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POPULATION STUDIES OF *BREVICORYNE BRASSICAE* (L.), ITS PARASITES AND HYPERPARASITES IN ENGLAND

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INTRODUCTION

Brevicoryne brassicae (L.) is a cosmopolitan aphid, feeding mainly on Crucifers (BONNEMAISON, 1965). It normally overwinters as eggs, but small colonies may survive mild winters (PETHERBRIDGE and WRIGHT, 1938). In the spring, freshly planted Cruciferous crops are colonized by fundatrices or immigrant alates. Throughout spring, summer and autumn, *B. brassicae* reproduces parthenogenetically. Later in the year, however, owing to low temperaturss and shorter photoperiods, sexual forms begin to appear and overwintering eggs are laid on the Cruciferous hosts. In the Netherlands, HAFEZ (1961) has shown that the number of generations per year to be between 6 and 11.

In the field, the aphid can increase to high numbers, causing damage to Cruciferous crops such as Brussels sprouts, cabbage, cauliflower etc. In Great Britain, outbreaks of aphid attack were recorded as early as 1929 (BARNES, 1931), and STRICKLAND (1957) estimated that *B. brassicae* costs England and Wales about £1 million per annum through damage to the sprouts crops.

The Braconid, *Diaretiella rapae* (MCINTOSH) is usually recorded as the only primary parasite of *B. brassicae* in the field. However, it does not appear to exercise much control on aphid populations (HAFEZ, 1961; SEDLAG, 1964; PAETZOLD and VATER, 1966; WAY *et al.*, 1969). This might in part be due to the following secondary parasites: *Alloxysta brassicae* (ASH.), *Asaphes vulgaris* WALKER, *A. suspensus* (NEES), *Pachyneuron minutissimum* (FÖRSTER) and *Dendrocerus carpenterii* (CURTIS). These hyperparasites, which have not been well studied, appear to be responsible for high level of parasitism of *D. rapae* particularly towards the end of the growing season (HAFEZ, 1961; PAETZOLD and VATER, 1966).

MATERIALS AND METHODS

Studies on the field populations of *B. brassicae* and its parasites were carried out at Silwood Park, near Ascot in Berkshire from 1973–1975. The Brussels sprouts, variety Irish Elegance, were planted one metre apart in a plot of area 20×20 metres.

Fifty sprouts plants were randomly sampled every week, with the restriction that

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at least 2, but not more than 3 plants were selected from each row or column of the plot. Thus every plant would be sampled once every 8 weeks. The choice of the plants was based on a set of random numbers generated on the CDC 6600 computer. Every leaf of a chosen plant was examined. The number of live aphids (divided into the different instars), mummies, and adult parasites were recorded and summed for the whole plant. Mummies were also collected for further study.

To estimate the aerial populations of alate aphids and adult parasites, both sticky and water traps were run simultaneously. Five each of flat horizontal and vertical cylindrical sticky traps (painted yellow) were placed at a height of half to one metre above the ground. Crease proof papers (37×45 cm) were attached to the trap surfaces and painted with tree banding grease. Water traps were used only in the 1974-75 season. Four yellow bowls of bottom diameter 26.5 cm were painted brown on the outside and the upper inside so that only the inside base remained yellow. They were filled to a depth of about 7 cm with a solution made up of stergene (15%), formaldehyde (10%) and water. All insects caught in the sticky and water traps were collected weekly and brought back to the laboratory for examination and counting under the binocular microscope.

In 1974, a varying number of live aphids (depending on the total aphid population on the sampled plants) were collected randomly during counting from at least 10 sprouts plants and reared at 20°C. The proportion of aphids which became mummies were then used for calculating the number of live parasitized aphids (on the 50 sampled plants), which added to the number of mummies would give the total parasitized aphids and hence the percentage parasitism could be obtained.

Results

Field populations of B. brassicae

Although the different aphid instars were distinguished during the counting, this could not be done with accuracy as noted by Way (1968) especially when the aphid colonies were large. Hence only total numbers of aphids are represented here. The populations of *B. brassicae* and the number of mummies in the field (Figs. 1 and 2) are given here as the geometric mean of the 50 plants sampled. The term 'aphid population' referred to hereafter includes all live aphids whether parasitized or not (i.e. excluding the mummies).

Although the levels of infestations and the rates of population growth might differ, the aphid populations tend to follow a 2-peak curve, as observed by Hafez (1961), Herakly and El Ezz (1970), and Akinlosotu (1973). There was an initial rise of aphid number from zero to a small peak as the immigrants began to arrive. This early peak was recorded about 3 to 4 weeks (on 19 June, 1974) or about 8 weeks (on 18 July, 1973) after the sprouts were planted. The number of aphids per plant were 15 (in 1973) and 24 (in 1974). Strickland (1957) also mentioned a similar

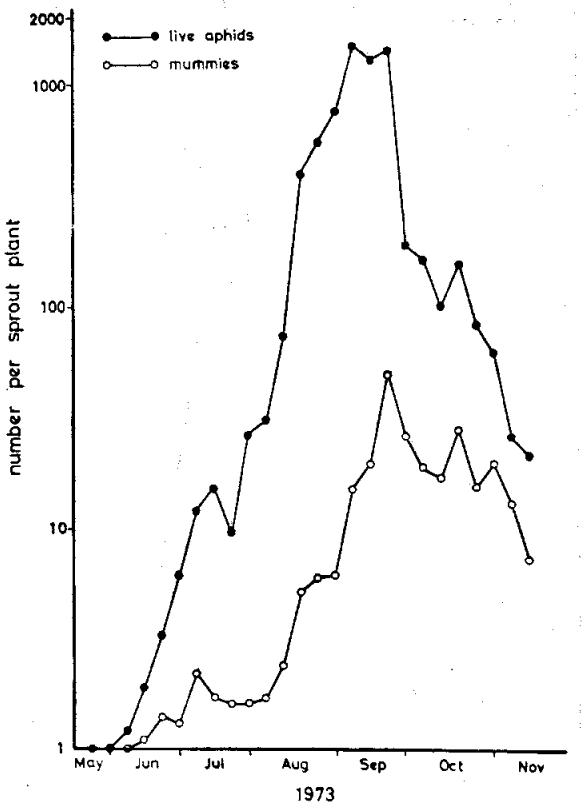

Fig. 1. The mean numbers (n=50 plants) of live *B. brassicae* and mummies on Brussels sprouts, 1973.

peak occuring in the middle of July, 6 to 8 weeks after the sprouts had been planted.

The aphid population then fell slightly which could be a result of the death or the mummification of some of the alates before they became settled and started reproducing. As the season progressed, the population increased to a much higher maximum before declining once more. The second peaks occurred about 13 to 16 weeks after the planting, *viz.* 12 September 1973 and 18 September 1974, and the geometric mean of aphids per plant was 1470 (in 1973) and 33 (in 1974). Although the early peak in 1974 was higher, the second or "seasonal peak" (STRICKLAND, 1957) was not so, indicating that the first peak may not affect the height of the second.

During the 3 year study, aphid eggs had never been recorded, although they could be encountered as early as September (HAFEZ, 1961; PETHERBRIDGE and MELLOR, 1936) or October (HERRICK, 1911). Egg laying usually commences in late September and terminates in December (PETHERBRIDGE and WRIGHT, 1938). Probably the absence of eggs was due to the mild winters during which the aphids could survive as virginoparae.

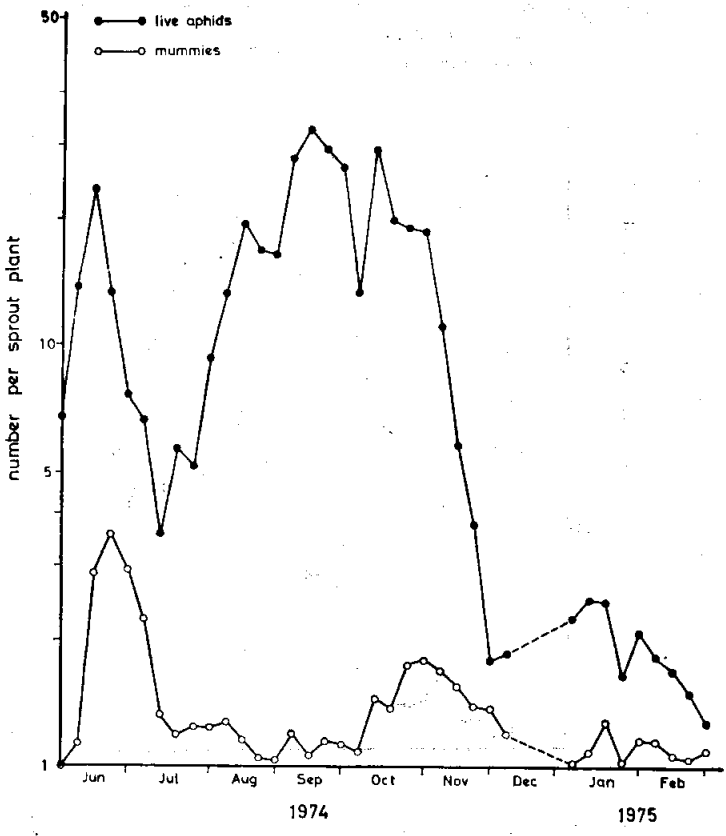

Fig. 2. The mean numbers (n=50 plants) of live *B. brassicae* and mummies on Brussels sprouts, 1974-75.

Percentage mummies and percentage parasitism

The number of mummies followed closely that of aphids, and also showed 2 peaks. The early peak was one week before or after the aphid peak, while the later peak occurred 2 to 6 weeks after the corresponding aphid peak (Figs. 1 and 2). The highest mummy number was 76 per plant recorded in 1973, which could be a result of the higher aphid population.

The percentage of mummies also showed a 2-peak pattern (Fig. 3). The first peak occurred around June to July, while the second around mid-November to mid-December. The values were low generally, with maximum of 13.4% (1973) and 27.8% (1974).

The percentage parasitism (for 1974 only) followed closely the percentage of mummies except in the beginning and the middle of the season (Fig. 3B). In the first 2 weeks, the percentage of mummies were zero and 0.8% compared to 50 and 56.6% for percentage parasitism. Later, as the aphids parasitized by immigrant parasites became mummified, an increase in percentage of mummies was noted.

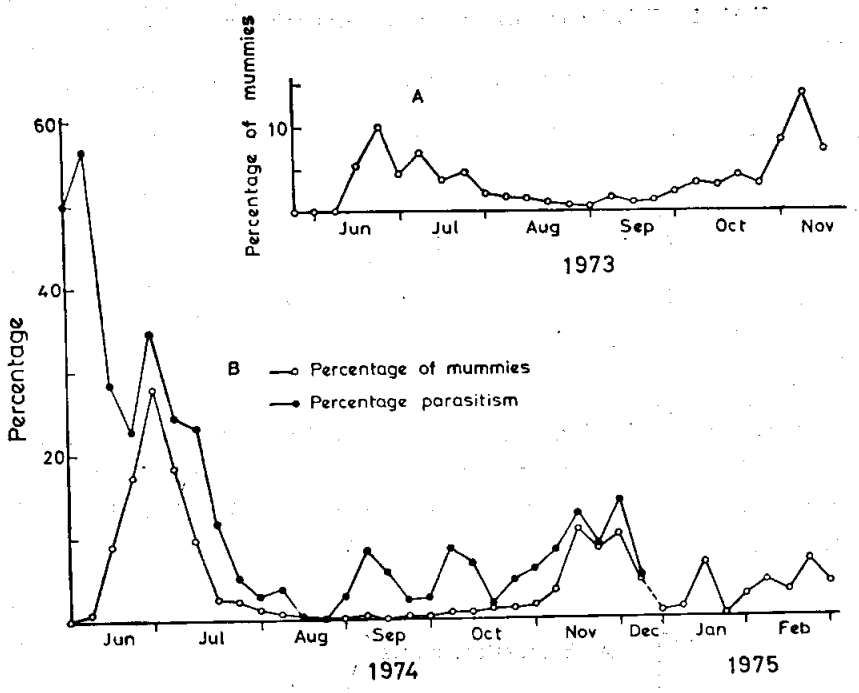

Fig. 3. The percentage of mummies and the percentage parasitism of *B. brassicae*, 1973-75.

Towards the end of the season, the decline in aphid number resulted in the apparent increase in mummy number. The mean percentage parasitism for the season was only 12.9%.

Parasites and hyperparasites of B. brassicae

From the mummies collected from the field, one species of primary parasite, *Diaretiella rapae* (McINTOSH) (Aphidiidae), and 5 species of hyperparasites were reared. The latter are *Alloxysta brassicae* (ASHMEAD) (Charipidae), *Asaphes vulgaris* WALKER, *A. suspensus* (NEES), *Pachyneuron minutissimum* (FÖRSTER) (all Pteromalidae) and *Dendrocerus carpenterii* (CURTIS) (Megaspilidae).

A. vulgaris and *A. suspensus* differ from each other in fine details only, and had been treated as a single species until GRAHAM (1969) separated them. However, both these two species have been clumped together as *Asaphes* sp. here as the author considers their taxonomy still problematical.

D. rapae and *A. brassicae* were the 2 major species, followed by *Asaphes* sp. (Table 1). *A. brassicae* accounted for more than 50% (range 54-74%) of the total while *D. rapae* only attained an average of 30%. *D. carpenterii* and *P. minutissimum* were recorded only occasionally and in very low numbers. They are clearly only incidental, since their main hosts are other aphid parasites (GRAHAM, 1969; DESSART, 1972).

Table 1. Eclosion of parasites and hyperparasites from mummies.

Year		Mummies	*D. rapae*	*A. brassicae*	*Asaphes* sp.	*D. carpenterii*	*P. minutissimum*	Mummies intact
1973	No.	5074	812	3259	296	8	—	699
	%		18.5	74.5	6.8	0.2	—	—
1974	No.	1059	395	485	15	2	1	161
	%		44.0	54.0	1.7	0.2	0.1	—
Mean			31.25	64.25	4.25	0.20	0.06	—

Sticky traps

D. rapae was caught in highest numbers, followed by *A. brassicae*, *Asaphes* sp. and then the 2 relatively uncommon species : *P. minutissimum* and *D. carpenterii*. The parasites usually had one peak: *D. rapae* had the earliest peak, followed by *A. brassicae* and *Asaphes* sp. (Figs. 4 and 5). In 1974, the peaks for these parasites and *B. brassicae*

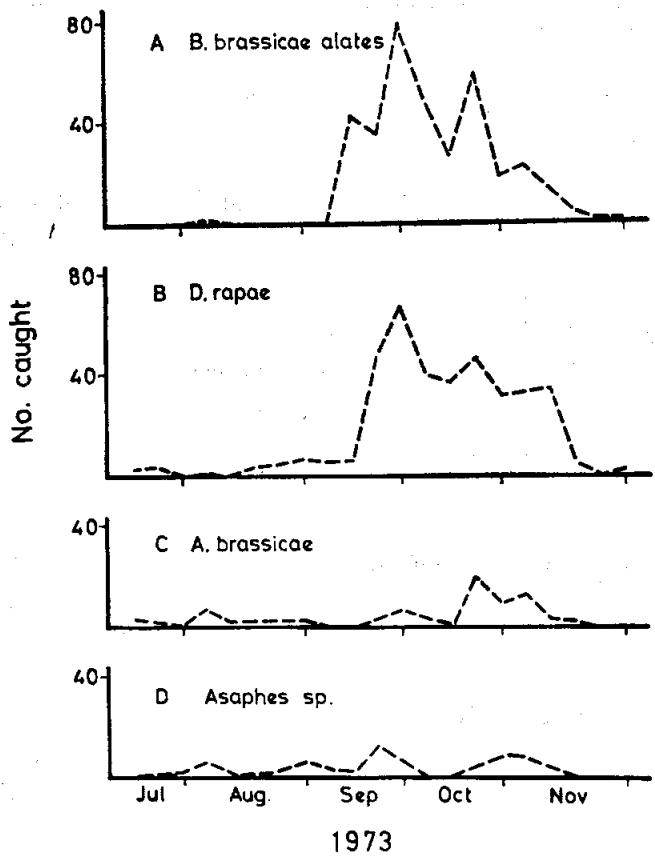

Fig. 4. The weekly total catch of 5 sticky traps (vertical cylindrical type), 1973.

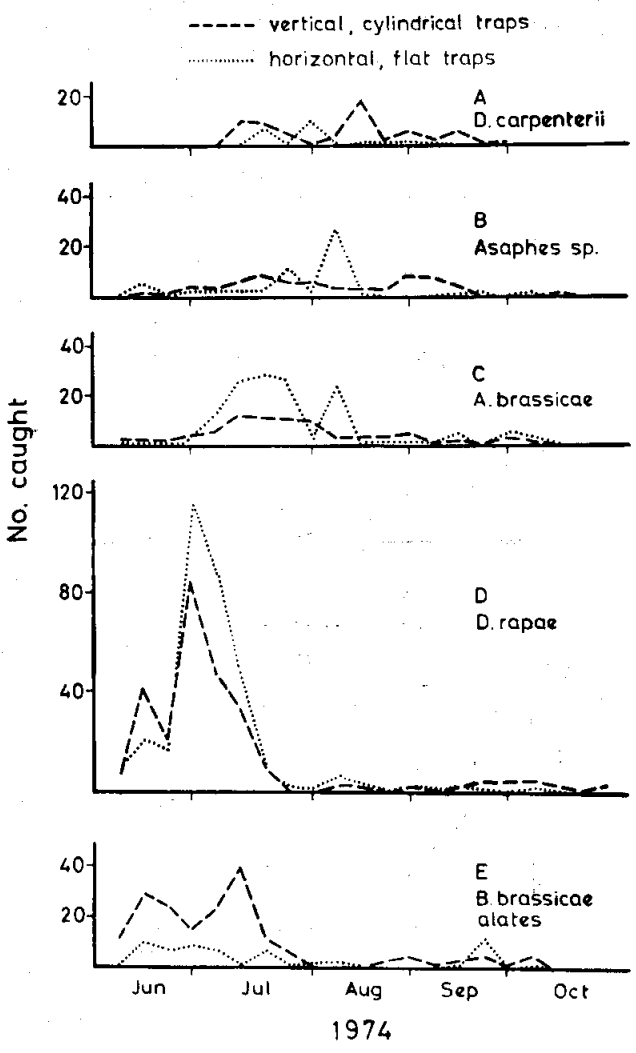

Fig. 5. The weekly total catch of 5 sticky traps, 1974.

alates were recorded earlier than in 1973. *P. minutissimum* and *D. carpenterii* were caught in very small numbers (e. g. in 1974, only 5 specimens of *P. minutissimum* were trapped). In 1974 the wave of immigrant *B. brassicae* alates occurred only at the beginning of the sprouts season (i. e. June to July).

Water traps

In 1974, *A. brassicae* was recorded in greatest number, followed by *D. rapae* and *Asaphes* sp. (Fig. 6). Almost twice as many *A. brassicae* as *D. rapae* were caught. *D. carpenterii* was recorded in very small numbers while only a female *P. minutissimum* was caught (in the week 10–17 July). Each species had a single peak with *D. rapae*'s peak being the earliest (26 June to 3 July), followed 2 weeks later by *A. brassicae*,

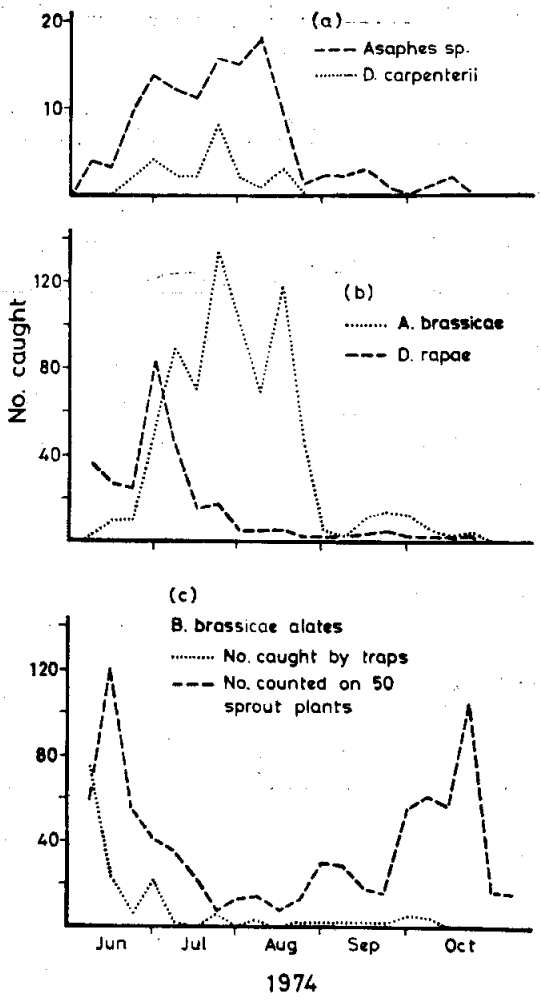

Fig. 6. The weekly total catch of 4 water traps, 1974.

Asaphes sp. and *D. carpenterii* almost simultaneously. Alates of *B. brassicae* were recorded in greatest numbers at the beginning of the season, and only in very small numbers after 3 July.

In 1975, the traps were set up about 8 weeks before the sprouts were planted. The results (Fig. 7) show that *B. brassicae* alates, adults of *D. rapae* and *D. carpenterii* were first trapped about 3 weeks (14 to 21 May) before the sprouts were planted. *A. brassicae* on the other hand, was first recorded much later (2 to 9 July) when *B. brassicae* and *D. rapae* populations were already well established.

Parasite and predator counts in the field

The number of parasites recorded for the earlier part of the season were less in 1973 (Fig. 8) than in 1974 (Fig. 9). For the later half of the season, the parasite numbers in 1973 continued to increase while in 1974 they were recorded in very low

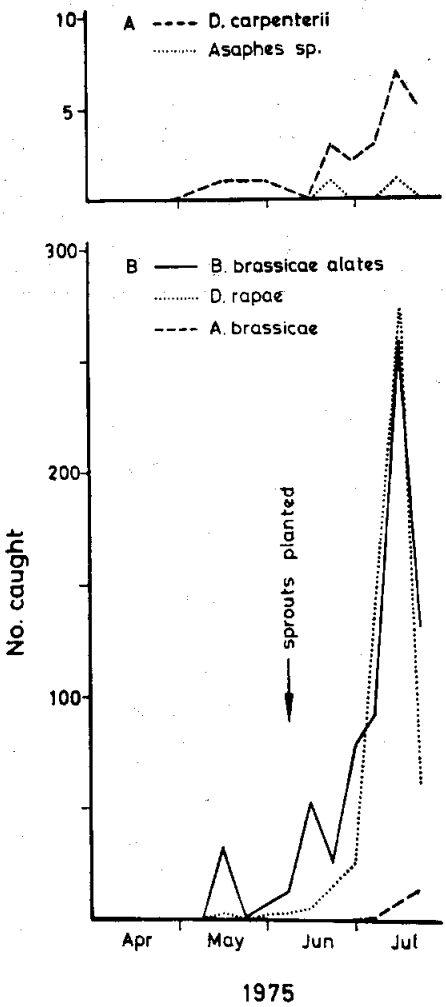

Fig. 7. The weekly total catch of 5 water traps, 1975.

numbers which was probably due to the much lower aphid polulations throughout the season. Generally the fluctuations of numbers counted agree with those caught by sticky and water traps.

The number of syrphid larvae and pupae showed a notable increase during September-October.

Percentage parasitism among immigrant B. brassicae *alates*

Immigrant alates were collected weekly from the field and reared at 20°C for 2 weeks. Many of them were found to be parasitized with percentage parasitism ranging from 3.3% to 46.2% (mean=22.7 to 26.6%) (Table 2). It is noteworthy that only *D. rapae* emerged from the mummies.

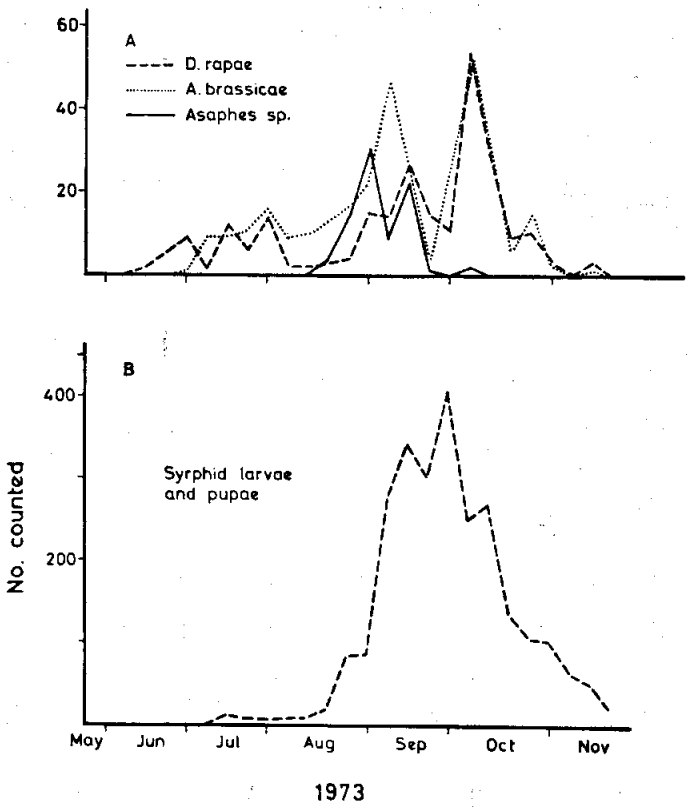

Fig. 8. The weekly counts of parasites and predators of ***B. brassicae*** on 50 sprouts plants, 1973. Syrphids included *Platycheirus peltatus* and *Syrphus balteatus*. Adult coccinellids (*Adalia bipunctata* and *A. decempunctata*) were recorded on 3 occasions only : one each on 27 June, 18 July and 15 August.

Percentage of parasite species

In 1973, the percentage of *D. rapae* never exceeded 45% and it decreased towards the end of the season (e. g. 14% on 21 November) (Fig. 10). In 1974, however, the percentage reached a higher value of 76.9% (on 21 August), and it increased as the season ended (e. g. 90% on 27 November).

The percentage of *A. brassicae* remained relatively steady throughout 1973, although in 1974, it decreased towards the end of the season. *Asaphes* sp. was recorded throughout 1973, but only occasionally in 1974. *D. carpenterii* and *P. minutissimum* were present only near the end of the season.

Generally, the hyperparasites were low in numbers in 1974, and this could be linked indirectly to the relatively low aphid population or directly to the resultant few *D. rapae* mummies available for attack.

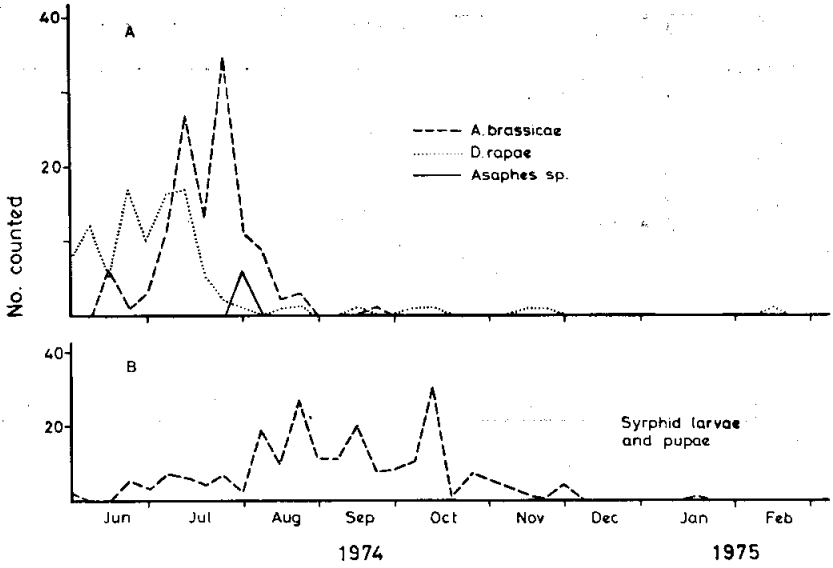

Fig. 9. The weekly counts of parasites and predators of *B. brassicae* on 50 sprouts plants, 1974–75. Syrphids included *Platycheirus peltatus* and *Syrphus balteatus*. Adult coccinellids (*Adalia bipunctata* and *A. decempunctata*) were recorded on 26 June (17 individuals), 3 July (8) and 31 July (1).

Table 2. The percentage parasitism among immigrant *B. brassicae* alates. Dates of planting were 24 May 1974 and 3 June 1975.

Date 1974	No. alates collected	% parasitised	Date 1975	No. alates collected	% parasitised
5 June	19	15.8	11 June	30	3.3
12 June	20	30.8	18 June	51	46.2
19 June	6	33.3	25 June	76	17.1
26 June	5	0.	2 July	152	29.6
3 July	2	0.	9 July	38	26.3
18 July	2	0.	16 July	36	13.9
Mean		26.6			22.7

Discussion

The aphid populations (on sprouts plants) which were started off by the immigrant alates, reached a seasonal peak around September before decreasing steadily. The percentage of mummies and percentage parasitism which were usually low (e.g. maximum percentage mummies: 13.4% in 1973; 27.8% in 1974; mean percentage parasitism: 12.9%) do not indicate that the sole primary parasite, *D. rapae* plays an important role in causing the decline of aphid numbers despite the fact that an average of 22.7 to 26.6% of the immigrant alates were already parasitized by *D. rapae*.

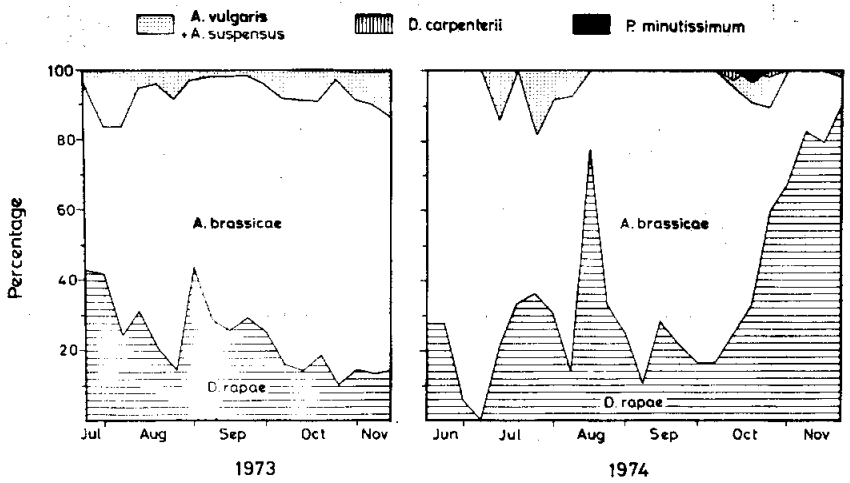

Fig. 10. Relative abundance (in percentage) of parasites and hyperparasites which emerged from *B. brassicae* mummies collected weekly between June (or July) and November 1973-74.

Among the hyperparasites recorded *viz. A. brassicae, A. vulgaris, A. suspensus, D. carpenterii* and *P. minutissimum*, *A. brassicae* is the dominant species and it appeared to have great effect on the number and hence the efficiency of *D. rapae* as a biological control agent of *B. brassicae*. For example, the percentage of *D. rapae* dropped from 42.8 to 14.6% within 5 weeks while *A. brassicae* increased from 54.3 to 77.0% in 1973 (Fig. 10). In 1974 *D. rapae* decreased from 27.7% to zero while *A. brassicae* increased from 72.3 to 100% within 3 weeks. HAFEZ (1961), PAETZOLD and VATER (1966, 1967) and AKINOLOSOTU (1973) also reported similar temporal changes in percentage of the parasites.

Field parasitism of *B. brassicae* had also been studied by GEORGE (1957), HAFEZ (1961), VAN EMDEN (1963) and DAIBER (1971a, b). HAFEZ found parasitism in the first generation of the immigrant aphids could be as high as 80 to 90%, but this was the only instance of high rate of parasitism observed. Generally he recorded low percentage and concluded that parasitism leads only to small fraction of the mortality of the aphid and is not the main factor causing the population changes. GEORGE and VAN EMDEN also recorded low field parasitism with the respective maximum of 14 and 30%. They and others (PETHERBRIDGE and MELLOR, 1936; OTAKE, 1961; OATMAN and PLATNER, 1973) concluded that the primary parasite could not control the aphid population. The unanimous reason given is that the effectiveness of the primary parasite was reduced drastically by the hyperparasites. However, a few workers think otherwise. For example, BARNES (1931) stated heavy parasitism controlled the aphids' attack late in the season, while HERRICK and HUNGATE (1911) and STRICKLAND (1916) claimed that the aphids never reached high densities because of the parasites.

The decline in the aphid population recorded from September onwards was largely due to the adverse weather conditions, as observed by HERRICK (1911), PETHERBRIDGE and MELLOR (1936), VAN EMDEN (1963), HERAKLY and EL EZZ (1970), and DAIBER (1971a). In 1973, an unidentified entomophagous fungus also killed off many aphids (which then appeared pink) especially in the larger colonies in which honeydew accumulated. HAFEZ (1961), VAN EMDEN (1963) and DAIBER (1971a) also reported similar fungal attacks on the aphids. The third factor was predation by syrphid larvae. This is shown by the increase in the number of larvae and pupae counted during September-October (Figs. 8 and 9). The importance of syrphids has already been stressed by PETHERBRIDGE and MELLOR (1936) GEORGE (1957), HAFEZ (1961), VAN EMDEN (1963), WAY *et al.* (1969) and POLLARD (1961). However, as pointed out by VAN EMDEN (1966), the syrphids reached the crop rather late for synchronization to be good with the cabbage aphids.

In 1975, the catches of water traps revealed that *B. brassicae* alates and adults of *D. rapae* were around the plot long before (3 weeks) the Brussels sprouts were planted. It is not certain where these migrated from, although *D. rapae* adults could have emerged from overwintering mummies left in the soil (WAY *et al.* 1969). These results seem to suggest *B. brassicae* and *D. rapae* were not well synchronized with their respective hosts. *A. brassicae* however appears to have better synchronization with its host as it was recorded only much later when *D. rapae* had already built up a sizeable population.

Finally the catches of the sticky and water traps show clearly the succession of species in terms of number. Maximum number of *D. rapae*, *A. brassicae* and *Asaphes* sp. were recorded on 26 June to 3 July, 17 to 24 July and 7 to 14 August respectively.

SUMMARY

Studies on populations of *Brevicoryne brassicae* (L.), its parasites and hyperparasites were carried out by actual counting in the sprouts field and by sticky and water traps. *B. brassicae* was found to be attacked by one primary parasite, *Diaretiella rapae* (MCINTOSH), which in turn is parasitized by *Alloxysta brassicae* (ASHM.), *Asaphes vulgaris* WALKER, *A. suspensus* (NEES), *Pachyneuron minutissimum* (FÖRSTER) and *Dendrocerus carpenterii* (CURTIS). The aphid population in the field was started by immigrant alates which were found flying too early to be synchronized with the sprouts plants. Similarly *D. rapae* was not synchronized with the aphids although many individuals could have been carried into a plot through parasitized immigrant alates, of which less than 30% were found parasitized. Because of high hyperparasitism (especially by *A. brassicae*) *D. rapae* was not able to maintain a high rate of parasitism to curb the aphid population growth. The maximum percentage mummies being 27.8%, while the maximum percentage parasitism being 56.6% recorded only during the early 1974 season (mean=12.9%). The decline of aphid population from

September onwards was largely due to the cold weather, Syrphid predation and occasionally fungal attack. The high rate of hyperparasitism by *A. brassicae* is attributed to its better synchronization with *D. rapae*. The mean percentage of parasite that emerged from mummies collected during 1973-74 were *D. rapae* 31.3%, *A. brassicae* 64.3%, *A. vulgaris* and *A. suspensus* 4.3%, *D. carpenterii* 0.2% and *P. minutissimum* 0.1%.

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ダイコンアブラムシの個体群の研究—イギリスにおけるその寄生蜂と2次寄生蜂

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芽キャベツの畑でのダイコンアブラムシ (*Brevicoryne brassicae*) とその1次および2次寄生蜂の個体群についての研究が行なわれた。*B. brassicae* には寄生蜂 *Diaretiella rapae* の，そしてこの寄生蜂には5種の2次寄生蜂，*Alloxysta brassicae, Asaphes vulgaris, A. suspensus, Pachyneuron minutissimum* および *Dendrocerus carpenterii* の寄生が見られた。*B. brassicae* の個体群は初期の有翅虫の飛来によってはじまるが，寄生蜂 *D. rapae* の出現との一致はあまりよくなく，また *A. brassicae* をはじめとする2次寄生蜂の働きが大きいため，*D. rapae* の寄生率はこのアブラムシの個体群生長を抑えるほど高率を維持できなかった。*B. brassicae* の個体群は10月以後低下したが，これは主に低温，ヒラタアブによる捕食，それに時には寄生菌の働きによるものであった。寄生されたアブラムシから羽化してきた蜂の構成は *D. rapae* が31.3%，*A. brassicae* が64.3%，*A. vulgaris* と *A. suspensus* が4.3%，*D. carpenteri* 0.2%，そして *P. minutissimum* が0.1%であった。