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Ecology of *Anthocoris nemorum* (L.) (Het. : Anthocoridae) and evaluation of its potential effectiveness for biological control of pear psylla

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SUMMARY

Ecology of *Anthocoris nemorum* (L.) and of pear psylla populations was studied in orchards in the Paris region. *A. nemorum* was abundant on pear trees only in autumn, apparently searching for hibernation sites. In summer, it preferred to stay in the herbaceous stratum, especially in nettle, where it preyed upon various species of insects, which were more favorable for its proliferation than *Psylla pyri* (L.). It was determined that in the Paris region, *A. nemorum* had 3 overlapping generations, and the hibernating females showed a simple slow-down of ovarian development, not a reproductive diapause. The predatory behavior of *A. nemorum* is described. Its voracity, the effect of prey density on predator voracity, and its reproductive performance were evaluated by presenting several potential prey species. The rather weak nutritive value of *P. pyri* as prey, and the poor quality of pear leaves as an egg-laying site for *A. nemorum*, indicate its low potential value in biological control of the pest.

Additional key words : *Voltinism, hibernation, predatory behavior, effect of prey density, reproductive performances, egg laying sites.*

RÉSUMÉ

Ecologie d'Anthocoris nemorum (L.) (Het. : Anthocoridae) et évaluation de son efficacité potentielle comme agent de lutte biologique contre le psylle du poirier.

L'évolution des populations d'*Anthocoris nemorum* (L.) et du psylle du poirier est étudiée dans des vergers de la région parisienne. *A. nemorum* est abondant en automne seulement sur les poiriers où, apparemment, il recherche des abris d'hibernation. En été, il préfère se tenir dans la strate herbacée, en particulier les orties, où il attaque divers insectes plus favorables que *Psylla pyri* (L.) à sa prolifération. Dans la région de Paris, *A. nemorum* développe 3 générations chevauchantes et les femelles hivernantes présentent un simple ralentissement de leur développement ovarien et non une diapause ovarienne. Le comportement de prédation d'*A. nemorum* est décrit. Sa voracité, l'effet de la densité de proies sur la voracité du prédateur et ses performances reproductrices ont été évalués en présence de plusieurs espèces-proies. La valeur nutritive assez faible de *P. pyri* comme proie et la mauvaise qualité des feuilles de poirier comme site de ponte pour *A. nemorum* font que ce prédateur est trop peu lié au psylle du poirier pour être considéré comme un agent biologique potentiel dans la lutte contre le ravageur.

Mots clés additionnels : *Voltinisme, hibernation, comportement de prédation, effet de la densité de proies, performances reproductrices, site de ponte.*

I. INTRODUCTION

It was established (BOUYJOU *et al.*, 1984 ; NGUYEN & DELVARE, 1984 ; HERARD, 1985) that the anthocorids were among the most abundant predators in all the orchards infested with *Psylla pyri* (L.), in France ; one species, *Anthocoris nemoralis* (F.) was found in northern and southern France. Although it is a very

polyphagous predator, its most common prey are psyllids (ANDERSON, 1962a). A literature review (HERARD, 1986 accepted for publication) showed that it is a permanent component of the biocomplex of the pear psylla in Europe, and the major limiting factor of the pest. *A. nemoralis* was introduced in 1963 in North America to be used in the control of *Psylla pyricola* Foerster. It was successfully established (Mc MULLEN & JONG, 1967 ; FIELDS & BEIRNE,

1973; CLAUSEN, 1978); it has dispersed and even replaced the native predators, *Anthocoris antevolens* White and *Anthocoris melanocerus* Reuter as the most common anthocorid predator in some orchards (FIELDS & BEIRNE, 1973).

A 2nd species of the same genus, *Anthocoris nemorum* (L.), was frequently observed by us on pear trees in the Paris region, where it was especially abundant in autumn. On the other hand, we never found it in southern France. Although *A. nemorum* was mentioned several times as a predator of pear psylla in Europe (BONNEMAISON & MISSONNIER, 1956; GEORGALA, 1957; WOJNAROWSKA *et al.*, 1960; BRONNIMANN, 1964; CARL & ZWÖLFER, 1965; SCHEURER *et al.*, 1975; NGUYEN *et al.*, 1981), its degree of association with the pest is unknown. Nevertheless, it was decided to attempt introduction in the USA of *A. nemorum*, using individuals from our USDA/EPL culture. First releases were made in pear-growing areas of the Yakima Valley (Washington) where *P. pyricola* occurs.

As a complement to evaluation of the effect of *A. nemorum* in the U.S., we made the following study to ascertain the degree of association between *A. nemorum* and the pear psylla (*P. pyri*) in France. We attempted to determine if the impact of the predator on its host is commensurate with its level of presence in orchards. In the field, we followed the evolution of predator and prey populations, and discovered some characteristics of *A. nemorum* ovarian development in winter. We observed in the laboratory the predatory behavior of *A. nemorum*, evaluated its reproductive performance when fed various prey, and evaluated quality of pear leaves as its egg-laying site.

II. MATERIALS AND METHODS

A. nemorum larvae and adults and *P. pyri* adults were sampled from July 1982 to September 1983 in three 5,000 m² pear orchard plots located in the truck farming plain of Carrières-sous-Poissy (Yvelines, France). Counting was made by beating 50 branches (1 branch per tree) above a 0.5 m² tray. The fauna of the herbaceous stratum, especially nettle close to the orchards, was also collected *via* 200 sweeps per site at each sampling date. Occurrence of *A. nemorum* was also recorded on various trees in the natural orchard environment. Collection of hibernating *A. nemorum* adults was accomplished using artificial hibernacula traps made from corrugated cardboard plates, which were stapled on pear tree trunks just above the ground, and on stakes placed in the nettles. Dissection of *A. nemorum* females revealed fat body and ovarian development.

A. nemorum was reared in the laboratory at 21 ± 1 °C and 60-70 % relative humidity,

(1) on barley sprouts infested with the aphid, *Metopolophium dirhodum* (Walker),

(2) on pear twigs infested with *P. pyri* dipped in aerated water,

(3) on nettle feeders such as the aphid, *Microlophium evansi* (Theobald), the psyllid, *Trioza urticae* L., and the cicadellids, *Eupteryx urticae* (F.) and *Eupteryx aurata* (L.), and

(4) on eggs of *Ephestia kuehniella* Zeller. Other prey species, *Myzus persicae* (Sulzer), *Schizaphis graminum* (Rondani), and *Brevicoryne brassicae* L., were also used in food choice and voracity evaluation experiments.

III. RESULTS

A. Development of *A. nemorum* and *P. pyri* populations

A. nemorum was absent from pear trees in July and August 1982 because of deltamethrin (Decis) applications against pear psylla in the orchards studied (fig. 1). During the same period, it was abundant in nettle. Reduction of its population on nettle in September and October corresponds with lack of prey on this host plant. At the same time the population of *A. nemorum* increased on pear trees due to cessation of spraying one month before harvest and the resultant abundance of psylla. COLLYER (1967) also noted that *A. nemorum* was quick to adjust itself to an adequate food supply.

Not one young *A. nemorum* larva was found on pear trees after late September. Although females had been fertilized, they did not lay eggs in autumn. Matings had been observed, and dissection of females showed that sperm pouches had been filled. However, ovarioles contained only one slightly developed oocyte. These adults were then prehibernating individuals, gathered on pear trees where they fed, increased their fat body, mated and found hibernation sites.

In October and early November, *A. nemorum* adults left pear tree branches and entered their hibernation sites in bark crevices at the bottom of trees. We trapped them there in corrugated cardboard traps. The sex-ratio of individuals occurring in autumn was one to one, and among hibernating adults, 7 females for one male. Most of the males died before winter, after they had inseminated the prehibernating females. Most of the hibernating adults survived the severe winter very well.

By the end of winter, the sex-ratio (7 females for one male) among adults resuming their hunting activity indicated the same small proportion of males recorded in the overwintering traps. These results corroborate those obtained in England by COLLYER (1967) and ANDERSON (1962b). In Scotland, HILL (1957) noted that only very exceptionally were males found in spring.

In 1983, *A. nemorum* resumed its activity the end of March in the Paris region (fig. 1), a little after the 1st oviposition by *P. pyri*, and at the moment of pear tree flowering. In using the pear tree as a habitat for overwintering, adults of *A. nemorum* were thus well situated for survival the beginning of spring. They were able to find there the eggs of psylla placed in abundance at the base of the buds, as well as other prey in the form of various small insects attracted by early flowering of the pear tree. However, their apparent level of population remained low (fig. 1), likely due to the 1st chemical sprays with deltamethrin and movement of adults towards nettle, where their population increased regularly until the end of June.

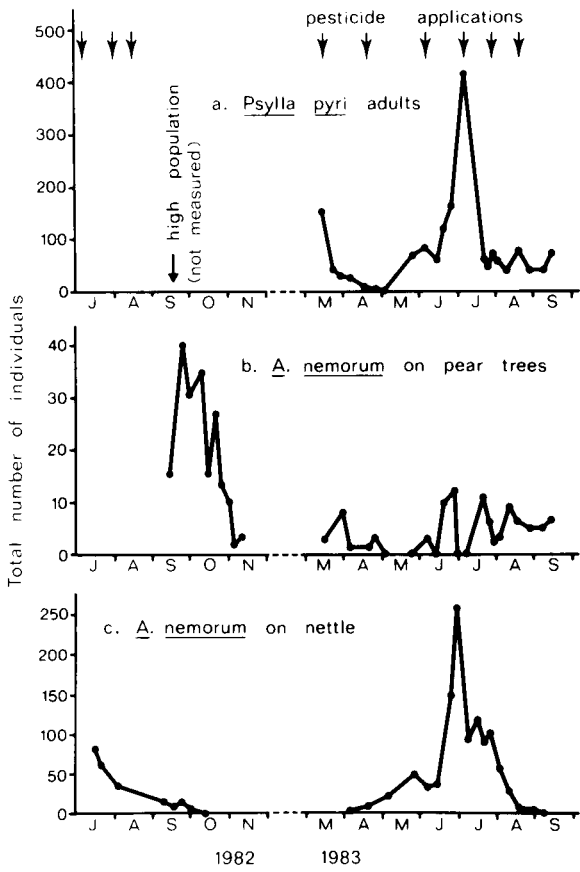


Figure 1
Populations of Anthocoris nemorum and Psylla pyri in the Paris region, 1982-1983.
 a, b. obtained by beating 50 branches (1 branch per tree) over a 0.5 m² tray ; c. obtained in 200 sweeps.
Populations d'Anthocoris nemorum et de Psylla pyri dans la région parisienne en 1982-1983.
 a, b. obtenu par battage de 50 branches (1 branche par arbre) au-dessus d'un plateau de 0,5 m² ; c. obtenu en 200 coups de filet fauchoir.

The *A. nemorum* populations remaining on pear tree during the summer, suffered fluctuations partly due to the depressive effect of repeated deltamethrin applications, and partly due to the fact that *P. pyri* is simply an occasional or alternate prey for this predator.

In 1982 and 1983, *A. nemorum* left nettle in July (fig. 1), as the prey became rare in this habitat. Although the pear psylla population was large, *A. nemorum* adults leaving nettle did not establish on pear trees because of the action of pesticides. On the other hand, we found high numbers of *A. nemorum* in July on hazel, maple, lime, and beech trees close to the orchards. These trees were heavily infested with aphids and could serve as reservoirs for beneficial insects and probably favor new colonizations of orchards.

B. Voltinism

HILL (1957) and PARKER (1975) determined that *A. nemorum* developed only one generation per year in Scotland. In Southern England, ANDERSON (1962c) and COLLYER (1967) showed that *A. nemorum* has 2 generations per year. PARKER (1975) determined that differences in reproductive physiology of these 2 races are of a genetic nature. BONNEMAISON & MISSONNIER (1956) presumed that *A. nemorum* has 3 generations in France. We confirmed the occurrence of 3 overlapping generations in the Paris region (fig. 2).

In 1983, adults coming out of hibernation in mid-March were found until late May. The 1st generation developed from mid-March to mid-July ; the 2nd from late June to late September ; the 3rd from mid-August to late October (fig. 2).

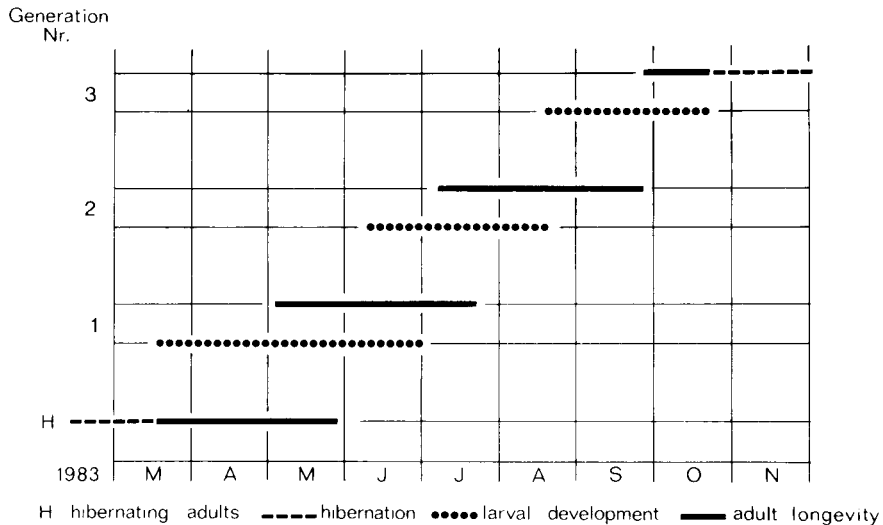


Figure 2.
Generations of Anthocoris nemorum in Paris region.
Génération d'Anthocoris nemorum dans la région parisienne.

C. Hibernation

Concerning the halt in ovarian development during winter, HILL (1957), PARKER (1975), ANDERSON (1962c) and COLLYER (1967), observed important differences in *A. nemorum* female populations from Scotland and from southern England. They stated that reproductive diapause is obligatory in females from Scotland and optional in females from southern England. In England, females collected any time after late December readily laid eggs within a few days, while females collected before late December laid no eggs unless they were first subjected to a period of cold. According to COLLYER (1967), reproductive diapause is induced in the summer while conditions are still favorable. Diapause stops after a period of cold equivalent to November and December of the English winter; after that, oviposition is only inhibited by low temperature and lack of food.

In Germany, the biology of *A. nemorum* was studied by LAUNSTEIN (1976, 1977, 1980a, 1980b). This author distinguished 2 groups of females in a population. Some (20 %) paired and oviposited during the same vegetation period in which they emerged, and 80 % paired but still needed exposure to cold before they would oviposit.

Results we obtained in the Paris region were different from those of English and German authors. We collected prehibernating and hibernating fertile females in nature from October 1982 to January 1983. They were held in the laboratory at 21 ± 1 °C, in 60-70 % relative humidity, and 16 h photophase, and fed aphids from barley. Table 1 shows that in October 1982, about an equal proportion of prehibernating females laid and did not lay eggs. Consequently, we can conclude that there was not an obligatory diapause in this population from the Paris region. Some females laid eggs after a period of ovarian maturation of 7-35 days following the date of collection (table 1). Three generations of predators had been developed by the end of March 1983 from these eggs. Table 1 shows that in the laboratory, the pre-oviposition period was longer in the females collected 1st, probably because they had not developed fat bodies which would have been used for

ovarian maturation. Conversely, overwintering females collected in December had already developed their reserves during autumn, and ovarian maturation was able to take place immediately after they were placed under laboratory conditions. Ovarian development was simply inhibited by cold, as was general activity of the insect; it resumed immediately when the insects were placed in an artificial springtime environment. No obligatory period of cold was necessary for resuming ovarian development among individuals collected in autumn. Therefore, one cannot speak of ovarian diapause in the ecological race occurring in the Paris region but rather of "ovarian slow-down" caused by winter temperatures.

Thus, adults of *A. nemorum* continue to be active in nature as temperature permit. They feed and mate, while the fat bodies of the female grow in volume and weight. Dissection of females collected at the beginning of autumn still showed, generally, a very thin fat body and very small ovarioles. At the end of autumn, fat bodies were larger, but the ovarioles were still fine. At the moment when the fat bodies were more or less developed (with very large individual variability), winter cold forced the females to seek shelter for overwintering, and it maintained them in ovarian pause.

In any case, ovarian pause was not total during winter. Females collected between October and the end of December 1982 and maintained at 4 °C during 90 days in total darkness in individual tubes embedded in plaster of Paris, were dissected March 1983. They showed a fat body of very large to medium size and oocytes in the course of maturation, and even some mature eggs (table 2). Another lot of females, hibernating under the same conditions, was placed in March 1983 at 21 ± 1 °C and 16 h photoperiod and 60-70 % relative humidity with cereal aphids on barley. A few of them began to lay eggs after 2 days. Therefore, there was no pre-oviposition period among these females. Their eggs had matured progressively during the course of hibernation.

PARKER (1975) observed in diapausing females from Scotland that diapause termination was a gradual process and to a certain extent related to the individual. He observed no clear relationship between

TABLE 1

Duration of preoviposition period in A. nemorum females collected in nature (1) by beating pear trees, (2) in artificial hibernacula traps on pear trees, (3) in artificial hibernacula traps on nettle.
Durée de la période de préoviposition chez des femelles d'A. nemorum récoltées dans la nature (1) par battage des poiriers, (2) dans des pièges d'hivernation sur poiriers, (3) dans des pièges d'hivernation dans les orties.

Date of collection	Number of females	Number of females which laid eggs	Duration of preoviposition period (days)	Average duration (days)
Oct. 12 to 16, 1982 (1)	17	9	35 to 38	35.7
Oct. 25 to Nov. 15, 1982 (1)	14	9	16 to 20	17.7
Dec. 28, 1982 (2)	22	20	7 to 13	9.5
Jan. 18, 1983 (3)	16	14	5 to 13	7

TABLE 2

Condition of fat body and development of ovarioles in pre-hibernating and hibernating *A. nemorum* females ;
(1) females 1 to 11 collected by beating pear trees, (2) females 12 to 19 collected in hibernacula.

Etat du corps adipeux et niveau de développement des ovarioles chez des femelles préhibernantes et hivernantes d'*A. nemorum* ;
(1) femelles 1 à 11 récoltées par battage des poiriers, (2) femelles 12 à 19 récoltées dans des pièges d'hivernation.

Female no.	Date of collection	Duration of cold period & darkness	Development of ovarioles	Condition of fat body	Condition of sperm pouch
	(1)				
1	21 XI 82	159	2d oocyte present	reduced	replete
2	—	—	2d oocyte present	reduced	replete
3	—	—	fully developed	very reduced	replete
4	—	—	2d oocyte present	reduced	replete
5	—	—	2d oocyte present	reduced	replete
6	—	—	2d oocyte present	reduced	replete
7	—	—	2d oocyte present	large	replete
8	—	—	3d oocyte present	reduced	replete
9	16 X 82	155	3d oocyte present	reduced	replete
10	9 XI 82	141	3d oocyte present	reduced	replete
11	—	—	2d oocyte present	large	replete
	(2)				
12	28 XII 82	90	3d oocyte present	very reduced	replete
13	—	—	3d oocyte present	large	replete
14	—	—	3d oocyte present	very reduced	replete
15	—	—	2d oocyte present	very reduced	replete
16	—	—	3d oocyte present	reduced	replete
17	—	—	3d oocyte present	very reduced	replete
18	—	—	2d oocyte present	reduced	replete
19	—	—	fully developed	very reduced	replete

length of cold period and state of ovariole development. He believed that state of the females before overwintering could be important, especially with regard to size of the fat body. ANDERSON (1962b) also had observed in England in diapausing females that a slight ovarian development occurred during March, though his specimens were held at 1 °C and had no access to food.

In our experiment photoperiod did not play any role in resumption of ovarian maturation, since the females were maintained for 3 to 5 months in total darkness. No particular factor exists to trigger ovarian maturation ; this occurs very slowly during winter.

Metabolic rate of *A. nemorum* females from the Paris region was therefore not reduced during overwintering as one may have expected. In overwintering adults, we measured weight loss, which would indicate utilization of their reserves for metabolic needs during winter. Average weight of pre-hibernating females collected in October 1982 was about 1.71 ± 0.13 mg. The end of winter (end of March 1983), these females weighed only 1.24 ± 0.13 mg. Average weight loss was 0.47 mg during 5 months, or 27 % of their weight. During a similar winter period, ANDERSON (1962b) noted a weight loss in overwintering individuals of 17 % at 1 °C.

Thus, metabolism seems to have been higher in non-diapausing overwintering females from the Paris region than in diapausing females from England.

Consequently, winter cold in the Paris region, at the very most, strongly slowed ovarian maturation. Females of this population neither showed ovarian diapause nor true ovarian quiescence.

D. *A. nemorum* feeding behavior

1. Sequence of predatory behavior

We continually observed a female *A. nemorum* during 8 h. She had not been fed for 24 h. This insect was placed in a 70 cu. cm. plastic cage in the presence of 6 prey belonging to 6 different species, the aphids, *M. persicae*, *S. graminum*, *M. dirhodum*, *B. brassicae*, and the psyllids, *T. urticae* and *P. pyri*. Observation was repeated with another female *A. nemorum*, resulting in the same pattern of behavior.

The predator 1st walked about at random in the cage. It accidentally came in contact with a prey in about 75 s. This was a 4th instar *P. pyri* nymph. This encounter set off the predatory reflex, a flexing of the proboscis and penetration of the stylets into the side of the thorax of the prey. The prey was very quickly lifted from the substrate, which impeded it from grasping it and attempting to escape. The prey was then paralysed by the saliva of the predator ; it ceased all movement 2 mn after the attack. The predator emptied its prey in 36 mn. During the lapsed time, it changed the point of insertion of its stylets 9 times. Curiously, the prey was turned without the stylets being withdrawn when the predator was bothered by an aphid which bumped it. Then it stretched, carrying its prey at the extremity of its rostrum without losing it. Only 5 s after having left its 1st prey, the predator encountered another and immediately attacked it successfully. This 2nd prey was a nymph of *B. brassicae* ; the contents were also totally consumed. During

the course of its meal, *A. nemorum* consumed successively 5 prey before becoming indifferent to additional encountered prey. Only the first 3 prey were totally emptied. The next 2 were only partially consumed. The encounter with a 6th prey stimulated only a reflex reaction, an extension of the rostrum, but there was no insertion of stylets. Then there was a period of quiescence. Total duration of the meal was about 2 h and 30 mn. During the following 3 h and 30 mn, *A. nemorum* did not attack any other prey ; it rested immobile for most of the time.

2. Voracity

Feeding was calculated daily in the laboratory using *A. nemorum* adults presented with the 6 prey species mentioned above. Fourteen pre-overwintering females, collected in nature between September 30 and October 10, 1982, were tested. Five fully grown nymphs belonging to 5 among these 6 species plus 10 individuals of the smaller *T. urticae* nymphs were presented simultaneously to one *A. nemorum* female in a 70 cu. cm. plastic cage. Number of prey killed in each species was recorded after a 2 h period. Results are reported in table 3.

Table 3 shows that they accepted all prey almost equally, at the rate of 2 to 3 individuals of each species. The number of nymphs of *T. urticae* consumed was the greatest among the proffered species, probably because they were more numerous and because of the predatory behavior of *A. nemorum*. When we placed the predator 1st in the cage, followed by the different successive prey, the prey 1st attacked was that presented 1st. When we placed several prey in the cage and the predator last, the 1st prey attacked was that encountered 1st. The higher number of nymphs of *T. urticae* consumed must have been due to the probability of its having been encountered more often, since they were more numerous at the beginning. The pre-overwintering females of *A. nemorum*, therefore, consumed about 19 prey per day, without showing any particular preference for any one species among the 6 species presented.

3. Effect of prey density on predator voracity

Two prey, *P. pyri* and *M. persicae*, were tested. Each was presented during 24 h, at densities of 10, 30, and 60 individuals per cage (measuring 70 cu. cm.) to a pre-overwintering female of *A. nemorum*. Fifteen *A. nemorum* females were tested with *P. pyri* and 18 females with *M. persicae*. Average values of voracity are presented for the 2 species at each density in table 4.

Voracity of *A. nemorum* doubled when number of nymphs of *M. persicae* ranged from 10 to 30, but it did not increase any more if the number went from 30 to 60. In the presence of *P. pyri*, *A. nemorum* showed the same voracity no matter what the density of prey. If we compare voracity of *A. nemorum* on *M. persicae* and on *P. pyri* at equal densities, we see that a density of 10 induced equal attack on the 2 species of prey. However, at densities of 30 and 60, the number of *M. persicae* consumed was significantly higher than *P. pyri*.

If we compare tables 3 and 4, we can see, for density 30-35 that the predator did not show the same daily voracity for various species of prey (19 prey attacked) (table 3), as compared with the situation where a single species was presented (14 prey attacked when *M. persicae* was presented ; and 6, when it was *P. pyri*) (table 4). If *A. nemorum*'s preference for varied prey is confirmed, there is little chance of its being very efficient in a habitat such a pear orchard infested mainly with pear psylla.

E. Reproductive performance of *A. nemorum*

Colonization of a habitat by a predator depends namely on its rate of proliferation, itself depending on the nutritive value of the prey. Thus, we compared in the laboratory the nutritive value of several prey by measuring reproductive performance of the predator fed on these prey.

Reproductive performance was evaluated on the following criteria : percentage of fertile females,

TABLE 3

Test of food choice and daily prey consumption by A. nemorum females.

Test de choix de nourriture et consommation journalière de proies par des femelles d'A. nemorum.

Prey species exposed as group to predators	Number of individuals exposed daily	Average number of prey consumed daily per <i>A. nemorum</i> female (14 individuals tested)
<i>Psylla pyri</i>	5	2.1 ± 0.6
<i>Trioza urticae</i>	10	5.8 ± 1.6
<i>Schizaphis graminum</i>	5	2.2 ± 0.5
<i>Metopolophium dirhodum</i>	5	2.7 ± 0.4
<i>Brevicoryne brassicae</i>	5	2.9 ± 0.7
<i>Myzus persicae</i>	5	3.1 ± 0.5
Total number of prey exposed daily to one <i>A. nemorum</i> female	35	
Total number of prey consumed daily per <i>A. nemorum</i> female		18.9 ± 1.4

TABLE 4

*Effect of prey density on predation by A. nemorum females.
Effet de la densité des proies sur la prédation des femelles d'A. nemorum.*

Prey species	Number of prey per 70 cm ³ cage	Average number of prey consumed daily per <i>A. nemorum</i> female	Comparison of the measures of voracity (!)
<i>Myzus persicae</i>	10	6.8 ± 2	$\left. \begin{array}{l} \left. \left. \begin{array}{l} * \\ * \end{array} \right] 0 \right. \right] * \\ * \\ * \end{array} \right\} 0 \left. \begin{array}{l} * \\ * \end{array} \right] * \\ * \end{array} \right\} *$
	30	13.7 ± 3.1	
	60	16.2 ± 5.5	
<i>Psylla pyri</i>	10	5.0 ± 3	
	30	5.8 ± 1.6	
	60	9.0 ± 4.1	

(!) Level of significance of the differences by variance analysis and test F.
0 : No significant difference.
* : Significant difference (threshold 5 %).
** : Highly significant difference (threshold 1 %).

TABLE 5

*Reproductive capabilities of A. nemorum.
Capacités reproductrices d'A. nemorum.*

Lot		1	2	3	4	5
Prey of <i>A. nemorum</i> larvae		varied (nature)	<i>M. dirhodum</i> (lab.)	eggs of <i>E. kuehniella</i>	<i>T. urticae</i> <i>M. evansi</i> <i>Cicadellidae</i>	<i>P. pyri</i>
Prey of <i>A. nemorum</i> adults		<i>M. dirhodum</i> (lab.)	<i>M. dirhodum</i> (lab.)	eggs of <i>E. kuehniella</i>	<i>T. urticae</i> <i>M. evansi</i> <i>Cicadellidae</i>	<i>P. pyri</i>
Average weight of unfed adults (mg)	♂		1.3	1.3		1.1
	♀		1.8	1.7		1.5
Growth Rate Index (GRI)	♂		4.9	5.3		4.7
	♀		6.9	7		6.1
Percentage of fertile females		65	18.6	31	47	23
Number of fertile females tested		13	70	12	14	11
Average longevity of females (days)		42	22	35.5	27.9	24
Average duration of the egg laying period (days)		29.3	9	17.5	17	13
Average fecundity per female		146	27	37.3	75	52.2
Average number of eggs laid daily per female		5	3	2	4.4	4

longevity of females, duration of egg-laying period, total number of eggs laid and number of eggs laid daily. Five lots were defined (table 5). In the 1st case, *A. nemorum* nymphs developed in the field with various unknown prey. They were collected at the end

of the 5th nymphal instar and reared at the laboratory on *M. dirhodum*. Adults resulting from these nymphs were paired and fed on this prey until death. In the 2nd case, *A. nemorum* was fed on *M. dirhodum* from hatching of eggs to death of adults. In the 3rd case,

A. nemorum was exclusively fed on eggs of *E. kuehniella*. In the 4th case, *A. nemorum* was fed on various prey collected on nettle: *T. urticae*, *M. evansi*, *E. urticae* and *E. aurata*. In the 5th case, *A. nemorum* was exclusively fed on *P. pyri* nymphs and adults. In each lot, barley leaves were provided as the egg-laying site.

Results listed in table 5 led us to the following conclusions:

1) The larvae fed in the field gave high-fecundity females. Average number of eggs laid was 146. Maximum number of eggs laid in the laboratory by an individual in our study was 175 comparable to PESKA (1931), 203; to HILL (1957), 213; to COLLYER (1967), 172. It was 5 times weaker in adults resulting from nymphs fed in the laboratory on *M. dirhodum*.

2) The best prey for rearing larvae in the laboratory were various prey living on nettle. However, fecundity was half the fecundity of individuals which accomplished their nymphal development in the field.

3) *P. pyri* was a prey of moderate value. At the lab, it induced an average fecundity equal to 1/3 the fecundity of individuals collected in the field.

4) *E. kuehniella* eggs were not favourable to *A. nemorum* development.

5) Nutritional value of *M. dirhodum* was very weak.

6) Nymphal development was revealed as the critical period during which the quality of food conditioned adults for reproductive performance.

It is notable that differences observed in fecundity of the various lots were not related to weight of adults, nor to nymphal development rate. For example, nymphs fed on *P. pyri* gave adults lighter than those from nymphs fed on *M. dirhodum*. However, fecundity of the 1st was almost twice that of the 2nd. Therefore, it is probable that quality of fat body used during ovarian maturation was more important than quantity and that this quality was directly related to quality of food consumed.

In conclusion, we can say that, although *A. nemorum* is a very polyphagous species, and not discriminating in the choice of its prey in the laboratory, differences in nutritional value of prey induce important differences in the reproductive performance of the predator. Our data clearly indicate that *P. pyri* does not belong to high nutritional value prey for *A. nemorum*. Herbaceous strata bearing varied prey species would thus be advantageous to *A. nemorum* when compared to the limited orchard environment.

F. Choice of egg laying site

A. nemorum inserts its eggs under the foliar epidermis of host plants of its prey. Presence of favourable egg laying sites is one of the essential conditions of establishment of a population in habitat, so we tested the value as an egg-laying site for *A. nemorum*, of young leaves of pear tree and barley, in the presence or absence of prey. Another objective was also to know if barley leaves could be considered a favourable egg laying site in rearing of the predator in the laboratory. The 1st choice was barley infested with *M. dirhodum* or pear leaves infested with *P. pyri*. The 2nd choice was pear without psylla or

TABLE 6

Choice of egg laying site by A. nemorum in relation to host plant and presence of prey.
Choix du site de ponte chez A. nemorum en fonction de la plante hôte et de la présence de proies.

	Egg laying site	Percentage of eggs laid on pear	Percentage of eggs laid on barley
1st choice	— pear	35	65
	— barley + <i>M. dirhodum</i>		
2nd choice	— pear + <i>P. pyri</i>	29	71
	— barley + <i>M. dirhodum</i>		
3rd choice	— pear + <i>P. pyri</i>	52	48
	— barley		

barley with aphids. The 3rd choice was pear with psylla or barley without aphids. Twenty female *A. nemorum* were tested.

The results noted in table 6 show that when the 2 host-plants were infested, barley was clearly preferred as an egg laying site. When only barley was infested, it was very clearly preferred to pear leaves. The percentages of eggs laid on pear leaves was about the same in the presence or absence of prey. When only pear leaves were infested, the same percentage of eggs was laid on both host plants. This shows that the presence of prey stimulated the egg-laying of *A. nemorum*, and pear leaves were not a very favourable egg-laying site for the predator. It was not more attracted by pear with prey than it was by barley leaves without prey.

The weak attraction of pear leaves as an egg-laying site helps explain why *A. nemorum* does not regularly frequent this habitat in high numbers.

IV. CONCLUSION AND DISCUSSION

Thus, it was shown that in the Paris region *A. nemorum* is much less abundant in summer on pear trees than in the herbaceous stratum (especially nettles) close to orchards. *A. nemorum* prefers a habitat where prey are not only abundant but varied. Although it is a very voracious predator, capable of predatory reflex against the 1st prey encountered, all prey do not have the same nutritive value, and their quality heavily influences the reproductive capability of the predator. The variety of prey species occurring on nettle is especially favourable to proliferation of *A. nemorum*. On the other hand, *P. pyri* is of rather weak value as prey, and pear leaves of poor value as an egg-laying site for *A. nemorum*. Interestingly only very few individuals were found in autumn and winter in traps placed in the nettles. Third generation adult abundance in autumn on pear trees, is directly tied to the feeding or prehibernating adults and to their search for a hibernation site, as evidenced by the trap catches in pear trees.

A. nemorum, thus, is an occasional predator of *P. pyri*, and its impact against this pest is quite limited. Its position in the biological complex of the pear psylla cannot be considered as equivalent to that

of *A. nemoralis*, this latter species being very closely tied to *P. pyri* and one of its most efficacious enemies.

It seems to us, that for reasons here indicated, *A. nemorum* cannot be considered as a potentially efficient biological control agent against the pear psylla, in its original area or in a potential area of introduction.

Moreover, according to PARKER (1975), variability with latitude of voltinism and of ovarian pause in *A. nemorum*, is genetically determined. In case *A. nemorum* were to be exported and released in another country, it is probable that specimens belonging to distinct geographical races from Europe, could be used only in areas where climatic conditions are close to those of their original habitat. Results from introduction of *A. nemorum* specimens from the Paris region, to combat *P. pyricola* in the Yakima Valley (Washington, USA) are not yet known but will be interesting to follow to see if they support these conclusions.

The study presented here indicates that only local presence of a species well known as a predator, even in high numbers, does not necessarily mean that its impact on the pest is important. Consequently, it seems to us, that selection of a particular beneficial insect from among many for biological control can only be accurate and useful when the main characteristics of biology, ethology and ecology are known.

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