Evaluation of Sampling Methods for Lady Beetles (Coleoptera: Coccinellidae) in Grain Sorghum

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ABSTRACT Four sampling techniques (visual counts on 50 plant samples, sweepnet, drop cloth, and pitfall traps) were evaluated over a 3-yr period to determine the most efficient methods in terms of time, effort, and precision for estimating coccinellid population densities in grain sorghum. Correlations were made among the four techniques, using visual counts as the absolute method, and estimates were made of the relative sampling variation (precision) and relative net precision (efficiency) for each technique. Visual counts were the most efficient sampling method when high precision is desired, regardless of time constraints. When time is a constraint, the drop cloth method is most precise and efficient, followed by sweepnet sampling.

KEY WORDS Coccinellidae, grain sorghum, sampling techniques

THE GREENBUG, *Schizaphis graminum* (Rondani), is a major pest of grain sorghum, *Sorghum bicolor* Moench, in the Texas High Plains. Kring et al. (1985) have shown that early season suppression of greenbugs in grain sorghum is primarily due to predation by coccinellids in the genus *Hippodamia*. Although economic thresholds exist for the greenbug, based on plant damage, they do not take into account the population densities of coccinellid predators in the field. It would be useful to be able to estimate coccinellid density accurately in grain sorghum with a minimal amount of time and effort.

This study was designed to compare four methods of sampling for predatory coccinellids in grain sorghum. The methods included (1) visual search of 50 plant samples, (2) sweepnet samples, (3) drop cloth samples, and (4) pitfall traps. Statistical analyses were used to correlate the data from the four sampling methods, and estimates were made of the mean relative variation and relative net precision of the methods. In addition, the diversity of coccinellid species associated with grain sorghum fields in the Texas High Plains was recorded.

Materials and Methods

The study was conducted for 3 yr (1988–1990) at the Texas Agricultural Experiment Station Research and Extension Center at Bushland, TX. The field used in the study was ≈5 ha, divided into equal strips of a wheat–sorghum–fallow rotation. Each year there were 40,300-m rows of sorghum available for sampling. A greenbug-susceptible grain sorghum hybrid (Funks 'RA-787') was planted each year on 102-cm rows. Conventional agronomic practices for furrow-irrigated sorghum in the High Plains were used each year. Sorghum planting dates were 28 April 1988, 23 May 1989, and 15 May 1990. The beginning sampling dates were 23 June, 16 June, and 13 June for 1988–1990, respectively.

The visual search of 50 plant samples ("Visual") consisted of randomly selecting a spot in the field, counting 50 consecutive plants in a row, and then visually searching each plant for coccinellids. The area covered was ≈10 linear m of row.

Sweepnet samples ("Sweep") consisted of 10 sweeps down a randomly selected sorghum row with a standard beating net (38 cm diameter), covering ≈20 linear meters of row.

The drop cloth samples ("Drop") consisted of a 1-4 by 0.5-m section of white cloth that had wooden dowels attached to the 1-m sides to keep the fabric taut when laid between the rows. The cloth was marked off in squares (15 by 15 cm) with a black marker pen to facilitate counting the coccinellids. Plants from two opposing rows were bent over the cloth and vigorously beaten by hand to dislodge the insects. The Drop samples covered 2 linear m of row.

Randomization for the Visual, Sweep, and Drop samples was determined by consulting a random number table (Steel & Torrie 1960). Two numbers were blindly selected from the table for each replication of each technique on each sampling date. If the last three digits of the first random number were <231, that number was

Table 1. Mean and log mean coccinellid numbers per meter of row associated with four sampling techniques, 1988–1990

Coccinellid Method	Yr						Overall $n = 35$	
	1988 $n = 13$[a]		1989 $n = 10$		1990 $n = 13$			
	Mean[b] ± SD	Log[c] Mean ± SD	Mean ± SD	Log Mean ± SD	Mean ± SD	Log Mean ± SD	Mean ± SD	Log Mean ± SD
H. convergens								
Drop	1.12 ± 1.67b	0.55 ± 0.60b	2.94 ± 4.72b	0.98 ± 0.84b	5.03 ± 9.94b	0.99 ± 1.13b	2.93 ± 6.54b	0.82 ± 0.90b
Pit	0.22 ± 0.82b	0.11 ± 0.34c	0.77 ± 2.49b	0.23 ± 0.61c	0.46 ± 1.24c	0.23 ± 0.46c	0.46 ± 1.63c	0.19 ± 0.48c
Sweep	0.98 ± 1.27b	0.51 ± 0.57b	4.21 ± 6.10b	1.11 ± 1.02b	3.56 ± 4.89b	0.99 ± 1.01b	2.77 ± 4.62b	0.84 ± 0.91b
Visual	7.77 ± 11.77a	1.55 ± 1.12a	15.32 ± 24.87a	1.78 ± 1.42a	11.27 ± 27.21a	1.39 ± 1.34a	11.45 ± 22.64a	1.57 ± 1.31a
H. sinuata								
Drop	3.08 ± 3.47b	1.05 ± 0.87b	1.34 ± 2.13b	0.58 ± 0.68b	1.52 ± 1.82c	0.70 ± 0.65b	2.08 ± 2.77b	0.80 ± 0.78b
Pit	0.78 ± 3.37b	0.21 ± 0.59c	0.09 ± 0.35c	0.06 ± 0.22c	1.04 ± 3.35c	0.33 ± 0.66c	0.66 ± 2.84c	0.21 ± 0.55c
Sweep	2.82 ± 4.09b	0.90 ± 0.90b	1.64 ± 2.36b	0.67 ± 0.73b	2.90 ± 4.81b	0.88 ± 0.92b	2.49 ± 3.97b	0.82 ± 0.86b
Visual	21.92 ± 29.70a	2.19 ± 1.53a	4.33 ± 7.56a	1.02 ± 1.08a	4.92 ± 6.13a	1.28 ± 1.01a	10.25 ± 19.56a	1.49 ± 1.32a
Larvae								
Drop	0.18 ± 1.17b	0.07 ± 0.31b	0.28 ± 0.62a	0.17 ± 0.35a	16.83 ± 57.26b	0.95 ± 1.55b	5.76 ± 33.91b	0.39 ± 1.01b
Pit	0.05 ± 0.29b	0.03 ± 0.16b	0.15 ± 0.46a	0.09 ± 0.27a	3.90 ± 12.03b	0.56 ± 1.10c	1.42 ± 7.34b	0.23 ± 0.71c
Sweep	0.08 ± 0.35b	0.05 ± 0.20b	0.20 ± 0.68a	0.10 ± 0.33a	10.49 ± 38.61b	0.70 ± 1.34bc	3.49 ± 22.47b	0.28 ± 0.84bc
Visual	0.59 ± 2.18a	0.20 ± 0.54a	0.37 ± 1.14a	0.18 ± 0.42a	37.48 ± 120.07a	1.29 ± 1.90a	13.43 ± 73.08a	0.58 ± 1.30a
Other adults								
Drop	0.17 ± 0.50ab	0.11 ± 0.29b	0.24 ± 0.65a	0.14 ± 0.33a	0.22 ± 0.57b	0.14 ± 0.32b	0.21 ± 0.57b	0.13 ± 0.31a
Pit	0.02 ± 0.14b	0.01 ± 0.09c	0.02 ± 0.15b	0.02 ± 0.10b	0.08 ± 0.30b	0.05 ± 0.19b	0.04 ± 0.21c	0.03 ± 0.14b
Sweep	0.27 ± 1.67a	0.11 ± 0.35b	0.19 ± 0.54a	0.12 ± 0.30a	0.63 ± 1.64a	0.26 ± 0.55a	0.36 ± 1.43a	0.16 ± 0.42a
Visual	0.35 ± 0.91a	0.19 ± 0.40a	0.34 ± 0.87a	0.18 ± 0.40a	0.27 ± 0.93b	0.14 ± 0.37b	0.32 ± 0.90a	0.17 ± 0.39a

Means followed by the same letter within a subgroup are not significantly different (SNK, $P \geq 0.05$).

[a] n, number of sampling dates.

[b] Number per meter of row; SD, standard deviation.

[c] Natural log of the number per meter of row.

used to determine the number of meters to measure into the field from the west side, down the rows. If the last three digits of the first random number were >230 and the last two digits were >19, the last two digits were used to determine the number of meters to measure into the field. Numbers <20 and >230 were not used to preclude sampling the margin of the field. The second random number was used to determine the number of rows to measure in from the north side of the field. If the number was less than 5, it was not used so as not to sample from the edge of the field. If the number was >35 and the first digit was >5, only the first digit was used. Two-digit numbers ranging from 35 to 40 were omitted to prevent sampling from the field margin. For example, if the two random numbers were 74,547 and 88,116, the sample would be taken at 47 m into the field from the west side and at row 16 from the north side of the field. Once a randomization was made, a flag was placed at the beginning of the row to be sampled. A second flag was placed at the end of the row when sampling was complete. If a randomization placed a sample within 10 m and five rows of a previously sampled row, another randomization was done to eliminate overlapping samples for a given sampling date. All flags were removed from the field after sampling was complete for a given sampling date.

Pitfall traps ("Pit") were constructed from three plastic cups. A 473-ml paper cup (Solo) was buried in the ground so that the top rim was level with the soil surface. A 104-ml cup (Solo) containing 70% ethyl alcohol was placed in the bottom of the buried 473-ml cup. A 208-ml cup (Cozy refill), with the bottom removed, was used as a funnel set inside the 104-ml cup. The traps were set up in the field 24 h before the Visual, Sweep, and Drop samples were taken. Each pitfall trap was considered a replication. Initial randomization for the Pit samples was determined in the same manner as the other techniques at the first sampling date for a given year; however, these traps were not moved at subsequent sampling dates during a given year.

Twelve replications of Visual, Sweep, and Drop samples and 15 replications of Pit samples were taken weekly beginning when the sorghum plants had reached plant growth stage 3–4 (Vanderlip 1972) and continued until the plants matured and insect densities declined. For all techniques evaluated, the number of mature and immature coccinellids was recorded.

In addition, 12 sorghum plants were examined visually for greenbug and corn leaf aphid, *Rhopalosiphum maidis* (Fitch), densities. The initial plant was randomly selected at each sampling date in the same manner as the Visual, Sweep, and Drop sampling techniques. Subsequent plants were selected at five-pace intervals down the row, from west to east.

After the field data were converted to number of coccinellids per meter of row, mean densities for *Hippodamia convergens* (Guérin-Méneville), *H. sinuata* Mulsant, coccinellid larvae, and other adult coccinellids for each year were determined. Because of large variances, the data were examined using Bartlett's χ^2 test for homogeneity of variance (Steel & Torrie 1960). Because the results of the test were significant, data were transformed using log $(x + 1)$ before statistical analyses. All coccinellid adults, except *H. convergens* and *H. sinuata*, were lumped together as a separate group because they occurred in very low numbers. Sampling precision was estimated by determining the relative variation (RV) of each sampling technique data set by year. The formula for determining RV was taken from Pedigo et al. (1972), where RV = (SEM/mean)100. Lower values of RV indicate better sampling precision. Sampling efficiency was also calculated for each technique as the relative net precision (RNP), where RNP = 1/(cost × RV)100 (Buntin & Isenhour 1989), with cost = time in minutes to sample using a given technique. As the calculated value for RNP increases, sampling efficiency improves. It should be noted that in Buntin & Isenhour (1989) there is a typographical error stating that sampling efficiency declines as RNP increases. This is not the case because, by that formula, if either the time to take a sample increases or RV increases (which would decrease sampling efficiency), RNP decreases. Mean RVs for each technique were compared using the Student-Newman-Keuls test (SAS Institute 1988). In addition, the association between coccinellid population densities from the four sampling techniques was determined using Pearson's correlation coefficients (R) in the SAS PROC CORR procedure (SAS Institute 1988).

Results and Discussion

When the log of the mean number of coccinellids per meter of row is considered (Table 1), significantly more *H. convergens* and *H. sinuata* were collected each year and over all years with the Visual technique than with the other three techniques. Results associated with Sweep and Drop techniques for *H. convergens* and *H. sinuata* were not significantly different from each other, and Pit results were always significantly lower than those from the other three sampling techniques for the same sampling periods. Results are mixed for larvae and other coccinellid adults. Visual samples generally captured significantly more individuals than the other techniques or were equivalent to Sweep and Drop samples. Pit samples were usually significantly smaller than those from the other techniques. Visual and Pit samples were not significantly different from each other on two occasions (1989 larvae and 1990 other adults). Because year-to-

Table 2. Correlation coefficients for four coccinellid sampling methods

Coccinellid Method	1988 n = 13[a]			1989 n = 10			1990 n = 12			Overall n = 35		
	Sweep	Pit	Visual	Sweep	Pit	Visual	Sweep	Pit	Visual	Sweep	Pit	Visual
H. convergens												
Drop	0.68[b]	0.68	0.44	0.73	0.58	0.99	0.69	0.06	0.83	0.56	0.16	0.76
	**[c]	**	NS	**	NS	**	**	NS	**	**	NS	**
Sweep	—	0.51	0.84	—	0.60	0.78	—	0.55	0.52	—	0.32	0.64
	—	NS	**	—	NS	**	—	NS	NS	—	*	**
Pit	—	—	0.19	—	—	0.67	—	—	0.18	—	—	0.16
	—	—	NS	—	—	*	—	—	NS	—	—	NS
H. sinuata												
Drop	0.81	0.43	0.72	0.78	0.51	0.92	0.60	−0.10	0.85	0.70	0.24	0.76
	**	NS	**	**	NS	**	*	NS	**	**	NS	**
Sweep	—	0.65	0.89	—	0.50	0.84	—	0.33	0.69	—	0.48	0.70
	—	**	**	—	NS	**	—	NS	**	—	**	**
Pit	—	—	0.28	—	—	0.67	—	—	0.07	—	—	0.19
	—	—	NS	—	—	*	—	—	NS	—	—	0.28
Larvae												
Drop	0.94	0.96	0.93	0.34	0.12	0.97	1.00	0.99	0.99	1.00	0.99	0.99
	**	**	**	NS	NS	**	**	**	**	**	**	**
Sweep	—	0.99	0.99	—	0.86	0.47	—	0.99	0.99	—	0.99	0.99
	—	**	**	—	**	NS	—	**	**	—	**	**
Pit	—	—	1.00	—	—	0.24	—	—	0.99	—	—	0.99
	—	—	**	—	—	NS	—	—	**	—	—	**
Other adults												
Drop	−0.14	−0.12	−0.19	0.09	−0.25	0.48	0.09	0.01	−0.18	0.09	−0.02	−0.08
	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sweep	—	−0.09	0.64	—	−0.21	0.40	—	0.80	—	−0.01	0.72	
	—	NS	**	—	NS	NS	—	NS	**	—	NS	**
Pit	—	—	0.21	—	—	−0.30	—	—	−0.18	—	—	−0.10
	—	—	NS	—	—	NS	—	—	NS	—	—	NS

[a] n, number of sampling dates.
[b] Pearson's correlation coefficient (R).
[c] $P > (R)$ under Ho: $\rho = 0$. **, ≤0.01; *, ≤0.05; NS ≥0.05.

year variation was high for larvae and other coccinellid adult samples, the overall results for these categories gave the best indication of the sampling technique that will collect the most individuals. Visual sampling was used to determine absolute coccinellid density to compare with other techniques. Visual was the most time-consuming of the four techniques, requiring ≈15 min per sample, and was not influenced by factors such as weather, plant condition, or plant growth stage. The Visual technique was also the only method tested that could estimate immobile stages (eggs and pupae).

The Sweep technique provided accurate estimates of coccinellid densities and correlated (over 50%) with visual samples in all cases except the 1989 sampling for other adult coccinellids and larvae (Table 2).

Sweepnet sampling is a commonly used method and does not require much practice to use proficiently. It is rapid, requiring an average of 7 min per sample. There were several negative aspects of the Sweep samples. First, the area sampled did not translate well into absolute densities per unit area. As plants grew larger, the sweepnet sampled proportionally less of the canopy so that estimates of actual density were increasingly lower. After sorghum heads emerged, determining which part of the plant to sweep became a problem. Sweeping heads did not catch many coccinellids, and sweeping the sides of plants was difficult. Also, when plants were small, the net damaged plants by shredding leaves and causing lodging. During cool weather, adult coccinellids hid near the stalk or on the soil surface where the net could not sample them, resulting in low estimates of coccinellid population density.

The Drop technique proved to be the best overall technique in this study. In all cases except for other adult coccinellids, it exceeded 70% correlation with the Visual technique, often reaching >90% correlation. This technique also correlated (R > 50%) with the Sweep technique, except for other adults and in one case for larval estimates (Table 2). The time required to collect the Drop samples was the least of the four techniques, averaging 5 min per sample. One person could easily handle the drop cloth after some practice, and the samples resulted in density estimates similar to those from the Sweep technique. Numbers per sample readily converted to densities per unit area because the samples were based on 2 m of row. One problem associated with this technique occurred with warm weather and high coccinellid population density. Adults, particularly, *H. convergens*, flew quickly after falling onto the cloth, making identification somewhat difficult or causing the observer to miss an occasional beetle. In that situation, it was

Table 3. Mean relative variation (RV) and mean relative net precision (RNP) associated with four sampling methods for coccinellids in grain sorghum

Coccinellid Method	Yr						Overall	
	1988		1989		1990			
	RV[a] ± SD[b]	RNP[c]	RV ± SD	RNP	RV ± SD	RNP	RV ± SD	RNP
H. convergens								
Drop	128.5 ± 59.4a	0.17a	87.2 ± 49.6a	0.31a	132.9 ± 68.6a	0.20a	120.8 ± 62.5a	0.17a
Net	111.2 ± 43.4a	0.13b	101.6 ± 58.1a	0.20b	135.2 ± 83.3a	0.15ab	118.3 ± 65.3a	0.12a
Pit	304.8 ± 119.6b	0.02c	258.7 ± 135.1b	0.03c	241.8 ± 116.2b	0.05c	264.9 ± 120.5b	0.04c
Visual	126.7 ± 102.4a	0.07b	61.8 ± 31.4a	0.14b	101.2 ± 59.9a	0.09bc	97.6 ± 74.3a	0.07b
H. sinuata								
Drop	126.7 ± 95.7a	0.25a	146.1 ± 98.4a	0.16a	100.8 ± 39.1a	0.21a	120.8 ± 79.0a	0.17a
Net	110.3 ± 87.0a	0.16b	148.3 ± 124.2a	0.13ab	128.6 ± 49.3a	0.13b	126.8 ± 83.5a	0.11a
Pit	273.2 ± 117.6b	0.03c	227.2 ± 111.1b	0.02c	196.5 ± 114.6b	0.05c	231.9 ± 115.6b	0.04b
Visual	83.4 ± 92.7a	0.13b	111.7 ± 92.6a	0.07bc	91.6 ± 57.6a	0.09bc	94.5 ± 79.7a	0.07ab
Larvae								
Drop	242.9 ± 69.0a	0.08a	166.9 ± 76.9a	0.11a	107.9 ± 52.6ab	0.11a	161.3 ± 84.4a	0.12a
Net	224.9 ± 109.7a	0.06a	265.3 ± 70.7b	0.07a	151.3 ± 95.5ab	0.07a	191.5 ± 100.2b	0.07a
Pit	201.6 ± 7.6a	0.05a	276.6 ± 132.8b	0.04a	184.4 ± 120.6b	0.04a	221.1 ± 121.1b	0.05a
Visual	234.0 ± 116.3a	0.03a	194.2 ± 78.9b	0.05a	91.0 ± 32.5a	0.05a	166.6 ± 96.0a	0.04a
Other adults								
Drop	205.3 ± 67.7a	0.05a	258.9 ± 99.5a	0.08a	169.6 ± 61.9a	0.06a	213.3 ± 83.5a	0.09a
Net	251.3 ± 49.9a	0.04a	226.0 ± 89.2a	0.05ab	229.8 ± 99.4b	0.06a	237.5 ± 77.6a	0.06a
Pit	263.9 ± 0.0a	0.01b	387.3 ± 0.0b	0.01b	290.3 ± 73.1b	0.02a	316.1 ± 72.1b	0.03b
Visual	251.4 ± 91.8a	0.02ab	223.4 ± 110.4a	0.02b	231.6 ± 83.3b	0.02a	237.7 ± 92.5a	0.03b

Means in a column within a subgroup followed by the same letter are not significantly different (SNK, $P \geq 0.05$).
[a] RV, (SEM/mean)100.
[b] SD, standard deviation.
[c] RNP, 1/(cost * RV)100; cost (in minutes) = 5 for Drop, 7 for Net, 5 for Pit, and 15 for Visual.

better to have two people, each counting insects on half of the cloth.

The Pit technique was an undesirable method of estimating coccinellid population densities. The primary idea behind the Pit technique was to estimate larval numbers as they moved on the ground between plants. In this instance the traps worked as intended in most cases, with correlations close to 100% when compared with the Visual samples. Correlation between Pit and Visual for adults was generally below 30%. The Pit technique captured high numbers of adults when plants were small and they had to move on the ground to search for plants, but very few were caught when plants exceeded growth stage 4. Although sampling time was rapid, the Pit technique required two trips to the field: first to set the traps and then again 24 h later, to sample them. An additional problem was the amount of soil and foreign matter that accumulated in the cups, often including parts of leaves that allowed adults and larvae a means to escape from the cups. Heavy rains also filled cups or heaved them out of the ground.

In terms of RV and RNP (Table 3), there were no significant differences in *H. convergens* or *H. sinuata* sampling RV for the Drop, Net, or Visual techniques. The Pit sampling technique in these cases always had a significantly higher RV than the other techniques and therefore was significantly less precise. Sampling RNP for *H. convergens* was most efficient using the Drop technique, which had significantly higher results than Net and Visual, which had significantly higher results than Pit. The exception was in 1990, when results from Visual and Pit were not significantly different. Sampling RNP for *H. sinuata* followed the same general trends, although there were more occurrences of results from Pit and Visual not being significantly different (1989 and 1990), and one occasion where results from Drop and Net were not significantly different (1989).

For other coccinellid adults, either RV was not significantly different among the four techniques or the Pit sampling resulted in significantly less precision (1988, 1989, overall). In 1990, the Drop sampling technique was significantly more efficient than all other techniques. The only clear trend in sampling RNP estimates for other adults was found with the Drop technique, which always had significantly better results than the Pit technique and often had significantly better results than the Visual method. Sampling RV for larvae showed no significant trends over the years, although overall RV estimates for larvae indicated that results from Drop and Visual techniques were equivalent and significantly better than results from Net and Pit techniques. There were no differences in larval sampling RNP for any year or overall. There was a trend for larval Drop sampling to have a higher RNP than the other three techniques.

General conclusions drawn from RV and RNP estimates depend on the specific needs of a researcher using these results. The most precise sampling, without regard to time limits, was the Visual sampling method, followed by Drop and

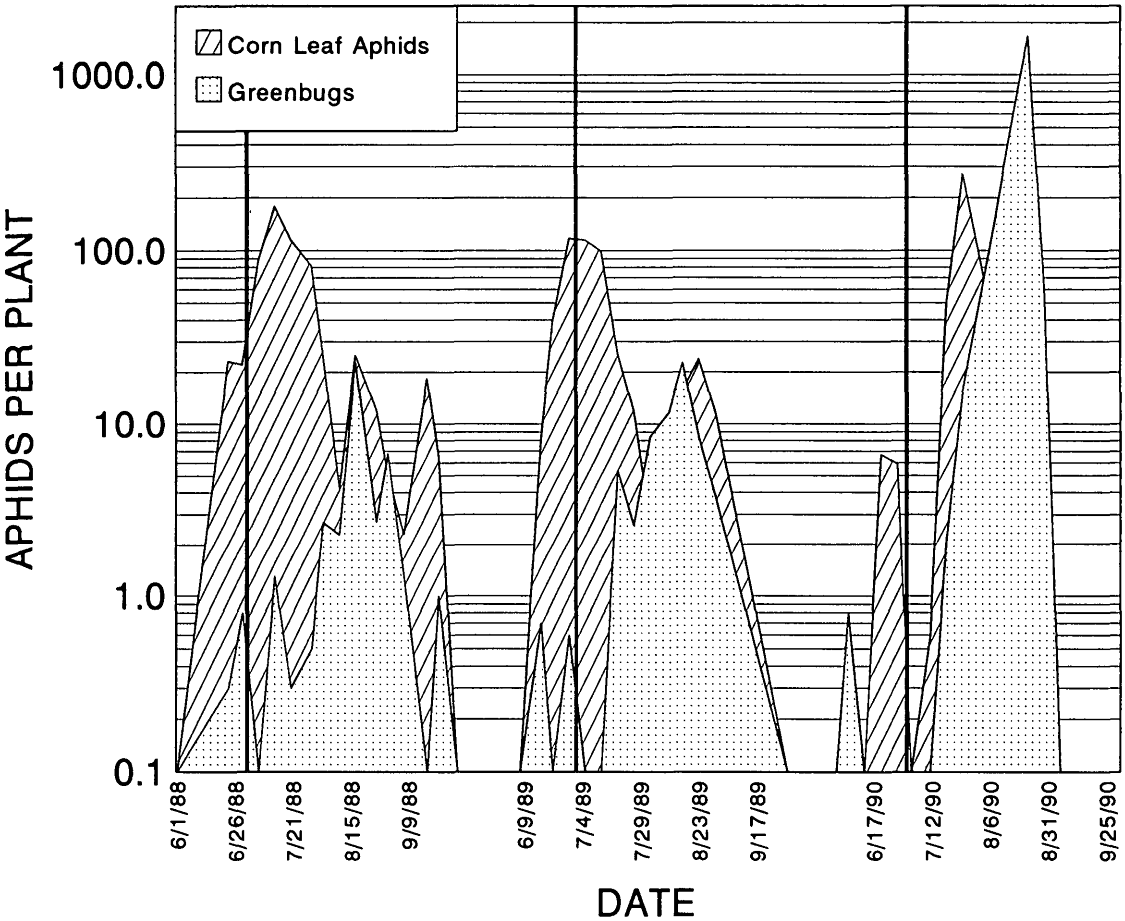

Fig. 1. Average number of aphids per plant in grain sorghum, 1988–1990, at Bushland, TX. Heavy vertical line indicates 1 July for a given year.

Net. This is especially true when sorghum reaches advanced growth stages. If a researcher is willing to trade lower RV (higher precision) for higher RNP (higher efficiency), the best technique for most situations is the Drop method because time is reduced by 66%. It should be kept in mind that our estimates for the cost factor in the RNP estimates (Table 3) could be altered by other researchers, and differing results may be encountered in terms of efficiency.

Although *H. convergens* and *H. sinuata* were the primary focus of this research, other data collected during the course of this study could be of importance to researchers in interpreting the results presented here. Greenbug and corn leaf aphid densities for the 3 yr of this study are presented in Fig. 1. These data show that corn leaf aphids are the primary prey species early in the season and greenbugs are late-season prey. In both 1988 and 1989, aphid densities were low and greenbugs probably did not damage sorghum. In 1990, aphid densities were much higher, and greenbugs caused damage. Peak greenbug numbers in 1990 reached nearly 2,000 per plant before they crashed ≈12 wk into the sampling period.

A listing of the other eight adult coccinellid species encountered in the sampling is contained in Table 4. We assumed that these species, with the exception of *Scymnus (Pullus)*

Table 4. Minor coccinellid species encountered in visual samples in sorghum, 1988–1990

Species	Subfamily	1988	1989	1990
Coccinella septempunctata L.	Coccinellinae	2	6	4
Coleomegilla maculata lengi Timberlake	Coccinellinae	2	1	16
Hippodamia parenthesis (Say)	Coccinellinae	5	8	2
Olla v-nigrum (Mulsant)	Coccinellinae	2	0	4
Hyperaspidius sp.	Scymninae	1	0	0
Scymnus (Pullus) loweii Mulsant	Scymninae	32	29	26
Scymnus americanus Mulsant	Scymninae	0	1	1
Microwesia misella (LeConte)	Sticholotidinae	3	0	0
Total		47	45	53

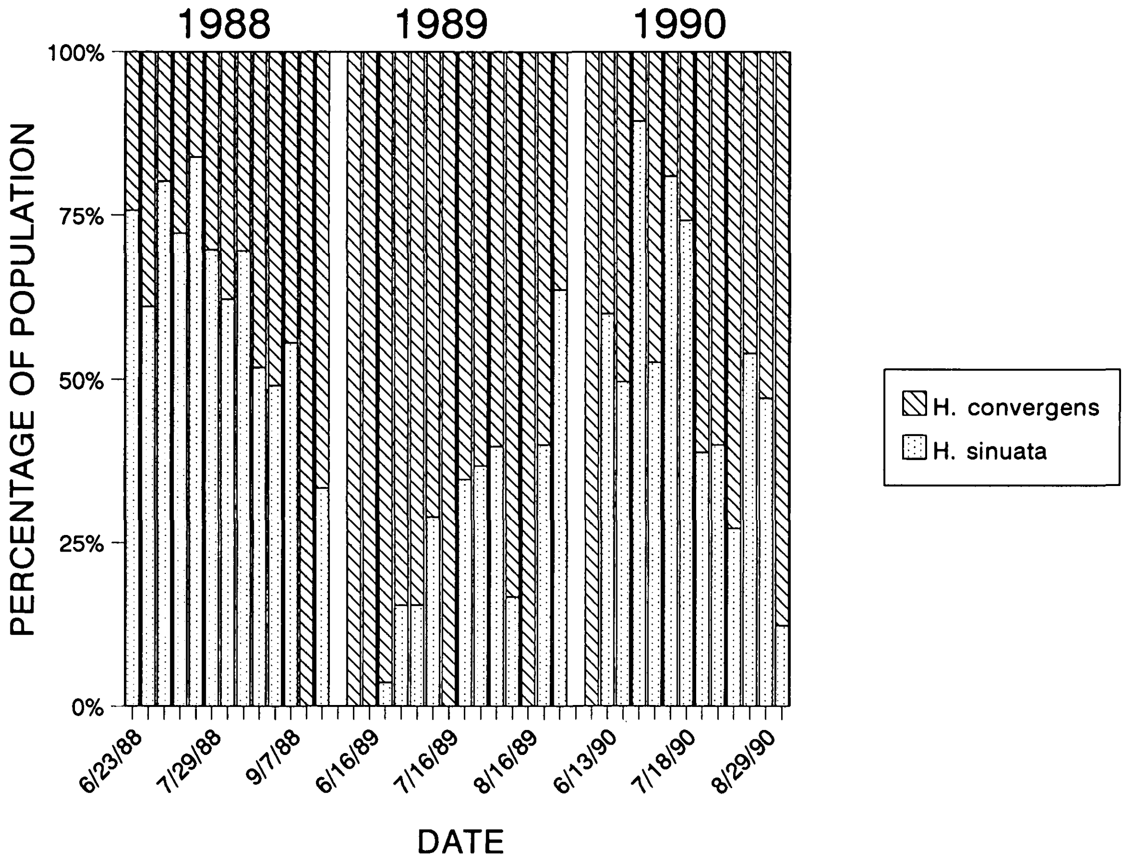

Fig. 2. Percentage distribution of major coccinellid adult species in grain sorghum, 1988–1990, at Bushland, TX.

loweii Mulsant, are occasional visitors to the sorghum field and probably do not play a major role in greenbug suppression. Their numbers are included to indicate the diversity of the coccinellid fauna that can be present in grain sorghum in the Texas Panhandle. The percentage of each coccinellid species collected by sample date is presented in Fig. 2. The seasonal distribution and density of *H. convergens* and *H. sinuata* changed dramatically from year to year. In 1988 and 1990, *H. sinuata* was the primary coccinellid encountered, but *H. convergens* dominated the collections in 1989. It is unclear why the densities of these two dominant predators fluctuate from year to year, but our data indicate that aphid density is not the primary cause.

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