Journal of AgriSearch 4(1):60-67
An Open Access International Peer Reviewed Quarterly
ISSN : 2348-8808 (Print), 2348-8867 (Online)
http://dx.doi.org/10.21921/jas.v4i1.7422

Efficiency of Optimum Plot Size using Information of Previous Experiments Conducted in Split Plot Design

RAMESH CHANDRA BHARATI, KAUSHAL KISHOR CHAUDHARY[1], ANIL KUMAR SINGH, ABHAY KUMAR, UJJWAL KUMAR AND NARESH CHANDRA

ICAR Research Complex for Eastern Region, Patna, Bihar, India

ARTICLE INFO

Received on	:	07.02.2017
Accepted on	:	15.02.2017
Published online	:	01.03.2017

ABSTRACT

The optimum plot size is required at the time of experiment lay out to obtain the accuracy and reliability of the experimental result. In absence of uniformity trail, an alternative procedure is described to get the idea of optimum plot size. The process involves for determining the accurate estimate of soil heterogeneity coefficient followed by optimum plot size through the past experimental data of split plot design and the expression for the determination of soil heterogeneity has been derived and illustrated through several artificial and real data. The result indicated the considerable gain in efficiency to the tune of 19 and 22 per cent in some cases. This procedure leads to the saving of plot size from 20 per cent to 75 per cent.

Keywords : Plot size, heterogeneity, split plot design,

INTRODUCTION

The size of the plot is an essential factor to be decided while laying out the field experiment. The estimates obtained from the experiment are based on the certain precision. The studies show that larger the plot size, lesser will be the variance, but we cannot have the much larger plot as it will invalidate the assumption of blocking and will increase the cost of experimentation. Thus the optimum plot size for an experiment is necessary, which is a function of soil heterogeneity and other cost considerations There are several methods for determining the optimum plot size. But the most widely used methods are maximum curvature method and Fair field Smith's variance law. The maximum curvature method involves combining the basic units of uniformity trials either row wise or column wise or both ways to form new units. The maximum curvature graph of C.V. against plot size is taken as optimum plot size. In case of Fair field Smith's variance law an empirical model describing the relationship between plot size and variances of mean per plot is fitted. The value of regression coefficient of equation Vx = V1/Xb gives the estimation of correlation between contiguous units and it ranges from 0 to 1.

In past, the estimate of the soil heterogeneity has been obtained from uniformity trial data which follows a widely used Fairfield Smith's variance Law (1938). Koch and Rigney (1951) obtained the soil heterogeneity through previously conducted experimental data. Hatheway and Williams (1958) used weighted regression coefficient for estimating the soil heterogeneity through randomized block design (RBD) on previously conducted experimental data. While Islam *et al.* (2000) used the unweighted regression coefficient through split-split plot design. Their study shows that weighing the variance-covariance matrix results in the efficient estimation of optimum plot size. But, no methodology has been defined to determine the optimum plot size through past experimental data using weighted regression soil heterogeneity coefficient in split plot design which is the most commonly and widely used design in agricultural field. This present study has been undertaken to define the procedure by deriving the expression for weighted regression coefficient in split plot design estimating soil heterogeneity and studying the cost estimates in the treatment of main and sub-plot with following objectives : To derive the expression for weighted regression coefficient in split plot design, the steps involved are (a) estimation soil heterogeneity, (b) estimation of plot size and (c) measuring the stability of ratio of cost estimates w.r.t. main plot and sub plot.

Numerous works on the determination of optimum plot size are available. But most of the work pertains to uniformity trial experiment. Very little work is available on determination of optimum plot size through past experimental data. Smith (1938) developed an empirical relationship between plot size and plot variance. This variance low is expressed by the equation.

Log Vx = Log V1- b log x

Where, Vx is the variance of yield per unit area among plots of size 'x' units. V1 is the variance among plots of size unity and 'b' the regression coefficient indicates the relationship between adjacent individuals or units.

Koch and Rigney (1951) estimated soil heterogeneity from past field experiments. The quantity used by them as the, measures of soil heterogeneity was the regression coefficient 'b' as described by Smith. They reported from 15 experiments on tobacco which gave an average 'b' value of 0.55 for yield. For eight of the experiments 'b' values were calculated for crop value also and gave an average 'b' for this character of 0.54. Ten cotton experiments were also examined by them and an average 'b' and value of 0.49 was obtained. Hatheway and Williams (1958) presented a method of weighting observed variances of different size plots which leads to estimates of soil

[1]Department of Statistic Mathematics and Computer Application, Dr. Rajendra Prasad Central Agricultural University, Pusa Samastipur Bihar, India
*Corresponding Author Email : drrcbharati@yahoo.com

heterogeneity coefficient with minimum variance. This method is suitable for both of uniformity trial data and experimental data. The ANOVA is constructed by them to simulate the variances of different sizes plot derived directly from uniformity trial data. Agarwal and Deshpande (1967) noted that the C.V. decreased with increase in plot size for any given shape of plot. The reduction in C.V. with increased plot size was practically negligible beyond 36.6m2 in the case of paddy. The number of replications required for a given level of accuracy for a fixed block size decreased with the increase in plot size and the area required with smaller plots was less. For a given size and shape of plot, block efficiency was more for compact block. There was an appreciable gain in information due to compounding with larger plots. Incomplete block with small plots for varietal trials were not advantageous as compared to R.B.D.

Sardana *et al.* (1967) noted that in the case of potato the C.V. was found to decrease with increase in the plot size upto 8.40 m beyond which the decrease was not appreciable. This indicated that the smallest plot was most efficient. When cost considerations were taken into account the smallest size was found to be optimum with given size and shape of the plot. Block efficiency generally decreased with increase in the block size, but the shape of the block had no consistent effect. Agarwal *et al.* (1968) found that by arranging the trees row wise the reduction in C.V. was more rapid than when the trees were arranged column-wise. This indicated row-wise arrangement of plots ensured more homogeneity than arranging them column-wise. The C.V. decreased with the increasing the size of plots. The formation of blocks was not helpful in reducing variation. Gopani *et al.* (1970) noted that the C.V. decreased with an in increase in the plot size. When a limited area was available for experiments, the smallest plot size was the most efficient. The number of replications required for a given level of accuracy decreased with an increase in the plot size. The block efficiency decreased with an increase in the plot size. Shankar *et al.* (1972) showed that for any given shape of plot the C.V. decreased with an increase in the plot size. For a given size of plot, the plots elongated in the North-South direction (across the rows) showed less variability than these elongated in the West-East direction. For a given experimental area, the efficiency of the smallest plot was the highest. Sreenath (1973) found that the C.V. decreased with increase in the plot size. The equation Y = aX-b gave a good fit to the relationship between C.V. and plot size. Plot shape had no consistent effect on the C.V. but long and narrow plots running East-West showed lower C.V. with fixed experimental resources or cost, small plots were more efficient. Sreenath and Marwaha (1977) found that in case of cowpea the C.V. decreased with the increase in the plot size. The well-known equation Y = aX-b gave a very good fit to the under lying relation between the C.V. (y) and plot size (xm2). The shape of the plot had no consistent effect on the C.V. The C.V. remained comparatively unchanged for the .block sizes 4, 6 and 10 and increased with the increase in block size thereafter. Babu and Agrawal (1980) found that the C.V. decreased with an increase in plot size upto 8 m^2. The equation Y = aX-b gave a good fit to the relationship between C.V. (y) and plot size (x). Plot shape had no consistent effect on C.V. for grasses.

Pahuja and Mehra (1981) noted that in case of chickpea with 4 replications maximum precision could be obtained from a plot of size 1.80m x 5.00 m (5 m long, 6 rows spaced 30 cm apart). However, with this C.V. values, a difference of less than 17 per cent of the mean could not be detected. Therefore, larger plots were recommended so that differences of 10-15 per cent were detectable. Handa *et al*.(1982) noted that the C.V. decreased with increase in plot size. The rate of decrease was higher for elongation in North-South direction compared with East-West direction. Blocking resulted in greater efficiency. Blocks having upto 9-12 plots and of a shape nearly square were efficient. For practical convenience plots longer in North-South direction and of smallest possible size in nearly square blocks of 9 to 12 plots were the best for oat. Reddy *et al.* (1983) found that a rectangular plot of about 18 m^2 with longer side across the crop rows appeared to be efficient. Blocks laid perpendicular to the above rectangular plots with sizes of about 275 m^2 for sandy loam field and 150 m^2 for loamy sand field were found to be efficient. Also in 1985 they suggested that a plot size of 23 m for caster crop was found to be optimum when the crop was sown as a sole crop on rain feddry land at its optimum inter row distance of 90 cm. Variability due to any given plot size was found to depend on the crop geometry, among other factors. Rao and Prasad (1991) estimated the optimum plot size for yield of black gram. They found orientation of the plots did not affect accuracy of yield estimation. Eye estimation and crop harvests gave similar results. Yield estimation using plot sizes of 15 or 16 m2 and including an adjacent field as a sample unit, improved efficiency compared with the normal 25 m plot size. Lin *et al.* (1996) found that the optimum plot size for field experiments depends on the soil heterogeneity of plots in the field. A field heterogeneity index can be used to calculate optimum plot size, but the use of this index is affected by whether the value is persistent over years and crops. Yield data from four fields at the central experimental farm, Ottawa from 1986 to 1991, were used to investigate the persistence of a field heterogeneity index (b-value). The index was derived from the intra-class correlation in 274 experiments of either barley, oats or soya beans. For each field, in each year, the field map of the index was drawn based on the actual position of experiments in the field. A grid template was placed over the maps and the b-value at each grid point was obtained. The persistence of the index across different years was measured by two statistics: (1) A simple correlation of b-value between two corresponding sets of coordinates and (2) A percentage of the total number of grid points, in each paired set, where the b-value categories matched (b = 0-0.3, 0.3 - 0.7 and 0.7 - 1.0). The former statistics measured the persistence of b- value across years, and the latter measured the pattern persistence, positive correlations were observed in two of the four fields, while the percentage of pattern persistence was 50 per cent or greater in five out of the 10 cases compared.

Saad (1996) investigated the relative efficiency of some experimental designs from optimum plot size and plots for evaluating faba bean yield. Optimum plot size for the two seasons studied was 0.6 x 3.5 m. In terms of experimental design, complete block was more efficient than complete randomization, double control was more efficient than single control, lattice designs were more efficient than randomized complete blocks and higher interaction was more efficient than lower and single factors. Islam *et al.* (2000) estimated soil heterogeneity from split-split plot design. They used a weighted regression analysis method to determine the soil heterogeneity from the ANOVA technique of the above design. They found optimum plot size depends on the relative costs per plot and per unit area. It also depends on high or low value of soil heterogeneity. In the field experiment of chickpea plot size had been taken as 72 m and using the technique they found optimum plot size should be 48 m and this shows approximately 33 per cent area of the field experiment as well as worker cost can be reduced. Hasiza and Kumar (2002) studied on the size and shape of plots with wheat. A uniformity trial conducted at Hisar, Haryana in 1998 on wheat cultivar WH- 533 showed that the percentage coefficient of variation decreased with increase in plot size. The decrease was more rapid for elongation in North-South direction as compared to East-West direction. For a given experiment area, smallest plot was found to be efficient. For a given plot size, the coefficient of variation generally increased. With increased in number of plots per block. For a given block size, blocks elongated in East-West direction were more effective in reducing error variation than those elongated in North-South direction were more effective in reducing error variation than those elongated in North-South direction. Blocking resulted in greater efficiency Smith's law describing relationship between C.V and plot size was found to be satisfactory. Optimum plot size came out to be 5 units (5 m^2) in most of the cases.

MATERIALS AND METHODS

An optimum plot size is the minimum size of the experimental unit for a given degree of precision. In other words the determination of optimum plot size requires the balancing between cost and precision. So, it depends upon soil variability (soil heterogeneity) and the cost structure involved at the various steps of experiments. The estimation of the cost is a tedious task and can be approximated by experienced agronomists. While for the evaluation of soil heterogeneity, the various schemes are available in the literature out of which Smith (1938) process has been proved useful till today. The data needed for the estimation of soil heterogeneity is taken from uniformity trial. This information can also be simulated from the past experimental data. This helps in evaluating the soil heterogeneity coefficient through the past experimental data. In the following sections different methods for determining soil heterogeneity coefficient and the optimum plot size have been described.

Fair Field Smith's Variance Law

The optimum plot size may be fixed using Fairfield Smith's variance law. Fairfield Smith developed an empirical model representing the relationship between plot size and variance of mean per plot. This model is given by the equation, $V_x=V_1/Xb$

Where,

x =The number of basic units in plot,

V_x = The variance of mean per plot of x units.

V_1 = The variance of mean per plot of one unit, and

b = The regression coefficient.

This equation can be written as

$\log Vx= \log V_1 - b \log_x$

The values of V_1 and b are determined by the principle of least squares. The computation of V_x is as in the case of maximum curvature method combine the r x c basic units to simulate plots of different sizes.

Using the equation, $V_x = V_1/x$ and solving for x, we can get the optimum plot size. Here V_x is substituted for C.V.

Estimation of soil heterogeneity from past experimental data

Koch and Rigney (1951) obtained variance of units of several sizes from the past experiment. For example consider a split plot design with 'd' replication 'c' main plot treatments 'b' subplot treatments and 'a' samples then the structure of analysis of variance has been obtained as (Table1).

Table1: Structure of analysis of variance of split plot design

Sources	Degree of freedom	Mean square	Expectation of mean squares
Whole plots	cd - 1		
Replications	d - 1	V 1	S + aP + abB + abcR
Treatments (1)	c - 1		S+aP+ abB + abd T1 + adT1x2
Error (1)	(c - 1) (d - l)	V 2	
Split - plots	cd(b - l)		
Treatments(2)	b - 1		S + aP + ad T 1x2 + acd T 2
Tr(l)xTr(2)	(b - l)(c - l)	V 3	S + aP + ad T 1x2
Error (2)	c (b 1) (d 1)	V 4	S + aP
Sampling error	bed (a-1)		S

Where, S, P, B, R, T1, T2 and T1x2 indicates variance components due to sampling error, subplot error, main plot error, replication effect, main treatment effect, sub-treatment effect and interaction of main and sub plot treatments, respectively.

The estimate of components of variates can be made from the ANOVA structure. The only difference in the expected mean square is split plot design and lattice design in the presence of λ coefficient (lattice design) which varies according to a different type of lattice design. In general, for K^2 lattice design, λ=b(d-1)/d, Where, b is the number of plots in a block and d is the number of complete replication.

To construct the variances of different sizes:

The variance for plot size of complete replication

V1'=V1

The variance between blocks within the whole area

V2' = S + aP + abB+(d-1)/ (cd-1)abc R

The variance between the plots within the whole area

V3' = S + aP+(cd-1)/ (bcd-1)abB +(d-1)/ (cd-1)abcR

The variance between the subplots within the whole area

V4' = S +(bcd-1)/(abcd-1) aP +(cd-1)/(abcd-1)abB +(d-1)/ (abcd -1)abcR

This variance has been reduced to per unit basis by dividing by the number of units in the plot. The regression coefficient of logarithm of variance per plot (y') on logarithm of number of unit (x') is obtained by un-weighted least square fit and is given as

b = {S x' y' -(Sx')(Sy')/n}/ {S (x')2 - S(x')2 /n}

and V(b) = [{ S(y')2 - S(x' y')2/ S(x')2}/(n-2)]/ S(x')2

Estimation of soil heterogeneity from experimental data

Hatheway and Williams (1958) presented a method of weighting observed variances of different size plots. It leads to an unbiased estimates of soil heterogeneity coefficient with minimum variance. This method is suitable for both of uniformity trial data and experimental data. The analysis of variance is reconstructed to simulate the variances of different sizes plot has derived directly from uniformity trial data. It is in the same manner as suggested by Koch and Rigney (1951).

Estimation of soil heterogeneity from experimental data

Islam *et al*.2000, considered arxqxpxs split-split plot design where they have 'r' replications, 'q' manipulates, 'p' subplots and 's' sub-sub plots. They estimated the variances corresponding to different sizes of plots and obtained from usual analysis of variance in split-split plot design (Table 2).

Table 2: Analysis of variance for split-split plot design

Sources	Degree of freedom	Mean square
Replication	(r -1)	V_1
Main plot	(q -1)	
Error (1)	(r -1) (q -1)	V_2
Sub plot	(p -1)	
Main plot x Sub plot	(q -1) (p -1)	
Error (2)	q(r-1) (P -1)	V_3
Sub -Sub plot	(s -1)	
Main plot x Sub-Sub plot	(q -1) (s -1)	
Sub x sub -Sub plot	(s - 1) (p -1)	
Main plot x Sub plot x Sub-sub plot	(q -1) (p -1) (s -1)	
Error (3)	q p (r -1)(s -1)	V_4
Total	r qps -1	

They obtained the variances of plots of various sizes and reduced to a sub plot basis. The replications were regarded as the largest plot, its variance V1' is equal to the replication mean square as it appeared in the analysis of variance, i.e.,

V1' = V1

The total sum of squares for whole plots over the entire area is r (q-1) V2 + (r-1) V1and there were r x q plots, the mean square is

V2' = [r(q-l)V2 + (r-l)V1]/ (rq - 1)

Similarly, they considered

V3' = [rq(p-l)V3 + r(q-l)V2 +(r-1) V1]/ (pqr - 1)

and V4' = [pqr (s-1) V4 + rq (p-1) V3 + r (q-1) V2 + (r-1) V1]/ (sprq-1)

The value of Vx were obtained by dividing each value of V' by the number of units per replication, main plot, sub plot and sub-sub plot putting them on a unit basis and the un-weighted regression coefficient has been obtained by the least square method.(Koch and Rigney, 1951).

Then the estimate of weighted regression coefficient has been obtained. V1, V2, V3 and V4 are independent and their estimated variances are

2V12/(r-1), 2V22/(r-1) (q-1), 2V32/ q (r-1) (p-1), and 2V42/pq (r-1) (s-1) respectively.

Thereafter they determined the variance and covariance of V1', V2, V3' and V4' which are linear function of the former set.

Now, the estimated variance of

V1'=2V12/(r-1)

V2' = [2(r-l)V12+ 2r2(q-l)V22/(r-1)]/ (rq-1)2

V3' = [(2r-l)V12+ 2r2(q-l)V22/(r-1) +2qr2 (p-l)V32/(r-1)]/ (rqp-1)2

V4' = [(2r-l)V12+ 2r2(q-l)V22/(r-1) +2qr2 (p-l)V32/(r-1)+ 2pqr2 (s-l)V42/(r-1)]/ (spqr-1)2

Then, the estimated covariance of V1' and V2' are as follows:

Cov (V1',V2')= {2(r-1)V12} /{(rq-1)(r-1)}
Cov (V1',V3')= {2(r-1)V12} /{(rpq-1)(r-1)}
Cov (V1',V4')= {2(r-1)V12} /{(rpqs-1)(r-1)}
Cov (V2',V3')= {2(r-1)V12+2r2(q-1)V22/(r-1)} /{(rq-1)(pqr-1)}
Cov (V2',V4')= {2(r-1)V12+2r2(q-1)V22/(r-1)} /{(rq-1)(spqr-1)}
Cov (V3',V4')= {2(r-1)V12+2r2(q-1)V22/(r-1)+2qr2(p-1)V32/(r-1)} /{(pqr-1)s(pqr-1)}

Indicating the inverse of above variance –covariance matrix by Zik , the weighted matrix Wikand is obtained by taking weights for Yi (=log Vi') and multiplying each row and column of the inverse matric by corresponding Vi'.

They considered x1 = area of largest plot, x2 = area of the main plot, x3 = area of the sub plot, x4 = area of the sub-sub plot and log(V1') = y1, log(V2') =y2, log (V3') = y3, log (V4') = y4, log (xl) =x1', log (x2) = x2', log(x3) =x3', log(x4) =x4'as well as Xi=∑ Wik xi' and Yi=∑ Wikyi ; for all k, the sum of squares for x' indicated by T is

T= ∑Xixi- (∑Xi)2/(∑∑Wik) and sum of product of y with x' indicated by U is

U=∑XiYi-(∑Xi)(∑Yi)/(∑∑Wik)= ∑Xixi'-(∑Xi)(∑Yi)/(∑∑Wik)

Thus the weighted regression coefficient b=-U/T. Therefore, according to Smith (1938), the optimum plot size Xopt=bK1/{(1-b)K2}, where, b is the soil heterogeneity, K1 is the over head cost per plot andK2 is the cost associated with unit size plot.The source of data for the present study is given in Table 3.

They obtained the variances of plots of various sizes and reduced to a sub plot basis. The replications were regarded as the largest plot, its variance V1' is equal to the replication mean square as it appeared in the analysis of variance, i.e.,

V1' = V1

The total sum of squares for whole plots over the entire area is r (q-1) V2 + (r-1) V1and there were r x q plots, the mean square is

V2' = [r(q-l)V2 + (r-l)V1]/ (rq - 1)

Similarly, they considered

V3' = [rq(p-l)V3 + r(q-l)V2 +(r-1) V1]/ (pqr - 1)

and V4' = [pqr (s-1) V4 + rq (p-1) V3 + r (q-1) V2 + (r-1) V1]/ (sprq-1)

The value of Vx were obtained by dividing each value of V' by the number of units per replication, main plot, sub plot and sub-sub plot putting them on a unit basis and the un-weighted regression coefficient has been obtained by the least square method.(Koch and Rigney, 1951).

Then the estimate of weighted regression coefficient has been obtained. V1, V2, V3 and V4 are independent and their estimated variances are

2V12/(r-1), 2V22/(r-1) (q-1), 2V32/ q (r-1) (p-1), and 2V42/pq (r-1) (s-1) respectively.

Thereafter they determined the variance and covariance of V1', V2, V3' and V4' which are linear function of the former set.

Now, the estimated variance of

V1'=2V12/(r-1)

V2' = [2(r-l)V12+ 2r2(q-l)V22/(r-1)]/ (rq-1)2

V3' = [(2r-l)V12+ 2r2(q-l)V22/(r-1) +2qr2 (p-l)V32/(r-1)]/ (rqp-1)2

V4' = [(2r-l)V12+ 2r2(q-l)V22/(r-1) +2qr2 (p-l)V32/(r-1)+ 2pqr2 (s-l)V42/(r-1)]/ (spqr-1)2

Then, the estimated covariance of V1' and V2' are as follows:

Cov (V1',V2')= {2(r-1)V12} /{(rq-1)(r-1)}

Cov (V1',V3')= {2(r-1)V12} /{(rpq-1)(r-1)}

Cov (V1',V4')= {2(r-1)V12} /{(rpqs-1)(r-1)}

Cov (V2',V3')= {2(r-1)V12+2r2(q-1)V22/(r-1)} /{(rq-1)(pqr-1)}

Cov (V2',V4')= {2(r-1)V12+2r2(q-1)V22/(r-1)} /{(rq-1)(spqr-1)}

Cov (V3',V4')= {2(r-1)V12+2r2(q-1)V22/(r-1)+2qr2(p-1)V32/(r-1)} /{(pqr-1)s(pqr-1)}

Indicating the inverse of above variance –covariance matrix by Zik, the weighted matrix Wik and is obtained by taking weights for Yi (=log Vi') and multiplying each row and column of the inverse matric by corresponding Vi'.

They considered x1 = area of largest plot, x2 = area of the main plot, x3 = area of the sub plot, x4 = area of the sub-sub plot and log(V1') = y1, log(V2') =y2, log (V3') = y3, log (V4') = y4, log (xl) =x1', log (x2) = x2', log(x3) =x3', log(x4) =x4'as well as Xi=∑ Wik xi' and Yi=∑ Wikyi ; for all k, the sum of squares for x' indicated by T is

T= ∑Xixi- (∑Xi)2/(∑∑Wik) and sum of product of y with x' indicated by U is

U=∑XiYi-(∑Xi)(∑Yi)/(∑∑Wik)= ∑Xixi'-(∑Xi)(∑Yi)/(∑ ∑Wik)

Thus the weighted regression coefficient b=-U/T. Therefore, according to Smith (1938), the optimum plot size Xopt =bK1/{(1-b)K2}, where, b is the soil heterogeneity, K1 is the over head cost per plot andK2 is the cost associated with unit size plot. The source of data for the present study is given in Table 3.

RESULTS AND DISCUSSION

The result in the form of variance-covariance matrix, inverse of variance-covariance matrix, weight matrix .and calculation of weighted and unweighted analysis have been presented in different tables from Tables 4 to 8 for each past experimental data. In Table 9 the weighted and unweighted value of 'b' has been produced.

Table 3: Source of data from previously conducted experiment

Character	No. of replications, main and and sub treatments and net plot size of smaller unit	Main, sub treatment	Source
Cane yield of Sugarcane	5,4,3 and 36x2.5=90m^2	Date of planting, Method of plaining	Data from page no. 193 book of Panse & Sukhatme
Grain yield of Oat	4,4,4 and Unit size	Varieties, Seed treatment by different chemicals	Data from page no. 385 book of Steel & Torrie
Yield of Alfalfa	6,3,4 and Unit size	Varieties, Date of cutting	Data from page no. 372 book of Snedecor & Cochran
Grain yield of hybrid Maize	3,3,3 and 9x5=45m^2	Spacing, Fertilizer level	Data from Anil Kumar, Deptt. Of seed Technology, Dholi Farm
Grain yield of wheat	3,3,7 and 1.61x7=11.27m^2	Nitrogen level, Varieties	Data from IrshadAlam, Deptt. Of Agronomy, Pusa Farm

The result depicted a wide difference between the estimates of weighted and unweighted soil heterogeneity coefficient in all the past experimental data. Also it was found that weighted 'b' is less than unweighted 'b' in all the past experimental data except the experiment on grain yield of oat. Hatheway and Williams (1958) also found lesser estimates of pea through weighted regression coefficient. Similarly the standard error of weighted regression coefficient were found to be less than unweighted regression coefficient in all the cases indicating the more precise estimates could be obtained through weighted regression coefficient technique for determining the soil heterogeneity. The estimates of soil heterogeneity coefficients were found to be highest29.03% for the experiment of grain yield of hybrid maize conducted at Dholi Farm of Rajendra Agricultural University (2003) followed by 19.45% for the experiment of grain yield of wheat conducted at Pusa Farm of Rajendra Agricultural University (2003). In the rest of the experiments, the efficiency obtained is minor.

Table 4: Computation of soil heterogeneity through weighted regression coefficient from cane yield data of sugarcane in past experiment

Variance covariance matrix		
2292.32	482 .59	155 .41
482.59	149 .17	48.03
155 41	48 03	15.64

Inverse of variance covariance matrix		
0.0014	− 0.0044	0
− 0.0044	0.6274	− 1.8829
0	− 1.8829	5.8469

Weighted matrix		
6.27	− 9.33	0
− 9.33	608 .73	− 685 .36
0	− 685 .36	798 .36

Weighted and Unweighted analysis	Weighted	Unweighted	efficiency
b	0.095	0.299	1.079%
S.E	0.059	0.568	
X_{opt}	$0.105K_1/K_2$	$0.247\ K_1/K_2$	

Table 5: Computation of soil heterogeneity through weighted regression coefficient from grain yield of oat in past experiment

Variance covariance matrix		
598655 .7763	119731 .1553	28507 .4179
1197 .31.1553	24617 .4759	5861 .3038
28507 4179	5861 3038	1408 8518

Inverse of variance covariance matrix		
0.0001	− 0.0003	0
−0.0003	0.0058	−0.0179
0	− 0 0179	0 0752

Weighted matrix		
55.0115	− 69.0293	0
69.0293	343 .7616	− 322 .426
0	− 322 .426	408 .1376

Weighted and Unweighted analysis	Weighted	Unweighted	efficiency
b	0.4123	0.0788	4.103%
S.E	0.1033	0.510	
X_{opt}	$0.166K_1/K_2$	$0.085\ K_1/K_2$	

Table 6: Computation of soil heterogeneity through weighted regression coefficient from yield of alfalfa in past experiment

Variance covariance matrix		
0.2756	0.0810	0.0194
0.0810	0.0257	0.0062
0.0194	0.0062	0.0015

Inverse of variance covariance matrix		
50.4233	−159.1007	0
− 159.1007	3385.2516	− 11879.173
0	− 11879.173	49613 0165

Weighted matrix		
34.7366	− 44.9324	0
− 44.9324	391.9311	−415.3804
0	−415.3804	523.9577

Weighted and Unweighted analysis	Weighted	Unweighted	efficiency
b	0.13095	0.15835	1.7435%
S.E	0.075	0.568	
X_{opt}	$0.1507K_1/K_2$	$0.188\ K_1/K_2$	

Table 7: Computation of soil heterogeneity through weighted regression coefficient from grain yield of hybrid maize in past experiment

Variance covariance matrix		
66 .7162	16 .6791	5.1320
16 .6791	4 .6227	1.4224
5. 1320	1. 4224	1. 0693

Inverse of variance covariance matrix		
0.153	− 0.552	0
−0.552	2.3578	− 0.4871
0	− 0.4871	1.5832

Weighted matrix		
1020.65	− 13.4976	0
−13 .4976	21.1320	− 4 .1824
0	− 4 .1824	13 .0214

Weighted and Unweighted analysis	Weighted	Unweighted	efficiency
b	0.2273	0.5236	29.03%
S.E	0.347	0.644	
$X\ opt$	$0.294K1\ /K\ 2$	$0.099K\ 1/K\ 2$	

Determination of optimum plot size under certain assumption

After having an idea of reliable soil heterogeneity coefficient from this studyoptimum plot size can be determined. For this purpose the ratio of cost of main plot and sub-plot has been calculated assuming the plot size taken as optimum plot size and the soil heterogeneity taken as an estimate of unweighted soil heterogeneity coefficient. In practice the ratio is difficult to determine and can be worked out by experienced agronomists.

The procedure adopted for the ratio of K1/K2 is as follows:

The ratio of K1/K2has been obtained by the formula Xopt={b/(1-b)}/(K1/K2); where, b is index of soil heterogeneity for unweighted regression coefficient. Putting the value of

Table 8: Computation of soil heterogeneity through weighted regression coefficient from grain yield of wheat in past experiment

Variance covariance matrix			Inverse of variance covariance matrix		
73.1196	18.2799	2.3587	0.0153	−0.0067	0
18.2799	42.1609	5.4401	−0.0067	0.037	−0.0827
2.3587	5.4401	2.2619	0	−0.0827	0.641

Weighted matrix			Weighted and Unweighted analysis			
				Weighted	Unweighted	efficiency
1.1216	−0.6147	0	b	0.8138	0.90039	19.45%
−0.6741	4.3546	−5.9843	S.E	0.228	0.517	
0	−5.9843	28.7218	X_{opt}	4.37K_1/K_2	9.07 K_1/K_2	

Table 9: ANOVA and soil heterogeneity coefficient of split plot design

Rep ms (r-1)	Eams [(r-1)(m-1)]	Ebms[m (r-1)(s-1)]	Weighted b	Unweighted b
V 1	V 2	V 3		
67.71(4)	21.400(12)	2.440(32)	0.095	0.299
947.62(3)	68.700	20.310(36)	0.142	0.079
0.83 (5)	0.140(10)	0.028(45)	0.131	0.158
8.168(2)	1.269	2.812(12)	0.227	0.524
8.551(2)	11.561(4)	6.084(36)	0.814	0.900

*Figures in parenthesis show d.f.

K1/K2Xopt is obtained by formula Xopt={b/(1-b)}/(K1/K2); where, b is the index of soil heterogeneity for weighted regression coefficient. The result has been presented in Table 10 which indicated the saving of the land to a considerable extent in almost all the past experiment except the experiment on grain yield of oat in which the optimum plot size comes to lesser than the actual plot size assumed. The result also indicated that in Pusa Farm the soil is more heterogeneous and in Dholi Farm the soil is less heterogeneous or to top soil is more heterogeneous and the bottom soil along with top soil is less heterogeneous. The exact comparison could be obtained by conducting an experiment with a similar crop at both the location.

Table 10: Optimum plot size of hybrid maize as affected by different values of b and ratio K1/K2 in the equation, Xopt=b K1/(1-b)K2

b→ K_1/K_2	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
40.88	0	4.54	10.22	17.52	27.25	40.88	61.32	95.39	163.52	367.92	∞
30.00	0	3.73	7.50	12.86	20.00	30.00	45.00	70.00	120.00	270.00	∞
50.00	0	5.56	12.50	21.43	33.33	50.00	75.00	116.67	200.00	450.00	∞

Table 11: Optimum plot size of past experimental data under certain assumptions

Net plot size taken of smaller unit (m^2)	Soil heterogeneity (Assumed)	K_1/K_2	Actual soil heterogeneity	Actual optimum plot size (m^2)	Plot size saving	Efficiency of 'b'
90	0.299	211.00	0.095	22.15	75.39%	1.079%
Unit	0.079	11.65	0.142	1.93	-93.00%*	4.103%
Unit	0.158	5.53	0.131	0.80	20.00%	1.744%
45	0.524	40.88	0.227	12.00	73.33%	29.03%
11.27	0.900	1.25	0.814	5.47	51.46%	19.45%

*Plot size should have been more than taken.

Table 12: Optimum plot size of sugarcane as affected by different values of band ratio K1/K2 in the equation, Xopt=b K1/(1-b)K2

b→ K_1/K	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
211	0	23.4	52.7	90.3	140.6	211.0	316.5	492.3	844.0	1899.0	∞
200	0	22.2	50.0	85.7	133.3	200.0	300.0	466.7	800.0	1800.0	∞
220	0	24.4	55.0	94.3	146.7	220.0	330.0	513.3	880.0	1980.0	∞

Table 13: Optimum plot size of wheat as affected by different values of b and ratio K1/K2

b→ K_1/K_2	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
1.25	0	0.14	0.31	0.54	0.83	1.25	1.88	2.92	5.00	11.25	∞
1.00	0	0.11	0.25	0.43	0.67	1.00	1.50	2.33	4.00	9.00	∞
1.50	0	0.17	0.38	0.64	1.00	1.50	2.25	3.50	6.00	13.50	∞

Effect of cost-ratio (K1/K2) on plot size at different values of weighted 'b' (index of soil heterogeneity)

As suggested by Smith (1938) the optimum plot size depends upon the soil heterogeneity and cost ratio. The different values of optimum plot size as affected by 'b' , K1/K2 for the crops sugarcane, hybrid maize and wheat at concerned locations have been computed in the Table 11 to 13 respectively. For a particular level of cost ratio and soil heterogeneity coefficient the bigger plot size are required for sugarcane followed by hybrid maize and then wheat. In case of sugarcane, the different values of ratio of K1 and K2 looks quite closer to each other. This indicated that the cost ratios do not play much role on the determination of the sugarcane crops, whereas in case of hybrid maize and wheat, cost ratios are quite apart to each other. This indicates that the cost ratio K1/K2 has the considerable effect in the determination of plot size.

In all the tables it can be seen that the optimum plot size are smaller for the low value of soil heterogeneity index and gradually increases in quadratic fashion for the higher values of soil heterogeneity indices. Having the good estimates of soil heterogeneity indices and the cost ratios, the above table can be utilized for obtaining the optimum plot size for sugarcane, hybrid maize and wheat.

CONCLUSION

Maximum curvature method and Fair field Smith's variance law are the two important methods for the determination of the optimum plot size of an experimental plot. Out of which the latter has been widely used till today. The information required is obtained from the uniformity trial experiment. The conduct of the uniformity trial is costly and time consuming. Therefore, in the present study an attempt has been made to attain the device a method using the data from the past experimental data conducted in the split plot design. Optimum plot size under certain assumptions indicated the saving of the land to a considerable extent in almost all thepart experiments except the experiment on grain yield of oat in which the optimum plotsizecomes to lesser than the actual plot size assumed. The result also indicated that in Pusa Farm the soil is more heterogeneous and the bottom soil along with top soil isless heterogeneous. The exact comparison could be obtained by conducting an experiment with a similar crop at both the locations.

REFERENCE

Agarwal KN and Deshpande MR. 1967.Size and shape of plots and blocks in field experiments with dibbled paddy. *Indian J. Agric. Sci*. **38**:445-4.

Agarwal KN, Bavappa KV and Khosla RK. 1968. Study of size and shape of plots and blocks and optimum number of pre-experimental periods on areca nut. *Indian J. Agric. Sci.* **38**: 444-64.

Babu R and Agarwal MC.1980. Note on the size of plots and blocks for field trials on natural grass lands in nills. *Indian J. Agric. Sci*. **47**: 527-8.

Gopani DD, Kabaria MM and Vaishanani NL. 1970. Size and shape of plots in field experiments on groundnut. *Indian J. Agric. Sci*. **40**: 1004-10.

Handa DP, Sreenath PR, Sastry JA, Rajpal SK and Shukla NP.1982.Size and shape of plots and blocks for experiments with oat grown for fodder. *Indian J. Agric. Sci.* **52**: 466-71.

Hasiza RCand Kumar M.2002. A study of size and shape of plots with wheat. *Annuals of Agri. Bio. Research* **7**(1): 89-93.

Hatheway WH and Williams EJ. 1958. Efficient estimation of the relationship between plot size and the variability of crop yields. *Biometrics* **14**: 207-22.

Islam MS, Sen K, Rahim K and Ali MY.2000.Estimation of plot size in split-split plot design. *Journal Ind. Soc. Ag. Statistics* **53** (2): 172-81.

Koch EJ and Rigney JA. 1951. A method of estimating optimum plot size from experimental data. *Agronomy Journal* **43**: 17-21.

Lin CS, Morrison MJ and Binn MR.1996. Persistence of a field heterogeneity index. *Canadian Journal of Plant Science* **76** (2): 245-50.

PahujaAN andMehra RB. 1981. Plot size for co-ordinated varietal trials in chickpea. Indian J. Agric. Sci. 51: 80-2.

Rao CS and Prasad ASR. 1991. Optimum plot size for estimating yield of black gram (*Phaseolus mungo*). *Indian J. Agric. Sci.* **61** (8): 574-8.

Reddy N, Chetty CK and Ramanatha. 1983. Modified use of Smith's law for coefficient of heterogeneity on the basis of field experiments conducted on the size and shape of plots and blocks for dry lands caster. *Indian J. Agric. Sci*. **53**: 250-5.

Saad AMM. 1996. The relative efficiency of some experimental designs from optimum plot size and plots for evaluating faba bean yield. *Annuals of Agricultural Science* **34** (3): 799-810.

Saradana MG, Sreenath PR and Malhotra VP. 1967. Size and shape of plots and blocks in field trials with potato. *Indian J. Agric. Sci.* **38**: 338-55.

Shankar K, Lai MS and Goswami V. 1972.Size and. shape of plots and blocks in yield trials of soyabean (*Glycine man* L.). *Indian J. Agric. Sci*. **42**: 901-4.

SmithHF.1938. An empirical law describing heterogeneity in the yields of agricultural crops. *Journal of Agricultural Science* **28**: 1-23.

Sreenath PR and Marwaha SP.1977. Preliminary study on the size and shape of plots and blocks in field trials with cowpea. *Indian J. Agric. Sci.* **47**: 52-4.

Sreenath PR. 1973.Size and shape of plots and blocks in the field trials with "MP Chari" sorghum (*Sorghum bicolor* L.). *Indian J. Agric. Science* **43**:110-2.

Citation:

Bharati RC , Chaudhary KK, Singh AK, Kumar A, Kumar U, Chandra N.2017. Determining Optimum Plot Size based on Information of Previous Experiments Conducted in Split Plot Design. *Journal of AgriSearch* **4**(1):60-67