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Plot Technique Studies on Sweetpotato Yield Trials

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Abstract. **The objective of this research was to determine optimum plot size and number of replications to evaluate yield of sweetpotato *(Ipomoea batatas* Lam.) clones. The optimum plot size was estimated using the methods of maximum curvature and comparison of variances. The adequate number of replications was determined using the Hatheway method. Using the maximum curvature method, the estimated optimum plot size was 10 basic units (b.u. = six plants or 1.2 m^2) for La Molina and San Ramon, and 5 b.u. for Tacna, Peru. Using the comparison of variances method, the optimum plot size was 15 b.u. for all locations tested. The adequate number of replications with a plot size of 15 b.u. was four.**

Sweetpotato has many desirable characteristics such as high yield, wide adaptability, multifunctional usage, and a wide range of nutritional components, yet requires low production inputs. These attributes make sweetpotato an attractive crop for tropical regions. However, field experiments carried out with sweetpotatoes often have large coefficients of variation (cv). This may be due in part to inherent crop variation or to inadequate field plot techniques.

Sweetpotato researchers use field trials to determine the potential of cultivars and experimental lines. In a breeding program, this procedure is a routine in which the main objective is to identify promising genotypes to be evaluated in additional trials as clonal accessions. To increase efficiency, optimum plot size and an adequate number of replications must be used.

Federer (1967) defined the experimental unit as the total amount of material to which a treatment in a particular replication is applied. The optimum plot size depends on the nature of the experimental material, experiment design, number of entries, number of replications, and available resources. The variability of the experimental material constitutes a main component of the experimental error that must be minimized using adequate experimental techniques.

In general, experimental error is reduced by increasing plot size (Immer and Raleigh, 1933; McClelland, 1926; McKenzie et al., 1964). Conversely, others found that the experimental error was reduced significantly when the number of replications rather than plot size was increased (Rampton and Petersen, 1962; Thomas and Abou-El Fittouh, 1968).

Li (1971) in Taiwan found that the optimum plot size for the winter sermon sweetpotato crop was 6 to 12 m long and three rows wide (18 to 36 m^2) in Changlma, and 8 to 12 m long and three rows wide (24 to 36 m^2) in Hsinchu. In the fall crop, the optimum plot size was 6 to 12 m long and two rows wide (12 to 24 m^2) in Yunlin, and 6 to 12 m long and two to three rows wide (12 to 36 m^2) in Tainan.

Boudreaux and Jones (1978) used 12% as an arbitrary level of acceptability for the cv, and found that a one-row plot of 15 to 20 hills 30.5 cm apart in length (4.6 to 9 m^2) and with nine to 11 replications appeared adequate to conduct research on the total weight of storage roots. A two-row plot (9.1 to 12.2 m^2). required five to seven replications, while a three-row plot (13.7 to 18.3 m^2) required three to six replications to be equally accurate.

Hautea (1977) found that the optimum plot size was 8.10 to 9.45 m^2 (36 to 42 hills). Optimum plot shape was not definitely established, but two-row plots presented the lowest variability. Biradar (1980) found that the cv decreased with an increase in plot size, while plot shape had no appreciable effect. Plot sizes of 2.88 to 3.6 m^2 were optimum.

The main objective of our research was to determine optimum plot size and number of replications for efficient yield evaluation of sweetpotato cultivars. This determination was done as a function of the variability of experimental material, soil heterogeneity, and the minimum of experimental error.

Materials and Methods

The research was conducted at three locations in Peru: La Molina (altitude 238 m), Tacna (altitude 100 m), and San Ramon (altitude 800 m). The two former locations are in coastal deserts and the latter in the hot jungle. In each location, a uniformity trial was run using *I. batatus* cultivars Nemañete, Morado de los Pales, and Jewel.

The uniformity trial consisted of 24 rows 54 m long (1 m between rows). At harvest, each row was divided into sections 1.2 m long (six hills) to evaluate the yield per basic unit. For the statistical analyses, the trial was subdivided following a criterion of hierarchical classification, simulating a split-plot design (Fig. 1). To determine optimum plot size and number of replications, the following methods were used:

Maximum curvature method. This method estimates the cv for each plot size. Then each plot size is plotted against its respective cv and a curve establishing the inverse relationship between these two variables is obtained. Finally, the point of maximum inflection is found visually. It is assumed that the location of this point corresponds to the optimum plot size (Immer, 1932; Justesen, 1932; MacDonald et al., 1939; Zuber, 1942).

Comparison of variances. In this method, the estimates of variances of average yield per basic units (b.u.) of different plot sizes $(V\bar{x}_j)$ were considered and they are calculated by: $V\bar{x}_j = V'_j/x_j$ where: x_j is the plot size in b.u.; V'_j is the variance of various plot sizes reduced with respect to one subplot in hierarchical order, e.g., $V'_1 = V_1$; $V'_2 = [f(e - 1)V_2 + (f - 1)V_1]/(ef - 1)$; $V'3 = [ef(d - 1)V_3 + f(e - 1)V_2 + (f - 1)V_1]/$

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Table 1. Analysis of variance of sweetpotato uniformity trials in three locations following a hierarchical classification with six subdivisions.[z]

Source of variation	df	X_j	La Molina V_j	La Molina V'_j	Tacna V_j	Tacna V'_j	San Ramon V_j	San Ramon V'_j
Replications	5	180	17.3703	17.3703	4.6128	4.6128	36.9360	36.9630
Blocks/replications	6	90	4.0434	10.1011	0.6607	2.4571	20.6554	28.0557
Plots/blocks	24	30	3.8222	5.7955	3.0364	2.8543	9.1711	15.1062
Subplots/plots	36	15	2.1974	3.9711	2.6189	2.7350	2.6546	8.7927
Sub-subplots/subplots	114	5	1.7721	2.4983	0.5787	1.2908	2.0468	4.2745
Sub-sub-subplots/sub-subplots	864	1	0.8262	1.1593	0.3042	0.5008	1.7700	2.2690

[z]X_j, plot size in basic units; V_j, mean square; V'_j, variances for different plot sizes reduced with respect to one subplot in hierarchical order.

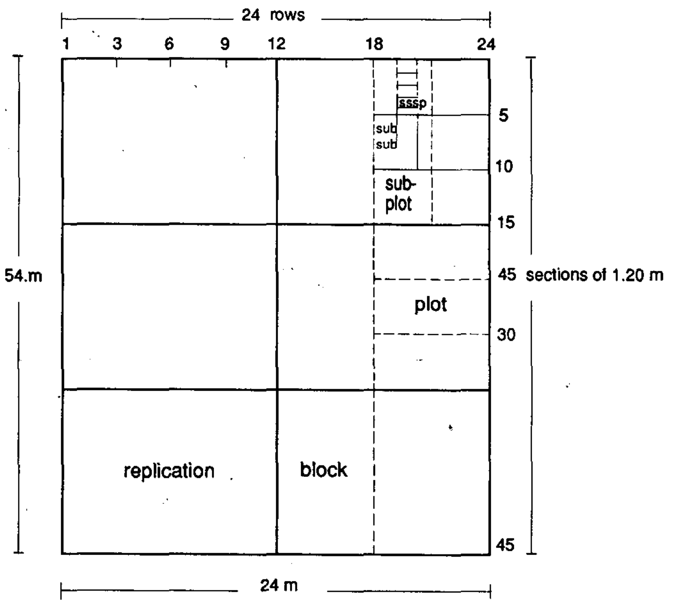

Fig. 1. Scheme for sweetpotato uniformity trials, subdivided following a hierarchical classification.

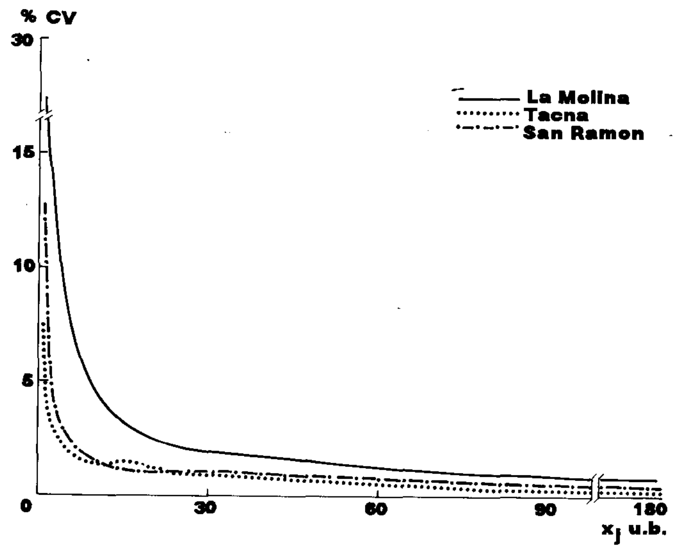

Fig. 2. Estimates of coefficient of variability for each sweetpotato plot size (x_j), at three locations.

Table 2. Coefficient of variability estimates of sweetpotato trials in three locations for diverse plot sizes (x_j) and number of plots (n_j).

x_j	n_j	Coefficient of variability: La Molina	Tacna	San Ramon
1	1080	27.45	7.35	12.76
5	216	8.04	2.02	2.74
15	72	2.98	1.43	1.04
30	36	1.96	0.77	0.96
90	12	0.67	0.12	0.48
180	6	0.69	0.15	0.32

Table 3. Variance estimates of average sweetpotato yield per basic unit ($V\bar{x}_j$) of different plot sizes and for three locations.

Plot size (x_j)	Estimates of $V\bar{x}_j$: La Molina	Tacna	San Ramon
1	1.1593 a’	0.5008 a	2.2690 a
5	0.4996 b	0.2581 b	0.8549 b
15	0.2648 **C**	0.1823 **C**	0.5862 **C**
30	0.1932 **C**	0.0951 *c*	0.5035 *c*
90	0.1122 *c*	0.0273 **C**	0.3117 *c*
180	0.0965 **C**	0.0256 **C**	0.2052 **C**

‘Separation of estimates by Bartlett’s test (α = 0.05),

(clef - 1). . .; $V'_6 = [bcdef(a - l)V_6 + cdef(b - 1)V_5 + \ldots + (f - 1)V_1]/(abcdef - 1)$.

Consecutive tests of homogeneity of variances were performed, excluding in each test the plot of lower size in which variance was statistically different. The test was continued until a group of plot sizes with statistically similar variances was obtained. Then it was inferred that the lower plot size of the group tested corresponded to the optimum plot size. The use of a larger plot size was not justified because the estimate of variance was not significantly reduced (Vallejo and Mendoza, 1988).

Hatheway’s method. True mean differences (d) were estimated using the equation proposed by Hatheway (1961). To detect these differences, several combinations of number of treatments (5, 10, 15, 20, 25, and 30) and number of replications (2, 3, 4, 5, 6, and 7) were used. In addition, the use of a randomized complete block (RCB) design and an optimum plot size estimated for each location were considered. The equation used was: $d = [2(t_1 + t_2)^2 cv]/rx^b$ where: t_1 is the critical Student’s value for a significant level of α= 0.05; t_2 is the tabular Student’s value for (1 – *P)* = 0.20, where *P is* the probability to obtain a significant result; cv is the plot size coefficient of variability included in the estimation; r is the number of replications considered; x is the plot size; b is the weighted coefficient of soil heterogeneity (Hatheway and Williams, 1958).

Table 4. Estimates of true differences of treatment means (%) for various combinations of sweetpotato entry numbers and replications in a randomized complete block design at three locations.[z]

Location and replications	Entries (no.)					
	10	15	20	25	30	35
La Molina						
2	23.62	21.26	20.83	20.60	20.44	20.35
3	17.06	16.71	16.56	16.45	16.41	16,37
4	14.50	14.30	14.21	14.17	14.14	14.11
5	12.77	12.72	12.67	12.64	12.59	12.49
6	11.66	11.58	11.53	11.50	11.40	11.40
7	10.76	10.70	10.65	10.56	10.56	10.56
Tacna						
2	15.32	14.67	14.37	14.18	14.11	14.04
3	11.77	11.53	11.43	11.35	11.33	11.30
4	10.00	9.84	9.81	9.78	9.76	9.71
5	8.81	8.87	8.74	8.72	8.69	8.62
6	8.05	7.99	7.96	7.91	7.87	7.87
7	7.42	7.37	7.35	7.28	7.28	7.28
San Ramon						
2	24.46	23.42	22.95	22.70	22.52	22.42
3	18.80	18.41	18.24	18.11	18.08	18.04
4	15.97	15.76	15.66	15.62	15.59	15.55
5	14.07	14.01	13.96	13.92	13.88	13.76
6	12.85	12.76	12.75	12.67	12.56	12.56
7	11.85	11.79	11.74	11.63	11.63	11.63

[z]Estimates made using optimum plot size of 15 basic units, $\alpha = 0.05$, and $(1 - P) = 0.20$.

Results and Discussion

The analysis of variance (ANOVA) of the uniformity trial including mean squares (V_j) and the variances for different plot sizes reduced with respect to one subplot in hierarchical order (V'_j) for each location are shown in Table 1.

Maximum curvature method. Using the ANOVA (Table 1), the cv for each plot size and location was calculated (Table 2). In general, an increase in plot size up to 15 b.u. significantly reduced the CV, after which there was little effect. Figure 2 shows the inverse relationship between plot sizes and their cv for the three locations. The points of maximum curvature were visually located at 10 b.u. for La Molina and San Ramon and 5 b.u. for Tacna. Optimum plot size was 60 plants (12 m^2) for the first two locations and 30 plants (9 m^2) for the last one.

Comparison of variances method. The variance of average yield per basic unit $(V\bar{x}_j)$ for different plot sizes and for each location was estimated (Table 3). These data confirm the inverse relationship existing between the plot sizes and their respective variances because the variances of means tend to decrease with increased plot size.

Afterward, we found for all locations that variances for plot sizes of 15, 30, 90, and 180 b.u. were statistically similar using consecutive tests of homogeneity of variance. Optimum plot size was 15 b.u. because variance was not reduced significantly when larger plot sizes were used. This optimum plot size was equivalent to plots of 90 plants (18 m^2).

Hatheway's method. Plots of 15 units were used to estimate true differences of treatments (d) for combinations of number of treatments and replications in a RCB design and for each location (Table 4). In general, experimental precision improved if the number of replications was increased. Precision was significantly increased up to four replications where true differences of treatments near 15%, 10%, and 16% were detected at La Molina, Tacna, and San Ramon, respectively. These d values are acceptable by statistical inference, which suggested that the use of four replications was adequate when an optimum plot size of 15 b.u. was used. Where resources are limited, three replications could be used with slightly reduced precision.

Our results indicate that no significant increases in either plot size or number of replications will contribute individually to appreciable reduction of experimental error. It seems that a balanced increase of these two components, within reasonable and manageable margins, will increase experimental accuracy.

We have found both coincidence and discrepancy in our research compared with previous experimental work on field plot techniques. Experimental materials, soil types, environmental conditions, and statistical procedures may explain the discrepancies.

In our research, three very different cultivars were used and soil conditions and environmental characteristics of the testing sites differed substantially. However, the statistical procedures were standard. Under these conditions, and accepting certain variations within a reasonable limit, the following conclusions can hold for the three experiment stations where the research was done: 1) Optimum plot size was 10 b.u. for La Molina and San Ramon and 5 b.u. for Tacna (using maximum curvature method). 2) Optimum plot size of 15 b.u. was found for La Molina, Tacna, and San Ramon (using comparison of variances method). 3) Since the comparison of variances method is more reliable, we recommend the use of experimental plots of 15 b.u.; or 90 plants (18 m^2). 4) The adequate number of replications was estimated as four for all locations tested (using Hatheway's method).

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