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Sampling Sunn Pest (*Eurygaster integriceps* Puton) in Overwintering Sites in Northern Syria

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Abstract: Sampling statistics for development of a sampling plan for adult Sunn Pest, *Eurygaster integriceps* Puton, in their overwintering habitat were generated based on numbers of live and total adults in 1 to 4 litter samples per tree. Taylor's power law was used to estimate optimum sample size, critical stop lines for sequential sampling and a sequential difference test. Sunn Pest were found primarily nearer to tree boles and had an aggregated distribution among trees. There was more statistical and practical advantage to taking 1 sample per tree and increasing the number of trees sampled, rather than in increasing the number of samples taken around a tree. With 1 litter sample (0.5m x 1m) per tree and 25% precision a minimum of 15 trees should be sampled if populations average 30 per tree; if populations average 1 per tree then 55 trees should be sampled. Our results suggest the feasibility of sampling Sunn Pest in its overwintering site. The reliability of the sampling statistics and planned approach to sample collection require further validation.

Key Words: Sunn Pest, *Eurygaster integriceps*, sampling, overwintering sites.

Kuzey Suriye'de Kışlama Yerleri'ndeki Süne Örneklemeleri

Özet: Süne (*Eurygaster integriceps* Puton)'nin kışlaklarındaki erginlerinin örnekleme planlamasını geliştirmek amacıyla 1 ile 4 litre bitki döküntüleri içinde bulunan canlı ve toplam birey sayısına bağlı larak örnekleme istatistikleri oluturulmuştur. Optimum örnek büyüklüğünü, ardışık örnekleme de karar verme sınırlarını ve ardışık faklılık testlerini hesaplayabilmek için Taylor güç yasası (Taylor's power law) kullanılmıştır. Süne erginleri temel olarak ağaç gövdelerine yakın yerlerde bulunmuş ve ağaçlar arası yığılımlı bir dağılım göstermiştir. Ağaç etrafından gittikçe artan örnek sayısı yerine her ağaçtan 1 örnek olacak şekilde gittikçe artan ağaç sayısı şeklinde örnekleme gerek pratik gerese istatistik açıdan daha avantajlı bulunmuştur. Bir litre (0.5 m x 1 m) örnek büyüklüğünde % 25 hassasiyet düzeyi için, ağaç başına populasyon yoğunluğu 30 olduğunda 15 ağaç, ağaç başına populasyon yoğunluğu 1 olduğunda 55 ağaç örnek alma gerekliliği görülmüştür. Sonuçlarımız, sünenin kışlaklarında da örneklenebileceğinin uygun olabileceği kanısını uyandırmıştır. Örnek almada, örnekleme istatistiklerinin geçerliliğinin ve planlanmış bir yaklaşımın güvenirliliğinin belirlenmesi için daha fazla araştırmalara gereksinim vardır.

Anahtar Sözcükler: Süne, *Eurygaster integriceps*, örnekleme, kışlama yerleri

Introduction

Sunn Pest, *Eurygaster integriceps* Puton, is a serious pest of wheat and barley in countries of West and Central Asia. Nymphs and adults cause damage by feeding on leaves, stems and grains (Cardona et al., 1983). During feeding they inject chemicals that reduce the baking quality of flour made from damaged grains (Williams et al., 1986; Jahavery, 1995).

Only a part of the insect's life cycle is spent in cereal fields (Miller, 1991). Adults spend autumn and winter in aestivation and diapause, respectively; in areas where they are protected from intense heat and severe cold temperatures. In northern Syria these areas are commonly found on hills or low elevation mountains where pine trees, *Pinus brutia* Tenore, have been planted for reforestation purposes. Sunn Pest settle beneath the litter that has accumulated under these trees and become inactive.

The objectives of this study were to determine the Sunn Pest distribution profile in these overwintering sites and define an appropriate way to sample the adult population. This information could be used in a management strategy developed to control the insect in these locations and as a survey tool to anticipate and predict potential damage to cereals.

Materials and Methods

Three sites where Sunn Pest were known to overwinter were chosen and these were sampled on the dates indicated in Table 1. Each site was predominant in the landscape and surrounded by extensive cereal fields. The sites contained even-aged pine trees that were 2-4 m in height and had litter of decomposing pine needles at their bases.

At each site we selected an area that was representative of the entire site. We divided it into 4 square blocks with sides 25 m long. Within each block there were 40-50 trees from which we randomly selected 12 trees for sampling. Around each tree we took 4 samples by collecting all the litter to bare soil within a 0.5 x 1.0 m area marked with a wooden frame. We considered this a convenient sample size to use and one that would yield a quantity of material that would allow us to detect Sunn Pest if they were there. The shorter side of the wooden frame was placed against the bole of the tree and each sample was taken at 90 degrees from the previous one. Additionally, we randomly selected 3 of the designated trees within each block for sampling at 2 increments equidistant to the nearest adjacent sample tree. This was done to determine if Sunn Pest were overwintering in areas other than within 1.0 m of the bole of sample trees.

Samples were placed in plastic bags and stored at 5ºC for a maximum of 5 days while data were taken. The litter in each bag was weighed to the nearest 0.1 g and numbers of live and dead Sunn Pest recorded. Individuals were considered dead if they were covered with fungi, had obvious damaged exoskeletons (i.e., only a portion of the dorsum found) or failed to respond to slight probing after having been placed at room temperature for about 10 min.

Statistical analyses. The percent survival of Sunn Pest was calculated based on the sum of the live and total insects from all four samples collected per tree. The percent survival of overwintering Sunn Pest at each site was compared using the general linear model of analysis of variance (GLM) (ANOVA) in SAS (1996). An arcsine transformation was used to improve homogeneity of variance of the survival data as suggested from visual inspection of residual plots and the transformed data was weighted in the analysis for the total number of Sunn Pest collected. The significance (alpha = 0.05) of collection site in the statistical model was evaluated using the type III mean squares for block within site. Collection site was considered to be random in this and other statistical analyses. Multiple comparisons (alpha = 0.05) of least significant means (lsmeans) were made using P-diff (SAS, 1996).

The average weight of litter and average total number of adults found in the four samples taken per tree were analyzed similar to percent survival. The data was log 10 (x+1) transformed to improve homogeneity of variance after averages for individual trees were taken, as suggested from visual inspection of residual plots. To determine effects of sample weight on the total number of Sunn Pest collected the data on total number of Sunn Pest were analyzed a second time with the average litter weight (g) included as a covariate in the statistical model. The litter weight covariate was evaluated on a within site basis to better ascertain its influence because concurrent differences between sites in population density, litter type and overall ground litter would most likely confound analysis of litter weight across the sites. Sample statistics (mean and SE) for the total number and number of live Sunn Pest found in samples taken at intervals between trees in each plot were calculated without transformation and are presented without further analysis.

Site name		Latitude	Longitude	Sample date	Elevation (m)
Elksabia	(1)	N36º 01. 593’	E36º 54. 588’	Jan. 17-18	369.5
Azzaz	(2)	N36º 38. 664’	E37º 03. 072’	Jan. 31-Feb.1	728.5
Tel Hadya	(3)	N36º 01. 079’	E36º 56. 506’	Feb. 11-12	355.4

Table 1. Sunn Pest overwintering sites selected in 2001 for sampling in northern Syria.

A nested ANOVA in SAS (1996) was performed on log 10 (x+1) transformed counts of total Sunn Pest to ascertain the relative contribution of sampling components (site, block, tree and sample error) to the overall variance (Buntin, 1994). Samples taken around each tree were treated individually in this analysis so that the error from individual samples could be evaluated.

Comparisons of Relative Variation (RV) were made to examine the influence of size of the area sampled around a tree on the precision for estimating Sunn Pest density. The total numbers of Sunn Pest found in the four samples per tree were summed randomly into groups of 1, 2, 3 and 4 samples per tree to provide sampling quadrants of increasing size. The corresponding counts for the number of live adults in each sample were also summed using the same series of random digits generated using the plan procedure in SAS (1996). Means (m) and standard errors ($SE = s / \sqrt{n}$) for each site were then calculated based on the size of the quadrant. Relative Variation (RV) expressed as a percentage ratio of the standard error to the mean (Ruesink, 1980) was then calculated as a measure of precision:

$$RV = (SE/m)(100)$$

Using sums for each of the trees sampled instead of the individual values developed into an average allowed the n used to calculate the standard errors to be constant (n=48).

The values generated above for the increasing sample size around each tree were also used in developing mean to variance relationships based on Taylor's power law (Taylor, 1961). This was done for total counts and the number of live Sunn Pest. Separate means and variances were calculated for the four blocks at each site (n=12) based on the sums from 1-4 samples. Regression analysis on the log of each value was then done. The slope of the regression coefficients was used directly as b in the formula below. Taylor's a is obtained from the anti-log of the intercept.

$$s^2 = a(m)^b$$

The value of b is the index of aggregation and indicates uniform, random and aggregated dispersion patterns for $b < 1$, $b = 1$, and $b > 1$, respectively (Buntin, 1994). A t-test was used to evaluate if the values of b were significantly different than 1 at alpha = 0.05 with two tails (Zar, 1974).

The optimum number of samples required at three levels (0.15, 0.20 and 0.25) of fixed precision ($C = SE/m$) for means of various magnitudes were calculated based on replacing the variance (s^2) component in the general case equation (Karandinos, 1976) with Taylor's power law (Buntin, 1994):

$$N = (am^{b-2}) / (C^2)$$

This was done only for the components of Taylor's power law obtained with 1 and 2 samples per tree. The data for both total and live adults were evaluated. For the purpose of visual comparison the results were standardized on the basis of Sunn Pest density (adults/m^2) and the number of 0.5 x 1 m samples required instead of the number of trees to be sampled.

Critical stop lines for sequential sampling were calculated for single samples per tree by substituting variance expressed as Taylor's power law (Ekbom, 1985) into Kuno's (1969) basic equation to yield:

$$T_n = (C^2 / a)^{1 / (b-2)} n^{(b-1) / (b-2)}$$

A sequential sampling plan can also be developed into a sequential difference test (Iwao, 1975) for density level classifications based on a probabilistic approach, the main difference being the inclusion of Student's t (Buntin, 1994). The variance components were replaced with Taylor's power law expressions (Ekbom, 1985) to yield this equation for the upper and lower confidence intervals (T_o) for the cumulative Sunn Pest collected:

$$T_o = qm_o \pm t(q(am_o{}^b))^{-2}$$

Data from single samples per tree were evaluated. Here q = the number of samples required, m_o = the critical average number of Sunn Pest adults, and t is the value Student's t at a specified alpha level. Alpha levels (2 tailed, df = ∞) of 0.05, 0.10 and 0.20 were used to generate 95, 90, and 80% confidence intervals, respectively (Zar, 1974). The critical value for m_o was arbitrarily set at 10 Sunn Pest adults, based on the range in populations from our current data set and other available data (Parker unpublished), to classify populations as low (average below 10) or high (average above 10).

Results

The percent survival of Sunn Pest was not significantly different among collection sites ($P > 0.14$, $F = 2.46$, $df = 2, 9$). Therefore, only data on the total number of Sunn Pest were analyzed by GLM. The average survival (±SE) was 77.6 (3.7), 91.2 (1.0) and 89.3 (0.9)% for sites 1, 2 and 3, respectively

The total number of Sunn Pest found was significantly affected by collection site ($P < 0.0001$, $F = 39.97$, df = 2, 9), and block within each site was also significant ($P < 0.0054$, $F = 2.77$, df = 9, 132). Site 1 had significantly lower Sunn Pest populations than sites 2 and 3, but the latter sites did not differ significantly from each other. The back transformed lsmeans for the total number of Sunn Pest per sample were 0.6, 6.6 and 9.5 adults for sites 1, 2 and 3, respectively.

The average weight of litter collected was significantly influenced by site ($P < 0.0254$, $F = 5.76$, df = 2, 9) and block within site ($P < 0.0001$, $F = 28.59$, df = 9, 132). The average weight (±SE) of litter in a sample was 1475 (120), 820 (32) and 1602 (102) grams for sites 1, 2 and 3, respectively -- only sites 2 and 3 differed significantly from each other. Inclusion of the sample weight covariate was significant in the statistical model ($P < 0.0004$, $F = 39.97$, df = 4, 129) but did not influence the significance of site in the analysis ($P < 0.0003$, $F = 22.38$, df = 2, 9) or the relative differences observed among the sites. Inclusion of the covariate did eliminate the significant effect of block within site ($P > 0.62$, $F = 0.80$, df = 9, 129) on Sunn Pest collections suggesting that the influence of blocking was related to the differences in the abundance of ground litter within a site.

The mean number of Sunn Pest for each site based on samples of increasing size around a tree are reported in Table 2. The relative variation based on these values generally decreased when more than one sample was taken per tree (Figures 1A & B). This was true for counts of total and live adults in the two sites having higher Sunn Pest densities, sites 2 and 3. However, for site 1 the RV was slightly higher for 2 samples with live adults. A smaller RV indicates greater precision. In general, precision was greater for sites with higher Sunn Pest populations regardless of the number of quadrants summed per tree. The average number of Sunn Pest collected at intervals between trees was comparatively low and relatively similar among the sample sites (Table 3).

The relative contribution of each sample component used in the nested analysis of variance of total Sunn Pest counts to the overall variance is contained in Table 4. The effect of block contributed least to the overall variance. Given the significant effect of site in the GLM analysis of total counts its contribution as a variance component is to be expected. The error variance associated with the samples taken around trees is approximately 10% higher than that of the tree component. Increasing the level of sub-sampling around each tree would reduce this variance component but it would not contribute to increasing the level of n as would occur if the number of trees sampled were increased. Given the roughly equivalent cost for either strategy, an increase in the number of trees sampled per site should provide the most benefit for reducing variance and increasing statistical power.

The results from Taylor's power law calculations on mean to variance relationships are shown in Table 5 for increasing sample sizes around a tree. All the values of b between 1.5 and 1.68, were found to be significantly different from 1 indicating that the population has an aggregated distribution. Differences among the values of a and b with increasing numbers of samples summed per tree were not evaluated statistically because they lacked independence. The values of a drop below 3 with more than one sample taken per tree. The narrow range in b estimates, with all less than 2, indicate the Taylor power law model should be useful for robust sample size estimates (Shelton and Trumble, 1991).

Table 2. The mean (± SE) number of Sunn Pest in each site based on randomly summing samples 1 – 4 gathered around each tree (n = 48 trees/site)

Samples per tree	Average count (± SE) of total adults			Average count (± SE) of live adults		
	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3
1	1.23 (0.36)	9.42 (1.65)	16.33 (3.26)	0.95 (0.29)	8.89 (1.61)	14.62 (3.04)
2	2.14 (0.61)	17.42 (2.04)	29.88 (4.93)	1.60 (0.52)	15.85 (1.94)	26.75 (4.60)
3	2.92 (0.75)	25.46 (2.60)	44.62 (6.62)	2.25 (0.66)	23.31 (2.44)	39.89 (6.16)
4	3.81 (0.91)	32.98 (3.35)	56.94 (8.58)	2.96 (0.79)	30.06 (3.16)	50.85 (8.00)

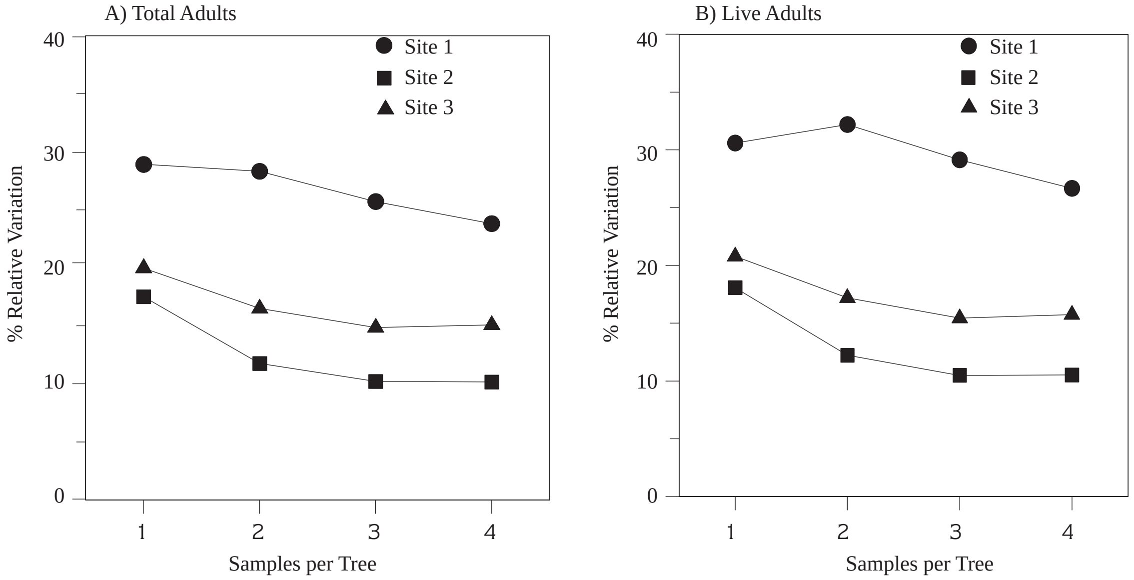

Figure 1. The relative variation (RV) when the counts of (A) total and (B) live Sunn Pest adults were summed in groups of 1-4 samples per tree.

Table 3. The average (± SE) total count and number of live Sunn Pest in samples taken at intervals between trees.

Count	Average count (± SE)		
	Site 1	Site 2	Site 3
Live	0.29 (0.13)	0.17 (0.08)	0.17 (0.13)
Total	0.46 (0.17)	0.17 (0.08)	0.21 (0.17)

Table 4. Nested analysis of variance for samples of total counts of adult Sunn Pest in overwintering sites located in northern Syria.

Source	df	Variance component	% of total*
Site (S)	2	1.114	36.64
Block (B) / S	9	0.198	6.50
Tree (T) / B / S	132	0.707	23.25
Sample / T /B / S	432	1.022	33.60
Total	575	3.041	100.00

*Values do not sum to 100 because of rounding.

The optimum number of total samples when one and two samples per tree are taken is presented for 15, 20 and 25% precision for both live and total counts (Figures 2A & B). Fewer total samples are required with one sample per tree compared to when two samples per tree are used. The optimum number of trees needing to be sampled when using a single sample per tree was 15 or more when average populations were 60 per square meter (30 adults per 0.5 x 1 meter sample) and precision was 25%. At low Sunn Pest populations, as were found at site 1, 55 samples would be required for the same level of precision.

The critical stop lines in the sequential sampling plan for the cumulative number of adults collected in a given number of samples are shown in Figures 3A & B. Here it is evident that with fewer than 15 samples Sunn Pest populations would need to be extraordinarily high to reach even the stop line for 25% precision. At 15 samples the average is about 40 total Sunn Pest per tree or a cumulative total of 600 adults. However, at 30 trees sampled the stop line is reached at a cumulative total of 139 adults for a sample average of 4.6 total adults per tree.

The plans for the sequential difference tests based on total counts and live Sunn Pest are outlined in Figures 4A & B for 80, 90 and 95% confidence intervals. The average number of Sunn Pest per tree at the lowest and highest population sites, based on a single sample per tree and 48 samples, would fall into the low and high population regions, regardless of the level of confidence chosen. The population at the remaining site would fall into the broad “continue sampling” zone.

Table 5. Results of Taylor's power law calculated by randomly summing the number of Sunn Pest adults in 1 to 4 samples taken around trees in 3 overwintering sites located in northern Syria.

Samples per tree	Total adults			Live adults		
	b (± SE)	a	r2	b	a	r2
1	1.615 (0.163)*	3.350	0.91	1.678 (0.130)*	3.072	0.94
2	1.661 (0.135)*	2.342	0.94	1.672 (0.118)*	2.419	0.95
3	1.555 (0.098)*	2.734	0.96	1.570 (0.094)*	2.752	0.97
4	1.599 (0.114)*	2.464	0.95	1.614 (0.106)*	2.483	0.96
Mean	1.607	2.724	na	1.634	2.681	na

* Slope significantly different from 1 (P £ 0.05 two-tailed, df=11) indicating an aggregated population.

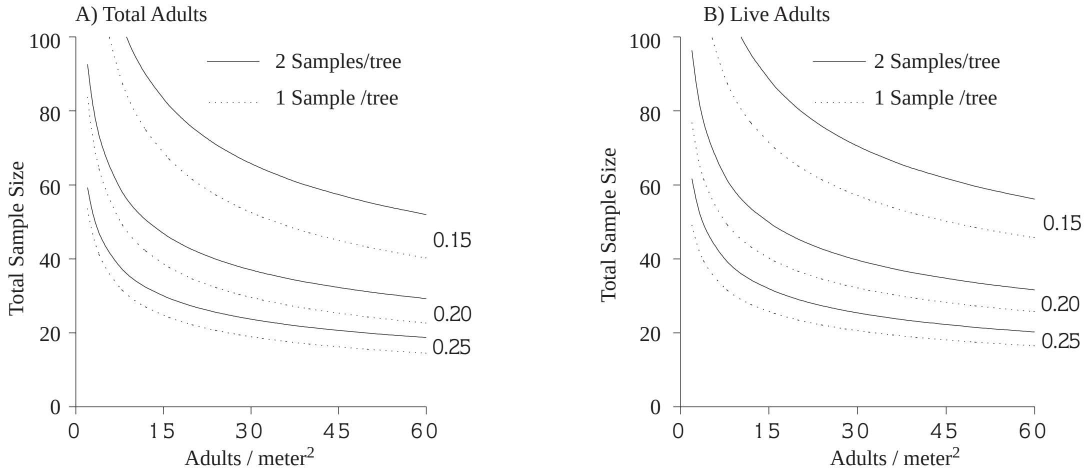

Figure 2. The total number of 0.5 x 1 meter samples required at various densities (adults/m2) of (A) total and (B) live Sunn Pest at three levels of precision (SE / mean). Calculations were based on optimum sample size analysis when 1 or 2 samples are collected per tree.

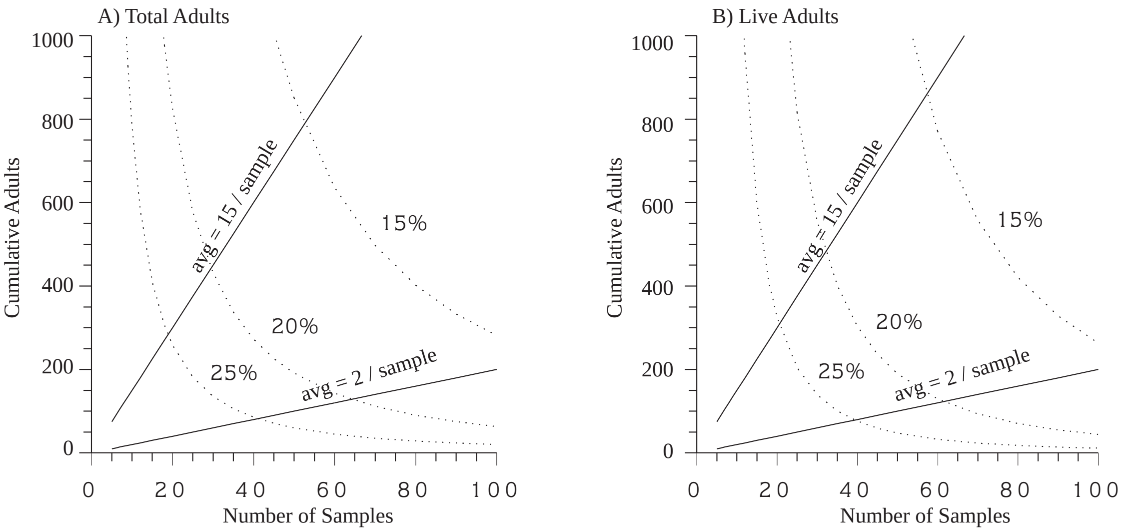

Figure 3. The critical stop lines (based on 1 sample per tree) at three levels of precision for a sequential count plan for (A) total and (B) live Sunn Pest adults in overwintering sites. Solid lines indicate cumulative adults at an average of 2 and 15 adults per sample.

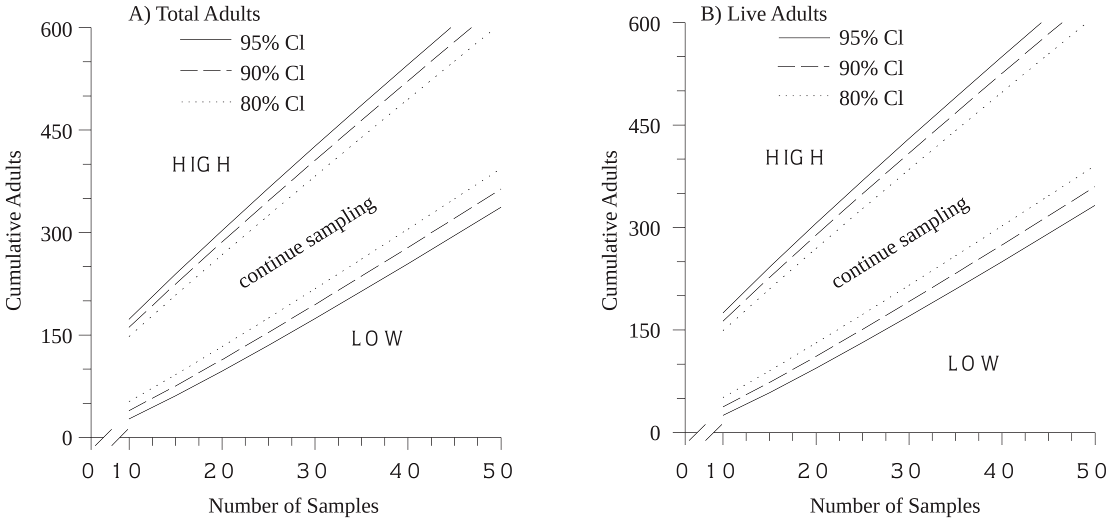

Figure 4. Sequential difference test (based on 1 sample per tree) for (A) total and (B) live Sunn Pest adults with an arbitrary inflection point at an average of 10 adults per tree sampled.

Discussion

Our results indicate that the abundance and distribution of Sunn Pest in its overwintering site make development of a sampling plan feasible. The components we set out to define were 1) where in the overwintering habitat should the samples be taken from, 2) how much area should be sampled, and 3) how many samples should be taken given the variance structure of the population and the preferred level of precision.

Sunn pest were found primarily near the tree boles. Population levels in the open spaces sampled between the trees were low and relatively uniform among the three sites, whereas the average number of Sunn Pest near the bole of a tree varied significantly among the sites. Therefore, for the pine landscape we examined, sampling should be done at the base of the trees. This differs from the strategy used in Romanian oak forests where samples were taken along a transect (Popov et al., 1996). The finding of a Taylor's power law b significantly greater than 1 for samples around the tree bole suggests that populations of overwintering Sunn Pest are aggregated or clumped. With aggregated populations more extensive sampling may be required.

The nested ANOVA indicates that blocking contributes only a small percentage to the overall variance within a site (6.08%). However, the significant effect of block within site in the GLM analysis and its elimination by inclusion of the litter weight covariate suggests that, if obvious differences in litter exist within a site, some form of blocking that samples are randomly selected from would be of benefit. The interpretation of the influence of site in the nested ANOVA needs to be treated with caution. To get an accurate indication of how much effort needs to be directed toward sampling different sites, samples need to be taken from different sites within a particular region. In this way we will be able to assess if multiple sites within a localized area need to be sampled to obtain reliable estimates of Sunn Pest populations.

The physical size of a sample can influence the level of precision that is obtained and ultimately affects the number of samples that need to be taken. Initially, it would appear that 2 samples per tree offer the greatest advantages; however, closer examination indicates that 1 sample per tree is probably of greater value. For instance, the decreases in RV (Figure 1) with more than one 0.5 square meter sample per tree suggests that at least two samples per tree might be beneficial. Also seemingly compelling is that the value of a in Taylor's power law, which is influenced by sample unit size (Elliot, 1983), drops substantially between 1 and 2 samples per tree, which would tend to decrease the number of samples required (Trumble et al., 1989). For example, if the sample average for live adults is expected to be 10 Sunn Pest per meter square, the number of trees that must be sampled based on precision = 0.20 and the values of a for 1 and 2 samples per tree are 45 and 26, respectively. However, each of the 26 trees in the 2 sample per tree scheme must be sampled in two locations around the tree bole, which translates into the collection and counting of 52 samples versus the 45 required in a 1 sample per tree scheme (Figure 2).

Evaluation through the nested ANOVA as to the contribution that each factor (sample, tree, block and site) makes to the overall variance component lends further support to taking only 1 sample per tree (Table 4). The samples taken around each tree and the tree both contributed substantially to the overall variance, 33 and 23%, respectively. The cost for taking a single, 1 x 0.5 m sample is relatively similar regardless of whether it is one of multiple samples from around a single tree or individual samples from separate trees. Therefore, the utility of directing resources toward reducing the sample component of the variance can be balanced directly against the advantages of increasing the number of trees sampled and thus the magnitude of n that might be used in statistical analysis. From the discussion above, it is evident that the greater number of trees sampled when a single sample per tree is taken would result in the collection of fewer total samples and contribute more towards increasing n.

The number of samples taken at a particular location ultimately depends on the level of precision desired and the average population size found in samples. The level of precision selected in deciding the optimum sample size depends on the purpose of the sampling program. For intensive sampling plans, Southwood (1978) suggests using a 5% standard error to mean ratio. Such a high level of precision may not be feasible because Sunn Pest are aggregated in their over winter site. For instance, if the population average is 4 Sunn Pest per tree sampled then 786 trees would have to be sampled to achieve the desired precision. However, in pest management programs usually the 25% level is employed (Buntin, 1994), which in the same scenario as above would require only 31 trees to be sampled using a single sample per tree.

Our results suggest that for 25% precision a minimum of 15 samples are required. This minimum sample is based on an average of 30 total adults per tree using a one sample per tree scheme, which is equivalent to a density 60 Sunn Pest per square meter (Figure 2). For counts with only live adults one additional sample would be required. A maximum of 55 samples will give a precision of at least 25% for averages of 1 Sunn Pest per tree, regardless of whether counts of live or total adults are used. A plan that requires from 15 to 55 samples would essentially include the population levels we observed for single samples per tree (Table 2). The stop lines depicted for sequential sampling (Figure 3) further illustrate the need to take at least 15 samples and the impracticality of using precision levels less than 20-25%.

The plan for sequential difference tests (Figure 4) arbitrarily divides populations into low and high classification zones. Selection of the zones was based on the populations observed in the current study and unpublished data from Tel Hadya that found average populations in excess of 30 Sunn Pest per tree. Although the classifications are not of immediate utility, they do serve as a foundation for development of future sampling plans as any relationship between Sunn Pest in overwintering sites and populations found in wheat fields becomes better understood. For the purposes of sampling in the immediate future use of the stop lines depicted in Figure 3 would serve the most purpose. The approach would be to collect a single sample per tree and to take 15 to 55 samples depending on Sunn Pest population levels.

Two questions that ultimately determine how the sample plan is executed are (1) Will total counts or the number of live adults be used when taking samples? and (2) Can samples taken in the field be evaluated on site without returning them to the laboratory? With regard to the first question, the sampling statistics for total and live counts are essentially the same. However, if live adults can be readily distinguished from the dead, particularly under field conditions, then live adults should be used. In the current study there was no significant difference among the sites in Sunn Pest mortality; however, this is unlikely to always be the case. More importantly, if control measures are to be evaluated then it is critical to be able to assess the proportion of adults that are still living. With regard to counting samples in the field, not having to return samples to the laboratory would be the most desirable circumstance. Firstly, it may be impractical to always return to a laboratory. Secondly, having to return samples to the lab complicates sequential sampling plans. If samples cannot be evaluated in the field then double sampling plans where samples are replicated twice may be necessary (Kuno, 1991).

For future research it is necessary to accumulate additional data sets for validation of the current sampling statistics and planned approach to sample collection. This will involve field validation and/or simulation. Field validation not only evaluates the sample plan but also provides an indication of how the plan tolerates person-to-person variability (Shufran and Raney, 1989). However, the time and expense to collect the substantial number of data sets (approx. 100) can be prohibitive. For simulations involving the use of the bootstrap approach (Efron and Tibshirani, 1986), the files from a limited number of data sets (approx. 15) can be re-sampled to generate additional data sets to examine the behavior of the sequential sampling plans (Naranjo and Hutchison, 1997). The availability of a reliable sampling strategy will contribute to our understanding of Sunn Pest population dynamics in overwintering sites and the evaluation of control measures targeted against them.

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