COCCINELLIDS (COLEOPTERA: COCCINELLIDAE) AND SYRPHIDS (DIPTERA: SYRPHIDAE) AS PREDATORS OF APHIDS IN CEREAL CROPS: A COMPARISON OF SAMPLING METHODS

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Abstract

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The reliability of three methods for sampling aphidophagous coccinellids and syrphids in a winter wheat field was compared.

In the first method, an observer recorded predators seen during 2 min per 25-m² sub-plot. In the second, two observers worked successively through each plot, scanning the full height of wheat plants and collecting predators. This method enables calculation of predator density using De Lury's technique. The third method consisted of collecting wheat plants from each sub-plot for examination in the laboratory.

The first method may be used for appraising populations of adult coccinellids on a large scale. The detailed searching method is appropriate for studies of the population dynamics of adult and fourth-instar coccinellids. The plant sampling method is the most accurate for assesssing densities of syrphid larvae and pupae.

Résumé

Trois méthodes d'échantillonnage des coccinelles et syrphes prédateurs de pucerons des céréales sont comparées.

Le champ de blé d'hiver est divisé en sous-parcelles élémentaires de 25 m². Dans la première méthode, un observateur note les prédateurs qu'il rencontre durant 2 min par sous-parcelle. Dans la seconde méthode, deux observateurs parcourent successivement la sous-parcelle en récoltant les prédateurs sur toute la hauteur de la plante. Cette méthode permet l'estimation de la densité des prédateurs dans la surface échantillonnée par la technique de De Lury. La troisième méthode consiste à récolter neuf plantes de blé dans chaque sous-parcelle échantillonnée et à les examiner au laboratoire.

La première méthode est utilisable pour apprécier la forme des courbes de populations de coccinelles à une large échelle. La méthode visuelle approfondie peut s'appliquer aux études détaillées de dynamique des populations d'adultes et de quatrièmes stades larvaires de coccinelles. La méthode de coupe de plantes est la seule qui donne un résultat quantitatif pour estimer la densité des larves et des pupes de syrphes.

Introduction

A major difficulty in implementing biological control programs is assessing the impact of entomophagous insects on pest populations. The development of sampling methods and the appraisal of their efficiency are necessary preliminaries to a quantitative approach (Frazer and Raworth 1985).

The most commonly used techniques for sampling aphid predators are based on the following: sweeping the upper plant canopy (Chambers *et al.* 1982; Clayhills and Markkula 1984); suction sampling by ''D-VAC''; trapping using light-traps and sticky surfaces (Dean 1982, 1983); or counting predators observed within a given period of time (Rautapaa 1976). Only relative densities are obtained by these methods. Except for the sampling procedure developed by Frazer and Raworth (1985) for adult coccinellids in strawberry crops, no method provides satisfactory absolute estimates of predator densities.

Here we report a study on the efficiency of three techniques for estimating the density of cereal aphid predators: a rapid survey, counting without collecting; detailed successive surveys of a limited area with collection of predators; and collection and subsequent examination of wheat plants in the laboratory.

The commonest aphid and predator species encountered were those usually found in cereal crops of western Europe: the aphids *Macrosiphum (Sitobion) avenae* F., *Metopolophium dirhodum* Walk., and *Rhopalosiphum padi* L.; the coccinellids *Coccinella septempunctata* L., *Adonia variegata* Goeze, and *Propylea quatuordecimpunctata* L.; and the syrphids *Syrphus corollae* Fabr., *Epistrophe balteata* L., and *Sphaerophoria scripta* L. Chrysopidae, Cecydomiidae, and polyphagous predators were not considered.

Methods

The experimental plot, 4125 m^2, was of winter wheat (var. Gala), surrounded by alfalfa and corn fields, in the Var valley (south-eastern France, 5°E, 43°N). A post-emergence selective herbicide has been applied but no insecticides or fungicides had been used for several years. The plot was divided by stakes into 165 sub-plots, 25 m^2 each. Three predator counting methods were used at weekly intervals, from April (tillering stage) to mid-July (harvest).

Quick visual method. An observer walked within each sub-plot for 2 min and counted the coccinellid and syrphid adults, pupae, and larvae seen.

Detailed visual method. The 165 sub-plots usually were classified weekly according to number of *C. septempunctata* adults previously observed with the quick visual method: 0, 1–2, 3–4, 5 or more. Sixteen sub-plots were selected among these four classes so that they were not sampled twice over several weeks.

One observer walked through each of the selected sub-plots, collecting coccinellids and syrphid larvae and pupae. Immediately thereafter, another observer walked through the same sub-plot repeating the search. The soil surface and the full height of wheat shoots were inspected. Collecting time (20–30 min) increased relative to searching time when predators were abundant.

De Lury's method (Laurent and Lamarque 1974) was used to estimate the density of predators in sub-plots. Let the number of a predator instar collected by the first observer be $C1$ and the number collected by the second observer be $C2$, then the most probable population density in the sub-plot, P, is given by

$$P = C1^2 / (C1 - C2).$$

Seber and Le Cren (1967) considered that, as a rough rule, the estimates are usually satisfactory if

$$D > 16$$

with

$$D = C1^2 \cdot (C1 - C2)^2 / [C2^2 \cdot (C1 + C2)].$$

If this condition is not satisfied, population density can only be estimated as higher than $C1 + C2$.

The efficiency of the count, E, expressed as the total numbers caught after two counts as a percentage of the population in the sub-plot, is found from

$$E = (C1 + C2) \cdot 100 / P.$$

This method is used on two assumptions. First, that the capture efficiency is equal for the two counts, i.e. a constant percentage of the remaining population is removed at each count. Second, that there is no immigration to or emigration from the sampled area between the two counts or during sampling. Migration within 1 h was considered to be negligible.

An assessment of the reliability of this method was provided by increasing the number of successive collections in sub-plots ($C1$, $C2$, $C3$ ...), to check the linearity of the relationship between numbers collected at each count and the cumulative numbers in previous counts. Linearity would result from a constant searching efficiency (Seber and Le Cren

1967). This method was used when coccinellid populations were large but concentrated in only a few sub-plots: for *Adonia variegata* on 21 May 1985 for four counts in six sub-plots and for *Propylea quatuordecimpunctata* adults on 25 June 1985 for six counts in five sub-plots.

Coccinella septempunctata were not numerous enough to use this method. To assess reliability of the method for third- and fourth-instar larvae and adults of this species, the population in a sub-plot surrounded by a plastic sheet was reduced to negligible levels by repeated collections and then a known number (>100) of a single instar was released into the sub-plot. Two successive counts were made 2 h later to compare the number P computed from $C1$ and $C2$ with the number released, decreased by the emigration observed during the settlement period.

Each week, three 50-cm-long samples of wheat rows were selected by throwing a 50-cm-long stick into sub-plots previously sampled by the detailed visual method. The plants were dug out to determine the number of plants per metre of row. The first three plants in each of the three samples were taken to the laboratory and examined for predators and aphids. The data were used to estimate aphid and predator densities per metre of row and per square metre.

Very mobile predators, especially coccinellid larvae and adults, probably were lost during plant collection. However, syrphid pupae, larvae, and eggs, which adhere strongly to the plant, were collected.

Results

Estimates of population density obtained from the detailed visual method were much higher than those from the quick method for all predators sampled (Table 1).

For syrphids, the differences between population estimates derived from both visual methods and that from plant sampling were substantial, especially for larvae. The population density of syrphid larvae estimated by the detailed visual method was less than 1% of that from plant sampling.

Coccinellids. (*a*) Reliability of De Lury's method. Table 2 shows that the mean capture efficiency of two counts of *C. septempunctata* adults and fourth-instar larvae, calculated from the release of a known number of individuals, is similar to the efficiency calculated from De Lury's method for all sampling dates. For first- to third-instar larvae, however, only 27.5% of the individuals released were recovered, compared with 66% and 86% over all sampling dates. The capture efficiency of *A. variegata* and *P. quatquatuordecimpunctata* adults, computed with 2 years data, was similar to that computed using four or six counts.

(*b*) Variability of sampling efficiency using De Lury's method. Capture efficiency of *C. septempunctata* adults remained relatively constant throughout the season, dropping sharply at only one date each year (Fig. 1A).

When numbers collected did not decrease from $C1$ to $C2$, the efficiency cannot be estimated (missing points on Fig. 1). Fluctuations in capture efficiency of third- and fourth-instar larvae could not be interpreted because numbers were often too low and the underlying assumption of De Lury's method (D>16) was seldom satisfied. The efficiencies were not related to crop growth stages (Fig. 1B). A decrease in efficiency only occurred in the early dough stage.

Analysis of the changes in capture efficiency of the other two coccinellid species was not possible because they were abundant only on a few sampling dates.

Capture efficiency was markedly lower at higher predator densities. A highly significant correlation (r=0.69, n=17, P<0.01) was found between the estimated density of *C. septempunctata* adults and capture efficiency, after arc sin transformation (Fig. 2). This

Table 1. Total annual numbers of predators counted with the three methods: A, quick visual method; B, detailed visual method; C, plant sampling method. For comparison with A and B, the estimated number of syrphids in C was calculated from the number observed in sampled area

	1984				1985			
			C				C	
	A	B	Obs.	Estim.	A	B	Obs.	Estim.
Sampled area (m^2)	8400	8400	30.2	8400	7200	7200	20.2	7200
Coccinella septempunctata								
Adults	355	970	—	—	408	1360	—	—
L4	41	373	—	—	89	753	—	—
L1–L3	4	80	—	—	—	—	—	—
Egg clusters	—	118	—	—	—	—	—	—
Adonia variegata								
Adults	65	270	—	—	254	1422	—	—
L4	—	40	—	—	—	235	—	—
L1–L3	—	12	—	—	—	21	—	—
Propylea quatuordecimpunctata								
Adults	17	245	—	—	32	476	—	—
L4	—	45	—	—	—	66	—	—
L1–L3	—	12	—	—	—	8	—	—
Syrphids (all species)								
Pupae	150	2547	97	26971	225	1888	43	15319
Larvae	4	157	167	46434	5	155	155	55220
Eggs	—	—	10	2780	—	—	64	22801

correlation was still significant ($r=0.49$, $n=16$, $P<0.05$) after removal of the most eccentric point (density $= 0.87/m^2$). None of the correlations between capture efficiency and temperature, rainfall, or prey density (in the same sub-plots) were significant.

(*c*) Comparison between the visual methods. The results of the two methods were linearly correlated for *C. septempunctata* adults and fourth-instar larvae, and for *A. variegata* and *P. quatuordecimpunctata* adults (Fig. 3A–3D). The shapes of the population curves estimated by the two methods were similar for *C. septempunctata* adults (Fig. 4).

Discussion and Conclusion

The visual methods were unsuitable for syrphid larvae; the low capture efficiency being due to their cryptic coloration, relative immobility, and habit of resting in leaf axils,

Table 2. Percentage efficiency of two successive counts based on De Lury's method: A, all sampling dates [$E=\Sigma(C1+C2\cdot 100/\Sigma P$]; B, after release of a known number of individuals; C, De Lury's method with four to six successive counts

	A			
	1984	1985	B	C
Coccinella septempunctata				
Adults	84.9	70.9	71.0	—
4th instar larvae	80.2	54.4	67.2	—
1st–3rd instar larvae	86.1	66.1	27.5	—
Eggs	—	70.1	—	—
Adonia variegata				
Adults	56.5	61.4	—	55.3
Propylea quatuordecimpunctata				
Adults	82.5	76.4	—	67.7

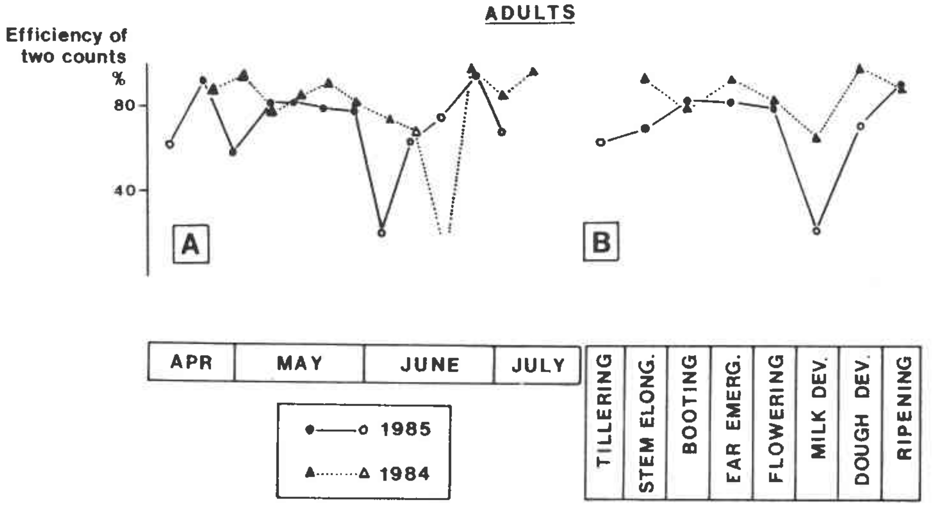

FIG. 1. Changes in capture efficiency in relation to (A) sampling date and (B) crop growth stage for *Coccinella septempunctata* adults and larvae. The points for which $D<16$ are shown as open symbols.

between spikelets and in leaf sheaths. The plant sampling method was the only method suitable for larvae and pupae of the two main species, *E. balteata* and *S. scripta*, as they adhered to the plant surface and were not lost during collection. Syrphid eggs are easily seen at the beginning of the season when leaf area is small, but are difficult to see later.

The quick visual method is satisfactory for determining seasonal trends in predator numbers, especially *C. septempunctata* adults (Fig. 4). The efficiency of this method is better than that obtained by Frazer and Raworth (1985) on strawberries, where "walking

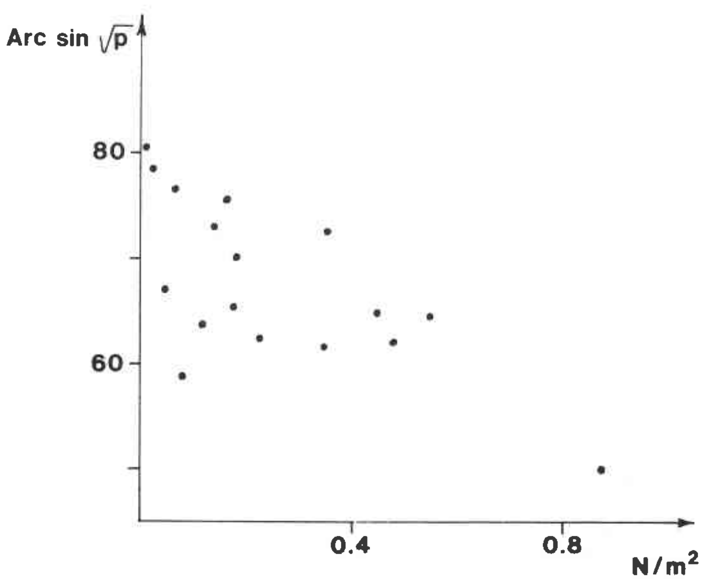

FIG. 2. The correlation between capture efficiency and the estimated density of *Coccinella septempunctata* adults.

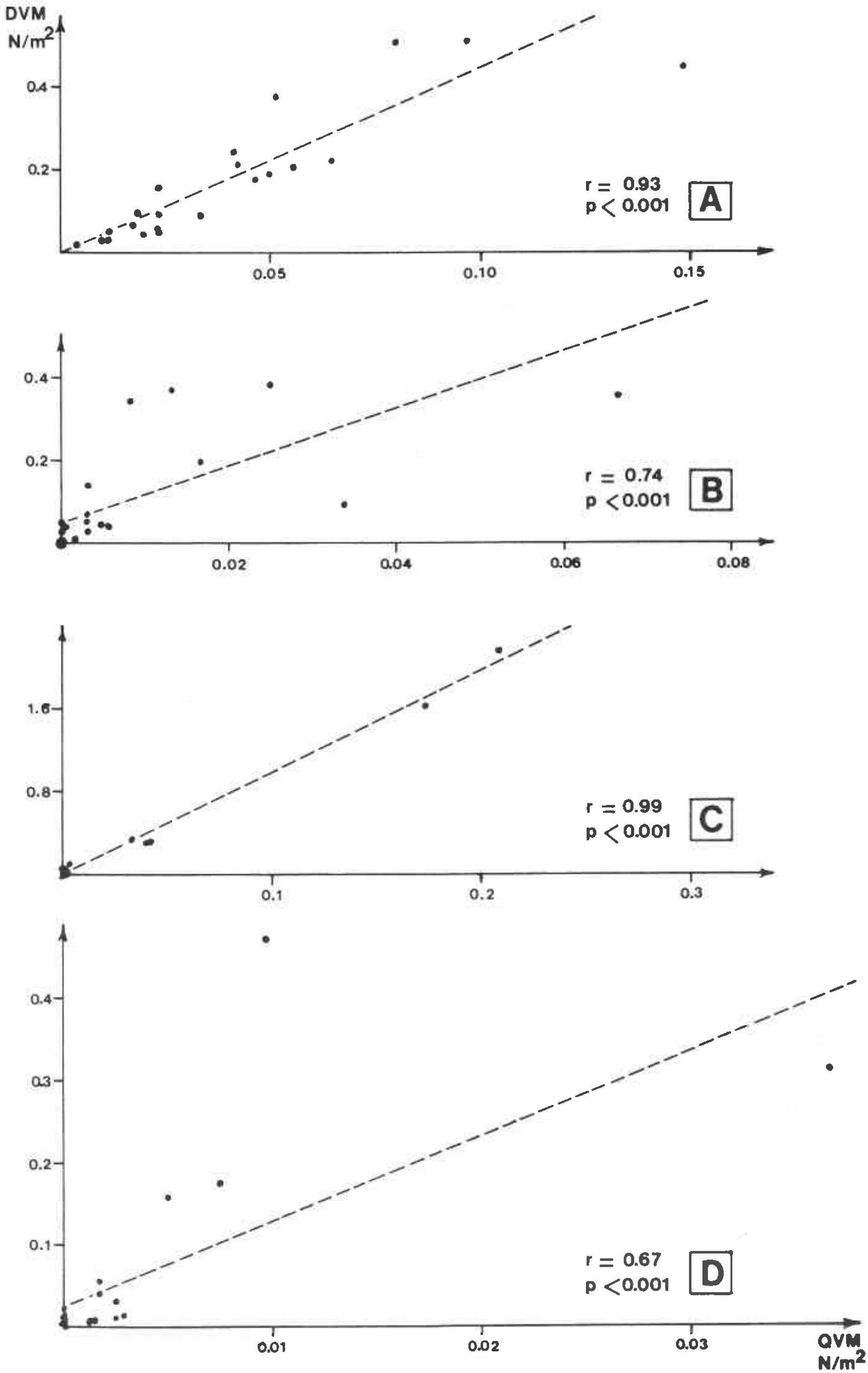

FIG. 3. Correlation between coccinellid density estimated from the quick visual method (QVM) and from the detailed visual method (DVM) for: A, *Coccinella septempunctata* adults; B, *Coccinella septempunctata* fourth-instar larvae; C, *Adonia variegata* adults; D, *Propylea quatuordecimpunctata* adults.

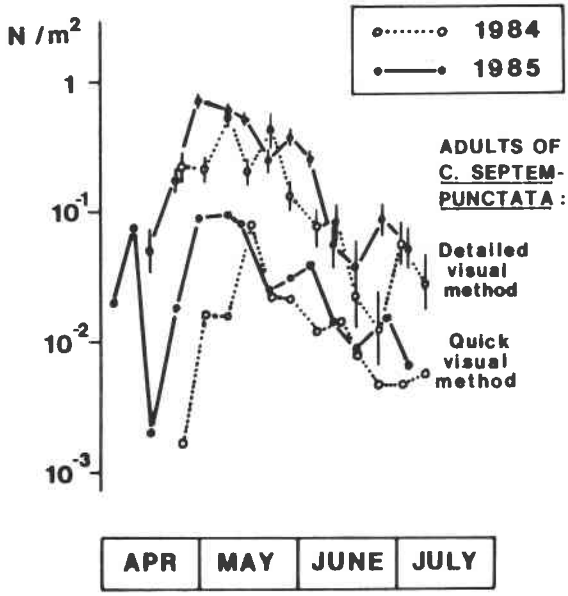

FIG. 4. Changes in population density of *Coccinella septempunctata* adults in 1984 and 1985, as estimated by the detailed visual method, with confidence intervals, and by the quick visual method.

counts'' gave unreliable results. As the time spent by each observer in a given area is similar, coccinellids probably are more visible in wheat.

Detailed visual assessment and De Lury's method are suitable for assessing absolute coccinellid numbers, especially adults and last-instar larvae, as seen in the release–recapture and multiple counts experiments. However, the method is not reliable for younger larvae. Eggs, which were laid mainly during the first 2 weeks of May, under clods and stones, on low weeds, or on the lowest wheat leaves, could be counted efficiently provided that the search was performed exclusively for them.

Several factors may affect the efficiency (E) of the detailed visual method. There may be observer-dependent variation (Frazer and Raworth 1985). Therefore, numerous observers are needed to ensure homogeneous results. Plant growth stage had limited influence on the efficiency of this method (Fig. 1B). The decrease in capture efficiency in early June (dough stage) probably was not due to environmental factors, because no major changes occurred at that time. It is known that temperature and solar radiation can influence the micro-distribution of coccinellids (Frazer and Gilbert 1976; Frazer and Raworth 1985; Honek 1979; Iperti 1965). Frazer and Raworth (1985) found a correlation between sampling efficiency, prey density, and temperature. These relationships were not observed here. This apparent contradiction probably results from differences in efficiency between the ''walking counts'', where 10% of the actual numbers are seen, and the detailed visual method, where 70% are seen.

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