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ABSTRACT: A sampling study was made of the number of bitterbrush seeds per trap from plots in northeastern California. The count per trap had a large variation for each plant. This variation was not reduced to an acceptable low level by grouping the seed traps according to their position relative to the plant crown. In the absence of additional information, it is recommended that seed traps should not be used and that a complete count of bitterbrush seeds per plant be made.

Measuring Bitterbrush Seed Production on Plants with Variable Crown Density . . .

complete counts per plant suggested

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How much seed a plant produces is one indication of its condition and consequently of its ability to reproduce. This information is usually obtained by sampling with seed traps. Factors affecting the variability of the estimated seed production include the number, placement, shape, and size of the traps. Standard statistical procedures are available for determining which sampling procedure gives the smallest standard errors of the estimates.

We investigated the pattern of seed fall of bitterbrush plants (*Purshia tridentata*) from Modoc County, California. Most of the seeds fell under the canopy and few seeds fell more than 2 feet from the edge of the canopy. The variance of the number of seeds per trap was quite high. The pattern of seed fall suggested that some method other than stratification by position of a trap relative to the canopy is needed to reduce the variation to an acceptable low level. Until more information is available, we suggest that a complete seed count per plant be made. Bagging the whole plant or some other technique should be useful in collecting seeds.

The Study

We selected four mature bitterbrush plants in 1963, at the Flukey Wells area for study. A plywood platform placed under each plant was completely covered by 10- by 14-inch metal seed traps (fig. 1). In this study we restricted our attention to total seed production. Frost and insect damage can kill seeds regardless of the condition of the plant, so that we considered the total number of seeds a better measure of seed production than the number of viable seeds.

In 1964, we increased the number of plants studied from four to five. The plants were from the same area and the placement of the seed traps was the same as in 1963. So that we could study the effect of trap size on the sampling requirements, we took a small number of the seed traps and subdivided each trap into four parts. We then had four contiguous 5- by 7-inch seed traps.

The distribution of seeds under the four plants studied in 1963 suggested that the traps should be grouped

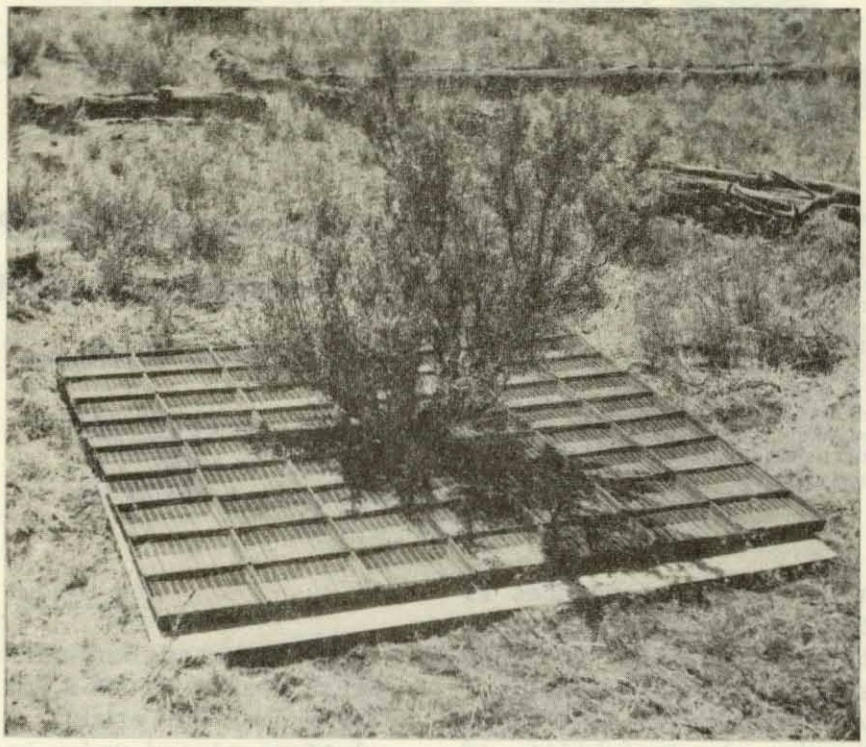

Figure 1.--*Seed traps placed on a wood platform beneath bitterbrush plant to measure seed production.*

by position relative to the edge of the crown. The density of seed was always higher inside the edge of the canopy than outside, while traps directly under the edge had an intermediate number of seeds. The groups or "strata" were defined as: (a) trap completely under canopy; (b) more than half of trap under the canopy; (c) less than half of trap under canopy; and (d) trap completely outside of canopy.

The five plants studied in 1964 showed the same pattern of seed fall as in 1963. The subdivided traps also indicated that the smaller traps may be better than the large traps.

Statistical Procedures

The seed traps within the stratum for the individual plants may be considered the whole population. The population mean per stratum is:

$$\bar{X}_s = \sum_{i=1}^{N_s} X_i / N_s \qquad (1)$$

and the variance is:

$$S_s^2 = \sum_{i=1}^{N_s} (X_i - \bar{X}_s)^2/(N_s - 1) \qquad (2)$$

in which X_i = number of seed in i^{th} trap in the s^{th} stratum, and N_s = number of traps in the s^{th} stratum.

If we were to sample the s^{th} stratum, then the sample variance is (dropping the subscript):

$$s^2 = \sum_{i=1}^{n} (X_i - \bar{x})^2/(n - 1) \qquad (3)$$

which is an unbiased estimate of S^2.

The sample variance of the mean is:

$$s_{\bar{x}}^2 = \frac{s^2}{n}\left(\frac{N-n}{N}\right) \qquad (4)$$

The term $\frac{(N-n)}{N}$ is called the finite population correction.

The sample variance of the mean is small if s^2 is small or n is large. If the whole population is measured, the variance of the mean is 0. Note that n would be equal to N and the finite population correction is equal to 0.

The half-confidence width squared is:

$$d^2 = t^2_{\frac{\alpha}{2}, n-1} s^2_{\bar{x}} \qquad (5)$$

in which $t^2_{\frac{\alpha}{2}, n-1}$ is the square of the critical value from Student's t table.

Solution of equation (5) gives:

$$n = \left[(d^2/t^2_{\frac{\alpha}{2}, n-1} s^2) + (1/N) \right]^{-1} \qquad (6)$$

Results

Most of the seeds fell into traps under the crown (table 1). The variance of the number of seeds per trap was large (table 2). The information in tables 1 and 2 was used in equation 6 to compute the number (n) of traps associated with a 95-percent confidence width squared of 20 percent of the mean. For large n, t^2 is about 4.0. The sampling fraction (n/N) is shown in table 3.

Table 1.--*The mean ($\bar{X}$) number of seeds per trap, by plant and stratum*

Year and plant	Stratum, or position of trap...			
	Completely out	Half out	Half under	Completely under
1963:				
1	16.6	48.4	125.4	206.2
2	15.2	45.6	81.6	116.8
3	.9	4.1	8.8	9.0
4	9.3	48.3	132.4	185.3
1964:				
1	3.6	24.7	26.5	58.7
2	1.6	10.3	44.9	66.2
3	6.5	20.7	35.5	40.0
4	2.0	4.4	12.6	15.3
5	.6	3.2	3.5	4.4

Table 2.--*The variance (S^2) of number of seeds per trap, by plant and stratum*

Year and plant	Stratum, or position of trap...			
	Completely out	Half out	Half under	Completely under
1963:				
1	305.7	1,529.4	3,307.8	2,254.9
2	165.7	683.3	1,403.1	1,189.9
3	2.4	29.4	63.8	10.0
4	108.6	1,011.3	3,970.0	3,577.9
1964:				
1	42.2	547.6	233.6	1,044.3
2	2.6	56.9	583.9	906.7
3	109.0	503.3	979.2	325.6
4	27.9	130.3	131.3	25.9
5	1.5	20.6	17.0	16.3

Table 3.--*Fraction (n/N) of seed traps needed to obtain a 95-percent half-confidence width squared equal to 20 percent of the mean, by plant and stratum*

Year and plant	Stratum or position of trap...			
	Completely out	Half out	Half under	Completely under
1963:				
1	28/37	11/12	7/9	2/4
2	26/39	11/16	8/12	6/16
3	33/37	10/10	10/11	3/4
4	27/33	11/14	7/9	4/6
1964				
1	30/33	9/10	11/16	3/3
2	20/25	10/12	9/13	5/5
3	26/28	10/10	11/12	3/3
4	37/39	14/14	14/16	5/7
5	49/51	15/15	17/19	5/5

The number (n) of traps needed was, in most cases, close to the total (N) in each stratum. In 8 of the 32 cases the whole stratum was needed to obtain the desired interval. The findings show that stratification of the traps by position did not reduce the variation to an acceptable level. The variation in seed fall was probably due to form of the plants examined. We made no attempt to use plants with uniform crowns. In fact, most of the plants in the Flukey Wells area have irregularly shaped crowns.

If we knew how crown density is related to seed fall, we could find better sampling procedures. The distribution of seeds in the subdivided traps showed a high intra-trap correlation: a trap with a high number of seeds was usually next to traps with high seed counts and vice versa. Also, the smaller 5- by 7-inch traps showed that much of the variation was due to the position relative to the edge of the crown. The small traps next to the edge and under the canopy had a higher seed count than the traps not under the canopy. If seed traps are used, they should be placed either completely under or outside the crown.

Our study did not give precise information on the efficiency of the smaller traps compared to the larger traps. It appears that the smaller traps may be better, however, because they are easier to place.

The area not under the canopy of a plant could--in theory--extend for an infinite distance. The seeds will, however, fall close to the plant. For high producing plants (plants 1, 2, and 4 in 1963) we found few seeds more than two traps or about two feet from the edge of the plant. For the low seed-producing plants, there were few seeds more than one trap from the edge. Therefore, sampling more than one foot from the edge of the canopy is unnecessary.

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