FIELD PLOT AND SAMPLING TECHNIQUES ON VIRGINIA TOBACCO

by

Francisca D. Sagisi* and Mariano B. de Ramos**

INTRODUCTION

Agricultural field experiments unlike laboratory studies are subject to a wide range of variation due to influences of soil variation, weather, genetic differences, plant competition within and between plots, and the inherent variability of the treatment themselves. These multiple factors that affect the conduct of field experiments, many of which are beyond the control of the experimenter compose the so called experimental error. Considering these variable factors, it is obvious that field experiments can never be conducted under strictly comparable conditions. Nevertheless, control should be exercised over these external factors such that treatments may be able to produce their effects under desired and comparable conditions.

The main source of experimental error in field experiments is soil heterogeneity. Harris as early as 1920 had worked on the measurement of soil heterogeneity by the use of correlation coefficient. Smith in 1938 worked out an empirical relationship describing soil heterogeneity in yields of agricultural crops from 39 uniformity experiments.

A uniformity trial as the name implies is an experiment where all applied inputs are uniform, i.e., an experiment with a single crop variety applying uniform cultural and management

---

*Senior Researcher, Philippine Virginia Tobacco Administration.

**Associate Professor, Department of Statistics, College of Arts and Sciences, U.P. at Los Baños.

practices. Based on the assumption that a uniform soil when cropped uniformly will consequently produce the same, soil heterogeneity can be measured as the difference in performance of plants grown in a uniformly treated area. Uniformity trial data give information on soil fertility pattern, proper orientation of plots and blocks, proper plot shape by comparison of plot variances and optimum plot size using Smith's index of soil heterogeneity.

Although a study on optimum plot size on Virginia tobacco was conducted by Crews *et al.* (1963) in North Carolina, no study has been made yet under Philippine conditions. This study was conducted to develop field plot and sampling techniques by conducting a uniformity trial on Virginia tobacco. In particular, the study was conducted to determine optimum plot size, number of replications, suitable orientation of plots and unplanted border effects. The results of this study are expected to provide a meaningful guide to Virginia tobacco researchers in their sampling procedures.

MATERIALS AND METHODS

This study was conducted during the regular tobacco season at the PVTA Nañgalisan Research Station, Laoag City from October 1977 to April 1978. The experiment covered an area of 1269 square meters (24 rows x 94 hills or columns). Distance of planting was 0.75 meter between rows and 0.75 meter between hills in a row. Variety used was MRS-3. Fertilizer rate was at 20-30-40 kg/ha. PVTA standard cultural practices were employed throughout the experiment. Leaves were primed six times at weekly interval. Data gathered were weight, plant height at maturity and number of leaves per plant.

Effective sampling area was 1012.5 square meters containing 20 rows x 90 hills/columns after removing two rows on all sides as borders. There were 360 basic units each composed of 5 plants or a plot of 3.75 meter long and 0.75 meter wide.

Field Plot Technique

Mean Square Among Strips

The experimental units were first combined to form vertical and horizontal strips. Variability among strips in each direction was measured by the sum of squares method. The relative size of two mean squares indicates the possible path of the fertility gradient and suitable orientation of both plots and blocks. Let,

$$\sum_{i=1}^{20} x_{i.} = \text{total of the i-th row}$$

$$\sum^{90} x_{.j} = \text{total of the j-th column}$$

$$\text{SS Vertical} = \sum_{i=1}^{20} x_i^2 - \frac{(\sum_{i=1}^{20} x_{i.})^2}{20} \qquad (1)$$

$$\text{MS Vertical} = \frac{\text{SS Vertical}}{19} \qquad (2)$$

$$\text{SS Horizontal} = \sum_{j=1}^{90} x^2_{.j} - \frac{(\sum_{j=1}^{90} x_{.j})^2}{90} \qquad (3)$$

$$\text{MS Horizontal} = \frac{\text{SS Horizontal}}{89} \qquad (4)$$

Smith's Index of Soil Heterogeneity

Smith's index of soil heterogeneity b is obtained from the following relationship between plot variance and plot size:

$$V_x = \frac{V_1}{x^b}$$

Taking the logarithms, the equation is reduced to a linear form,

$$\log V_x = \log V_1 - b \log x \qquad (5)$$

where

V_x = variance per unit area for plots of size x basic units

x = basic units

b = Smith's index of soil heterogeneity

Different combinations were used to simulate plots of different sizes and shapes to get V_x. Only plot size that fitted into the sampling area was used. V_x was computed as,

$$V_x = \frac{V_{(x)}}{x^2} \qquad (6)$$

where $V_{(x)}$ = variance among plots.
b then can be computed using regression technique.

The b values were adjusted such that they are independent of the size of the area used.

Optimum Plot Size

Given an estimate of soil heterogeneity index b, and cost estimates in man hours for conducting the experiment, optimum plot size was computed as,

$$x_{opt} = \frac{b(K_1 + K_3 A)}{(1-b)(K_2 + K_3 B)} \qquad (7)$$

where

K_1 = part of the cost associated with the number of plots only

K_2 = cost per unit area

K_3 = cost associated with borders
b = Smith's index of soil heterogeneity
A = area of plot and borders
B = ratio of side borders to test area

Plot Shape

Given an estimate of the variance per unit area of comparable variance V_x (computed from Equation 6) the effect of plot shape on plot variability was determined. Comparable variances of plots of equal size but of different shapes were compared by the use of the F-test. For each plot size the larger comparable variance was divided by the smaller comparable variance to obtain the computed F-value.

Number of Replications

Given an estimate of soil heterogeneity index b and an estimated variance among plots of basic unit size $V_{(x)}$, the number of replications required to satisfy a given degree of precision (expressed as variance of treatment mean) was estimated as follows:

$$r = \frac{V_{(x)}}{V_o\, x^b} \qquad (8)$$

where

$V_{(x)}$ = variance among plots of basic unit size
V_o = variance among treatment means
x = plot size under consideration expressed as number of basic units
b = Smith's index of soil heterogeneity

Plot Sampling Techniques

Unplanted Border Effects

The border rows situated along the perimeter of the entire experimental area were utilized to provide information on unplanted border effect. The different rows were considered as the treatments. The outermost row was designated as R_1, the second outermost row was R_2 and the third, fourth and fifth rows were considered as the inner rows. The four sides were divided into sections such that 20 hills in each five rows composed one section. These sections made up the 10 replications. Analyses of data followed that of a randomized complete block design.

RESULTS AND DISCUSSION

Fertility Pattern

Smith's index of soil heterogeneity is a measure of correlation between adjacent units. The index b ranges from zero to unity. A value zero indicates perfect positive correlation, i.e., nothing is to be gained by the use of larger plots and $b = 1$ means no correlation between the adjacent units, i.e., the units are independent. A low b would mean the existence of a strong gradient due to soil, diseases, etc. High b values indicate more or less random soil variability pattern varying from extreme uniformity to extreme heterogeneity.

Estimates of adjusted and non-adjusted b values for cured weight, plant height and number of leaves per plant are given in Table 1, together with the analysis of mean square among strips for both horizontal and vertical arrangements. The estimate of b for yield was similar to those obtained by Koch and Rigney (1951) from regular field experiments with tobacco. The b value obtained indicates the existence of a gradient in the field which is confirmed by the relatively higher mean square among the vertical strips which means that the gradient is more pronounced along the width of the experimental field.

In this connection, manipulation of block and plot arrangement in the field is called for in order to maximize the differences among blocks and minimize the variation of plots within the blocks. The length of the block should cut across the direction of the gradient; in this particular case blocks should be oriented such that its length should be perpendicular to the vertical side of the field and length of plots in the blocks should run along the vertical length of the field, i.e., the plots should be arranged such that its length should run parallel to the gradient. Such manipulative techniques would reduce the size of the experimental error and consequently assure reliable results of the experiment.

TABLE 1. SMITH'S INDEX OF SOIL HETEROGENEITY AND MEAN SQUARE AMONG STRIPS FOR THREE PLANT CHARACTERS.

TYPE OF ANALYSIS	CURED WEIGHT (gm/hill)	PLANT HEIGHT (cm)	NO. OF LEAVES/ PLANT
1. Mean square among strips			
Horizontal	208.66499	134.59565	21.34755
Vertical	719.01790	453.06523	59.48489
2. Smith's index of soil heterogeneity			
Adjusted	0.45580	0.48905	0.58763
Unadjusted	0.42453	0.45910	0.56726

Plot Size

Two major aspects are involved in choosing appropriate plot size: practical considerations include ease of management in the field. For variability, the size of the experimental error is directly related to soil heterogeneity from the relationship devised by Smith (Equation 5), the variability becomes smaller as the plot size becomes larger, but the gain in precision decreases as the plot becomes increasingly large. Very large plots involve higher costs, therefore the experimenter should aim for a plot size that is a happy compromise between precision and cost.

Table 2 contains the coefficients of variations for cured weight, plant height and number of leaves per plant for different plot sizes and shapes.

Among the three characters, cured weight is the most variable, about twice the magnitude of plant height and number of leaves per plant. The behavior of the cv followed that of the relationship devised by Smith, i.e., cev decreases as plot size increases. This is true for all three plant characters. However the decrease in cv is gradual and not so drastic or pronounced. This can be attributed to the relatively large plot sizes used which is inherent in tobacco experiments because of wide distance of planting involved. No appreciable gain in precision was observed for plots larger than two basic units containing 10 plants.

The relationship between cv and plot size for the three plant characters are best reflected in Figure 1. They cv for a particular plot size includes all the combinations of plot shape for that given plot size.

To check the goodness of fit of the data to Smith's empirical relationship, results of the analysis of variance test are given in Table 3. Based on the high R^2 values for all three plant characters, it is obvious that the data closely adhere to the stated relationship (Figure 2). These results therefore indicate the validity of obtaining estimates of b.

Optimum Plot Size

Cost estimates of conducting the experiment in man-hours are given in Table 4. Given an estimate of b, optimum plot size, the size that minimizes cost per unit information was computed using Equation 7, to be 4.47 m^2, 5.10 m^2 and 7.60 m^2 for cured weight, plant height and number of leaves per plant respectively

TABLE 2. VARIANCES AMONG PLOTS AND COEFFICIENTS OF VARIATION (CV) OF DIFFERENT PLOT SIZES AND SHAPES FOR THREE PLANT CHARACTERS.

NUMBER OF BASIC UNITS	PLOT SHAPE Width (no. of rows)	Length (no. of columns)	TOTAL NUMBER OF PLOTS	CURED WEIGHT (GM/HILL) Varince Among Plots	C.V. (%)	PLANT HEIGHT (CM) Variance Among Plots	C.V. (%)	NO. OF LEAVES/PLANT Variance Among Plots	C.V. (%)
1	1	5	360	8,144.40	14.2	3,536.00	6.9	79.89	6.7
1	5	1	360	7,281.47	13.4	3,299.43	6.7	78.12	6.6
2	2	5	180	22,261.99	11.8	10,092.69	5.8	214.26	5.5
2	5	2	180	19,112.76	10.9	9,000.04	5.5	198.34	5.3
2	10	1	180	18,846.75	10.8	7,619.93	5.1	185.60	5.1
2	1	10	180	23,370.36	12.0	9,649.34	5.7	191.15	5.2
3	5	3	120	37,150.12	10.1	17,416.60	5.1	358.72	4.7
3	1	15	120	42,485.24	10.8	17,377.88	5.1	347.70	4.6
4	4	5	90	62,107.32	9.8	28,582.83	5.9	572.76	4.5
4	10	2	90	54,565.39	9.2	20,960.36	4.2	491.15	4.2
4	2	10	90	70,164.12	10.4	30,090.07	5.0	559.28	4.4
4	20	1	90	427,269.26	8.1	18,040.81	3.9	454.65	4.0
5	5	5	72	84,105.00	9.1	35,313.57	4.4	759.89	4.1
6	5	6	60	124,116.56	9.2	55,495.59	4.6	994.14	3.9
6	10	3	60	112,956.69	8.8	41,428.61	3.9	862.64	3.7
6	2	15	60	139,233.62	9.8	56,897.08	4.6	1,091.25	4.1
6	1	30	60	132,794.56	9.6	48,969.76	4.3	912.81	3.8
8	20	2	45	127,284.31	7.0	52,445.09	3.3	1,200.73	3.2
8	4	10	45	205,056.00	8.9	90,356.31	4.4	1,498.54	3.6
9	5	9	40	224,112.69	8.3	94,206.62	4.0	1,877.74	3.6
10	5	10	36	286,317.69	8.4	117,101.69	4.0	2,101.03	3.4
12	10	6	30	399,308.93	8.3	142,410.00	3.6	2,655.47	3.2

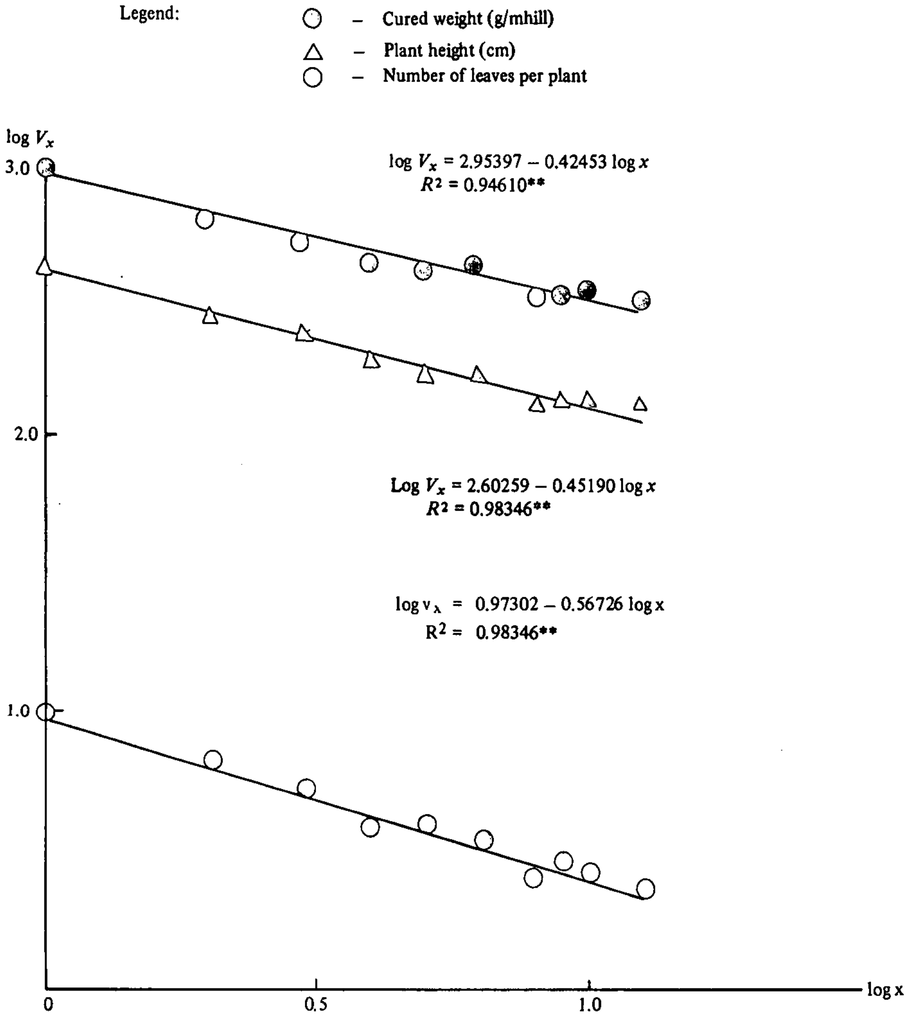

Figure 1. Relationship between variance per unit area, Vx and plot size (x) for three plant characters.

TABLE 3. ANALYSIS OF VARIANCE ON THE LOGARITHMIC RELATIONSHIP BETWEEN PLOT VARIANCE AND PLOT SIZE FOR THREE PLANT CHARACTERS.

S.V.	D.F.	MEAN SQUARE Cured Weight (gm/hill)	 Plant Weight (cm)	 No. of Leaves Per Plant
Regression	1	0.18923	0.22130	0.33786
Deviation from Regression	8	0.00135	0.00098	0.00071
Computed F		140.43**	226.68**	475.76**
R2		0.94610**	0.96593**	0.98346**

** – Significant at the 1% level.

for the test area only. Considering bordered plots, the size amounted to 20.22 m^2, 20.85 m^2 and 23.35 m^2 for cured weight plant height and number of leaves per plant respectively (Table 5).

It is apparent that b estimates obtained differed from character to character, hence resulting in different sample sizes for different characters. By and large, the optimum plot size will be based on the most important character which is yield in this particular case.

Optimum plot size will naturally be different for experiments in which cost estimates differ from the ones used in this study. In other words, the present estimates of optimum plot size may not be applicable to all types of tobacco experiments and in future experiments which may use different procedures like bulk curing. However, plot size for such experiments can be estimated with the use of the estimated b derived from this study with appropriate estimates of K^1 and K^2.

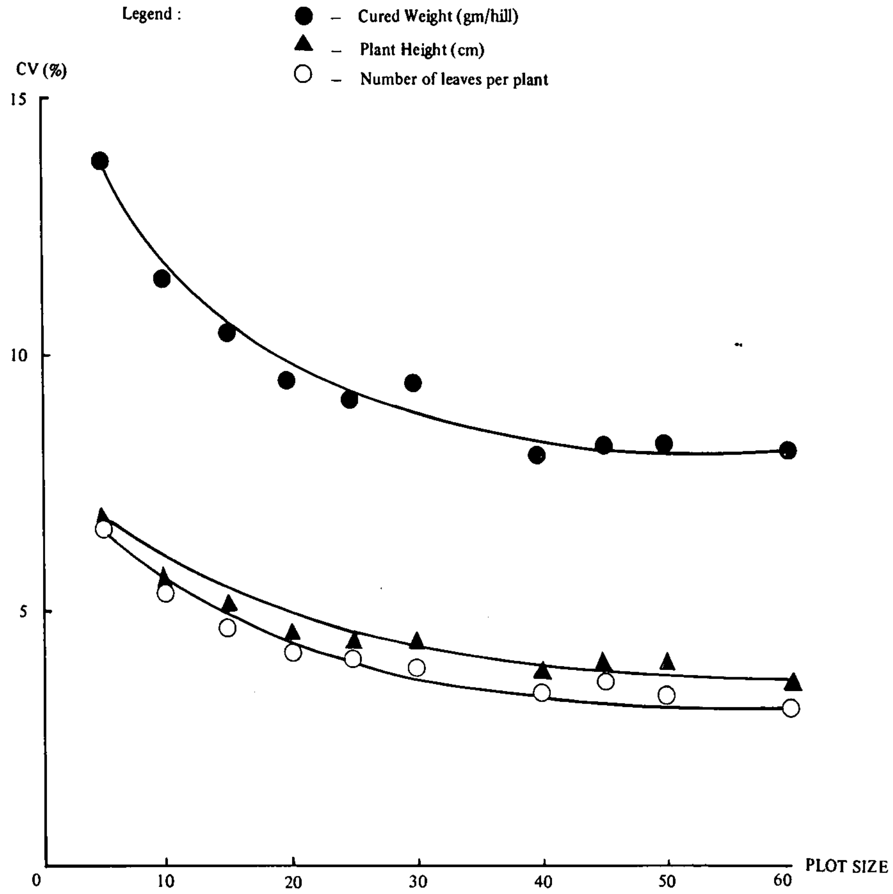

Figure 2. Relationship between cv (%) and plot size for three plant characters.

TABLE 4. ESTIMATES OF COSTS IN MAN-HOURS FOR CONDUCTING A TOBACCO FIELD EXPERIMENT.[1]

OPERATION	K_1 (Man-Hour/Plot)	K_2 (Man-Hour/Sq. M)
1. Seedbed preparation and management	–	0.02080*
2. Land preparation	–	0.00346*
3. Labelling, etc.	0.03714	–
4. Plot lay-out	0.00198	–
5. Transplanting	–	0.04491*
6. Watering	–	0.00630*
7. Fertilization	–	0.01891*
8. Irrigation (2x)	–	0.00630*
9. Replanting	–	0.00315*
10. Spraying (6x)	–	0.02372*
11. Off-barring	–	0.00158*
12. Hilling-up	–	0.00158*
13. Priming and sticking (6x)	0.03635	0.02900*
14. Curing (6x)	0.02583	0.20615
15. Plot observation[2]	0.48276	0.38518
16. Statistical analysis	0.94815	–

[1] K_g – cost associated with borders is computed as ΣK_2 – items marked *.

[2] Includes plant height measurement, counting of number of leaves and weighing of samples.

Plot Shape

The smaller the differences among plots within the block the smaller is the experimental error. The choice of suitable plot shape therefore should aim at keeping the plots within the blocks as uniform as possible or to reduce the differences in soil productivity from one plot to another within a block. For areas with a unidi-

TABLE 5. OPTIMUM PLOT SIZE FOR THREE PLANT CHARACTERS.

CHARACTER	OPTIMUM PLOT SIZE (M^2)		NUMBER OF PLANTS PER PLOT	
	Bordered Plots	Unbordered Plots	Bordered Plots	Unbordered Plots
Cured Weight (gm/hill)	20.22 (4.47)	1.95	36 (8)	4
Plant Height (cm)	20.85 (5.10)	2.22	37 (9)	4
Number of Leaves per Plant	23.35 (7.60)	3.31	41 (14)	6

Figures in ( ) refer to optimum plot size and number of plants per plot for test area only.

rectional gradient, rectangular plots are desirable and its length should run along the fertility gradient. For areas with fertile areas in spots square or nearly square may be better.

Table 6 shows the results of F-tests using comparable variance to determine the effect of plot shape on variability. The results revealed that for number of leaves per plant, no significant differences were found for all plot shapes. Except for plots containing 20 plants, all other plot shapes revealed no significant differences for cured weight. For plant height, all shapes resulted in non significant differences except for plots containing 20 plants, all other plot shapes revealed no significant differences for cured weight. For plant height, all shapes resulted in non significant differences except for plots containing 20 and 60 plants. This agree with what Smith opined (1938) that plot shape generally had no consistent effect on variance.

Comparison of variances between long narrow plots and nearly square ones of the same plot size showed very little difference. Lesser variance generally occur in single row plots. Based on

TABLE 6. COMPRARABLE VARIANCES AND F-TEST ON PLOT SHAPE FOR THREE PLANT CHARACTERS.

NUMBER OF BASIC UNITS	PLOT SHAPE Width (no. of rows)	Length (no. of columns)	D.F.	CURED WEIGHT (GM/HILL) Comparable Variance	F	PLANT HEIGHT (CM) Comparable Variance	F	NO. OF LEAVES/PLANT Comparable Variance	F
1	1	5	359	1,029.61	1.12^{ns}	447.02	1.07^{ns}	10.10	1.02^{ns}
1	5	1	359	920.52	–	417.12	–	9.88	–
2	2	5	179	703.59	1.18^{ns}	318.99	1.32^{ns}	6.77	1.15^{ns}
2	5	2	179	604.06	1.01^{ns}	284.44	1.18^{ns}	6.27	1.06^{ns}
2	10	1	179	595.65	–	240.88	–	5.87	–
2	1	10	179	738.62	1.24^{ns}	304.96	1.27^{ns}	6.04	1.03^{ns}
3	5	3	119	521.83	–	244.65	1.00^{ns}	5.04	1.03^{ns}
3	1	15	119	596.77	1.14^{ns}	244.12	–	4.88	–
4	4	5	89	490.72	1.45^{*}	225.85	1.58^{*}	3.58	1.25^{ns}
4	10	2	89	431.13	1.28^{ns}	165.61	1.16^{ns}	3.88	1.08^{ns}
4	2	10	89	554.38	1.64	237.73	1.68^{**}	4.42	1.23^{ns}
4	20	1	89	337.93	–	142.54	–	3.59	–
6	5	6	59	435.86	1.10^{ns}	194.88	1.34^{ns}	3.49	1.15^{ns}
6	10	3	59	396.66	–	145.48	–	3.03	–
6	2	15	59	488.94	1.23^{ns}	199.81	1.37^{ns}	3.83	1.26^{ns}
6	1	30	59	466.32	1.18^{ns}	171.96	1.18^{ns}	3.20	1.05^{ns}
8	20	2	44	254.42	–	103.60	–	2.37	–
8	4	10	44	405.05	1.61^{ns}	178.47	1.72^{*}	2.96	1.27^{ns}

* – Significant at the 5% level.

** – Significant at the 1% level.

ns – Not significant

the F-tests, plot shape effect is not critical and orientation of plots with respect to shape can be done in any manner suitable to the needs and desires of the researcher. The same results were also noted by Rampton and Peterson (1962) for orchardgrass seed, Widemann and Leininger (1963) for safflower and Lessman and Atkins (1963) for grain sorghum. However, considering the b values obtained which indicated the existence of a fertility gradient the length of the plots should run parallel to the gradient. And since wider distance of planting is employed in Virginia tobacco, it is desirable to have three row plots rather than multiple row ones.

Number of Replications

Number of replications is dependent on several factors, the most important of which is the precision desired. The simplest means of improving precision is increasing the number of replications. However, there is little point in conducting an experiment with 10 replications to detect a difference that four replications can find in most cases. With the use of the computed estimate of soil heterogeneity index b, the number of replications was computed using Equation 8 and presented in Table 7.

Considering that cured weight is relatively more variable than both plant height and number of leaves per plant, 15% level of precision is warranted. The choice would narrow down to between four replications with ten samples and three replications with 15 samples per plots. Four replications containing ten samples closely agree to the computed optimum plot size which contain eight samples for cured weight. Of course it is always desirable to work with fewer number of samples (40 samples from four replications vs. 45 samples from three replications), however in cases where land area is limited, a constraint common in research institutes where numerous experiments are being conducted at the same time, then the researcher should opt for one with lesser number of replications. In such an occasion, three replications with 15 samples is the most likely choice.

TABLE 7. NUMBER OF REPLICATIONS AT VARYING DEGREES OF PRECISION AND DIFFERENT SAMPLE SIZES FOR THREE PLANT CHARACTERS.

NUMBER OF SAMPLES/ PLOT	LEVEL OF PRECISION (%)		
	10	15	20
		Cured Weight (gm/hill)	
5	11	5	3
10	8	4	2
15	7	3	2
20	6	3	2
25	6	2	1
30	5	2	1
40	4	2	1
		Plant Height (cm)	
5	3	1	1
10	2	1	1
15	2	1	–
20	1	1	–
25	1	1	–
30	1	1	–
40	1	1	–
		Number of Leaves/Plant	
5	3	1	1
10	2	1	–
15	2	1	–
20	1	1	–
25	1	1	–
30	1	–	–
40	1	–	–

---

[1] Computed value is zero.

Plant height and number of leaves being less variable could settle for a 10 degree of precision, would have three replications with 5 samples. If the computed optimum plot size of nine and eight sample plants for plant height and number of leaves respectively be followed, the choice would be 10 samples with two replications. However, since plant height and number of leaves per plant are not the only characters of interest in any experiment, having two replications may not be sufficient to attain the desired precision in the other characters under study.

The number of replications to be used then considering precision and optimum plot size would be between three and four.

Unplanted Border Effects

Plants situated along the sides or ends of plots usually give higher yields than those in the interior. This is particularly evident when the plots are surrounded by unplanted alleys. The amount of this border effect may be important in comparative yield determination.

Analyses on unplanted border effect for the three plant characters are presented in Table 8. It is apparent that unplanted alley effect is not serious in Virginia Tobacco as reflected in the non-significant differences between the outermost row and the inner ones. The same findings were also observed by Crews *et al* for Virginia Tobacco (1963) in North Carolina. This is usually true for crops planted at a wider distance of planting since competition for solar energy, fertilizer, moisture and other nutrients are not as keen as in closely spaced crops. Therefore border rows at the end or side of plots adjacent to unplanted alleys are not warranted under this study. However, further studies should be made when other treatments like fertilizer, distance of planting, etc. are involved.

Furthermore, investigations should be made likewise to evaluate inter-plot competition effects due to fertilizer, varietal and other treatment differences, to guide researchers on how many buffer rows to use between treatment plots.

TABLE 8. SUMMARY OF ANALYSIS OF VARIANCE ON UPLANTED BORDER EFFECTS ON THREE PLANT CHARACTERS.

S.V	D.F.	CURED WEIGHT (gm/hill)		PLANT HEIGHT (cm)		NO. OF LEAVES/PLANT	
		M.S.	F	M.S.	F	M.S.	F
Total	49						
Rep	9	513.70276	16.93**	265.90067	18.29**	4.53842	11.82***
Row	4	34.64920	1.14^{ns}	6.04475	0.42^{ns}	0.50170	1.31^{ns}
R_1 vs. rest	(1)	79.70700	2.63^{ns}	16.06000	1.10^{ns}	0.73633	1.92^{ns}
R_2 vs. rest	(1)	4.21880	0.14^{ns}	2,16000	0.14^{ns}	0.61633	1.60^{ns}
Among rest	(2)	29.42800	0.97^{ns}	0.80135	0.06^{ns}	0.10234	0.27^{ns}
Error	36						
c.v. (%)		4.4		2.3		2.3	

** – Significant at the 1% level.

ns – Not significant

TABLE OF MEANS

ROW	CURED WEIGHT (gm/hill)	PLANT HEIGHT (cm)	NUMBER OF LEAVES PER PLANT
1	128.6	166.7	27
2	126.1	164.7	26
3	123.4	164.9	26
4	126.3	165.4	26
5	126.4	165.4	26
Grand Mean	126.1	165.4	26.4

SUMMARY AND CONCLUSION

A uniformity trial on Virginia tobacco was conducted at the PVTA Nañgalisan Research Station from October 1977 to April 1978. The study was conducted to determine specifically the fertility pattern, optimum plot size and shape, number of replications and unplanted border effects on Virginia tobacco.

Statistical analyses revealed the existence of a gradient along the width of the experimental field. As such, plots within blocks should be oriented along the direction of the gradient, and the blocks should cut across the path of the gradient to be able to minimize variation within plots in order to reduce the size of the experimental error.

As plot size increased variability decreased. The decrease in cv is gradual and not so drastic which could be attributed to the relatively large plot sizes involved which is inherent in Virginia Tobacco due to the wide distance of planting used. No appreciable gain in precision was noted for plots larger than two basic units containing ten plants.

Optimum plot size takes into consideration not only the size of plots per se but the shape of plots as well. Size of plots is likewise affected by the number of border rows to be included. Although unplanted border effects were found to have no significant influence, bordered plots are still to be recommended, since interplot competition effects have not yet been fully investigated. Therefore, buffer rows between plots are needed as an insurance that only plots with appropriate borders can give good representative samples of the whole plot. Besides if unbordered plots be used, four plants per plot to constitute the optimum plot size is too small to leave a comfortable margin for missing and replanted hill occurrence. Considering plot shape, narrow plots are more desirable than multiple row ones. In particular, three row plots (3 rows x 12 hills) would serve as the optimum plot size with both outside rows serving as side borders and one row on each end of the plot to serve as plot end borders and finally having the 10 sample hills from the center row as the sample plants. Although optimum plot size was computed to contain eight sample hills for the test area, past experience has shown that it is always prudent to leave allowance for incidence of missing and replanted hills. More so in Virginia tobacco where distance of planting is wide, exclusion of two or three hills from the sample area due to a missing hill or replanted one would drastically reduce the already small sample area by 25-30%.

Considering the precision desired and optimum plot size, number of replications was computed to be between three and four.

LITERATURE CITED

ABRAHAM, T. P. and G. C. MOHANTY. 1956. An experimental investigation in sampling for yield, tillers and height in replicated field experiments on rice. Indian J. Agric. Sci. 25(4): 253-264.

ALICBUSAN, R. C. 1969. Sampling in rice field experiments. IRRI Saturday Seminar Paper No. 21.

American Society of Agronomy Committee on Standardization of Field Experiments. Report 1933. J. Am. Soc. Agron. 25: 803-828.

GOMEZ, K. A. and R. C. ALICBUSAN. 1969. Estimation of optimum plot size from rice uniformity data. Phil. Agric. 52: (9 & 10): 586-600.

GOMEZ, K. A. and A. A. GOMEZ. 1976. Statistical Procedures for Agricultural Research, with Emphasis on Rice. IRRI, Los Baños, Philippines.

CREWS, J. W., G. L. JONES and D. D. MASON. 1963. Field plot technique studies with flue-cured tobacco. I. Optimum plot size and shape. Agron. J. 55: 197-199.

HARRIS, J. A. 1920. Practical university of field heterogeneity as a factor influencing plot yields. Jour. Agr. Res. 19: 279-314.

HATHWAY, W. H. and E. J. WILLIAMS. 1959. Efficient estimation of the relationship betwen plot size and the variability of crop yields. Biometrics 14: 207-222..

HULBERT, H. W. and J. D. REMSBERG. 1927. Influence of border rows in variety tests of small grains. J. Am. Soc. Agron. 19: 585-589.

IMMER, F. R. 1932. Size and shapes of plots in relation to field experiments with sugar beets. J. Agric. Res. 44: 633-648.

JUSTESEN, S. A. 1932. Influence of size and shape of plots on the precision of field experiments with potatoes. J. Agric. Sci. 22: 366-372.

KELLER, K. R. 1949. Uniformity trial on hops, *Humulus lupulus L.* for increasing precision of experiment. Agron. J. 41: 389-392.

STADLER, L. J. 1921. Experiments in field plot technic for the preliminary determination of comparative yields in small grains. Jour. Agr. Sci. 28: 1-23.

STEEL, R. G. D. and J. H. TORRIE. 1960. Principles and procedures of statistics. McGraw Hill Book Co., Inc. New York, Toronto and London.

SUMMERBURY, R. 1923. Replication in relation to accuracy in comparative field tests. J. Am. Soc. Agron. 15: 192-199.

TORRIE, J. R., D. R. SCHMIDT and G. H. TENPAS. 1963. Estimates of optimum plot size and shape and replicate number of forage yields of alfalfa-bromegrass mixture. Agron. J. 55: 258-260.

WASSOM, C. E. and R. R. KALTON. 1953. Estimation of optimum plot size using data from bromegrass uniformity trials. Iowa State College Res. Bull. 396.

WEIDEMANN, A. M. and L. N. LENINGER. 1963. Estimation of plot size and shape for safflower yield trials. Agron. Jour. 55: 222-225.

APPENDIX TABLE 1. CURED WEIGHT (GM/HILL) DATA ON BORDER ROW EFFECT. MRS-3.

REP	ROW				
	1	2	3	4	5
1	127.2	120.9	116.7	125.6	121.4
2	152.9	135.7	147.0	125.2	128.3
3	121.6	127.2	122.5	119.0	123.8
4	120.3	121.9	123.8	129.5	132.6
5	124.5	123.0	117.8	122.9	125.7
6	138.0	139.7	137.9	140.0	138.4
7	114.3	111.0	98.2	116.8	115.8
8	118.8	118.6	108.6	109.5	116.9
9	125.3	122.8	120.3	130.2	122.2
10	143.0	140.0	140.7	144.0	138.6

APPENDIX TABLE 2. PLANT HEIGHT DATA (CM) ON BORDER ROW EFFECT. MRS-3

REP	ROW				
	1	2	3	4	5
1	176.9	173.1	172.9	173.2	174.6
2	182.4	176.0	179.2	170.4	167.6
3	163.2	161.7	163.1	163.7	167.6
4	155.7	154.7	154.5	151.2	167.8
5	156.0	155.3	159.3	156.2	163.4
6	164.5	164.5	167.8	168.0	164.0
7	157.9	156.8	155.7	160.1	156.7
8	164.0	162.8	160.3	163.7	256.1
9	166.6	164.1	163.3	170.9	165.4
10	179.4	177.6	172.6	176.1	170.5

APPENDIX TABLE 3. NUMBER OF LEAVES PER PLANT DATA ON BORDER ROW EFFECT. MRS-3

REP	ROW				
	1	2	3	4	5
1	28.0	28.3	26.6	27.0	27.8
2	27.2	26.8	27.2	25.6	27.0
3	25.7	25.8	26.5	25.9	26.0
4	25.0	24.8	25.6	25.9	26.5
5	27.5	27.0	27.2	28.0	27.8
6	28.2	27.6	27.6	27.3	26.2
7	26.2	24.2	24.0	25.3	25.9
8	25.2	24.8	24.8	25.6	24.7
9	26.8	25.1	26.2	26.7	26.3
10	27.1	26.5	26.9	27.0	26.2