SAMPLING PROCEDURES FOR SPITTLEBUG ADULTS IN PASTURES OF BRACHIARIA DECUMBENS[1]

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ABSTRACT - A sampling study of spittlebug adults in pastures of *Brachiaria decumbens* was conducted to find an appropriate number of sweep-net sweeps/sample. Considering the relative variation (SE/x) X 100, and the total number of sweeps in the sampling, 10 sweeps/sample were found to be better than 5,20 or 40. The number of samples required for a particular level of relative variation at population densities > 16 spittlebug adults/10 sweeps remained the same, whereas at densities < 16, the number increased inversely. A regression model to convert relative estimates obtained by sweep-net method to the absolute estimate was presented. Considering the degree of precision and the time spent in sampling, the sweep-net method was superior to cage method. The distribution pattern of numbers of spittlebug adults in samples of 10 sweep-net sweeps, generally fitted the Poisson series. A sequential plan presented here would reduce the sampling time over the conventional (fixed sample numbers) sampling.

Index terms: *Zulia entreriana, Deois flavopicta,* Cercopidae, sampling efficiency, sequential sampling.

PROCEDIMENTO DE AMOSTRAGEM DE ADULTOS DE CIGARRINHAS EM PASTAGENS DE BRACHIARIA DECUMBENS

RESUMO - Foi conduzido um estudo sobre amostragem de adultos de cigarrinhas em pastagens de *Brachiaria decumbens* para se determinar o melhor número de batidas em uma amostra de rede entomológica. Considerando-se a variação relativa (EP/$\bar{x}$) X 100, e o número total de batidas na amostragem, encontra-se 10 batidas/amostra ser melhor do que 5,20 ou 40. O número de amostras necessárias para determinado nível de variação relativa nas populações de cigarrinhas > 16 adultos/10 batidas foi o mesmo, ao passo que, nas densidades < 16, o número aumentou inversamente. Foi construído um modelo de regressão para converter a estimativa relativa obtida pelo método de rede entomológica em estimativa absoluta. Considerando-se o nível de precisão e o tempo gasto em amostragem, o método de rede entomológica foi superior ao método de gaiola. O número de adultos de cigarrinhas em amostras de 10 batidas de rede entomológica mostoru uma distribuição tipo Poisson. Esta apresenta em plano de amostragem tipo sequencial, que deveria reduzir o tempo gasto na amostragem convencional (onde o número de amostras é fixo).

Termos para indexação: *Zulia entreriana, Deois flavopicta,* Cercopidae, eficiência da amostragem, amostragem seqüencial.

INTRODUCTION

Spittlebugs are one of the important limiting factors in attaining full potential of meat production in Brazil. They suck sap and inject toxins in grass plants. This reduces plant growth and in turn carrying capacity of the pasture. e.g. Pacheco (1981) cited several other papers about the quantitative aspects of spittlebug losses to pastures. The majority of spittlebugs damaging pastures in Brazil belong to genera *Zulia, Deois* and *Mahanarva.*

Because the intensity of spittlebug damage is partly a function of the insect density, there is a great interest in knowing its population at a farm level for the pest management decision, as well as for various research purposes. Although the eggs and nymphs of spittlebug are sampled to determine the population levels, sampling of the adults with a sweep-net seems to be the most popular method.

Before proceeding with sampling of spittlebug adults with a sweep-net, the first things one needs to decide are: 1) number of sweeps per sample (10, 20, 40 or 60 etc.); 2) number of samples; and 3) locations of these samples in the sampling area. The objective in sampling plan is to obtain the information with an acceptable level of precision or relative variation (proportion of standard error to mean expressed as a percentage) with the minimum possible effort. Herein a study is report-

[1] Accepted for publication on 23 February, 1984

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ed that helps answer the above mentioned three points. Studies about conversion of adult counts in a sweep-net sample (relative estimate) to absolute estimate and development of sequential sampling plan are also included.

MATERIALS AND METHODS

The 40 fields of ca. 2 ha, *Brachiaria decumbens* Stapf. used in the study to determine the appropriate numbers of samples, and sweeps per sample were located near Campo Grande and Dourados. Each field was a part of a larger pasture under grazing. The mean grass height based on 25 grass-plants/field varied from 5-46 cm with a grand mean of 22.2 cm and SE of 1.50. Tewnty-four of the 40 fields had grass height $\geqslant$ 25 cm. To obtain the proportion of spittlebug species, a minimum of 100 adults/field were examined. Overall, 68.8% of the adults belonged to species *Zulia entreriana* Berg., 30.6% to *Deois flavopicta* Stal. and 0.6% to *Mahanarva fimbriolata* Stal. In only three fields, > 50% of the adults belonged to *D. flavopicta.*

The sweep-net used for sampling of spittlebug adults had 40 cm diameter ring, a cone-shaped bag made of strong muslin 70 cm deep, and a handle about 130 cm long. Each field was divided in 36 equal-sized square plots. Within each plot of two fields, one sample each of 5, 10, 20 and 40 sweeps of the sweep-net were taken on the same day in such a way that no overlapping of the area sampled occurred. In a similar manner, 10, 20 and 40 sweep samples in 6 fields; 5, 10 and 20 sweep samples in 2; 5 and 10 sweep samples in 13; and 5 or 10 or 20 sweep samples in 17 fields were taken. The adults appearing in sweep-net samples were counted in the field itself. For each sweep, pasture in semicircle of 1.3 m radius (distance between the person and the outermost point of the ring) was swept and the person walked a distance of 1.5 m (two small steps). The samplings were done during September 82 to March 83.

With use of the random-number table (Steel & Torrie 1960), 5, 10 and 20 samples were drawn form 36 samples of the field. This was done for each of the four sample sizes, i.e., 5, 10, 20 and 40 sweeps/sample. The distribution pattern of adults within a field was tested for conformity to the Poisson by calculating the index of dispersion (I_D). I_D is approximately distributed as X^2 with n-1 degrees of freedom (Southwood 1978). I_D values between limits of 0.95 and 0.05 for 35 degrees of freedom were considered as conforming to the Poisson distribution. Values of the negative binomial parameter (k) were determined as $k = \bar{x}^2/(s^2-\bar{x})$ (Southwood 1978). A common k was calculated using procedures given by Southwood (1978), also.

The mean grass heights of 21 fields of *B. decumbens* used in the study to compare sweep-net sampling method to the cage sampling varied from 16 to 54 cm, with a grand mean of 33.0 and SE of 2.74. Nine of the 21 fields had grass height of $\geqslant$ 25 cm. Overall, 80.9% of the adults belong to *Z. entreriana,* 18.4% to *D. flavopicta* and 0.7% to *M. fimbriolata.* In only two fields, > 50% of the adults belonged to *D. flavopicta.*

Each field was divided in 16 equal-sized square plots, and in each plot a sweep-net sample of 10 sweeps and a cage sample were taken. The methodology for the sweep-net sample was given earlier. For cage sample, a cage of 1 m^3 made with wooden frame and saran screen was used. One side of the cage was open and the opposite side had a lid. A hook was fastened in the center of the two opposite sides of the top part of the frame. A 3 m - long x 3 cm - diameter light weight metal pipe was inserted through the two hooks in such a way that either side of the cage remained exactly 1 m from the respective ends of the pipe. Thereafter, two persons lifted the cage by holding on to the ends of the pipe and arms in upright position. In this manner the cage was carried to the randomly selected location in the plot. While carrying, the cage remained ca. 1 m above the soil level and the distance between the cage and the person was also maintained at 1 m. Carrying the cage in this manner, did not alert the spittlebug adults that were directly below the cage; thus no adults entered through the open end of the cage facing the pasture. Upon reaching the desired location, the cage was gently lowered to the ground. One person entered the cage through the lid on the top, while the other kept count of the adults escaping through the lid, which rarely exceeded 5. Adults inside the cage were collected by using an aspirator. To obtain the hiding adults, plants inside the cage were shaken vigorously. When the adults in the cage were collected, the plants were clipped at ground level, and the clipped plants and the stubs were examined carefully for any remaining adults. The sampling was done during February, 83.

The sequential sampling was developed as per procedures given by Onsager (1976). Populations of 20 - 25 spittlebug adults/m^2 of *B. decumbens* was suggested as the economic injury level (Nilakhe 1983 a). The levels of the lower and upper decision lines of the sequential sampling plant were set at the 3/4 of the economic injury level.

RESULTS

Mean number of adults and relative variation (RV) for sample of 40, 20, 10 and 5 sweeps of a sweep-net are given in Tables 1, 2, 3 and 4 respectively. Considering the four tables together, as the number of samples increased, the RV values became less variable; e.g., RV exceeded 40%, 12 times in 5 samples, and 5 times in 10 samples, whereas in the case of 20 samples the RV was always < 40%. The authors wanted to estimate popula-

TABLE 1. Mean number of spittlebug adults in 5, 10 and 20 samples of 40 sweeps of a sweep-net, and the relative variation (RV) in pasture of *Brachiaria decumbens*, Mato Grosso do Sul, 1982-83.

Field	No. of samples					
	5		10		20	
	$\bar{x}$ no. of adults	RV[1]	$\bar{x}$ no. of adults	RV	$\bar{x}$ no. of adults	RV
1	107.6	6.0	159.0	4.0	171.4	2.4
2	29.2	24.0	20.5	7.6	25.4	5.8
3	8.8	9.8	13.2	13.0	8.9	14.9
4	57.4	7.6	49.8	10.0	55.4	6.9
5	48.0	8.0	43.6	9.0	44.9	5.2
6	41.2	18.7	37.0	14.3	35.9	10.3
7	217.2	15.6	204.8	5.2	215.4	5.0
8	96.6	15.7	70.0	13.6	81.3	7.2

[1] RV = (SE/$\bar{x}$) X 100.

TABLE 2. Mean number of spittlebug adults in 5, 10 and 20 samples of 20 sweeps of a sweep-net, and the relative variation (RV) in pasture of *Brachiaria decumbens*, Mato Grosso do Sul, 1982-83.

Field	No. of samples					
	5		10		20	
	$\bar{x}$ no. of adults	RV[1]	$\bar{x}$ no. of adults	RV	$\bar{x}$ no. of adults	RV
1	98.4	7.8	114.9	3.2	108.8	3.0
2	10.4	30.4	11.3	11.4	13.8	10.5
3	5.2	10.6	5.1	18.8	4.6	12.6
4	57.4	7.6	30.8	9.6	27.5	7.6
5	27.8	6.6	25.4	7.5	22.6	6.5
6	22.8	8.8	17.8	15.4	20.6	22.4
7	93.6	8.1	109.1	6.6	98.7	9.0
8	50.4	13.9	40.4	11.6	40.7	6.3
9	9.2	8.7	11.2	9.0	9.9	4.2
10	22.4	16.9	26.1	12.1	17.1	7.0
38	3.6	44.4	3.1	17.0	2.5	17.3
39	1.6	50.8	1.1	34.4	1.2	27.4
40	1.4	36.4	1.6	21.2	1.4	13.1

[1] RV = (SE/$\bar{x}$) X 100.

TABLE 3. Mean number of spittlebug adults in 5, 10 and 20 samples of 10 sweeps of a sweep-net, and the relative variation (RV) in pasture of *Brachiaria decumbens*, Mato Grosso do Sul, 1982-83.

Field	No. of samples					
	5		10		20	
	$\bar{x}$ no. of adults	RV[1]	$\bar{x}$ no. of adults	RV	$\bar{x}$ no. of adults	RV
1	39.4	8.2	41.4	10.9	41.9	5.9
2	11.4	19.7	7.6	24.7	8.8	22.2
3	2.2	16.9	3.9	13.5	2.9	13.0
4	17.4	12.3	16.1	14.1	16.4	6.1
5	14.0	6.0	14.7	10.0	12.0	6.2
6	9.6	50.2	14.8	14.2	11.7	15.5
7	51.4	16.0	56.6	11.1	54.4	5.1
8	22.2	9.5	21.3	10.4	21.3	5.5
9	9.0	11.6	7.0	10.4	8.1	9.1
10	15.2	9.7	14.9	11.0	12.7	10.2
17	6.2	16.4	5.9	12.0	6.8	9.7
18	17.0	32.9	25.2	14.0	24.6	9.6
19	7.8	22.4	7.8	13.6	6.6	4.7
20	2.6	31.2	1.7	39.3	1.4	19.0
21	0.6	66.7	0.6	55.9	0.4	37.5
22	3.2	46.8	1.5	24.8	1.5	23.4
23	2.8	13.4	3.2	17.9	3.2	14.6
27	5.2	14.1	4.5	12.9	4.7	9.9
28	43.0	7.3	38.0	8.7	42.2	4.0
29	28.8	8.9	24.4	12.2	26.4	7.9
30	13.2	13.2	12.6	11.4	13.2	7.4
32	5.4	26.6	6.4	9.9	4.1	10.7
33	4.8	32.5	5.1	17.4	5.4	17.6
34	29.2	17.2	28.1	10.1	23.5	9.4
35	19.4	6.2	16.7	5.9	18.6	6.2
36	61.0	14.1	59.5	13.8	58.1	6.2
37	39.8	17.3	54.5	9.4	44.1	8.2

[1] RV = (SE/$\bar{x}$) X 100.

tions of spittlebug adults with the least possible work but with acceptable value of RV (< 20%) also. Using this standard, and the total number of sweeps in the sampling (no.of samples X no. of sweeps per sample), the selection of the most appropriate number of sweeps per sample and the sample numbers was done as follows: in the samples taken with 40 sweeps, the RV was < 20% for all of the 10 and 20 samples but the total number

TABLE 4. Mean number of spittlebug adults in 5, 10 and 20 samples of 5 sweeps of a sweep-net, and the relative variation (RV) in pasture of *Brachiaria decumbens*, Mato Grosso do Sul, 1982-83.

Field	No. of samples					
	5		10		20	
	$\bar{x}$ no. of adults	RV[1]	$\bar{x}$ no. of adults	RV	$\bar{x}$ no. of adults	RV
6	12.3	23.1	9.1	23.0	3.6	7.9
7	28.4	11.1	32.1	10.9	32.4	11.1
9	4.8	3.7	12.8	12.8	3.6	7.9
10	13.8	13.6	10.2	8.4	11.0	9.7
11	4.2	20.5	5.3	19.1	8.3	12.1
12	8.8	22.0	10.0	8.0	8.0	13.9
13	13.2	10.0	12.6	8.1	11.4	7.0
14	16.0	9.9	13.1	9.6	11.3	6.2
15	10.8	23.3	13.3	14.4	14.7	7.8
16	17.2	6.2	18.5	5.0	18.0	4.0
17	4.0	37.1	4.5	12.5	3.9	13.6
18	13.2	29.0	12.6	18.8	12.9	16.2
19	5.2	14.1	3.5	18.2	3.6	23.4
20	1.2	61.2	0.3	71.2	0.7	26.0
24	0.4	61.2	0.3	50.9	0.8	22.0
25	0.6	40.8	0.3	71.2	0.9	23.3
26	2.0	27.3	1.3	20.0	1.4	16.7
27	2.6	35.7	1.8	28.5	2.2	14.1
28	29.0	8.0	26.6	5.2	23.7	4.5
29	18.0	14.9	16.3	12.9	15.4	8.7
30	6.0	21.7	5.5	10.6	6.2	12.6
31	1.0	44.7	1.7	41.2	2.0	33.5
33	1.0	63.2	1.6	38.6	1.6	17.8
34	8.8	21.4	11.6	11.5	10.7	7.7
35	6.0	18.3	6.9	10.2	7.1	12.6
36	30.4	10.7	29.3	14.7	27.7	7.6
37	13.4	50.2	15.1	11.3	13.6	10.5

[1] RV = (SE/$\bar{x}$) X 100.

TABLE 5. Number of fields out of 27 in which the relative variation was > 20%[1].

No. of sweeps/sample	Sample numbers		
	5	10	20
5	17	8	6
10	8	4	3
20	10	4	4

[1] Sampling with 10 and 5 sweeps/sample were done in 27 fields (Tables 3 and 4) whereas for 20 sweep samples only 13 fields were used (Table 2). To compare en equal basis, the relevant number of fields in the latter was doubled.

of sweeps taken were 400 and 800, respectively; whereas for 5 samples (200 sweeps), it exceeded only once (24%, field 2) (Table 1). In 10 samples of 20 sweeps, the RV exceeded 20% in two of the 13 cases (Fields 39 and 40) (Table 2), and in these 2 cases the population was extremely low--one and 2 adults/20 sweeps, respectively. If 5 samples of 40 sweeps were taken in these 2 fields, the RV values probably would have exceeded 20 also. Therefore, sampling efficiency of 5 samples of 40 sweeps was considered equal to 10 samples of 20 sweeps.

Further selection was done by using Table 5, which gives the number of fields out of 27 in which the RV was > 20% for samples of 20, 10 and 5 sweeps (Tables 2, 3 and 4). Since 20 sweep samples were based on only 13 fields (Table 2), the number of fields with RV > 20 was doubled.

Irrespective of the number of sweeps per sample, the sampling efficiency was the poorest when only 5 samples per field were taken. It improved as the number of samples increased up to 10. Since the efficiency of 10 samples was similar to 20, it is not worthwhile to take 20 samples. Disregarding the number of samples, it is observed that the sampling efficiency was better for 10 sweep samples than for 5, but was similar to that for 20 sweep samples.

We have already chosen 10 as an appropriate sample number. Now, the appropriate number of sweeps for the 10 samples was chosen as follows: with 5 sweeps, the RV was > 20% in 8 of 27 fields, but better efficiency was obtained for 10 and 20 sweeps, where the designated RV value was exceeded only in 4 fields (Table 5). Since the sampling efficiency with 10 samples of 10 sweeps (a total of 100 sweeps) was the same as of 10 samples of 20 sweeps (a total of 200 sweeps), the former is the preferred combination.

So far, efficiency of only 3 sample numbers (5, 10 and 20) was compared. However, for better understanding, the number of samples necessary

TABLE 6. Mean number of spittlebug adults in 36 samples of 10 sweeps of a sweep-net in 2 ha fields of *Brachiaria decumbens*, variance, coefficient of variation (CV), estimates of no. of samples for three levels of precision, and the mathematical distribution characteristics of the counts, Mato Grosso do Sul, 1982-83.

Field	$\bar{x} \pm SE$	s^2	CV	No. of samples required for SE of[1]			Index of aggregation (k)[2]	Index of dispersion (I_D)[3]
				10	15	20		
1	41.4 ± 1.9	129.8	27.5	8	3	2	19.4	106.6
2	8.8 ± 0.8	23.2	54.7	30	13	5	5.4	89.6
3	3.0 ± 0.3	2.8	55.2	30	14	8	-	31.2
4	15.3 ± 0.4	5.4	15.2	2	1	1	-	12.0
5	13.4 ± 0.6	13.5	27.4	8	3	2	1796.0	34.3
6	12.7 ± 1.3	56.9	59.4	35	16	9	3.7	156.8
7	55.1 ± 2.5	229.5	27.5	8	3	2	17.4	145.8
8	21.4 ± 1.0	31.3	26.1	7	3	2	46.3	49.7
9	7.9 ± 0.5	8.5	36.8	14	6	3	107.8	36.5
10	14.1 ± 0.8	25.5	35.8	13	6	3	17.5	63.2
17	8.5 ± 0.8	25.3	59.2	35	16	9	4.3	104.2
18	24.4 ± 2.1	159.2	51.7	27	12	7	4.4	228.4
19	6.7 ± 0.5	7.9	42.1	18	8	4	34.5	41.4
20	1.5 ± 0.2	2.2	98.9	98	43	24	3.2	51.3
21	0.5 ± 0.1	0.6	164.8	272	121	68	1.7	44.7
22	1.7 ± 0.3	3.4	108.5	118	52	29	1.7	69.6
23	3.1 ± 0.3	3.3	59.3	35	16	9	36.5	38.0
27	5.2 ± 0.3	3.6	36.5	13	6	3	-	24.2
28	40.2 ± 1.6	87.7	23.3	5	2	1	34.0	76.4
29	25.0 ± 1.3	62.5	31.6	10	7	4	16.7	87.5
30	12.0 ± 0.7	17.6	34.8	12	5	3	26.1	51.1
32	5.1 ± 0.4	6.1	48.9	24	11	6	24.4	42.3
33	5.4 ± 0.6	14.2	70.0	49	22	12	3.3	92.5
34	21.3 ± 1.5	78.5	41.6	17	8	4	7.9	129.0
35	16.7 ± 1.0	36.3	36.1	13	6	3	14.2	76.1
36	63.7 ± 2.9	307.9	27.5	8	3	2	16.6	169.2
37	43.0 ± 2.6	250.3	36.8	14	6	3	8.9	203.7

[1] No. of samples for SE of a certain probability (P) = $(CV/P)^2$.

[2] $k = \bar{x}^2/(s^2-\bar{x})$. In fields 3, 4 and 27, th k was negative.

[3] $I_D = s^2(n-1)/\bar{x}$.

for the 3 levels of precision at various population densities was calculated by using the 36, ten-sweep samples (Table 6). The resulting sampling plan illustrated graphically (Fig. 1) shows that at densities of > 16 adults/10 sweeps, the number of samples required for the precision levels of 10, 15 and 20% was 10, 6 and 3, respectively. At population levels < 16, the number of samples required was inversely proportional to the population density. Table 6 also shows that values of index of aggregation (k) were ca. 8 or greater in 17 of 24 fields, indicating Poisson distribution in these 17 fields (Southwood 1978). In the remaining 7 fields, excepting fields 21 and 22, the counts did not show a high degree of clumping also. Values of the index of dispersion (I_D) showed agreement to Poisson distribution in 10 of the 27 fields (fields 3, 4, 5, 8, 9, 19, 21, 23, 27 and 32). The same 10 fields, excepting field 21, indicated Poisson distribution by values of k also. Generally variance was greater than the respective mean. However, considering k and I_D values, for practical purposes, the mathematical distribution of counts of spittlebug adults in samples of 10 sweeps was consi-

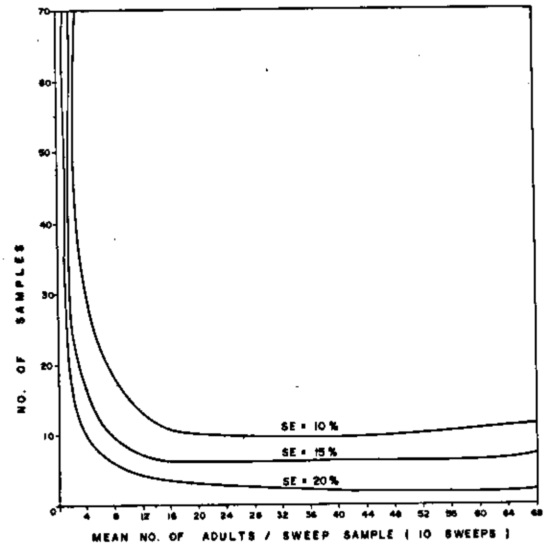

FIG. 1. Relation between population density and number of samples necessary for three levels of precision for sampling of spittlebug adults in pastures of *Brachiaria decumbens.*

dered Poisson. A nonsignificant correlation coefficient ($r = -0.03$) ($P > 0.05$) for the mean and k values indicated that k was independent of density and therefore calculation of a common k would be justified (Rudd 1980); a common k of 13.8 was obtained.

Because the spatial pattern of spittlebug adults was considered Poisson, variance was stabilized by using transformation $\sqrt{x + 0.5}$, where x is equal to the observed count. The analysis of variance for each of the 27 sets of counts showed that differences between rows were significant 7 times and between columns 9 times.

Table 7 shows that mean number of spittlebug adults varied from 1.6 to 59.3 for the sweep-net sample, and from 0.8 to 29.7 for the 1 m^3 cage sample. Thus, the population densities varied considerably in these 21 samplings. To obtain all the adults present inside the cage, the plants inside the cage were shaken vigorously with the idea that the hiding adults would be visible. However, clipping of the plants and examination of the stubs was essential. An average of 15.2% of all the adults inside the cage were recovered while clipping the plants and in examination of the clipped plants and the stubs. Majority of this 15.2% was found while clipping the plants and in examination of the stubs.

The sampling efficiency of the sweep-net method was better than that of the cage method. In the sweep-net sampling, the RV values exceeded 20% in 4 fields (fields 1, 4, 15 and 16) and for the cage method in 9 fields (fields 1, 2, 4, 7, 9, 12, 14, 15 and 16). A good association between the cage and the sweep-net method was obtained ($r = 0.83$) ($P < 0.01$). The high value of coefficient of determination ($r^2 = 0.69$) indicated that 69% of variation in the sweep-net counts is attributable to the variation in the counts by the cage method. The regression model of the mean number of spittlebug adults collected by sweep-net and cage method is shown graphically in Fig. 2.

The variance of the counts of spittlebug adults by the cage method was greater than the corresponding mean, except in the field 17 (Table 7). In 9 of the 20 instances, the value of k was < 2 indicating a strong clumping in these fields, in 5 fields the k was > 8 indicating agreement with the Poisson distribution and in the remaining 6 fields the k values were intermediate, indicating weak clumping. The values of index of dispersion (I_D) indicated agreement to the Poisson distribution in fields 13, 19 and 21 only. Thus, considering both k and I_D, it can be concluded that spittlebug adults counts/m^2 of pasture showed a moderate degree of clumping. Again, the k was independent of mean ($r = 0.08$) ($P > 0.05$).

To develop the sequential sampling plan, the lower and upper limits of the decision lines (15 and 18.8 adults/m^2 of the pasture) were first converted to the number of adults/sweep sample of 10 sweeps (Fig. 2). The resulting plan using $\alpha = \beta = 0.1$, and 34 and 41 adults/sweep sample as the limits of the lower and upper decision lines is presented in Fig. 3. The average sample number (ASN) of 2.8 was obtained using the following formula given by Onsager (1976).

$$ASN = \frac{LP\,(a_1 - a_2) + a_2}{\lambda' - b}$$

TABLE 7. Mean number of spittlebug adults in a sweep-net (10 sweeps) and cage (1 m^3) sample, and distribution characteristics of the counts in cage samples in 1 ha fields of *Brachiaria decumbens*, Mato Grosso do Sul, 1983[1].

Field	$\bar{x}$ grass height ± SE (cm)	$\bar{x}$ no. of adults/ sweep-net sample ± SE	Counts of adults in cage sample			
			$\bar{x}$ ± SE	s^2	Index of aggregation (k)[2]	Index of dispersion (I_D)[3]
1	45.5 ± 3.4	42.6 ± 8.7	13.1 ± 2.9	138.7	1.4	156.5
2	40.4 ± 3.7	26.8 ± 4.1	8.6 ± 2.3	84.7	1.0	148.4
3	45.5 ± 3.4	59.3 ± 4.4	29.7 ± 3.4	188.0	5.6	94.9
4	53.8 ± 4.9	32.6 ± 7.0	6.7 ± 1.7	45.1	1.2	101.4
5	50.2 ± 4.2	41.5 ± 4.3	7.9 ± 1.0	14.9	8.8	28.4
6	53.8 ± 4.9	32.8 ± 2.6	8.8 ± 1.0	17.4	9.1	29.6
7	50.2 ± 4.2	6.6 ± 1.1	1.5 ± 0.4	2.5	2.2	25.3
8	34.9 ± 2.3	10.9 ± 1.3	4.9 ± 0.7	8.7	6.3	26.6
9	24.4 ± 2.4	12.7 ± 1.5	6.4 ± 1.4	33.1	1.9	76.3
10	22.8 ± 2.0	9.5 ± 1.1	3.8 ± 0.6	6.5	5.1	25.8
11	34.4 ± 1.5	34.1 ± 4.0	21.5 ± 2.7	117.7	4.8	82.1
12	30.3 ± 1.7	10.7 ± 2.0	4.7 ± 1.2	22.1	1.3	70.7
13	30.8 ± 1.9	20.4 ± 1.6	9.1 ± 0.9	11.5	35.9	18.8
14	31.0 ± 2.4	22.9 ± 2.9	5.4 ± 1.9	55.2	0.6	152.2
15	24.9 ± 2.0	9.9 ± 2.6	3.5 ± 0.8	10.1	1.9	43.4
16	16.9 ± 1.2	1.6 ± 0.5	0.8 ± 0.5	3.5	0.2	64.7
17	23.8 ± 1.8	3.6 ± 0.7	1.4 ± 0.2	0.7	-	6.8
18	24.2 ± 2.3	13.6 ± 2.2	8.6 ± 1.3	25.6	4.3	44.9
19	19.8 ± 1.9	16.1 ± 2.1	7.7 ± 0.8	10.2	23.4	19.9
20	20.0 ± 7.7	15.3 ± 2.2	6.5 ± 1.0	14.8	5.1	34.2
21	16.0 ± 1.6	19.3 ± 1.2	5.6 ± 0.7	8.3	11.5	22.3

[1] Each field was divided in 16 equal-sized square plots, and per plot a cage and a sweep sample was taken.

[2] $k = \bar{x}^2/(s^2-\bar{x})$. For field 17, the k was negative.

[3] $I_D = s^2\ (n-1)/\bar{x}$.

in our case, LP = 1 - α = 0.9, a_1 = -11.7, a_2 = 11.7, λ' = 34 and b = 37.4.

Using the criterion of Goulden (1952), the ASN of 2.8 was multiplied by 3. Thus, in those instances when the accumulative count of spittlebug adults would constantly fall in the continue sampling zone (Fig. 3), the sampling should be ceased upon taking 8 samples, and a decision be taken according to whether the count approximates to the lower or the upper decision line.

The adequacy of plan (Fig. 3) was checked using the 36 sweep-net sample counts from each of the 21 fields (Table 7). In 4 fields, a decision "to treat", and in 17 "no treat" decision was made. The number of samples required to reach the decision was 1 in 14 fields, 2 in 4, 3 in 2 and 5 samples in 1 field.

DISCUSSION

To sample spittlebug adults in pastures of *B. decumbens*, the sample size of 10 sweeps of a sweep-net was found to be more efficient than 5, 10 or 40 sweeps. In absence of similar studies on other grasses, e.g., *Brachiaria humidicola* (Rendel) Schweickerdt, *Hyparrhenia rufa* (Ness) Stapf., *Panicum maximum* Jacq. etc., the same sample size of 10 sweeps could be used. Because the number of samples required for a particular level of precision at population densities of < 16 adults/10 sweeps, was inversely proportional to the density, it is difficult to suggest one particular number of samples for all the population levels. Generally, 10 samples of 10 sweeps would provide precision levels between 10 and 15%. In areas

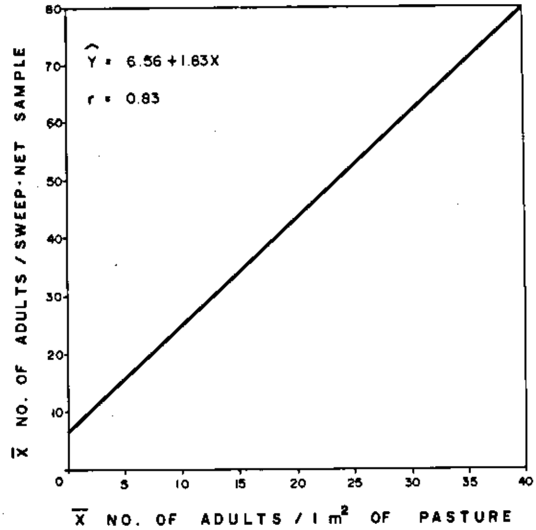

FIG. 2. Regression model of the mean number of spittlebug adults collected by sweep-net (10 sweeps/sample) and the cage method in pasture of *Brachiaria decumbens.*

where the population densities are always < 16 adults/10 sweep, one may consider taking more samples. On an average, differences between rows and between columns of a field were significant in 8 of the 27 instances. Thus, unless for specific reason, blocking within the sampling area may not be necessary; however, choosing well-distributed sampling sites may be beneficial.

In our study, the population densities of spittlebug adults varied from 0.04 to 7/sweep. At times we have found spittlebugs in excess of 7/sweep. However, in terms of the sampling efficiency, this would not be a problem; generally, with higher density the efficiency also improves.

The spatial distribution of counts of spittlebug adults collected in samples of 10 sweeps was Poisson (common k = 13.8). Evans (1974) studied spatial distribution pattern of the sugarcane froghopper *Aeneolamia varia saccharina* (Distant) by counting the adults on sugarcane stems. These counts showed the Poisson distribution pattern also. However, our counts of spittlebug adults in 1 m² of pasture showed moderate clumping (common k = 3.3). A higher degree of clumping was reported for spittlebug nymphs (Nilakhe 1983 b) and eggs (Nilakhe et al. 1984).

On an average, the sweep sample of 10 sweeps required 5 min, which was much less than the average 40 min of the cage sample. In terms of precision (RV values), the sweep samples were superior to cage samples also. Thus, considering, these two aspects, the sweep-net method was found to be superior to the cage method.

The relative estimates of spittlebug adult populations obtained in sweep-net sampling are commonly presented as the number of adults/m² of pasture, (Pacheco 1981, Oliveira & Curt 1979, Empresa de Pesquisa Agropecuária de Minas Gerais 1980).

Such relative estimates obtained in pastures of *B. decumbens* could be converted to crude absolute estimates (Fig. 2) in the following manner: In our sampling, the pasture area swept for the sample of 10 sweeps was 13.8 m². In the regression equation ($\hat{y}$ = 6.56 + 1.83 x) (Fig. 2), $\hat{y}$ equals the number of adults in the sample of 10 sweeps. Thus, e.g., 4 adults/m² of the swept pasture would give absolute estimate of 27 adults $(4 \times 13.8 = 6.56 + 1.83 \cdot x)/m^2$.

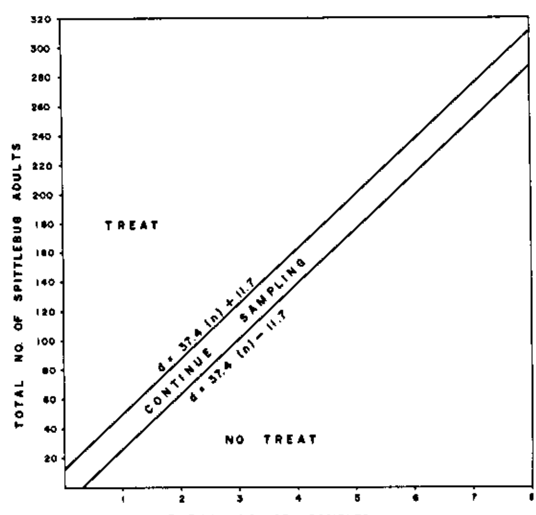

FIG. 3. Sequential sampling plan for spittlebug adults in pastures of *Brachiaria decumbens.* A sample consists of 10 sweep-net sweeps.

In this study, the sampling was done from 8-11 A.M. and 1-4 P.M.; however, no sampling was done when the foliage was wet with rain drops or dew, or in severe windy conditions. Thus, whenever possible, it would be appropriate to sample during the same two periods. One may also consider sampling for half the number of replications during the morning and, for the remaining half, during the afternoon. This would give more confidence in the results obtained by use of the regression model (Fig. 2).

Sampling for development of the regression model (Fig. 2) was done during February, i.e. during the latter part of the wet season. It is not known if the spittlebug adult location on the grass plant and the degree of aggregation would be different during the early (November - December) and the latter part of the wet season. If there does exist any difference, then it may influence somewhat the numbers captured.

To evaluate influence of the grass-height on capture of the adults in the sweep-net, the following calculations were made: For the shorter grass (grass-height $<$ 25 cm), the total number of adults per sweep-net sample in fields 9, 10 and 15 to 21 was 101.6 and the total for cage samples from the same fields was 44.3 Similarly, the totals for the taller grass (the remaining 12 fields) were 341.2 and 121.9, respectively (Table 7). Thus, for the shorter grass, the number of adults in the cage samples was 44% as that of the sweep-net samples, whereas for the taller grass the respective percentage was 36. However, it was felt that this difference of 8% was not large enough to warrent separate regression models for the shorter and the taller grass.

According to Delong (1932), the factors that influence the sweep-net sampling include temperature, humidity, wind velocity, position of the sun, plant size, density of the canopy and pubescence of leaves and stems. Probably the greatest variation in sweep-net sampling is caused by human factors. In our sampling sweeping method and length of the sweep-net stroke was standardized. While sweeping it was tried as much as possible to cover the entire grass height (in plants taller than 40 cm, the top 40 cm). An attempt was also made to keep the sweep ring perpendicular to the ground. However, the denser grass plants provide more resistance and this in turn causes the net ring to be oblique to the ground, and plant area swept is reduced accordingly. Therefore, some of the spittlebug adults present in the denser grass plants may not have chance to escape either due to the disturbance, or even be included in the sweep-net. Thus, we felt that force applied in sweeping would cause the most variation in sweep-net sampling. Such a variation due to the human factor could be reduced by allowing one sampler to sample the entire replication of the experiment. Although, sweep-net sampling has its problems, it is still the most economical and reliable sampling procedure for spittlebug adults.

The use of the sequential sampling scheme presented here (Fig. 3) required an average of ca. two samples to reach a decision. Thus, use of this scheme would reduce the sampling time over the conventional fixed sample number scheme, in insecticide application or certain other management tactics. The adult densities chosen in development of this plan were only for an example. By using information presented here, plans with different densities and α and β levels could be developed easily.

Information about sampling in large pasture fields (e.g. 100 ha) is not available. However, because of the necessity the following is suggested: Use of the sequential sampling scheme (Fig. 3) for every 10 ha may be sufficient. Sampling should be done sufficiently far from the field edge to avoid a "border effect". For every 100 ha, choose well-distributed 10 spots along "Z" pattern in the field. When for any 5 spots a decision "to treat" is reached, then the decision "to treat" for the field is made, and the likewise. In subsequent samplings rotate the "Z" in such a way that all four sides of the fields are covered. If it becomes necessary to modify the sequential scheme presented in Fig. 3, and if the modified scheme becomes unsuitable, then use of the fixed sample number scheme such as five, 10 sweep samples at the 10 locations could be made.

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