COMPARING DROP CLOTH, SWEEP NET AND SUCTION SAMPLING METHODS FOR ARTHROPODS IN COTTON

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Abstract

A large data set was compiled containing arthropod capture records from drop cloth, sweep net and suction sampling. The precision and efficiency of these sampling method are compared. Generally, each sampling method had similar precision, but the drop cloth caught more arthropods per unit of sampling effort. The drop cloth also caught greater numbers of arthropods on a per meter row basis. Compared to the drop cloth, higher proportions of adult insects were caught in sweep net samples for at least some insect taxa (i.e., tarnished plant bug, lady beetles and big eyed bug). Regression analysis indicated a relative weak relationship between numbers of tarnished plant bugs in sweep net versus drop cloth samples.

Introduction

A lack of understanding of sampling precision and efficiency limits the successful implementation of IPM programs for arthropods in cotton. The reliability of different sampling methodologies changes depending upon the target insect, stage of cotton growth, and other factors. Typically, sampling methods that count more insects per unit of sampling effort are considered "better". Drop cloth samples for tarnished plant bug populations, for example, may be more suitable than a sweep net for populations comprised mostly of nymphs because the sweep net catches relatively few nymphs (Snodgrass 1993). However, the inherent precision of a sample method also influences reliability, and thus its efficiency. Depending upon the precision of the sample, a sampling method that catches fewer insects can still be a reliable indicator of population size. Ultimately, sampling efficiency is determined by the precision of the sample, relative to the mean number of arthropods caught, and the time required making the sample. In this paper we will compare the sampling efficiency of sweep net, drop cloth, and to a limited extent, suction sampling approaches for tarnished plant bug and selected beneficial arthropod taxa.

Materials and Methods

Data from multiple locations, each including numerous drop cloth and sweep net samples, were collected over a five-year period (1995-1999) in cotton. A limited amount of suction sampling data was also collected in 1998 and 1999 using a modified leaf blower (Smith and Stewart 1999), using 16-mesh nylon for the capture bags. The sample unit for the drop cloth, sweep net and suction samples were 2 m of row, 25 sweeps with a 15-inch (38 cm) diameter net, and 2 m of row, respectively. Samples were collected in grower fields and experimental test plots located throughout Mississippi. Insects that were consistently counted included tarnished plant bug, lady beetles (excluding *Scymnus* and *Stethorus* spp.), big-eyed bugs (predominately *Geocoris punctipes*), lacewing larvae (predominately *Chrysoperla* and *Chrysopa* spp.), damsel bugs (*Nabis* spp.), various ant species (Formicidae), and insidious flower bugs. Spiders, comprising many species, were also collectively counted. We generally distinguished between immature and adult insects for tarnished plant bug, big-eyed bugs, and lady beetles. This was not done in all drop cloth and sweep net samples. Thus, mean values for the total populations do not necessarily equal the sum of adult and nymph populations.

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The above data sets were merged such that each line of the data set represented the number of insects in a single drop cloth, sweep net or suction sample unit. For each taxon, the overall mean number and variance within these samples was determined for each sampling method. The ratio of the mean divided by the variance was used as one index of relative sampling precision, where a high ratio is indicative of greater precision (or uniformity in population distribution). For each population, mean/variance ratios were calculated for each sample where insect were found (sample = sample location*date*sample method). The average of these ratios, weighted by the number of samples units used in their calculation, is presented. Means are also shown for samples made prior to 4 July (representing samples in prebloom cotton) and for samples made thereafter.

Means were also calculated on a per meter row basis by dividing by the number of row meters included in each sample (= 2 m for drop cloth and suction samples). For sweep net samples, data were divided by 9.5 because this number approximates the number of row meters sampled by 25 sweeps with a 15-inch diameter sweep net.

Simple linear regressions were also done to compare the relationship between sampling methods for each taxon sampled (Proc Reg, SAS Institute 1998). Regressions used mean numbers of arthropods per sample unit, for each date and location, and the regressions were weighted by the number of samples units used to calculate these mean values. Comparisons between any two sampling methods only used data where arthropods were sampled on the same date and at the same location. The intercept was forced through zero. The slope estimates represent the approximate proportion of insects caught, per sample unit, in one sample method versus another.

In 1999, data were collected to determine how much time was spent taking and processing drop cloth, sweep net and suction samples. A total of 108 drop cloth, 48 sweep net, and 108 suction sample units were taken across 15 fields at different times during the growing season. Data recorded included the time spent physically taking the sample (e.g., to make 25 sweeps), the time spent processing (counting) each sample unit, time spent starting and handling bags for the suction-sampling device, and the total time to complete the entire process. The individual (1 of 6) taking the sample was also recorded. Prior to analysis, timing data were standardized to a per meter row basis by dividing by the number of row meters included in each sample as previously described. These data were analyzed using standard analysis of variance procedures (Proc GLM, lsmeans with pdiff; SAS Institute 1998) to determine effects of sample type, sampling person, time of season (prebloom vs. later), and sample type by time of season interactions. These data were also used to estimate the sampling "return" per unit of sampling effort, that is, the number of insects caught per the amount of time invested in sampling.

Results and Discussion

A total of about 3000, 5000, and 575 sample units with a drop cloth, sweep net and suction device were taken over the five-year period, respectively. Across all samples, 2787 tarnished plant bugs, 18637 lady beetles, 1349 big-eyed bugs, 5037 spiders, 1435 insidious flower bugs, and 2319 ants were counted. The number of samples units in which these insects were recorded was 9595, 9603, 9603, 7899, 7900, and 7899, respectively. Only 941and 263 lacewing larvae and damsel bugs were found in 7915 and 9162 sample units, respectively. As noted previously (Snodgrass 1993), a greater percentage of tarnished plant bugs caught in sweep net samples (72%) were adults as compared with drop cloth samples (31%)(Table 1). The same was also true of suction versus drop cloth samples, where a higher proportion of plant bugs in suction samples was adults. For lady beetles and big-eyed bugs, sweep nets caught a higher proportion of adult insects than did drop cloth samples.

The overall mean numbers of insects caught in our samples are presented for all methods (Table 2), for samples prior to 4 July (Table 3), and for samples after 4 July (Table 4). Per sample unit, the sweep net caught about 23 and 175% more arthropods than the drop cloth and suction sampling methods, respectively. The average overall density of tarnished plant bugs, the only pest included in our samples, was well below established economic thresholds. However, their density increased substantially after 4 July. This was true for most other arthropods sampled as well, and it is not surprising that arthropod populations tended to increase as the cotton grew. During the time of this study, several locations were in an active boll weevil eradication program. Thus, it should be considered that the use of malathion in this program reduced the overall numbers of arthropods in our samples.

The precision (i.e., mean/variance ratios) of samples can serve as an index of sampling efficiency. It is apparent that variances for most arthropods were slightly greater than the mean values (mean/variance < 0, Table 2), indicating populations were somewhat aggregately distributed in general. However, because mean/variance ratios were typically near 1.0, most populations would be considered randomly distributed. The precision of ant samples was relatively low across all sampling methods, indicating that ant distribution was more clumped than other populations. Often, the precision of samples for a given arthropod population was relatively consistent across sampling method. For example, relatively low precision in drop cloth samples corresponded to a relatively low precision in sweep net or suction samples (e.g., ants and lady beetles). When precision was relatively high in drop cloth samples (e.g., spiders), it was relatively high for other sample methods as well. This may indicate that the sampling methods gave a similarly reliable estimate of population density.

The results of regressions of a) sweep net data on drop cloth data, b) suction data on drop cloth, c) and suction data on sweep net data are presented in Table 5. A comparison between suction and sweep net data was only made for tarnished plant bugs and lady beetles. Too few other arthropods were sampled to allow for a meaningful comparison between suction and sweep net samples. For almost all arthropod populations, there was a strong statistical relationship between the numbers caught in one method versus numbers caught in another sampling method. Numbers of lady beetles, big-eyed bugs and spiders on drop cloth samples correlated relatively well with numbers in suction or sweep net samples. However, correlation coefficients for some taxon (e.g., lacewing larvae and damsel bugs) were low. The number of tarnished plant bugs caught in drop cloth samples versus suction samples correlated relatively well. However, the correlation among sweep net and drop cloth samples for plant bugs was weak, regardless of the segment of the population regressed (i.e., total population, nymphs or adults; Table 5). There was a moderately good correlation between nymphs and adults caught in drop cloth samples ($R^2 = 0.52$, $F = 192.2$, $P < 0.01$), but the relationship between nymphs and adults in sweep net samples was less strong ($R^2 = 0.31$, $F = 79.3$, $P < 0.01$).

For no population did the correlation coefficient between two sampling methods exceed 80%, so a significant amount of variation between sampling methods was not explained by our simple linear models. Some variation likely resulted from the person taking the sample (as shown below), which varied among years and locations.

On a per meter row basis, the results from analysis of variance (Table 6) indicate that the method of sampling significantly affected the total time needed to take and process a sample. The individual taking the sample also influenced the time spent sampling. Suction sampling took much longer that the other kinds of sampling, and sweep net samples required less time than drop cloth samples (Table 7). Using these data and those presented in Table 8, we can calculate the total number of insects caught per unit of sampling effort. In general, more arthropods were caught in one minute of drop cloth sampling than in one minute of sweep net sampling (Table 9). For all populations, suction samples caught fewer insects per unit of sampling effort than the other methods. However, it should be considered that increasing the sample unit size is easy to accomplish for sweep net and suction samples relative to drop cloth samples. Taking an additional 75 sweeps or suctioning 8 m or row would quadruple the sample unit size and the numbers of insects caught. However, this would not quadruple the time required to take a sample. For example, bag-handling time would remain the same in a 2 or 8 meter suction sample. Unlike drop cloth samples, the actual counting of insects in sweep net or suction samples would also not be quadrupled, although time spent counting insects would likely increase.

Summary

The time of the growing season (e.g., size of cotton), the life stage(s) of the insect being samples, and sample unit size all can potentially influence sampling efficiency. We did not consider how the size of cotton impacted sampling efficiency. Also, some taxa sampled included multiple species (e.g., lady beetles and spiders). Had individual species been considered, different relationships among the sampling methods would likely be found. However, it could generally be concluded that the drop cloth was the "best" sampling method because it caught the most arthropods in the least amount of time. It also had comparable precision in estimating the size of arthropod populations compared with the other sampling methods. The suction sample method caught very few insects relative to the sampling effort, and in part, the low numbers of insects caught may have inflated the precision of these samples.

For tarnished plant bugs, numbers of insects and sweep net and drop cloth samples did not correlate well, indicating that one or both sampling methods may be inadequate for this pest, or that both methods should be used in unison. This poor relationship can be partially explained by the observation that sweep net samples catch predominately adults, whereas drop cloth samples catch predominately nymphs. So when plant bug populations are dominated by only one life stage, the relationship between these sampling methods may be weak. Overall, the drop cloth appeared better suited for sampling tarnished plant bug populations because the correlation between nymphs and adults in samples was relatively strong compared to that for sweep net samples.

These results represent a preliminary examination of the comparative efficiency of different sampling methods. They do not consider intangible factors, such as a general dislike by employees for drop cloth and suction sampling methods.

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Table 1. Percent of adults (total number of insects) caught in drop cloth, sweep net, and suction samples.

Taxon	Drop cloth	Sweep net	Suction
Tarnished plant b.	31 (638) a	72 (1554) b	80 (20) b
Lady beetles	42 (2870) a	61 (13341) b	36 (426) a
Big-eyed bugs	67 (436) a	86 (849) b	85 (68) ab

Percentages within rows not followed by a common letter are different ($P < 0.05$, Frequency distribution analysis, Chi square).

Table 2. Overall mean number (and mean/variance ratio) of arthropods caught per drop cloth (2 m row), sweep net (25 sweeps), and suction (2 m row) sample.

Taxon	Drop cloth	Sweep net	Suction*
Tarnished plant b.	0.235 (0.89)	0.347 (0.91)	0.035 (1.02)
adults	0.074 (0.97)	0.317 (0.89)	0.028 (1.01)
nymphs	0.160 (0.88)	0.120 (0.96)	0.007 (0.50)
Lady beetles	1.507 (0.88)	2.302 (0.68)	0.741 (0.75)
adults	0.753 (0.99)	1.774 (0.75)	0.268 (0.80)
larvae	1.035 (0.70)	1.126 (0.59)	0.473 (0.72)
Big-eyed bug	0.135 (0.96)	0.146 (0.94)	0.111 (0.88)
adults	0.107 (1.01)	0.160 (0.96)	0.097 (0.85)
nymphs	0.053 (0.96)	0.025 (0.93)	0.014 (1.05)
Spiders	0.740 (0.99)	0.606 (0.95)	0.403 (0.91)
Ants	0.417 (0.49)	0.250 (0.55)	0.078 (0.76)
Insidious flower b.	0.117 (0.85)	0.247 (0.78)	0.009 (1.01)
Lacewing larvae	0.110 (0.94)	0.132 (0.80)	0.064 (0.96)
Damsel bugs	0.028 (1.00)	0.029 (0.94)	0.033 (0.94)
All arthropods	3.289 (N/a)	4.059 (N/a)	1.474 (N/a)

* The reader is cautioned that mean values for suction samples are not directly comparable to those in other samples because suction samples were only taken in 1998 and 1999 at some locations.

Table 3. Mean number of arthropods caught per drop cloth (2 m row), sweep net (25 sweeps), and suction (2 m row) samples taken prior to 4 July. Numbers of sample units, N, are in parentheses.

Taxon	Drop cloth	Sweep net	Suction
Tarnished plant b.	0.126 (1708)	0.193 (3047)	0.061 (147)
adults	0.047 (1456)	0.219 (1881)	0.034 (147)
nymphs	0.081 (1456)	0.041 (1881)	0.027 (147)
Lady beetles	0.637 (1709)	0.820 (3047)	0.088 (147)
adults	0.198 (1447)	0.487 (2362)	0.048 (147)
larvae	0.554 (1447)	0.572 (2362)	0.041 (147)
Big-eyed bug	0.114 (1709)	0.172 (3047)	0.102 (147)
adults	0.114 (1447)	0.213 (2362)	0.068 (147)
nymphs	0.020 (1447)	0.008 (2362)	0.034 (147)
Spiders	0.719 (1447)	0.674 (2362)	0.224 (147)
Ants	0.460 (1447)	0.321 (2362)	0.020 (147)
Insidious flower b.	0.062 (1447)	0.009 (2362)	0.007 (147)
Lacewing larvae	0.068 (1456)	0.075 (2370)	0.034 (147)
Damsel bugs	0.021 (1639)	0.037 (2705)	0.020 (147)

Table 4. Mean number of arthropods caught per drop cloth (2 m row), sweep net (25 sweeps), and suction (2 m row) samples taken after 4 July. Numbers of sample units, N, are in parentheses.

Taxon	Drop cloth	Sweep net	Suction
Tarnished plant b.	0.356 (1521)	0.512 (2744)	0.026 (428)
adults	0.103 (1277)	0.427 (1679)	0.000 (428)
nymphs	0.250 (1277)	0.208 (1679)	0.026 (428)
Lady beetle	2.483 (1523)	3.944 (2749)	0.965 (428)
adults	1.381 (1277)	3.132 (2239)	0.343 (428)
larvae	1.580 (1277)	1.710 (2239)	0.621 (428)
Big-eyed bug	0.159 (1523)	0.119 (2749)	0.114 (428)
adults	0.099 (1277)	0.104 (2239)	0.107 (428)
nymphs	0.090 (1277)	0.042 (2239)	0.007 (428)
Spiders	0.764 (1277)	0.535 (2238)	0.465 (428)
Ants	0.367 (1277)	0.169 (2238)	0.098 (428)
Insidious flower b.	0.181 (1277)	0.371 (2239)	0.009 (428)
Lacewing larvae	0.156 (1277)	0.203 (2237)	0.075 (428)
Damsel bugs	0.035 (1521)	0.022 (2722)	0.037 (428)

Table 5. Results of simple linear regressions for numbers of arthropods caught in one sample method versus numbers caught by another method.

Taxon	Slope (SE)	R^2	df	F	P<F
Numbers in sweep net samples on numbers in drop cloth samples					
Tarnished plant b.	0.56 (0.07)	0.25	1,198	67.4	0.01
adults	0.26 (0.04)	0.18	1,177	38.3	0.01
nymphs	0.88 (0.13)	0.21	1,177	48.3	0.01
Lady beetles	0.44 (0.02)	0.63	1,199	341	0.01
Big-eyed bugs	0.77 (0.06)	0.46	1,199	170	0.01
Spiders	0.56 (0.03)	0.70	1,177	416	0.01
Ants	1.02 (0.08)	0.44	1,177	138	0.01
Insidious flower b.	0.56 (0.05)	0.44	1,177	138	0.01
Lacewing larvae	0.69 (0.07)	0.36	1,177	101	0.01
Damsel bugs	0.58 (0.07)	0.26	1,195	67.1	0.01
Numbers in suction samples on numbers in drop cloth samples					
Tarnished plant b.	0.99 (0.09)	0.77	1,33	113	0.01
Lady beetles	1.27 (0.15)	0.69	1,33	73.4	0.01
Big-eyed bugs	1.14 (0.16)	0.61	1,33	51.8	0.01
Spiders	1.56 (0.14)	0.78	1,33	120	0.01
Ants	0.85 (0.16)	0.46	1,33	28.6	0.01
Insidious flower b.	1.57 (0.23)	0.56	1,33	44.9	0.01
Lacewing larvae	0.46 (0.27)	0.08	1,33	2.77	0.12
Damsel bugs	0.60 (0.14)	0.37	1,33	19.2	0.01
Numbers in suction samples on numbers in sweep net samples					
Tarnished plant b.	1.07 (0.41)	0.39	1,11	7.08	0.03
Lady beetles	2.71 (0.56)	0.68	1,11	23.0	0.01

Table 6. Results of analysis of variance concerning the influence of sampling methods and other factors on the time to sample 1 m of row.*

	F values, P<F for treatment effects			
Variable	Sampling method	Early vs. late season	Person sampling	Method x Season
Total time	87.7, 0.01	3.67, 0.06	1.89, 0.10	3.03, 0.06
Sample	142, 0.01	1.07, 0.31	32.9, 0.01	0.31, 0.74
Process	84.0, 0.01	2.15, 0.15	3.51, 0.01	0.80, 0.45
Sample + process	158, 0.01	0.53, 0.47	2.87, 0.02	0.26, 0.77
D. freedom	2,253	1,253	5,253	2,253

* Assumes 25 sweeps with 15-inch diameter net samples a total of 9.52 meter of row.

Table 7. The mean amount of time needed to sample 1 m of row.

	Time in seconds per meter row		
Variable	Drop cloth	Sweep net*	Suction
Total time	8.9 a	3.8 b	24.8 c
Sample	3.5 a	1.5 b	5.8 c
Process	5.4 a	2.2 b	7.1 c
Handling	----	----	4.5
Start-up	----	----	7.4

Means within rows not followed by a common letter are different (P < 0.05; Proc GLM, lsmeans, pdiff; SAS Institute 1998).

* Assumes 25 sweeps with 15-inch diameter net samples a total of 9.52 meter of row.

Table 8. Seasonal mean number of arthropods caught per meter of row sampled.

Taxon	Drop cloth	Sweep net*	Suction
Tarnished plant b.	0.1174	0.0364	0.0174
adults	0.0368	0.0333	0.0139
nymphs	0.0799	0.0126	0.0035
Lady beetles	0.7534	0.2418	0.3704
adults	0.3765	0.1863	0.1339
larvae	0.5174	0.1183	0.2365
Big-eyed bug	0.0675	0.0154	0.0557
adults	0.0536	0.0168	0.0487
nymphs	0.0264	0.0026	0.0070
Spiders	0.3702	0.0637	0.2017
Ants	0.2085	0.0260	0.0391
Insidious flower b.	0.0587	0.0253	0.0043
Lacewings	0.0545	0.0138	0.0322
Damsel bugs	0.0137	0.0030	0.0165
All arthropods	1.6439	0.4261	0.7373

* Assumes 25 sweeps with 15-inch diameter net samples a total of 9.52 meters of row.

Table 9. Number of insects caught per minute of sampling effort. Does not include time spent starting suction sampling device.

Taxon	Drop cloth	Sweep net*	Suction
Tarnished plant b.	0.791	0.575	0.060
Lady beetle	5.079	3.818	1.277
Big-eyed bug	0.455	0.243	0.192
Spiders	2.496	1.006	0.696
Ants	1.406	0.411	0.135
Insidious flower b.	0.396	0.399	0.015
Lacewings	0.367	0.218	0.111
Damsel bugs	0.092	0.047	0.057
All arthropods	11.082	6.717	2.543

* Assumes 25 sweeps with 15-inch diameter net samples a total of 9.52 meters of row.