:4	8:1	20.60		2	1:2	2:6	21.93
	4	2:2	2:4	17.22		2	1:2	6:2	15.35
	4	2:2	4:2	20.60		2	1:2	3:4	17.72
	4	4:1	1:8	17.22		2	1:2	4:3	21.93
	4	4:1	2:4	20.60		3	1:3	12:1	14.62
	6	2:3	4:2	20.14		3	1:3	6:2	20.02
	6	3:2	2:4	13.90		3	1:3	3:4	13.77
	6	6:1	1:8	13.90		3	3:1	1:12	13.77
	8	1:8	8:1	16.03		3	3:1	2:6	20.02
	12	2:6	4:2	10.98		3	3:1	4:3	14.62
	12	4:3	2:4	10.98		4	1:4	12:1	12.32
	12	6:2	2:4	7.36		4	1:4	2:6	12.46
	12	12:1	1:8	7.36		4	1:4	6:2	13.90
	24	6:4	4:2	4.70		4	1:4	4:3	12.75
	24	12:2	2:4	4.70		4	4:1	1:12	12.75
12	2	2:1	12:1	20.03		4	4:1	6:2	14.55
	2	2:1	1:12	15.19		4	4:1	2:6	20.14
	2	2:1	2:6	21.93		4	2:2	12:1	14.55
	2	2:1	6:2	15.35		4	2:2	1:12	12.46
	2	2:1	3:4	20.92		4	2:2	2:6	12.75
	2	2:1	4:3	22.48		4	2:2	6:2	12.32
	2	1:2	12:1	15.35		4	2:2	4:3	20.14

Contd....

Table 5. (contd...)

Block size	Plot size	Plot shape L:B	Block shape L':B'	CV	Block size	Plot size	Plot Shape L:B	Block shape L':B'	CV
12	6	1:6	12:1	13.68	12	12	1:12	12:1	6.37
	6	1:6	6:2	12.50		12	12:1	1:12	6.37
	6	1:6	3:4	11.89		12	6:2	1:12	8.93
	6	6:1	1:12	12.50		12	6:2	2:6	6.37
	6	6:1	2:6	13.68		12	2:6	12:1	12.82
	6	6:1	4:3	13.68		12	2:6	6:2	6.37
	6	3:2	1:12	11.89		12	3:4	2:6	8.93
	6	3:2	4:3	13.68		12	4:3	6:2	12.82
	6	2:3	12:1	14.29		24	1:24	12:1	5.57
	6	2:3	3:4	12.50		24	24:1	1:12	3.51
	8	1:8	12:1	7.36		24	2:12	6:2	5.57
	8	8:1	1:12	10.98		24	2:12	12:1	3.51
	8	4:2	2:6	10.98		24	12:2	1:12	5.57
	8	4:2	6:2	11.56		24	12:2	2:6	3.51
	8	4:2	1:12	9.54		24	3:8	4:3	5.57
	8	4:2	3:4	7.36		24	8:3	3:4	3.51

Where

L - the number of units in a row

B - the number of units in a column

L'- the number of plots in a row

and B'- the number of plots in a column.

Table 6. The efficiency of a plot (= 1/x (cv)).

Plot size	CV Without blocking	1/x (cv) Without blocking	CV 2-plot blocks	1/x (cv) 2-plot blocks	CV 4-plot blocks	1/x (cv) 4-plot blocks
2	50.66	0.0099	36.94	0.0135	30.31	0.0165
3	44.38	0.0075	32.54	0.0102	23.78	0.0140
4	39.49	0.0063	30.31	0.0082	23.74	0.0105
6	33.12	0.0050	24.80	0.0067	18.87	0.0088
8	29.64	0.0042	24.89	0.0050	18.91	0.0066
12	23.58	0.0035	18.37	0.0045	14.26	0.0058
24	19.20	0.0022	14.65	0.0028	9.86	0.0042

Plot size	CV 6-plot blocks	1/x (cv) 6-plot blocks	CV 8-plot blocks	1/x (cv) 8-plot blocks	CV 12-plot blocks	1/x (cv) 12-plot blocks
2	24.08	0.0208	23.14	0.0216	1[illegible].[illegible]7	0.0265
3	22.88	0.0146	18.00	0.0185	16.14	0.0207
4	20.18	0.0124	18.91	0.0152	14.09	0.0177
6	20.02	0.0083	15.98	0.0104	[illegible]	0.0127
8	20.14	0.0063	12.89	0.0097	9.63	0.0130
12	13.29	0.0063	9.17	0.0091	8.62	0.0097
24	9.59	0.0043	4.70	0.0089	4.54	0.0092

Effect of plot size on variability FIGURE - 1.

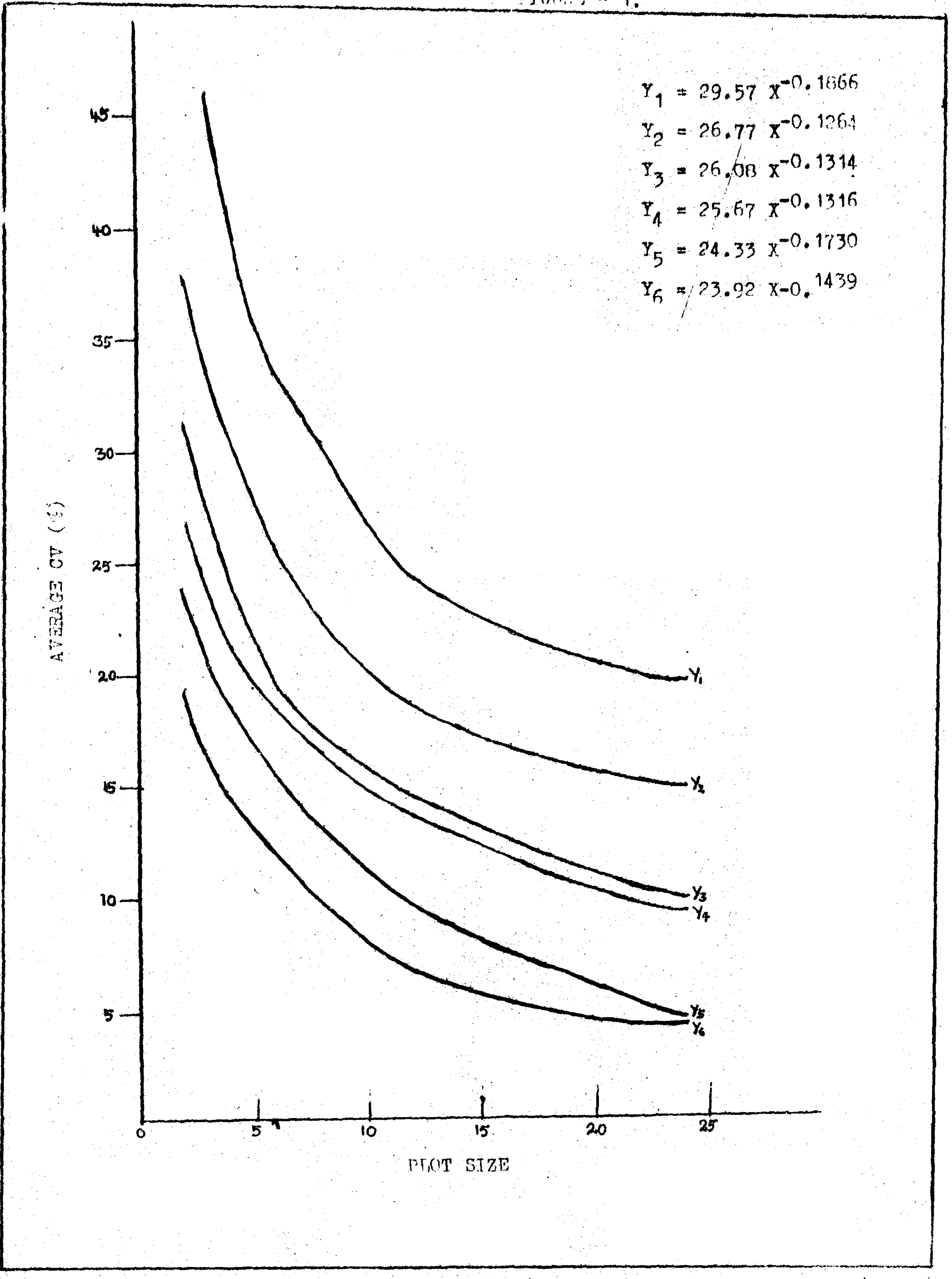


Table 7. Plot size, CV, and Relative efficiency

Plot size (m^2)	Without blocking		2-plot blocks		4-plot blocks		6-plot blocks		8-plot blocks		12-plot blocks	
	CV	RE	CV	RE	CV	RE	CV	RE	CV	RE	CV	RE
2.16	50.66	1.000	36.94	1.000	30.31	1.000	24.08	1.000	23.14	1.000	18.87	1.000
3.24	44.38	0.579	32.54	0.881	23.73	0.785	22.88	0.950	13.00	0.773	16.14	0.697
4.32	39.49	0.414	30.31	0.821	23.74	0.783	20.18	0.838	18.91	0.817	14.09	0.609
6.48	33.12	0.260	24.80	0.671	18.87	0.623	20.02	0.831	15.98	0.691	13.09	0.566
8.64	29.64	0.183	24.89	0.674	1[illegible].91	0.624	20.14	0.836	12.89	0.693	9.63	0.416
12.96	23.58	0.123	18.37	0.497	14.26	0.470	13.29	0.552	9.17	0.396	8.62	0.373
25.92	19.20	0.048	14.65	0.397	9.86	0.325	9.69	0.398	4.70	0.203	4.54	0.196

Table 8. Relation between CV (y) and plot size (x)

Yield data.

Blocks	Smith's equation $Y = a\, x^{-b}$	% amount of variation explained
Without blocking	$29.5678\, x^{-0.1866}$	99.40
2	$26.7659\, x^{-0.1264}$	97.02
4	$26.0787\, x^{-0.1314}$	96.97
6	$25.0705\, x^{-0.1336}$	93.19
8	$24.3334\, x^{-0.1730}$	93.89
12	$23.9228\, x^{-0.1439}$	93.69
24	$19.2742\, x^{-0.1463}$	93.[illegible]9

Table 8(a) Smith's equation fitted to data on fruits/pt. | Table 8(b) Smith's equation fitted to data on Primary branches/pt. | Table 8(c) Smith's equation for ht/pt.

Blocks	Smith's equation $Y = a x^{-b}$	Smith's equation $Y = a x^{-b}$	Smith's equation $Y = a x^{-b}$
Without blocking	$26.52 x^{-0.2264}$	$26.6729 x^{-0.1725}$	$28.64 x^{-0.2475}$
2	$24.95 x^{-0.1861}$	$26.0106 x^{-0.2247}$	$24.68 x^{-0.2564}$
4	$24.85 x^{-0.1075}$	$25.6856 x^{-0.1895}$	$25.34 x^{-0.2436}$
6	$24.85 x^{-0.1648}$	$24.8037 x^{-0.1650}$	$24.11 x^{-0.1952}$
8	$24.93 x^{-0.2417}$	$25.9415 x^{-0.2026}$	$25.17 x^{-0.2200}$
12	$28.13 x^{-0.1625}$	$23.8954 x^{-0.2528}$	$21.27 x^{-0.2491}$
24	$23.44 x^{-0.1607}$	$24.8569 x^{-0.2243}$	$16.28 x^{-0.1113}$

Table 9. Minimum number of replications and minimum area required at 5% SE of the mean

Plot size		Without blocking		2-plot blocks		4-plot blocks		6-plot blocks		8-plot blocks		12-plot blocks	
λ	a	r	a	r	a	r	a	r	a	r	a	r	a
2	2.16	103	222.48	55	118.80	37	79.92	23	49.68	21	45.36	14	30.24
3	3.24	79	255.96	42	136.08	23	74.52	21	68.04	13	42.12	10	32.40
4	4.32	62	267.84	37	159.84	23	99.36	16	69.12	14	60.48	8	34.56
6	6.48	44	285.12	25	162.00	14	90.72	16	103.68	10	64.80	7	45.36
8	8.64	35	302.40	22	190.08	14	120.96	16	138.24	8	69.12	6	51.84
12	12.96	22	285.12	14	181.44	8	103.68	7	90.72	4	51.84	3	38.88
24	25.92	15	388.80	9	233.28	4	103.68	5	129.60	4	103.68	4	103.68

λ - number of units

a - area in sq. m.

r - number of replications

Table 10. Plot size and block efficiency(%) for yield data

Plot size (m^2)	2-plot blocks	4-plot blocks	6-plot blocks	8-plot blocks	12-plot blocks
1.08	86.85	76.37	74.46	64.25	53.84
2.16	88.92	79.31	68.99	70.[illegible]9	61.06
4.32	90.02	81.10	75.85	75.56	66.08
6.48	89.58	79.30	75.69	75.45	69.45
8.64	90.96	81.22	78.66	77.64	69.37
12.96	90.63	79.28	77.60	76.51	75.[illegible]

Table 11. Plot size and block efficiency(%) for data on fruits per plant.

Plot size (m^2)	2-plot blocks	4-plot blocks	6-plot blocks	8-plot blocks	12-plot blocks
1.08	84.15	74.19	72.18	63.14	52.43
2.16	88.91	80.06	72.08	71.11	60.94
4.32	90.59	83.97	75.22	74.12	73.23
6.48	89.12	79.75	78.60	73.95	59.48
8.64	92.67	84.83	82.06	81.06	67.40
12.96	91.63	82.29	66.59	76.79	69.81

Table 12. Plot size and block efficiency(%) for data on primary branches.

Plot size (m^2)	2-plot blocks	4-plot blocks	6-plot blocks	8-plot blocks	12-plot blocks
1.08	86.57	80.[illegible]4	78.68	72.91	60.92
2.16	93.22	87.17	79.64	72.68	69.57
4.32	93.84	89.43	80.49	75.70	73.01
6.48	91.92	84.00	81.[illegible]8	80.79	74.66
8.64	89.92	89.77	82.41	84.27	76.47
12.96	86.50	82.77	79.66	74.55	73.63

Table 13. Plot size and block efficiency(%) for data on height of the plant.

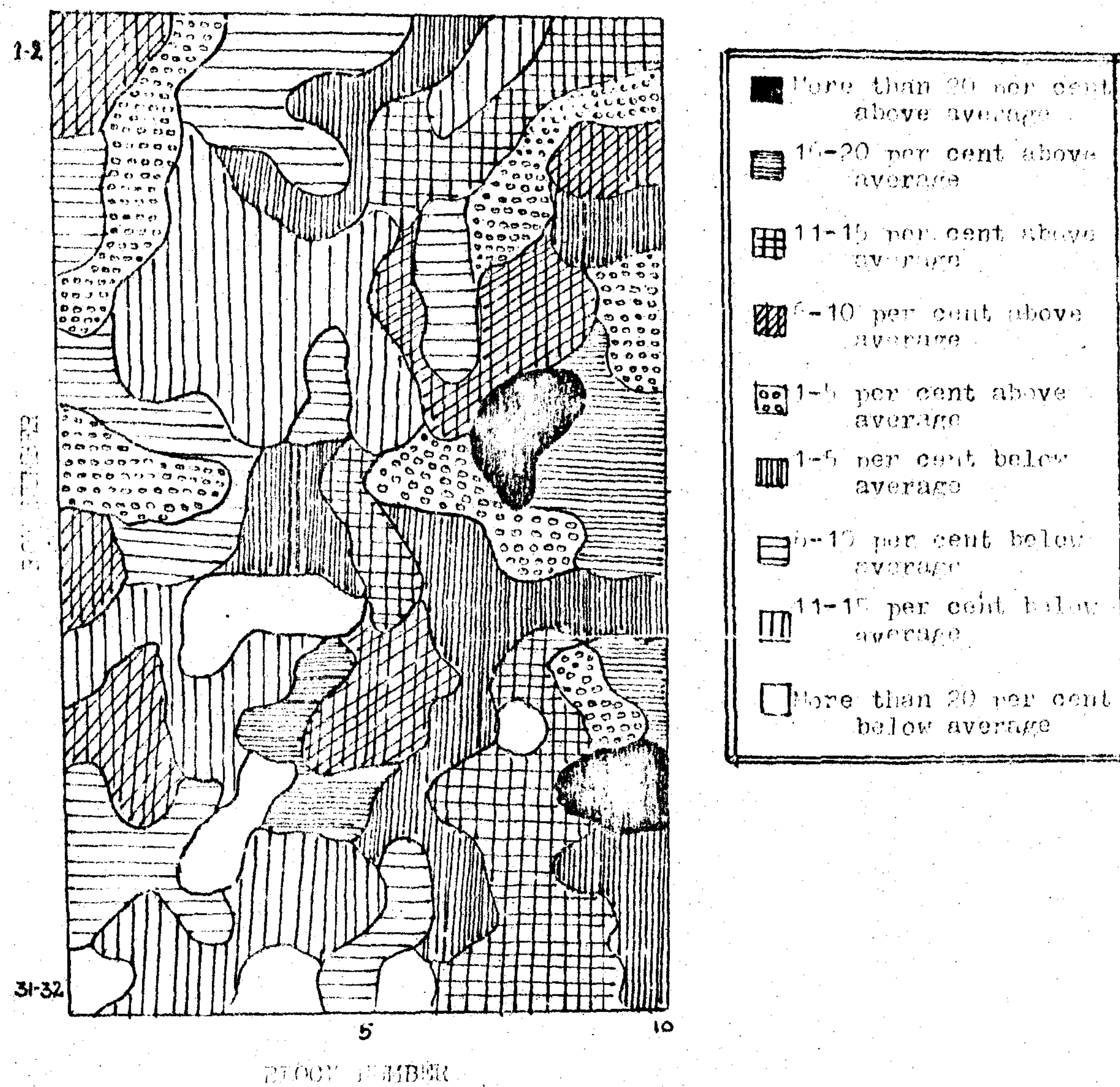
Plot size (m^2)	2-plot blocks	4-plot blocks	6-plot blocks	8-plot blocks	12-plot blocks
1.08	85.49	75.28	73.32	63.70	53.14
2.16	88.92	79.69	70.54	71.00	61.00
4.32	90.31	82.54	75.54	74.84	69.66
6.48	89.35	79.53	77.15	74.70	64.47
8.64	91.82	83.03	80.36	79.35	72.72
12.96	91.13	82.79	78.10	76.65	72.45

Table 14. Optimum plot size

When cost of experimentation is also considered.

C_1	C_2	Basic units	Area (m^2)
4	1	0.65	0.70
4	2	0.32	0.35
4	3	0.22	0.24
4	4	0.16	0.17
8	1	1.29	1.39
8	3	0.43	0.46
12	1	1.93	2.08
12	2	0.97	1.05
12	4	0.48	0.52
24	1	3.87	4.18
32	1	5.16	5.57
32	2	2.58	2.79
32	3	1.72	1.86
48	1	7.74	8.36
50	4	2.02	2.18
50	3	2.69	2.91
50	2	4.03	4.35
50	1	8.06	8.70

Fertility Contour map of weight of brinjal fruits, Fig. - 2.



DISCUSSION

DISCUSSION

5. 1. Effect of plot size on variability

The variability of each plot size and shape was determined by means of coefficient of variation.

An increase in the size of plots in either direction decrease the coefficient of variation (Table 1). Generally the coefficient of variation for rectangular plots was slightly less than that for square or nearly square plots. The reduction in CV was not proportional to the number of basic units combined.

The above result is in agreement with the observations made by Smith (1907-09). McClelland (1926b), and Bryan (1931, 1933) in corn, Justesen (1932) and Kalamkar (1932a) in potatoes, Kulkarni and Bose (1936) in sorghum, Vagholkar et al. (1940) in sugarcane, Bose (1935) in wheat, Sardhana et al. (1967) in potatoes, Prabhakaran and Thomas (1974) in tapioca, George et al. (1979) in cardamon, Joshi et al. (1972) and Kripashankar et al. (1972) in soyabean, Kaushik et al. (1977) in mustard, Saxena et al. (1972) in oat fodder, Sreenath (1973) in fodder sorghum, Jayaraman (1979) in sunflower and George et al. (1979) in turmeric. Also similar was the observations by Abraham (1969) in blackpepper, Abraham and Vachhani (1964) in rice, Agarwal et al. (1968) in arecanut, Bhargava and Sardhana (1975) in apple, Menon and Tyagi (1971) in orange and Ram babu et al. (1980) in grasses.

But the reports of Batchelor and Reed (1918) in oranges, Lyon (1911) and Kiessalback (1923) in wheat and Smith (1958) in beans, who concluded that long and narrow plots were no longer superior to square ones, is contradictary to the above result. Some other workers reported that square plots were more effective in reducing variability than long and narrow plots when the length of the plot was oriented in the direction of soil fertility (Day, 1920 and Iyer, 1942 in wheat and Siao, 1935 in cotton).

5. 2. Effect of plot shape on variability

To examine the shape of plots the CV for different plot sizes and shapes were obtained (Table 5). It will be seen from the table that the CV was smaller in general for plots elongated in the direction of the row.

The shape of plot had no consistent effect on CV. But long and narrow plots along east-west showed lower CV. This might be due to field slope in east-west direction. Similar was the observation made by Sreenath (1973) in fodder sorghum.

As the efficiency of a plot of a given size is 1/x (cv) where x is the number of basic units constituting the bigger plot (Kalamkar, 1932), the efficiency decreased as the size of the plot was increased (Table 6). This decrease in the efficiency of the bigger plot implies that higher variability can be counter balanced by using smaller plots. When the plot size is increased, soil differences are averaged out, but this introduces more error due to larger variation within blocks. Similar reports were also made by Prabhakaran and Thomas (1974) in tapioca, Sreenath (1973) in fodder sorghum and Kalamkar (1932) in potatoes.

5. 3. <u>Optimum plot size through maximum curvature method</u>

For determining the optimum plot size by the method of maximum curvature the yield of adjacent units are combined to form plots of different sizes and shapes. A free hand curve has been drawn in which the plot size is plotted against the average CV(%). The optimum plot size is one just beyond the point of maximum curvature. From figure 1, it will be seen that the CV is decreased as the size of the plot was increased upto 8 m^2, thereafter the decrease is rather slow. Jayaraman (1979) also tried this method for obtaining the optimum size of plot in sunflower and arrived at a fairly good result.

5. 4. Relative efficiency

Taking the efficiency of the smallest plot as unity, the relative efficiencies of various plot sizes are given in Table 7.

The efficiency was the highest for the smallest plot; so the objective should be to decrease the plot size as far as possible, subject to practical considerations and to increase the number of replications proportionally.. As plot shape was found to be only of minor importance in affecting variability for the ranges of plot sizes under consideration, the error will not be serious if an average CV is used for (i) a given plot size for all shapes of plots and (ii) for the purpose of determining the number of plants required for a given level of accuracy of the treatment mean, with a given number of treatments per block.

The above result is in agreement with the observations made by Agarwal et al.(1968) in arecanut and Kaushik et al.(1977) in mustard.

5. 5. Smith's law

The average CV shows a certain relationship with the size of plot, the number of plots per block being the same. Smith's law (1938), $Y = aX^{-b}$ where Y is the average CV for fixed plot size of X units, fitted to the observed values of CV for different block sizes separately.

For the yield data the value of 'b', Smith's coefficient of heterogeneity, varied from 0.1264 to 0.1730 for different block sizes and was 0.1866 without arrangement in blocks. Thus there appears to be a high positive correlation between the neighbouring plots. Similar results were also obtained by Singh et al.(1975) and Sreenath (1978) in bhindi and fodder sorghum respectively. The correlation between the neighbouring plots was further confirmed by the data on other biometrical characters, as the ranges of 'b' values for data on fruits per plant is 0.11 to 0.24; for number of primary branches per plant is 0.165 to 0.253 and for height of the plant is 0.11 to 0.249 respectively (Tables 8, 8(a), 8(b) and 8(c)).

5. 6. Block efficiency

To study the variability in blocks, plots of different sizes and shapes were grouped together in blocks of 2, 4, 6, 8 and 12 plots. The arrangement of plots within blocks were as given in Table 10.

The coefficient of variation per plot was worked out for each of these arrangements for comparing the relative efficiency of blocks with respect to the control of soil heterogeneity (Table 10).

For any given plot size, the coefficient of variation was less for the blocks of smaller sizes. For the plots of smaller dimensions, the coefficient of variation was high in each of the blocks. As the size of the plot was increased from 2.16 m^2 to 25.92 m^2 a considerable reduction in the coefficient of variation was obtained. Upto 8 plots in a block, the shape of the block did not affect the precision of the blocks.

On careful observation on different block efficiencies (Tables 10, 11, 12 and 13) for data on yield a block size of 8 and 12 were found most efficient whereas in the cases of number of fruits per plant, number of primary branches per plant and the height of the plant generally a plot size 8 was found to be most efficient.

5. 7. Minimum number of replications

The reduction in experimental error for treatment comparisons can be achieved by (i) taking larger plots and (ii) increasing the number of replications (Agarwal et al., 1968)

The two criteria are complementary for a fixed experimental area. Therefore a plot size which achieves a balance between these two criteria is defined as optimum plot.

Hayes _et al_. (1955) recommended that increasing replications would decrease the standard error more rapidly than increasing the size of plots. Therefore the number of replications necessary for given standard of accuracy were studied.

The efficiency of blocks is closely linked with the number of replications. Hence for a particular block size and shape, it is necessary to know the number of replications required to obtain five per cent error of the mean. With this standard of accuracy, the effective number of replications and the total area required per treatment were worked out for various plot sizes (Table 9).

For smaller plots, a fairly large number of replications were required to achieve 5 per cent accuracy in any of the block sizes. But as the plot size was increased from 2.16 m^2 to 25.92 m^2, there was a considerable reduction in the number of replications required to obtain the same precision. For instance, for plots of size 12.9 m^2 in blocks of 4-plots or 8-plots, only 8 or 4 replications, respectively, were needed, whereas for plots of size 2.16 m^2, 37 or 21 replications were required. But the total area required by smaller plots was much less than that by bigger plots. It is therefore better to have smaller plots with more replications.

Since the number of replications required to achieve 5 per cent accuracy is directly proportional to the square of variation, a decrease in the coefficient of variation implies a decrease in the number of replications. Hence less replications are required if bigger plots are used and vice versa. To achieve p per cent accuracy, the number of replications should be multiplied by the factor $(5/p)^2$. Kulkarni et al.(1936) working with sorghum, Hutchinson and Panse (1935) working with cotton, Abraham et al.(1969) in blackpepper, Bhargava and Sardhana (1975) in apple, Gopani et al.(1970), Joshi et al.(1972) and Kripashankar et al.(1972) in soyabean, Prabhakaran et al.(1978) in banana, Saxena et al.(1972) in oat fodder, Sreenath (1974) in fodder sorghum and Rambabu et al.(1980) in grasses reported similar findings and pointed out that though the error of the experiment was reduced by a decrease in the per cent standard deviation due to an increase in the plot size, the error was at the same time increased by the loss in the number of replications.

5. 8. Cost function

It has been shown that the smaller plots were much more efficient than the bigger ones and the total area required by them was also comparatively less. Bryan (1933) working with maize, also got similar results. However to obtain a practical minimum, it is necessary to work the optimum plot size for field experiments in brinjal. With Smith's (1938) empirical relation for determining the optimum plot size, viz., $X_{opt} = b\ c_1 / (1-b)\ C_2$, where 'b' is the regression coefficient of log (cv) on log (plot size), C_1 is the cost proportional to the number of plots per treatments, i.e., number of replications, and C_2 is the cost proportional to the total area per treatment, the optimum plot size was computed by assuming arbitrary values of the ratio $C_1 : C_2$ (as it is difficult to obtain accurate values of C_1 and C_2 in practice) and then taking the average value of 'b' over blocks of various sizes to be equal to 0.1368 (Table 14).

The optimum plot size varied between 0.646 and 8.05 basic units for various ratios. For wider ratios, the optimum plot sise was bigger and for narrower ones, it was smaller. An increase in the cost per unit area and decrease in the cost per replication had reduced the optimum plot size.. Assuming the cost due to plot area to be 2%, the optimum plot size was 8.05 basic units or about 8.65 m^2. This was reduced to approximately one basic unit or 1.08 m^2 when the cost due to area increased to 88% of the total.

5. 9. Fertility contour map

A study of the direction of the fertility contour of the experimental area was made based on the yield data by pooling plot yields of homogeneous nature. The fertility contour map thus obtained was as shown in figure 2. From this figure it could be concluded that there is no specific trend for the soil fertility and on the whole the land can be considered not very homogeneous as far as the fertility is concerned.

Fertility contour maps were published for bajara by Kadam and Patel (1937), for barley, wheat and lentils by Bose (1935), for carrots by Currence (1936), for cotton by Hutchinson and Panse (1935a), for groundnuts by Hodnett (1953), for potatoes by Kalamkar (1932a) and for sugarcane by Iyer and Agarwal (1970).

SUMMARY

SUMMARY

A uniformity trial in brinjal was conducted at the Main Campus of the Kerala Agricultural University, Vellanikkara during the third crop season, 1980. The main objective of the experiment was to study the variations among plots of different sizes and shapes, orientation among blocks of different sizes, having prior knowledge on soil heterogeneity for the estimation of optimum plot size. The crop was planted in North-South rows with a row to row spacing of 60 cm and plant to plant distance of 45 cm. Harvesting of the crop was done in small units of 4 plants with two lines each having two plants, the size of the unit being 1.2 m x 0.9 m. Two rows on both sides and one unit on either sides of each row were left as non-experimental area before harvest, thereby leaving 32 rows of 30 units each for statistical examination.

At the time of harvest, biometrical observations were made on height, primary branches, number of fruits and weight of brinjal fruits harvested, from all the plants.

The data on all these trials were pooled in both the directions by combining adjacent 1, 2, 3, 4, 6, 8 and 12 units. It was observed that an increase in

the plot size in either directions decreased the CV, but the decrease was more rapid along the N-S direction. Long and narrow plots yielded lower CV than approximately square plots. The efficiency of plots decreased as the size of the plot was increased.

The CV averaged over all the different shapes of plots followed closely the relation $Y = a\, x^{-b}$ (Fairfield Smith's law). The values of 'b', Smith's coefficient of heterogeneity, for all biometrical characters in various block sizes were nearer to zero ($b < 0.2$) revealed that there exists a high positive correlation between neighbouring plots. The fits were seen to be good in all cases as the coefficient of determination obtained for various block sizes were very nearer to unity.

At larger plot sizes, the regression line showed a tendency to curve doun although negligible. The optimum plot size obtained through Fairfield Smith's method and maximum curvature method showed only a slight difference. From the above considerations, a plot size of 8.64 m^2 (9.6 m x 0.9 m) was found advisable for conducting most of the field experiments in brinjal.

Taking the efficiency of the smallest plot as unity, the relative efficiencies of various plots were computed. The efficiency was the highest for the smallest plot. So the objective should be to decrease the plot size as far as possible and to increase the number of replications.

For working out the relative efficiency of various block sizes, the ratio of the error variance of a particular block arrangement to that without block arrangement was worked out. This ratio was expressed as percentage and was taken as the efficiency of that block arrangement.

There is a general decrease of block efficiency with increasing block size. More compact blocks of the same size show a higher efficiency. Blocks of identical size and shape but consisting of long plots also show a somewhat higher efficiency than blocks with short plots of the same size. Arrangement of plots in more than one row decreased block efficiency and the effect is more pronounced with long plots.

The minimum number of replications per treatment for standard error of 5 per cent and minimum area required per treatment for varying plot size was calculated. The number of replications required for a given level of accuracy decreased with an increase in plot size and increasing the number of replications rather than plot size was found more advantageous for a fixed experimental area.

To study the nature of soil heterogeneity of the vegetable fields of the main campus, at Vellanikkara, a fertility contour map of the plot was prepared. The figure showed that the land was not very homogeneous as far as the fertility pattern is concerned.

By assuming arbitrary values of the cost proportional to the number of replications and the cost proportional to the total area per treatment the optimum plot size was computed. An increase in the cost per unit area and decrease in the cost per replication had reduced the optimum plot size. The optimum plot size for any field experiment in brinjal was worked out to be about 8.64 m^2.

REFERENCES

REFERENCES

Abraham, T.P.; Khosla, R.K. and Agarwal, K.N. (1969). Uniformity trials on blackpepper (*Piper nigrum* L.). *Indian J. agric. Sci.* **39**: 790-807.

Abraham, T.P. and Vachhani, M.V. (1964). Investigations on field experimental techniques with rice crop. Size and shape of plots and blocks in field experiments with transplanted rice crop. *Indian J. agric. Sci.* **35**: 152-165.

Agarwal, K.N.; Bavappa, K.V.A. and Khosla, R.K. (1968). Study of size of plots and blocks and number of pre-experimental periods of arecanut. *Indian J. agric. Sci.* **38**: 444-460.

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**:445-455.

Anonymous (1964). Uniformity trial on tomato. *Statist. News letter*. IARS, (ICAR). **13**: 8-9.

Baker, G.A.; Huberty, M.R. and Veihmeyer, F.J. (1952). A uniformity trial on unirrigated barley of ten year's duration. *Agron. J.* **44**: 267-270.

Batchelor, L.D. and Reed, H.S. (1918). Relation of the variability of yields of fruit trees to the accuracy of field trials. *J. agric. Res.* **12**: 245-283.

*Beattie, J.H. and Boswel, V.R. (1936). Statistical studies on apperently uniform fields of carrots and onions on peat soils. Die Gartenbauwissenschaft 10: 279-288.

Bose, R.D. (1935). Some soil-heterogeneity trials at Pusa and the size and shape of experimental plots. Indian J. agric. Sci. 5: 579-608.

Bose, S.S.; Khanna, K.L. and Mahalanobis, P.C. (1939). Note on the optimum shape and size plots for sugarcane experiments in Bihar. Indian J. agric. Sci. 9: 807-816.

Brim, C. . and Mason, D.D. (1959). Estimates of optimum plot size for soyabean yield trials. Agron. J. 51: 331-334.

*Bryan, A.A. (1931). A statistical study in the relation of size and shape of plot and number of replications to precision in yield comparisons with corn. Rep. Iowa agric. Exp. Stn.

*Bryan, A.A. and Arthur, A. (1933). Factors affecting experimental error in field plot tests with corn. Res. Bull. Iowa agric. Exp. Stn. 163:243-280.

Christidis, B.G. (1931). The importance of the shape of plots in field experimentation. J. Agric. Sci., Camb. 21:14-37.

*Cochran, W.G. (1937). Catalogue of uniformity trial data. Suppl. Jl. R. statist. Soc. 4:233-253.

Cochran, W.G. (1940). A survey of experimental design. Mimeo. USDA.

Cochran, W.G. and Cox, G.M. (1957). Experimental designs. John Wiley & sons, NewYork, 2nd ed. pp. 611.

Crews, J.W.; Jubian, W.; Johnes, G.L. and Mason, D.D. (1963). Field plot technique studies with flue-cured tobacco. Agron. J. 55: 197-199.

*Crowther, T. and Bartlett, M.S. (1938). Experimental and statistical technique of some complex cotton experiments in Egypt. Emp. J. exp. Agric. 6:53-68.

Currence, T.M. (1936). Relation of plot size and shape to variability of carrot yields on peat soils. Proc. Amer. Soc. Hort. Sci. 33:484-488.

Currence, T.M. (1947). Studies related to field plot technique with tomatoes. Proc. Amer. Soc. Hort. Sci. 50: 290-296.

Currence and Krantz, F.A. (1936). The relation of plot size and shape to potato yield variations. Am. Potato J. 13: 310-313.

Das, M.N. and Giri, N.C. (1979). Design and analysis of experiments. Wiley Eastern Ltd., New Delhi. 1st ed.

Day, J.W. (1920). The relation of size, shape and number of replications of plots to probable error in field experimentation. J. Am. Soc. Agron. 12:100-105.

*Dendrions, A.D. (1931). The question of the shape of plots in field experimentation, Intl. Assn. Plant Breeders Bull. 4: 106-113.

Elliot, F.C.; Darroch, J.G. and Wang, H.L. (1952). Uniformity trials with spring wheat. Agron. J. 44: 524-529.

Federer, W.T. (1963). Experimental design. Theory and Application. Macmillan Co. Newyork. pp. 58-85.

Fisher, R.A. (1925). Statistical methods for research workers. Oliver and Boyd, London. 1st Ed.

Fisher, R.A. (1951). The design of experiments. Hafner Publ. Co., New York, 6th Ed. pp. 244.

Fisher, R.A. and Yates, F. (1963). Statistical tables for biological, agricultural and medical research. Hafner Publ. Co. New York, 6th Ed. pp. 146.

*Forester, H.C. (1937). Design of agronomic experiments for plots differentiated in fertility by past treatments. Res. Bull. Iowa agric. Exp. Stn. 226: 139-172.

Garber, R.J. and Hoover, M.M. (1936). Persistence of soil differences with respect to productivity. J. Am. Soc. Agron. 22: 883-890.

Garber, T.C. and Hoover, M.M. (1926). A study of soil heterogeneity in experimental plots. J. agric. Res. 33: 255-268.

George, M.V.; Pattan shetty, M.V.; Narasimhayya, G.; Nambiar, M.C. and Sathe, K.V. (1979). Uniformity trial, optimum sise and shape of plots and blocks for cardamom experimentation

Indian J. agric. Sci. (in press).

George, M.V.; Sannamarappa, M. and Bhagawan, S. (1979). Optimum plot size and shape in blocks from the uniformity trial on turmeric. 33rd Ann. Conf. Indian Soc. Agric. Stat., Mannuthy, December, 1979.

Gomez, K.A. (1972). Techniques for field experiments with rice. The International Rice Research Institute, Philippines. pp. 1-18.

Gopani, D.D.; Kabaria, M.M. and Vaishnani, N.L. (1970). Size and shape of plots in field experiments on groundnuts. Indian J. agric. Sci. 40: 1004-1011

*Harris, J.A. (1915). On a criterion of substratum homogeneity in field experiments. Am. Nat. 49:430-454.

*Harris, J.A. (1920). Practical university of field heterogeneity as a facto influencing plot yields. J. agric. Res. 19: 279-314.

*Harris, J.A. and Scofield, C.S. (1920). Permanence of differences in the plots of an experimental field. J. agric. Res. 20: 335-356.

Hayes, H.K. and Garber, R.J. (1927). Breeding crop plants. McGraw-Hill Publ. Co., New York, 2nd Ed. pp. 438.

Hayes, H.K. and Immer, F.R. (1942). Methods of plant breeding. McGraw Hill Book Co., New York. pp.432.

Hodnett, G.E. (1953). A uniformity trial on groundnuts. J. agric. Sci., Camb. 43: 323-328.

Holle, M. and Pierce, L.C. (1960). Plot technique for field evaluation of earliness, pod number and total yield in the lima beans. Proc. Amer. Soc. Hort. Sci. 76: 403-408.

Hutchinson, J.B. and Panse, V.G. (1935a). Studies in the techniques of field experiments. I. size, shape and arrangement of plots in cotton trials. Indian J. agric. Sci. 5: 1-14.

Hutchinson, J.B. and Panse, V.G. (1935b). Studies in the technique of field experiments. IV. A study of margin effect in variety trials with cotton and wheat. Indian J. agric. Sci. 5: 671-692.

Immer, F.R. (1932). Size and shape of plot in relation to field experiments with sugarbeets. J. agric. Res. 44: 649-668.

Immer, F.R. and Raleigh, S.M. (1933). Further studies of size and shape of plot in relation to field experiments with sugarbeets. J. agric. Res. 47: 591-598.

Iyer, P.V.K. (1942). Studies with wheat uniformity trial data. II. Balanced versus randomized arrangements. Indian J. agric. Sci. 12: 263-273.

Iyer, S.S. and Agarwal, K.C. (1970). Optimum size and shape of plots for sugarcane. Indian J. agric. Sci. 40:124-139.

Jacob, W.C. (1953). Some general considerations of plot technique in horticulture. Proc. Amer. Soc. hort. Sci. 62: 35-45.

Jayaraman, K. (1979). Optimum size and shape of plots and blocks and relative efficiency of design for field experiments in sunflower (Helianthus annus. L.). Unpublished M.Sc.(Ag.) thesis, University of Agricultural Sciences, Bangalore.

Johnson, I.J. and Murphy, H.C. (1943). Lattice and Lattice square designs with oat uniformity trial data and in varietal trials. J. Am. Soc. Agron. 35: 291-305.

Joshy, S.N.; Kabaria, M.M. and Babaria, L.H. (1972). Note on the estimates of optimum plot size for field experiment on soyabean(Glycine Max.(L.) Merr.). Indian J. agric. Sci. 42: 936-940.

Justesen, S.H. (1932). Influence of size and shape of plots on the precision of field experiments with potatoes. J. agric. Sci., Camb. 22: 366-372.

*Kadam, B.S. and Patel, S.M. (1937). Studies in field plot techniques with P. typhoideum. Emp. J. exp. Agric. 2: 219-230.

Kalamkar, R.J. (1932a). Experimental error and the field-plot technique with potatoes. J. agric. Sci., Camb. 22: 373-385.

Kaushik, L.S.; Singh, R.P. and Yadava, T.P. (1977). A uniformity trial with mustard. Indian J. agric. Sci. 47: 515-518.

Kempthorne, O. (1974). The design and analysis of experiments. John Wiley & Sons, NewYork. 1st Ed. 1951, 2nd reprint, 1974. pp. 206-210.

Kiesselbach, T.A. (1923). Competition as a source of error in comparitive corn yields. J. Am. Soc. Agron. 15: 199-215.

Koch, E.J. and Rigney, H.J. (1951). A method of estimating plot size from experimental data. Agron. J. 43: 17-21.

*Krantz, F.A. (1923). Further studies in field plot technique in potato yield tests. Proc. Tenth. ANN. Meeting Potato Assn., America. 174-179.

Kripashanker, M.S.; Lal, M.S. and Goswami, U. (1972). Size and shape of plots and blocks in yield trials of soyabean (Glycine Max. (L.) Merr.). Indian J. agric. Sci. 42: 901-904.

Kulkarni, R.K. and Bose, S.S. (1936). On the influence of shape and size of plots on the effective precision of experiments with sorghum. Indian J. agric. Sci. 6: 460-474.

Lana, E.P.; Homeyer, P.G. and Haber, E.S. (1953). Field plot techniques in vegetable crops. Proc. Amer. Soc. Hort. Sci. 62:21-30.

*LeClerg, E.L.; Warren, H. and Clark, A.G. (1962). Field plot technique. Burgess Publ. Co., Minneapolis, 2nd Ed. pp. 373.

Livermore, J.R. (1927). A critical study of some of the factors concerned in measuring the effect of selection in the potato. J. Am. Soc. Agron. 19: 857-895.

Lyon, T.L. (1911). Some experiments to estimate errors in field plot tests. Proc. Am. Soc. Agron. 3:89-114.

McClelland, C.K. (1926b). Some determinations of plot variability. J. Am. Soc. Agron. 18: 919-923.

MacDonald, D. Fielding, W.L. and Ruston, D.F. (1938). Experimental methods with cotton. The desing of plots for variety trials. J. agric. Sci., Camb. 29:35-47.

Marane, A. (1963). Estimation of optimum plot size using Smith's procedure. Agron. J. 55: 503.

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

Mercer, W.B. and Hall, A.D. (1911). The experimental error of field trials. J. agric. Sci., Camb. 4: 107-132.

Miller, J.D. and Koch, E.J. (1962). A plot technique study with birdsfoot trefoil. Agron. J. 54: 95-97.

*Nonnecke, I.L. (1959). The precision of field experiments with vegetable crops as influenced by plot and block size and shape. I Sweetcorn. Canad. J. Plant. Sci. 39: 443-457.

Nigam, A.K. and Gupta, V.K. (1979). Handbook on analysis of agricultural experiments. First ed. IASRI, New Delhi. pp. 1-7.

Pahuja, A.N. and Mehra, R.B. (1981). Plot size for co-ordinated varietal trials in chickpea. Indian J. agric. Sci. 51:80-82.

Panse, V.G. (1941). Studies in the technique of field experiments. Size and shape of blocks and arrangement of plots in cotton trials. Indian J. agric. Sci. 11: 850-865.

Panse, V.G. and Sukhatme, P.V. (1954). Statistical methods for agricultural workers. ICAR, New Delhi. pp.137-141.

Prabhakaran, P.V.; Balakrishnan, S. and Mary George (1978). optimum plot size for field trials with banana. Agri. Res. J. Kerala 16: 35-38.

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

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.

Pointer, J. . and Koch, E.J. (1961). Estimates of optimum plot size from uniformity data in Maryland tobacco. Tobacco, N.Y. 153: 26-31.

Rambabu; Agarwal, M.C.; Samraj, P. and Chinnamani (1980). Size and shape of plots and blocks for field trials on natural grasslands in Nilgiri hills. Indian J. agric. Sci. 50: 598-603.

Rampton, H.H. and Peterson, R.G. (1962). Relative efficiency of plot sizes and number of replications as indicated by yields of orchard grass seed in a uniformity test. Agron. J. 54: 247-249.

*Rigney, J.A. (1948). Techniques in field plot experimentation. Proc. Auburn Conf. on Statistics, 1948, pp. 39-44.

*Robinson, H.F.; Rigney, J.A. and Harvey, P.H. (1948). Investigations in plot technique with peanuts. Tech. Bull. N. Carol. agric. Exp. Stn. 86: 1-19.

Sardhana, M.G.; Sreenath, P.R. and Malhotra, U.P. (1967). Size and shape of plots and blocks in field trials with potato. Indian J. agric. Sci. 37: 348-355.

Saxena, P.N.; Kavitkar, A.G. and Monga, M.K. (1972). Optimum plot size for oat grown for fodder. Indian J. agric. Sci. 42: 63-69.

Sen, A.R. (1963a). Use of pre-treatment data in designing experiments on tea. Emp. J. exp. Agric. 31:41-49.

Siao,F. (1935). Uniformity trials with cotton. J. Am. Soc. Agron. 27: 974-979.

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

Smith, F.L. (1958). Effects of plot size, plot shape and number of replication on the efficiency of bean yield trials. Hilgradia. 28: 43-63.

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

Smith, L.H. (1907-1909). Plot arrangement for variety experiments with corn. Proc. Am. Soc. Agron. 1: 84-89.

Sreenath, P.R. (1973). Size and shape of plots and blocks in field trials with "M.P.Chari" sorghum. Indian J. agric. Sci. 43: 110-112.

Stephens, J.C. and Vinall, H.N. (1928). Experimental methods and probable error in field experiments with sorghum. J. agric. Res. 37: 629-646.

Swanson, A.F. (1930). Variability of grain sorghum yields as influenced by size, shape and number of plots. J. Am. Soc. Agron. 22: 833-838.

Taylor, J.W. (1907-1909). The size of experimental plots for field crops. Proc. Am. Soc. Agron. 1: 56-58.

Torrie, J.H.; Schmidt, D.R. and Tenpas, G.H. (1963). Estimates of optimum plot size and shape and replicate number for forage yield of alfalfa-bromegrass mixtures. Agron. J. 55: 258-260.

Vagholkar, B.P.; Apte, V.N. and Iyer, S.S. (1940). A study of plot size and shape technique for field experiments on sugarcane. Indian J. agric. Sci. 10: 388-403.

*Wassom, C.E. and Kalton, R.R. (1953). Estimation of optimum plot size using data from bromegrass uniformity trials. Res. Bull. Iowa agric. Exp. Stn. 396: 296-320.

Weber, C.R. and Horner, T.W. (1957). Estimates of cost and optimum plot size and shape for measuring yield and chemical characters in soyabeans. Agron. J. 49: 444-449.

*Westover, K.C. (1924). The influence of plot size and replication on experimental error in field trials with potatoes. Res. Bull. W. Va. agric. Exp. Stn. 189:1-32.

Wood, T.B. and Stratton, F.J.M. (1910). The interpretation of experimental results. J. agric. Sci., Camb. 3: 417-440.

* Originals not referred.

APPENDIX

Appendix I. The yield data.

Weight of brinjal fruits in Kg.

Rows	1	2	3	4	5	6	7	8	9	10	11
1	2.14	0.68	0.86	0.73	0.34	0.24	0.10	0.43	0.62	0.75	0.18
2	.50	.67	.16	1.02	1.56	1.02	.16	1.48	1.30	.20	.52
3	.70	.60	.44	.38	.28	.12	.40	.12	.48	.36	.27
4	.16	1.76	1.48	1.07	1.44	.68	.76	1.04	.20	.42	.80
5	.62	.80	.52	.14	.72	.38	.36	.38	.47	.42	.12
6	.72	.66	.14	.38	.90	1.14	.54	.97	.14	.24	1.14
7	.90	.40	.61	1.28	.60	.60	.78	1.07	.10	.11	.56
8	.54	1.01	.42	.36	.63	.42	.12	.22	.32	.53	.30
9	.65	.80	.55	.33	.54	.50	.17	.14	.33	.98	.52
10	1.19	.80	.42	.40	.65	.16	.80	.38	.40	.49	.36
11	.38	.60	1.03	.36	.28	.70	.48	.42	.42	.44	.60
12	.12	.58	.65	.62	.20	.23	.20	.16	.60	.42	.24
13	.65	.65	.39	.34	1.19	.18	.3	1.28	.54	.20	.68
14	.07	1.60	.24	1.14	.38	.16	.58	.48	.19	.40	.14
15	.71	.82	.86	.56	.28	1.70	.30	.16	.60	.96	.14
16	.38	.30	.46	.60	.70	.52	1.28	.96	.92	.22	.78
17	1.68	.93	.98	.75	.12	1.12	1.32	.36	.42	.47	.80
18	.20	.76	.49	.62	.16	.62	.62	.33	.66	.36	.82
19	.61	.38	.44	.44	.25	.32	.34	.14	.14	.16	.69
20	1.14	.68	.[illegible]6	.42	.65	.25	.10	.70	.28	.44	.18
21	.50	.72	.16	1.02	1.56	1.06	.16	.46	.34	1.30	.20
22	.70	.17	.44	.38	.28	.12	.18	.12	.48	.30	.27
23	.16	1.76	1.48	1.07	1.44	.68	.76	1.04	.20	.42	.80
24	.07	.48	.47	.14	.50	.38	.38	.16	.15	.42	.12
25	.05	.66	.14	.38	.58	.34	.54	.97	.19	.24	.16
26	.90	.40	.42	1.28	.60	.60	.78	.61	.10	.11	.56
27	.80	.66	.42	.80	.14	.42	.12	.22	.32	.53	.30
28	.23	.80	.14	.33	.55	.52	.17	.60	.33	.22	.52
29	1.19	.80	.42	.40	.18	.16	.80	.56	.40	.36	.36
30	.38	.29	.34	1.00	.28	.52	.48	.42	.40	.65	.18
31	.12	.18	.30	.65	.20	.23	.20	.16	.60	.42	.24
32	.66	.23	.20	.34	.07	.18	.30	.60	.54	.20	.68

Contd..

Appendix I (contd...)

rows	Columns 12	13	14	15	16	17	18	19	20	21	22
1	0.18	0.20	0.67	0.30	0.46	0.48	0.55	0.32	0.50	1.12	0.56
2	.20	.52	1.14	.66	.24	.98	.54	.42	.56	1.04	.62
3	.27	.30	.03	.48	.44	.62	.44	1.03	.42	.16	.42
4	.80	.80	.36	.41	1.87	.74	.65	.38	.66	.44	.54
5	.12	1.08	.88	.20	.78	.49	.94	.26	.36	.84	.96
6	1.14	.93	.80	.71	.58	.28	1.19	.66	.20	.60	.72
7	.56	.76	.80	1.69	.14	.44	.23	.49	.16	.97	.98
8	.30	.12	.24	.24	.29	.30	.40	.91	.12	.20	.70
9	1.04	.52	.76	.34	.80	.38	.78	1.15	.55	.20	.22
10	.98	.60	.70	.61	.42	.62	.65	.90	.17	.48	1.09
11	.20	.58	.14	.80	.86	.20	1.18	.60	.20	.60	.93
12	.68	1.30	.30	.56	.30	.20	.16	.68	.61	.44	1.08
13	.14	.65	.38	.25	.24	.12	.24	2.23	.78	.92	.84
14	.60	.08	.40	.26	.16	.65	.75	.24	.10	.78	.72
15	.66	.56	.66	1.04	.92	1.30	.40	1.74	.30	.52	2.32
16	.72	1.60	1.15	.14	.20	1.12	.20	1.03	.22	.56	1.18
17	.21	.82	1.08	.98	.44	.62	.25	.32	.78	1.08	1.03
18	1.06	.40	.13	.94	.23	.[illegible]8	.28	.20	.78	.70	.86
19	.24	.22	.40	.33	.71	.20	.78	.78	1.13	.58	1.28
20	.18	.20	.20	.30	.20	.48	.39	.32	.50	.18	.56
21	.52	1.14	.60	.24	1.48	.52	.24	.40	.20	.12	.10
22	.40	.63	.48	.44	.62	.84	.86	.19	.60	.42	.25
23	.80	.36	.41	1.87	.74	.58	.38	.66	.44	.54	.46
24	1.08	.68	.20	.78	.20	.94	.26	.36	.84	.96	.12
25	.24	.41	.15	.58	.28	.36	.66	.20	.60	.72	.71
26	.62	.60	1.69	.14	.60	.23	.49	.74	.61	.67	.40
27	.12	.24	.24	.29	.30	.40	.91	.12	.20	.70	.60
28	1.04	.52	.76	.34	.80	.29	.78	1.15	.55	.20	.22
29	.30	.12	.70	.12	.42	.62	.12	.90	.17	.28	1.09
30	.20	.26	.14	.80	.44	.20	1.18	.46	.20	.60	.55
31	.16	1.30	.30	.56	.30	.20	.16	.68	.51	.44	1.08
32	.14	.40	.14	.25	.24	.24	.24	2.23	.78	.92	.84

Contd....

Appendix II. The data on number of fruits.

Rows	Columns 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	10	4	5	3	2	1	2	5	6	2	3	1	1	2	3
2	4	6	1	11	13	7	1	4	2	8	1	2	5	5	2
3	6	2	2	1	2	1	4	1	6	2	5	5	4	4	5
4	1	13	13	12	12	4	5	10	1	3	6	7	1	5	9
5	4	4	6	3	5	5	4	6	5	5	1	8	6	1	6
6	4	6	3	3	4	2	7	2	2	6	4	9	7	3	4
7	12	3	4	11	6	6	4	1	3	5	2	7	4	16	3
8	9	2	3	7	4	5	3	5	2	5	3	1	1	2	1
9	6	4	3	2	7	3	2	4	4	2	5	5	4	5	3
10	2	5	2	9	1	4	10	6	1	2	3	5	7	2	2
11	4	3	10	2	2	6	2	1	7	8	3	2	9	2	5
12	3	7	6	4	1	2	1	4	6	6	1	8	4	6	5
13	9	4	1	2	7	1	3	9	5	2	6	3	7	4	2
14	8	3	1	5	2	8	6	3	1	3	6	8	8	2	2
15	1	4	7	3	2	11	2	2	4	7	2	5	4	5	4
16	7	4	4	6	4	11	3	7	2	6	3	4	7	2	2
17	11	3	2	6	9	6	10	4	2	4	4	3	7	3	5
18	1	8	2	5	1	3	6	2	5	7	8	7	3	3	5
19	4	8	4	3	1	6	2	3	1	5	2	4	2	3	2
20	5	3	2	7	8	4	3	9	2	5	1	2	4	1	3
21	9	6	5	12	2	4	2	4	6	3	3	1	4	2	2
22	5	2	1	3	13	5	1	1	2	5	1	3	1	4	5
23	7	13	2	3	2	2	4	10	6	6	5	9	6	5	9
24	2	4	13	11	12	6	7	6	1	5	6	7	7	1	6
25	3	6	6	7	5	5	4	2	5	5	1	1	4	3	4
26	2	3	4	2	4	3	3	1	2	2	4	5	1	12	3
27	10	2	5	2	6	1	2	5	3	1	2	3	4	2	1
28	11	4	2	2	4	6	4	4	2	8	3	2	5	5	3
29	5	2	3	4	7	2	2	11	4	6	5	8	9	7	2
30	4	4	4	2	9	2	2	1	6	2	2	3	4	2	5
31	3	8	8	5	2	8	3	4	7	3	3	8	7	6	5
32	9	3	9	3	2	10	6	9	6	7	1	5	8	4	2

Contd....

Appendix II (Contd...)

columns

Rows	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	3	5	2	2	5	3	4	2	4	3	4	3	5	4	6
2	3	1	4	2	1	6	1	4	3	11	2	6	4	9	7
3	5	3	2	1	3	2	4	2	2	2	2	6	5	8	11
4	5	2	3	2	4	5	3	4	1	5	1	5	2	3	20
5	4	12	2	6	6	11	4	1	5	6	1	4	4	5	4
6	9	7	6	4	5	5	6	17	7	8	7	11	7	5	12
7	2	2	5	10	12	4	[illegible]	3	9	4	16	5	7	3	4
8	4	4	7	2	1	6	4	4	7	6	5	2	2	6	5
9	4	1	8	11	5	2	8	5	11	4	6	3	2	3	6
10	2	4	1	6	2	4	6	1	16	10	16	12	6	2	3
11	2	1	9	4	1	6	2	1	7	3	7	5	5	2	10
12	3	1	1	4	2	1	8	15	3	7	3	3	8	8	2
13	2	3	5	14	6	10	4	6	1	11	9	10	12	3	2
14	5	2	4	2	1	4	12	11	5	13	1	4	3	4	11
15	6	8	9	2	10	4	5	13	4	4	6	7	4	6	8
16	6	7	8	4	7	6	5	9	8	2	2	6	5	2	1
17	2	7	2	3	4	7	5	6	2	4	8	3	22	9	24
18	2	6	2	2	5	6	2	1	5	5	2	3	1	1	7
19	13	5	3	8	9	4	9	6	1	4	6	2	7	7	2
20	6	1	8	4	2	4	3	3	1	5	6	7	3	8	2
21	3	2	2	2	5	2	4	4	5	3	4	3	5	4	6
22	3	12	4	1	1	5	1	2	5	4	2	6	4	9	7
23	5	7	12	2	2	3	11	4	4	7	5	2	6	4	8
24	6	2	3	6	4	5	3	1	9	6	2	5	7	3	20
25	4	4	2	4	6	4	4	17	7	7	7	11	7	5	6
26	9	1	6	10	5	6	6	3	11	4	16	4	2	5	12
27	2	4	5	2	12	2	3	4	15	6	5	5	2	3	3
28	4	1	7	11	1	4	8	5	8	4	6	2	6	6	5
29	4	1	8	6	5	6	6	1	3	10	16	3	5	3	6
30	2	3	2	4	2	1	2	1	1	3	7	9	8	2	6
31	2	2	9	4	1	10	8	15	5	7	3	4	12	2	10
32	3	8	5	14	2	4	4	6	4	11	9	8	3	8	3

Appendix III. Data on primary branches.

Columns

Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	6	3	3	3	3	2	3	2	2	5	4	4	3	3	4
2	6	9	4	3	3	6	6	4	2	4	3	5	3	3	4
3	3	5	2	4	5	2	4	3	6	3	4	1	3	3	2
4	2	3	5	3	9	6	5	5	2	3	4	3	2	4	4
5	3	4	5	3	4	4	3	4	4	7	5	4	4	5	9
6	3	3	4	2	4	3	4	7	2	3	3	4	3	4	4
7	5	4	3	4	7	8	8	10	4	6	2	3	7	4	2
8	6	3	4	7	6	1	5	4	3	4	4	5	3	6	4
9	3	6	5	4	2	5	4	4	6	7	4	5	7	4	1
10	5	5	6	3	3	2	3	5	2	4	8	5	2	5	3
11	5	6	5	2	3	5	4	8	3	1	5	4	1	3	8
12	9	2	1	3	3	9	3	4	3	4	5	1	15	6	9
13	3	9	7	4	12	6	6	7	2	6	6	6	5	6	4
14	2	4	6	5	2	2	6	4	3	3	2	5	4	3	6
15	8	6	4	9	3	7	4	3	6	6	2	3	6	3	7
16	2	5	4	8	5	4	10	5	8	6	9	7	3	5	6
17	9	3	1	5	5	7	7	2	7	4	9	5	9	3	7
18	1	4	9	4	4	4	2	9	6	3	6	4	6	8	11
19	3	6	4	6	2	2	3	5	9	5	5	5	5	3	7
20	4	4	3	4	4	7	5	4	4	5	9	4	8	6	7
21	3	4	7	2	3	3	4	3	4	4	3	5	4	4	6
22	5	3	6	4	4	5	4	5	4	5	4	5	3	2	2
23	2	4	3	5	3	3	4	4	3	1	2	5	3	3	5
24	8	8	1	5	4	1	3	8	3	2	1	2	5	4	7
25	2	3	6	8	7	9	3	6	3	10	4	2	14	6	2
26	3	4	4	9	4	4	10	3	7	8	4	15	6	6	9
27	7	4	5	1	6	4	2	3	5	6	2	12	3	8	4
28	9	3	3	6	8	7	9	5	3	6	7	3	2	6	6
29	10	6	9	9	4	8	4	3	1	6	5	8	3	4	6
30	8	4	3	1	6	5	8	2	2	3	4	4	3	4	4
31	5	3	1	2	5	4	4	5	4	7	3	4	9	6	11
32	3	9	2	6	5	4	8	3	2	6	3	4	5	7	5

Contd....

Appendix III (Contd....)

Rows	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	2	2	3	2	3	3	5	4	5	4	2	4	3	4	4
2	4	3	1	2	5	3	3	5	4	4	2	2	5	6	4
3	3	4	9	5	6	3	2	5	4	3	4	5	8	3	6
4	5	3	3	6	4	3	3	6	5	7	1	2	2	2	2
5	4	8	6	7	7	7	4	4	2	3	3	3	3	4	9
6	3	5	4	4	6	3	3	5	5	6	8	5	8	6	5
7	4	5	3	8	4	6	7	11	7	7	7	5	5	4	6
8	4	5	4	5	4	5	3	2	2	5	6	9	5	2	6
9	5	6	4	7	6	3	5	6	7	5	4	4	4	2	9
10	6	6	5	7	3	6	7	5	4	5	5	6	4	4	4
11	3	2	1	2	5	4	7	5	3	2	2	2	4	5	5
12	1	5	3	6	6	11	9	3	9	7	3	8	9	9	11
13	3	12	16	8	6	3	6	6	5	9	3	7	3	3	9
14	2	3	9	2	5	8	6	5	11	6	2	3	3	7	8
15	9	3	6	3	10	4	2	14	6	2	2	3	4	12	1
16	8	7	5	8	7	6	10	5	5	3	4	6	4	6	5
17	3	4	5	6	7	8	9	9	4	5	4	4	5	5	6
18	8	1	8	1	2	9	8	4	4	4	6	7	5	4	5
19	8	5	4	3	9	12	5	6	8	9	4	1	6	2	8
20	7	4	4	4	4	3	3	3	3	4	9	3	4	5	3
21	3	5	5	6	8	5	8	6	5	3	3	4	2	4	3
22	5	6	9	5	2	6	6	3	4	7	6	1	5	4	3
23	4	4	2	2	5	6	4	6	9	4	3	3	6	6	4
24	5	3	2	2	2	5	4	5	5	6	5	2	3	5	4
25	2	3	4	12	1	5	8	7	7	3	4	5	6	7	8
26	7	5	1	9	3	5	3	9	6	4	3	3	5	6	3
27	4	5	5	5	3	3	5	2	4	2	6	4	5	2	3
28	3	2	6	3	2	7	3	3	3	4	3	3	5	16	2
29	3	5	4	0	7	1	6	2	3	8	5	4	10	9	4
30	4	5	6	1	6	6	8	2	5	4	4	4	3	4	6
31	2	4	4	5	2	3	3	4	3	3	6	4	4	5	5
32	4	4	6	5	9	9	5	5	4	7	3	5	5	2	9

Appendix IV. The data on height of the plant.

Height in cm. Columns

Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	56	62	66	48	39	62	60	55	44	45	40	38	55	27	22
2	100	88	47	59	45	52	40	29	38	58	53	47	55	56	43
3	60	53	52	60	56	50	25	48	39	41	45	68	53	66	60
4	45	54	59	74	54	70	57	58	57	59	80	58	70	60	80
5	37	42	40	43	48	49	47	56	61	48	55	50	59	55	55
6	37	65	60	31	48	49	50	77	40	45	46	49	52	49	60
7	58	56	48	46	65	60	70	62	52	58	43	46	75	69	70
8	45	4[illegible]	6[illegible]	40	40	40	40	50	47	54	52	30	21	33	47
9	45	51	49	10	33	48	44	63	35	63	51	69	66	50	58
10	51	51	55	54	53	56	57	46	56	54	50	43	44	60	43
11	40	60	47	51	46	49	50	56	46	32	48	53	42	45	69
12	43	48	49	39	48	47	38	24	44	30	41	54	60	43	54
13	42	43	48	30	61	45	42	77	62	63	73	48	45	50	50
14	46	48	52	44	18	57	56	26	47	50	47	46	60	49	50
15	59	56	54	57	40	56	44	39	55	56	29	53	57	56	62
16	39	44	55	52	49	48	57	59	62	63	62	69	26	62	48
17	68	63	48	38	48	52	69	67	65	55	60	39	48	53	54
18	49	58	56	46	27	35	38	43	50	32	45	39	56	48	56
19	33	55	47	46	18	26	32	43	46	49	60	67	46	43	45
20	70	45	49	73	78	50	62	63	71	50	52	80	77	57	60
21	52	48	65	68	59	38	83	51	48	79	60	55	53	84	61
22	57	58	93	64	65	[illegible]8	60	65	45	57	41	45	50	57	65
23	77	63	70	56	43	57	64	35	59	66	66	57	60	65	71
24	65	62	59	61	104	107	82	110	112	50	54	65	54	78	[illegible]8
25	4[illegible]	48	104	68	51	56	61	60	62	56	65	54	73	68	60
26	57	55	52	60	65	62	58	60	67	69	48	62	54	46	49
27	61	59	54	90	65	58	54	56	53	57	5[illegible]	45	53	5[illegible]	46
28	59	52	66	56	58	56	66	68	78	82	51	51	5[illegible]	45	76
29	56	59	48	57	50	73	77	54	66	40	40	3[illegible]	35	38	75
30	57	74	52	63	60	46	50	72	10[illegible]	45	57	63	89	75	[illegible]1
31	70	102	64	64	60	56	54	54	55	74	58	54	67	44	56
32	42	54	78	88	44	[illegible]9	63	[illegible]5	64	49	54	50	49	48	3[illegible]

Contd....

Appendix IV (Contd...)

Columns

Rows	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	34	28	49	32	47	32	47	63	51	51	43	32	36	44	47
2	50	75	48	45	34	33	38	47	50	55	29	43	61	40	48
3	41	45	53	57	49	63	43	60	56	48	52	59	60	37	74
4	75	46	52	68	53	48	49	64	80	65	50	58	[illegible]	60	74
5	52	68	63	60	71	59	48	57	20	30	23	45	52	71	90
6	52	57	49	[illegible]	40	60	62	62	88	80	75	65	80	50	61
7	67	58	54	57	46	54	54	97	68	79	68	70	66	62	67
8	68	40	44	54	50	36	40	87	57	77	60	40	45	52	62
9	50	41	74	52	30	50	87	75	50	62	60	46	50	50	64
10	46	50	62	65	30	56	55	57	49	69	64	56	60	39	50
11	64	52	48	45	40	47	55	56	52	22	74	78	66	35	71
12	55	43	30	56	52	60	68	60	47	72	69	62	62	62	57
13	46	49	60	66	69	30	70	60	48	97	63	66	23	32	58
14	53	52	69	35	48	72	71	65	62	80	64	72	50	50	69
15	66	40	70	76	62	50	49	82	75	46	46	56	50	76	51
16	59	67	51	66	59	65	68	49	72	47	62	63	60	62	30
17	26	[illegible]	42	26	56	69	68	73	45	47	39	52	54	62	57
18	60	55	53	71	68	42	49	42	20	43	48	59	56	50	52
19	40	39	49	39	69	27	58	52	47	50	63	46	50	52	55
20	64	68	64	59	61	106	67	52	57	68	120	50	61	48	97
21	59	64	49	99	95	45	57	59	70	67	64	49	45	84	103
22	57	39	77	46	39	69	67	82	52	48	70	75	59	54	83
23	63	72	62	54	49	39	45	49	56	60	48	43	53	62	63
24	67	62	51	49	54	51	73	58	62	50	55	57	61	103	71
25	70	57	69	48	68	73	74	73	62	90	97	78	77	74	70
26	53	58	73	60	70	62	40	67	44	39	69	60	47	60	63
27	45	52	49	63	74	51	56	45	51	56	45	51	56	63	50
28	56	87	42	51	56	58	67	50	43	48	51	52	52	53	42
29	47	49	48	88	48	50	47	44	45	58	57	46	48	49	49
30	80	65	53	44	64	53	55	50	58	56	38	42	52	[illegible]	53
31	60	104	72	70	67	50	99	40	42	48	48	64	51	44	66
32	44	52	22	38	55	89	39	68	49	40	43	72	81	42	44

OPTIMUM PLOT SIZE FOR FIELD EXPERIMENTS ON BRINJAL

BY
V. HARIHARAN

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the

requirements for the degree of

Master of Science (Agricultural Statistics)

Faculty of Agriculture

Kerala Agricultural University

Department of Statistics

COLLEGE OF VETERINARY & ANIMAL SCIENCES

Mannuthy, Trichur.

1981

ABSTRACT

A uniformity trial in brinjal (*Solanum melongena* L.) was conducted at the Main Campus of the Kerala Agricultural University, Vellanikkara during the third crop season, 1980. Observations on yield, number of fruits, primary branches and height of each plant was recorded at time of harvest in small units each of size 1.08 m^2 (2 rows x 2 plants at 60 x 45 cm spacing).

The variability of each plot size and shape was determined by calculating the coefficient of variation. It was observed that an increase in the plot size in either direction decreased the CV. But the decrease was more rapid along N-S direction. Long and narrow plots yielded lower CV than approximately square plots.

The observed relation between plot size and variance was in conformity with the Fairfield Smith's variance law. At larger plot sizes, the regression line showed a tendency to curve down although negligible.

The optimum plot size observed through Smith's method and maximum curvature method was almost the same. From the above considerations, a plot size of 8.64 m^2 (9.6 m x 0.9 m) was found to be most advisable for conducting most of the field experiments in brinjal.

The efficiency of the plot decreased as the size of the plot was increased. There is a general decrease of block efficiency with increasing block size. More compact blocks of the same size show a higher efficiency. Blocks laid out perpanticular to the direction of fertility gradient removed largest variation.

The number of replications and total area of land required to give 5% SE of the mean were calculated. For the same number of lots per block smaller plots require more replication but less total area than larger plots. But increasing the number of replications rather than plot size was found more advantageous for a fixed experimental area.

The fertility contour map of the field revealed that the land is not very homogeneous as far as the fertility pattern is concerned.

By assuming arbitrary values of the cost proportional to the number of replications and the cost proportional to the total area per treatment, the optimum plot size for field experiments in brinjal was computed using a linear cost function.

*Beattie, J.H. and Boswel, V.R. (1936). Statistical studies on apperently uniform fields of carrots and onions on peat soils. Die Gartenbauwissenschaft 10: 279-288.

Bose, R.D. (19[illegible]5). Some soil-heterogeneity trials at Pusa and the size and shape of experimental plots. Indian J. agric. Sci. 5: 579-608.

Bose, S.S.; Khanna, K.L. and Mahalanobis, P.C. (1939). Note on the optimum shape and size plots for sugarcane experiments in Bihar. Indian J. agric. Sci. 9: 807-816.

Brim, C. . and Mason, D.D. (1959). Estimates of optimum plot size for soyabean yield trials. Agron. J. 51: 331-334.

*Bryan, A.A. (1931). A statistical study in the relation of size and shape of plot and number of replications to precision in yield comparisons with corn. Rep. Iowa agric. Exp. Stn.

*Bryan, A.A. and Arthur, A. (1933). Factors affecting experimental error in field plot tests with corn. Res. Bull. Iowa agric. Exp. Stn. 163:243-280.

Christidis, B.G. (1931). The importance of the shape of plots in field experimentation. J. Agric. Sci., Camb. 21:14-37.

*Cochran, W.G. (1937). Catalogue of uniformity trial data. Suppl. Jl. R. statist. Soc. 4:233-253.