

Dynamics of Common Green Lacewing (Neuroptera: Chrysopidae) in Israeli Cotton Fields in Relation to Whitefly (Homoptera: Aleyrodidae) Populations

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ABSTRACT Population fluctuations of the common green lacewing, *Chrysoperla carnea* Stephens, and those of the sweetpotato whitefly, *Bemisia tabaci* (Gennadius), were followed for 4 yr in cotton, *Gossypium hirsutum* L., fields in Israel. Samples were taken and insecticidal controls were applied to determine the importance of *C. carnea* as a controlling factor of *Bemisia* in cotton. The results showed that although the lacewings occurred in the field together with *Bemisia* and their larvae fed on *Bemisia* nymphs, *C. carnea* was not an efficient controlling agent of whiteflies. This lack of efficiency probably was related to behavioral preferences of the predator as well as to its nutritional demands that were met only marginally by feeding on whiteflies. Application of the insecticide monocrotophos often resulted in an increase in lacewing egg populations. Influence of other insecticides on the eggs and larvae was often detrimental.

KEY WORDS *Chrysoperla*, *Bemisia*, predators, cotton, lacewings

COTTON, *Gossypium hirsutum* L., constitutes a seasonal agroecosystem. In Israel, the crop is sown between mid-March and mid-April and is harvested between September and November, according to regional characteristics and cotton variety. Insects and mites of the 2nd (herbivores) and 3rd (predators and parasites) trophic levels abound in cotton. Sussman (1988) recorded 397 species of insects and spiders in Israeli cotton fields. These included 65 species of direct phytophages that do or may cause damage to the crop, 98 species of parasitoids and predators, and an additional 243 species of insects whose role was not determined clearly.

Severe attacks by sweetpotato whitefly, *Bemisia tabaci* (Gennadius), were first registered in Israel on cotton about 1976 (Gerling et al. 1980). Ever since, this whitefly has been considered a pest that is capable of causing moderate to severe damage to cotton (Gerling 1996). During the past 10 yr, it has been determined that either a new species, *B. argentifolii* Bellows & Perring, or a new biotype (designated 'Biotype B' [Byrne et al. 1995]) of *Bemisia* has replaced the one that originally occupied cotton fields. Because the exact period of transition between the 2 has not been recorded in Israel, we prefer to use the generic name *Bemisia* in referring to the whitefly that we studied.

It has been demonstrated that very few of the phytophages found in cotton cause economic damage. For example, Sussman (1988) found that only 14 of the 65 plant-eating species in Israeli cotton

fields were considered pests. Moreover, many of the pest species are often controlled by natural enemies (e.g., Reynolds et al. 1975, Sterling et al. 1989) (i.e., parasitoids, predators, and disease-causing organisms).

The presence and role of predators in cotton fields has been the subject of many studies (e.g., Whitcomb and Bell [1964], van den Bosch and Hagen [1966], Sugoyev et al. [1971], Eveleens et al. [1973], Reynolds et al. [1975], Sterling et al. [1989], and Dean and Sterling [1992]). These and other studies showed that, to reduce the prey population sufficiently, native predators must colonize the crop rapidly and in large enough numbers. Thus, the migration and the colonization rates of cotton fields by predators and their coincidence with the pest species in space and time are crucial for their success in biological control.

A study of predator dynamics became especially important after the decline in the severity of outbreaks of *Bemisia* in Israel (Gerling 1996). We were unable to associate this decline with a successful establishment of newly introduced parasitoids, so it was of interest to determine the role of local predators. Questions that were asked included the following: which predators occur in the cotton fields, do they coincide with whiteflies in time and space, are they abundant enough to affect the whitefly populations, do they actually feed on whiteflies, and finally, can we detect correlations between population fluctuations of the whiteflies and the predators. Such information would con-

tribute to the general knowledge of dynamics of cotton insects. In addition, it could be used in integrated pest management (IPM) programs and facilitate the construction of pest suppression programs that will avoid harming the more relevant natural enemies. In preliminary observations (Sussman 1988) we established that the 3 most prevalent predators in our cotton fields were *Chrysoperla carnea* (Stephens) *Orius* spp., and *Deraeocoris pallens* Reuter.

Therefore, we ran a series of field experiments in which *Bemisia*, these predators, and the parasitoids *Encarsia lutea* (Masi) and *Eretmocerus mundus* Mercet were counted regularly in both untreated and treated cotton fields. The current article reports the results of these experiments in relation to the green lacewing, *C. carnea*.

Materials and Methods

Field Location, Cotton Varieties, Sampling Season, and Frequency. Samples were taken in 2 regions, the Bet Shean area, which is a low-lying valley (≈ 250 m below sea level) with maximal daily temperatures for July through September of ≈ 35 – 42°C , and the fields of Kibbutz Zora (1992 and 1993), some 30 km east of Tel Aviv in the Judean foothills with maximal daily temperatures for July through September of ≈ 29 – 34°C . In the Bet Shean valley we sampled either the fields of the Eden Experimental farm (1990) or of Kibbutz Maale Gilboa (1992 and 1993). Both Zora and Maale Gilboa are commercial farms, but untreated cotton plots that were otherwise identical with the commercial fields were placed at our disposal. The cotton variety in the Bet Shean area was 'Eden 1', which is a cultivar of Acala. In Zora, the cotton variety was 'Acala SJ2'. Cotton is sown in the Bet Shean region during the 2nd half of March and in Zora in late April. Sampling began during June, and ended in September.

Field observations were made during September of 1991 on experimentally grown, young cotton plants that were planted in July. The plants supported a predator population during August and September that was absent from the normally grown cotton, planted in March. These results suggested that the very low predator numbers that normally are observed during August and September might not only be correlated with a decline in prey abundance, but also with plant age. To examine this pattern we included 2 experimental fields in Maale Gilboa in 1992: one planted as scheduled in March (i.e., regular) and the other planted 2 mo later in May (i.e., late).

Field Sizes and Sampling Design. In each field we were allotted a plot of ≈ 1 – 4 ha. It was subdivided into 6 replicates for each treatment, ranging in size from 8 by 10 m each (Zora field in 1993) to 36 by 36 m each (Maale Gilboa field in 1993). The replicates were separated by at least equally large buffer zones. Each replicate was sampled

once each week. Predators were sampled by the 'visual' method (Gonzalez and Wilson 1982). Within each replicate, 1 m row of cotton was selected randomly. Each plant was examined in detail from top to bottom and any predator that was sighted was registered. Immature whiteflies were sampled by randomly choosing 10 plants in each replicate. On each of these, leaves 5–7 from the plant top were checked and the most infested one ("maximally infested" leaves, Gerling et al. [1980]) was chosen and examined in the laboratory under a stereomicroscope. Third- and 4th-instar whiteflies and the presence of parasitoids therein were counted and registered.

Insecticide Control Plots. The influence of specific spraying programs on the insect populations was examined on 2 occasions. In both, we used monocrotophos (6 grams/liter [AI], at 2,000 liter/ha) because our greenhouse observations showed that this material had only a minor effect on the whiteflies, whereas the predators seemed to be strongly affected. During 1990 in the Eden experimental farm, we applied monocrotophos twice (19 June and 10 July) when other fields in the region were treated with that material against pink bollworm, *Pectinophora gossypiella* (Saunders). In 1993, we set up an experiment in Zora on 12 plots (8 by 10 m each) within an untreated cotton field. Six plots were treated with monocrotophos and 6 were left as controls. Three successive treatments were made on 4, 10, and 17 August. Treatments with insecticides were carried out with tractor-pulled boom sprayers or in 1 case with a back-pack sprayer. Spraying was conducted in the early morning hours in calm air and care was taken in all cases to avoid drift from reaching adjacent plots. Statistical differences between means of population levels were determined by performing a *t*-test following a square-root transformation (Sokal and Rohlf 1981).

Results

The current work confirmed previous observations (Bar 1982) that *C. carnea* occurred in all fields throughout the season. However, the relative abundance of populations as a whole and of the different instars was not uniform among sampling sites and/or seasons. For example, in Zora in 1992, egg populations showed 2 peaks (6 July and 19 August) and the larval population was very low (0 to <0.2 larvae per meter row) until August when it rose to a continuously high level of 2.8–4.1 larvae per meter row (Fig. 1A) and decreased in mid-September.

A year later, eggs in the same field were most abundant around 12 July after which their numbers declined. Egg population was followed by a peak larval population around 20 July. Later, much lower egg and larval peaks occurred between 19 August and 14 September (Fig. 1B). In Maale Gilboa (regular), during 1992, the highest numbers of

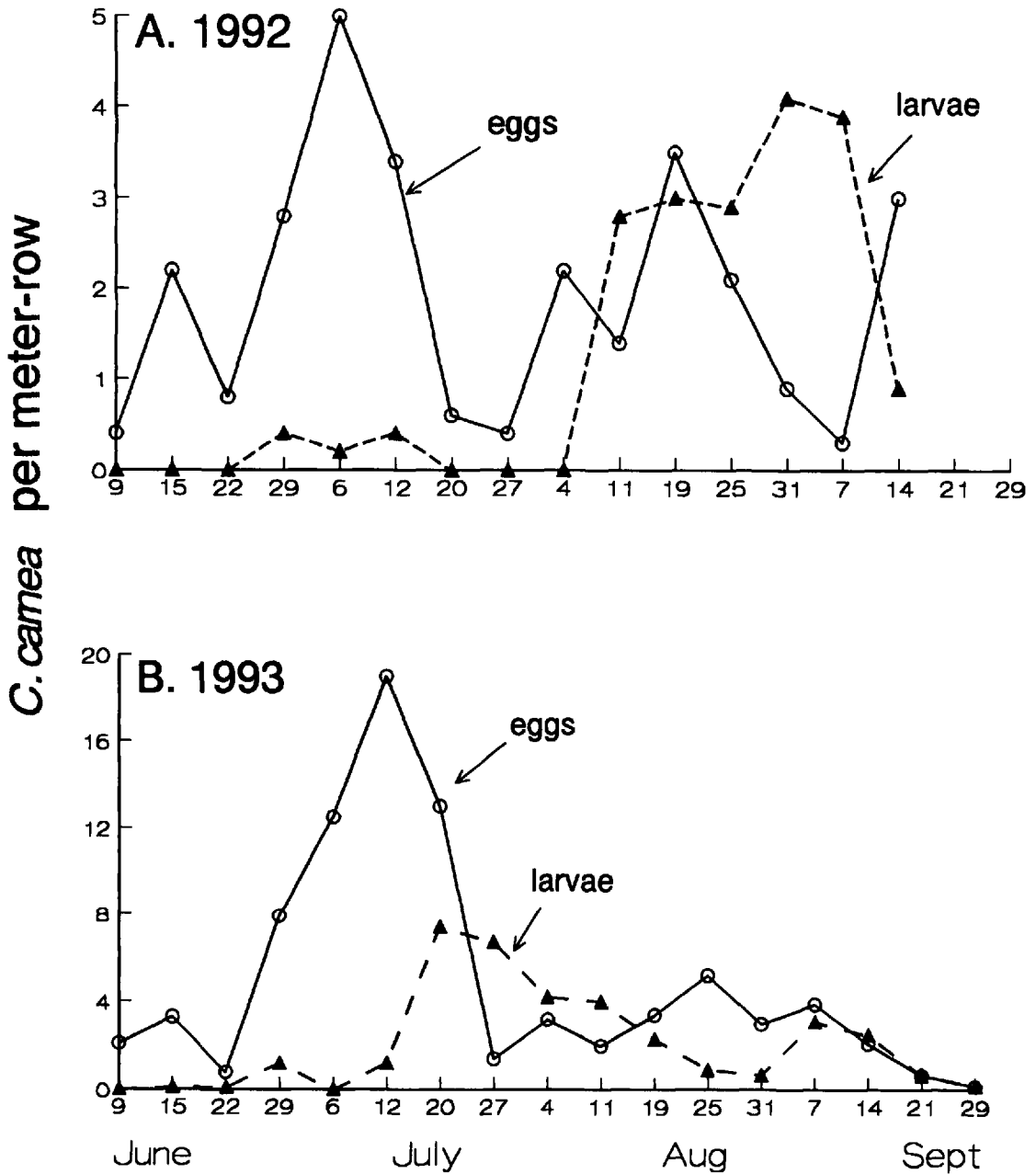


Fig. 1. Population fluctuations of eggs and larvae of *C. carnea* in untreated cotton fields in Zora during (A) 1992 and (B) 1993.

eggs occurred on 12 and 30 June and 27 August, but the larval population remained very low, reaching a maximum on 3 September (Fig. 2A). During 1993, three peaks of egg deposition in Maale Gilboa were recorded on 17 June, 7 July, and 20 August, and 3 distinct peaks of larval population occurred on 22–30 June, and on 3 and 30 August (Fig. 2B).

Egg population peaks that were recorded in all locations and years reached between 5 and 70.4 eggs per meter row, whereas larval populations

never exceeded 14.1 and usually reached 4–7 per meter row (Table 1). Peaks of egg abundance often were followed by a rise in larval populations, but a substantial numerical gap occurred between the 2. With the exception of Zora 1992, where late larval populations slightly exceeded the egg populations (3.5 eggs versus 4.1 larvae) and Zora 1993 where larval populations neared 40% of the egg population (19 eggs versus 7.4 larvae), the larvae never exceeded 20% of the egg population (Table 1; Figs. 1 and 2). Significant correlation coeffi-

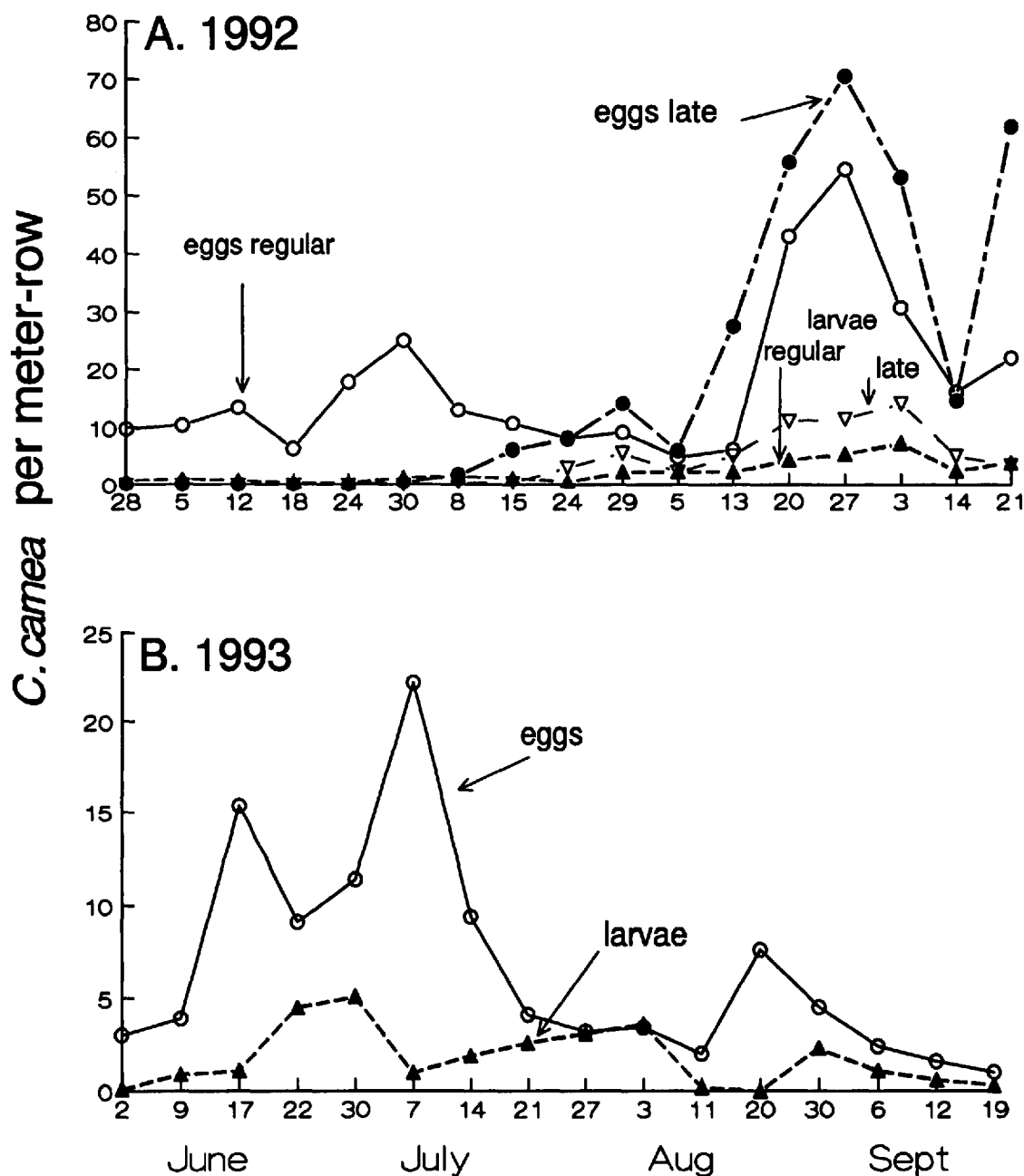


Fig. 2. Population fluctuations of eggs and larvae of *C. carnea* in untreated cotton fields in Maale Gilboa during (A) 1992 and (B) 1993. Regular, cotton sown in mid-March; late, cotton sown in mid-May.

icients between the number of eggs and the number of larvae 1 wk later were found in Eden 1990 ($r = 0.54$, $P = 0.028$, $n = 16$), Maale Gilboa 1992 (regular: $r = 0.72$, $P = 0.018$, $n = 16$; late: $r = 0.86$, $P < 0.0001$, $n = 11$), and Zora 1993 ($r = 0.6$, $P = 0.013$, $n = 16$). However, only those of Maale Gilboa 1992 exceeded 0.6, indicating a strong relationship between egg and larval populations.

Presence of Whitefly and Other Prey and Correlation with *C. carnea*. Many of the whitefly populations did not reach high levels. Using the

terminology of Horowitz (1986), a normal phase of moderate growth was often observed in May and June. During that time, whitefly adults and their progeny appeared in low numbers. The later exponential growth and the resulting outbreak and high whitefly numbers that typify large populations usually did not develop (Table 2). Populations exceeding 10 nymphs per leaf were only observed in 2 cases. In Zora during 1993, a whitefly population developed on sunflowers near the experimental cotton field. The sunflowers dried out during June,

Table 1. Occurrence of maximal levels of *C. carnea* eggs and larvae in the sampled cotton fields

Field	Date	Eggs (m-row)	Larvae (m-row)	Lag, d	% Larvae ^a
Eden 1990	7 Aug.	24.7		14	19.5
	21 Aug.		4.82		
Maale Gilboa 1992 regular	27 Aug.	54.4		7	13.4
	3 Sept.		7.3		
Maale Gilboa 1992 late	27 Aug.	70.4		7	20
	3 Sept.		14.1		
Zora 1992a ^b	2 July	5		7	8 ^c
	9 July		0.4		
Zora 1992b ^b	19 Aug.	3.5		12	117
	31 Aug.		4.1		
Zora 1993	12 July	19		8	38.9
	20 July		7.4		
Maale Gilboa 1993	7 July	22.2		27	10 ^c
	3 Aug. ^c		3.6		

^a Index of survival (number of 4th instar nymphs/number of eggs \times 100).

^b Early and late population dynamics differed markedly, therefore both are presented here.

^c Maximal larval populations in Zora 1992a and Maale Gilboa 1993 did not follow the maximal egg population. The numbers and survival index given here represent the larval population peaks calculated for 10 d after the highest egg population.

resulting in a mass migration of the whitefly to the adjacent cotton field. From July on, populations reached averages of 55 (July) and 92.9 (August) nymphs per leaf. These populations declined to \approx 30–40 nymphs per leaf during September (Fig. 3B).

A 2nd case of high whitefly populations occurred in the young cotton field experiment in Maale Gilboa in 1992. During July this cotton was only lightly infested. During August, the population rose abruptly to \approx 44 nymphs per leaf, only to drop to few individuals per leaf at the end of the month (Table 2; Fig. 4A). The low populations during many of the counting periods prevented the formation of clear population peaks that would indicate discreet generations. However, examination of the fluctuations in the different fields suggests the development of \approx 3–4 generations during the season, depending on the 1st appearance of whiteflies (e.g., Zora 1993, Fig. 3B).

During weekly samples, we also noted the existence of additional insect species in the cotton field. No exact counts were taken, but information was obtained about the presence of species that could serve as prey for the predators. Aphids occurred abundantly on 1 occasion, in Maale Gilboa 1991. Various other pest insects were also occasionally present. Pink bollworm was often very abundant, especially in Maale Gilboa, where numerous insecticide treatments were necessary for its control in commercial cotton fields.

Based on the census results, regression analyses were run to determine the relationships between the population fluctuations of the lacewings and the whiteflies. The relationships of *Bemisia* were examined versus *C. carnea* eggs found on the same date, and versus *C. carnea* larvae present in the

Table 2. Maximal numbers of whitefly nymphs per leaf found each month in the experimental, untreated cotton fields

Field	June	July	Aug.	Sept.
Eden 1990	2.7	3.5	4.3	5.1
Maale Gilboa 1991	—	10.7	8.9	3.4
Maale Gilboa 1992 regular	1.5	1.4	6.4	5.8
Maale Gilboa 1992 late	—	7.7	44.0	6.7
Zora 1992	0	0	6.2	5.0
Maale Gilboa 1993	2.4	3.4	2	2.5
Zora 1993	16	55	92.9	47.3

Each number represents the highest weekly mean of 10 leaf samples during the respective month.

field 1 and 2 wk later (Table 3). The rationale for choosing these dates was based on the fact that we sampled the fields once each week. It was assumed that if lacewing females responded to fluctuations in whitefly populations by changing their oviposition rates, these changes should be apparent almost contemporaneously with whitefly population changes (i.e., within the same sampling week). Larvae develop over some 20 d and therefore the response of their populations may manifest itself later, during the next 2 wk. Results (Table 3) show that correlations between the numbers of whiteflies and those of lacewing progeny fluctuated widely, and, except for the late planting date of Maale Gilboa 1992, were weak and statistically insignificant.

The examination of the 2 fields in which whitefly populations reached damaging levels was of particular interest. These included Zora 1993 in which no correlation between the lacewing populations and those of the whiteflies could be found, and the late planting date of Maale Gilboa 1992 which had an upsurge of whiteflies that lasted for only 3 wk. The latter showed a high and significant correlation with the larval population of *C. carnea* (Table 3). Because the rise in whitefly populations in that field was very sudden, from 7.4 larvae per leaf on 8 August to 44.3 on 13 August, we also examined the correlation between the lacewing egg population on the week following that of the whiteflies. Here the correlation proved positive and nearly significant ($r = 0.64$, $P = 0.059$, $n = 11$). In the light of these results, we also examined the relationships between whitefly abundance and oviposition a week later for all other fields. None showed strong or significant correlations.

Influence of Insecticides. Monocrotophos spraying programs in the Eden experimental farm in 1990 were made on lightly infested cotton with counts of 5 or fewer nymphs per leaf (Fig. 4B). As noted, application was timed to correspond with the normal period of treatment in commercial fields. The whitefly populations rose after the early monocrotophos treatments. However, the new whitefly level reached significantly higher numbers ($t = 2.55$, $df = 97$, $P < 0.01$) than the untreated level only 2 wk after the 2nd application.

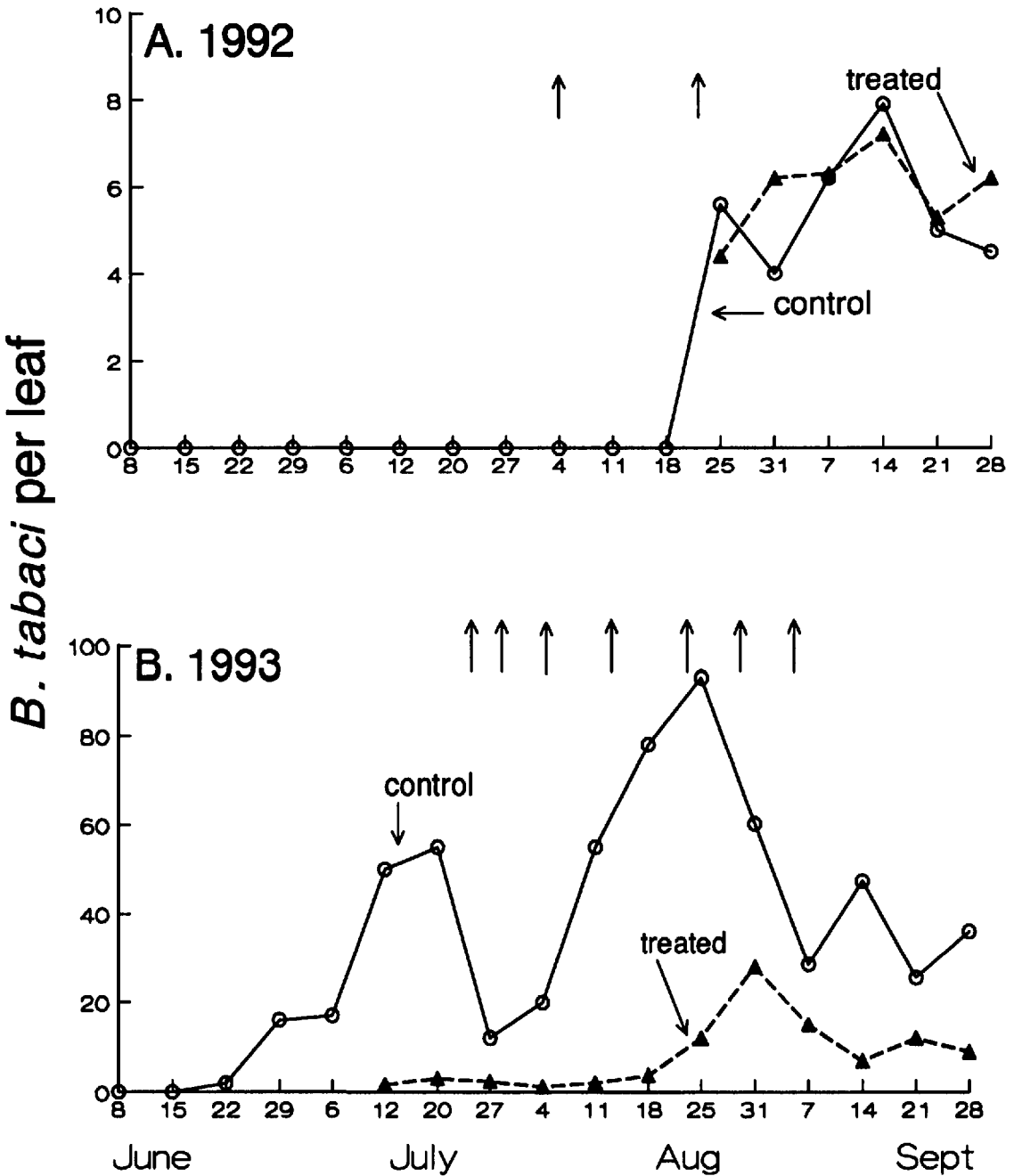


Fig. 3. Effect of commercial insecticide treatments on population fluctuations of *Bemisia* in Zora during (A) 1992 and (B) 1993. Arrows indicate insecticide treatments.

Applications of monocrotophos in Eden 1990 were followed by a significant rise in the number of *C. carnea* eggs found in the field (Table 4; Fig 5A). It is noteworthy that the significant rise in the number of eggs after the 2nd application occurred after a natural decline in both control and treated populations.

The 2nd experiment with monocrotophos took place in 1993 at Zora. Whitefly populations reached 20 or more nymphs per leaf. Applications

of the insecticide were followed by a significant rise in the number of whiteflies. From 42.6 to 109 nymphs per leaf ($t = -12.14$, $df = 39$, $P < 0.0001$) (Fig. 5B). This rise was accompanied by a rise in *C. carnea* populations. However, a similar, though somewhat lower, rise was recorded in *C. carnea* in the control plot where no increase in the *Bemisia* population occurred.

Commercial treatments often resulted in the reduction of both whitefly and predator populations.

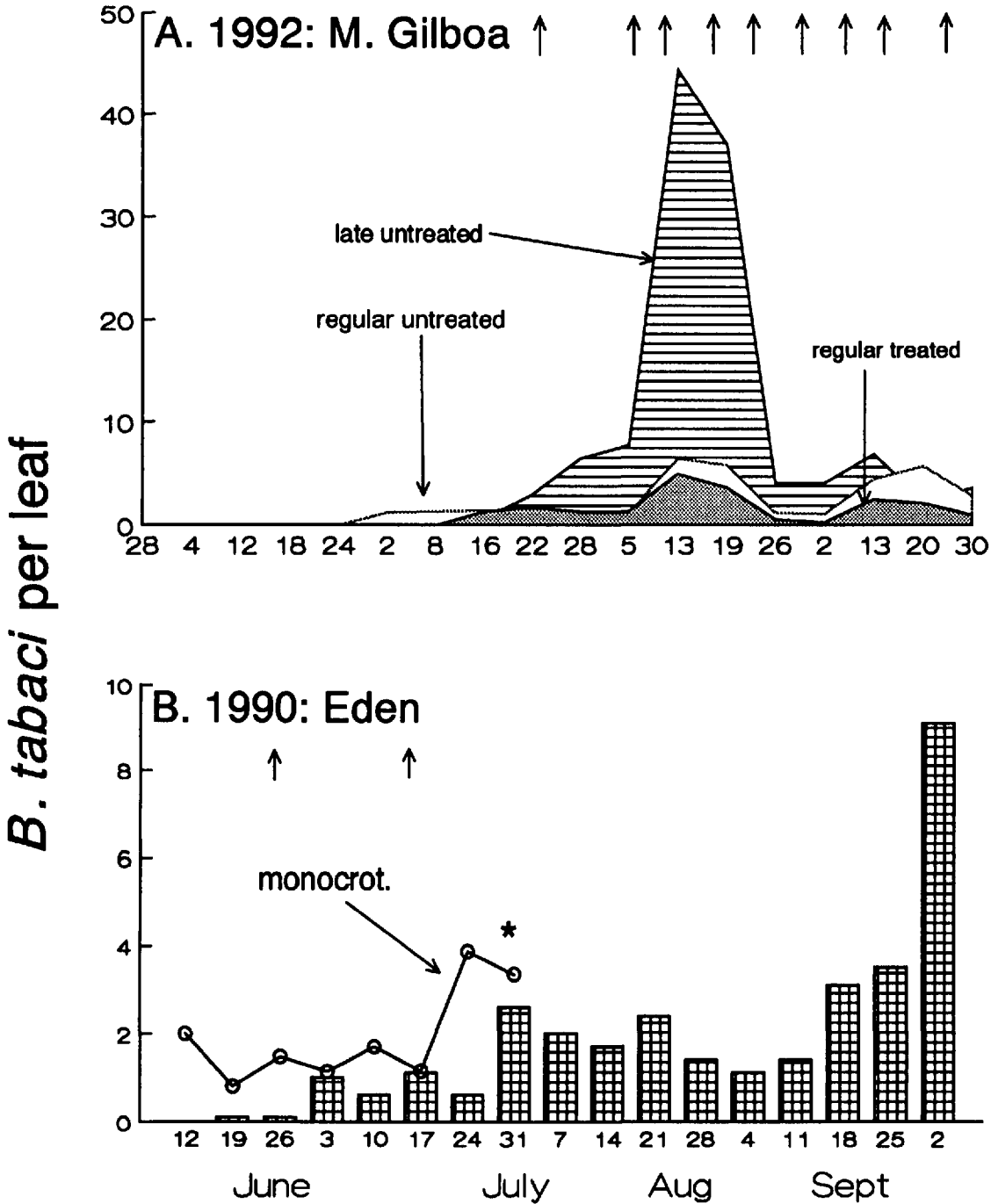


Fig. 4. Effect of commercial insecticide treatments on population fluctuations of *Bemisia* (A) in Maale Gilboa during 1992 in regular, cotton sown in mid-March and late, cotton sown in mid-May and (B) in the Eden farm in 1990 (bars are the untreated control populations). Arrows indicate insecticide treatments, stars indicate significant differences between treatments at the 5% level.

In 1992, in Maale Gilboa, where only the regular cotton was treated with insecticides, both adults and larvae of *C. carnea* were affected. The effect on adults was apparently detrimental, because oviposition dropped significantly (Table 4) both after the 1st treatment and later from the 3rd treatment

onward (Fig. 6A). The effect on larvae was consistent, but minor, and significant only on 3 September ($t = 3.375$, $df = 6$, $P < 0.01$) (Fig. 6B). In Zora, populations of *C. carnea* declined significantly both in 1992 and 1993 after commercial insecticide treatment (Table 4; Fig. 7).

Table 3. Correlation coefficients between the numbers of *Bemisia* nymphs per week and the numbers of *C. carnea* eggs and larvae

Field	Correlation coefficients (n) for stage:		
	Larvae, 1 wk lag	Larvae, 2 wk lag	Eggs, no lag
Eden 1990	0.07 (16)	0.11 (15)	0.41 (17)
Maale Gilboa 1992 regular	0.22 (13)	0.46 (11)	0.34 (14)
Maale Gilboa 1992 late	0.56 (9)	0.80 (8)	0.13 (10)
Zora 1992	0.25 (16)	-0.84 (15)	0.64 (17)
Maale Gilboa 1993	0.08 (16)	0.40 (15)	0.38 (17)
Zora 1993	0.21 (16)	0.18 (15)	0.12 (17)

Correlation coefficient was significant at the 5% level or less. Numbers of *C. carnea* used were those obtained 1 or 2 wk after those obtained for the whiteflies.

Discussion

Records of whitefly outbreaks since 1977 have shown that *Bemisia* may reach very high populations in Israeli cotton fields (Gerling et al. 1980, 1986). However, our sampled areas, with the exception of Maale Gilboa 1992 late and Zora 1993, were typified by very low populations of the pest. The studies of *C. carnea* populations presented here cannot explain this observed decline.

The role of *C. carnea* as a predator of *Bemisia* in cotton can be assessed using several criteria: coexistence with the prey in time and space, predatory capacity, prey preference, abundance in the field, and mobility.

Although *Bemisia* and *C. carnea* coexisted in the field, we found no direct relationship between their numbers. Neither could the differences in predator abundance in different years be explained by whitefly abundance. This resulted in a general lack of correlation between *C. carnea* and *Bemisia* nymphs (Table 3). The fact that *C. carnea* populations in Maale Gilboa 1992 late were significantly correlated with those of *Bemisia* and that a sudden rise in predator populations followed an upsurge that occurred in the hosts may suggest a strong response of *C. carnea* to changes in the populations of *Bemisia*. However, examination of Fig. 2A shows that a similar rise in predator populations occurred also in the regular field in which *Bemisia* populations were low. Considering that predators are not associated with the extensive mortality often encountered by whitefly eggs and 1st-instar nymphs (Horowitz et al. 1984), we must assume that the fluctuations of *C. carnea* were caused by other, nonwhitefly factors.

The reasons for the apparent lack of response of *C. carnea* to *Bemisia* may be linked to the feeding preferences of the predator and predatory capacity (i.e., which stages of whiteflies and how many individuals of these stages will lacewing larvae eat). Butler and Henneberry (1988) showed that lacewing larvae will consume all whitefly instars. Depending on instar, *C. carnea* larvae took half a minute or less to consume each whitefly egg, up to 1 min to consume nymphs, and between 4 and 5 min

Table 4. Significance values for the influence of monochlorophos treatments on *C. carnea*

Field and date	Stage	Mean control	Mean treatment	t-value	df	P<
Eden 1990						
3 July	Eggs	14.0	25.6	2.8	18	0.01
10 July		12.9	23.5	3.9	18	0.001
24 July		5.2	10.0	2.2	18	0.05
Eden 1990						
10 July	Larvae	2.3	5.5	2.1	18	0.05
7 Aug.		3.5	5.7	2.1	18	0.05
Maale Gilboa 1992						
20 July	Eggs	9.4	3.8	2.5	6	0.05
20 Aug.		48.3	24.6	2.5	6	0.05
27 Aug.		58.1	23.1	3.7	6	0.01
3 Sept.		34.7	14.3	5.3	6	0.001
14 Sept.		18.9	1.6	7.9	6	0.001
21 Sept.		23.7	2.6	9.9	6	0.001
Zora 1992						
5 Aug.	Larvae	2.8	0.2	4.0	5	0.01
11 Aug.		3.0	0.7	3.3	5	0.05
18 Aug.		2.8	0.7	3.3	5	0.01
25 Aug.		4.2	0.7	3.4	5	0.01
2 Sept.		3.7	1.3	2.4	5	0.05
Zora 1993						
25 Aug.	Eggs	3.8	0.0	—	5	—
Zora 1993						
20 July	Larvae	7.2	0.2	4.8	5	0.005
27 July		6.5	0.3	5.6	5	0.005
4 Aug.		4.0	0.0	—	5	—
11 Aug.		3.8	0.2	4.4	5	0.005
18 Aug.		2.3	0.3	3.2	5	0.05

to consume pupae or adults. Afzal and Kanh (1978) reported that each *C. carnea* consumed 23.3 whitefly pupae per day, or ≈ 511 pupae during their development. Kappadia and Puri (1992), who used a mixture of nymphs rather than pupae alone, reported an average of 21.3 nymphs consumed per day, or 203.2 during their development. Both also observed that *C. carnea* preferred aphids to whiteflies. Moreover, Kappadia and Puri (1992) reported that the development of the 2nd and 3rd instars of the lacewing were prolonged significantly when their diet was whiteflies as compared with aphids. These observations conform with those of Lazare (1994) who showed that *C. carnea* larvae prefer to attack nymphs of *Aphis gossypii* Glover over those of *Bemisia*. The preference of aphids over *Bemisia* corresponds also to observations that *Bemisia* nymphs constitute a poor diet for nonspecialized predators such as *C. carnea* larvae, especially because of their low methionine levels (A. C. Cohen, USDA-ARS Western Cotton Research Laboratory, unpublished data).

In addition to the temporal synchronization of population patterns, our results also point to numerical inadequacy of the lacewings in relation to whitefly nymphs. Except for Maale Gilboa in 1992, populations of *C. carnea* reached a maximum of ≈ 4 –7 larvae per meter row (Table 1) even when there were nearly 100 whitefly nymphs per leaf as

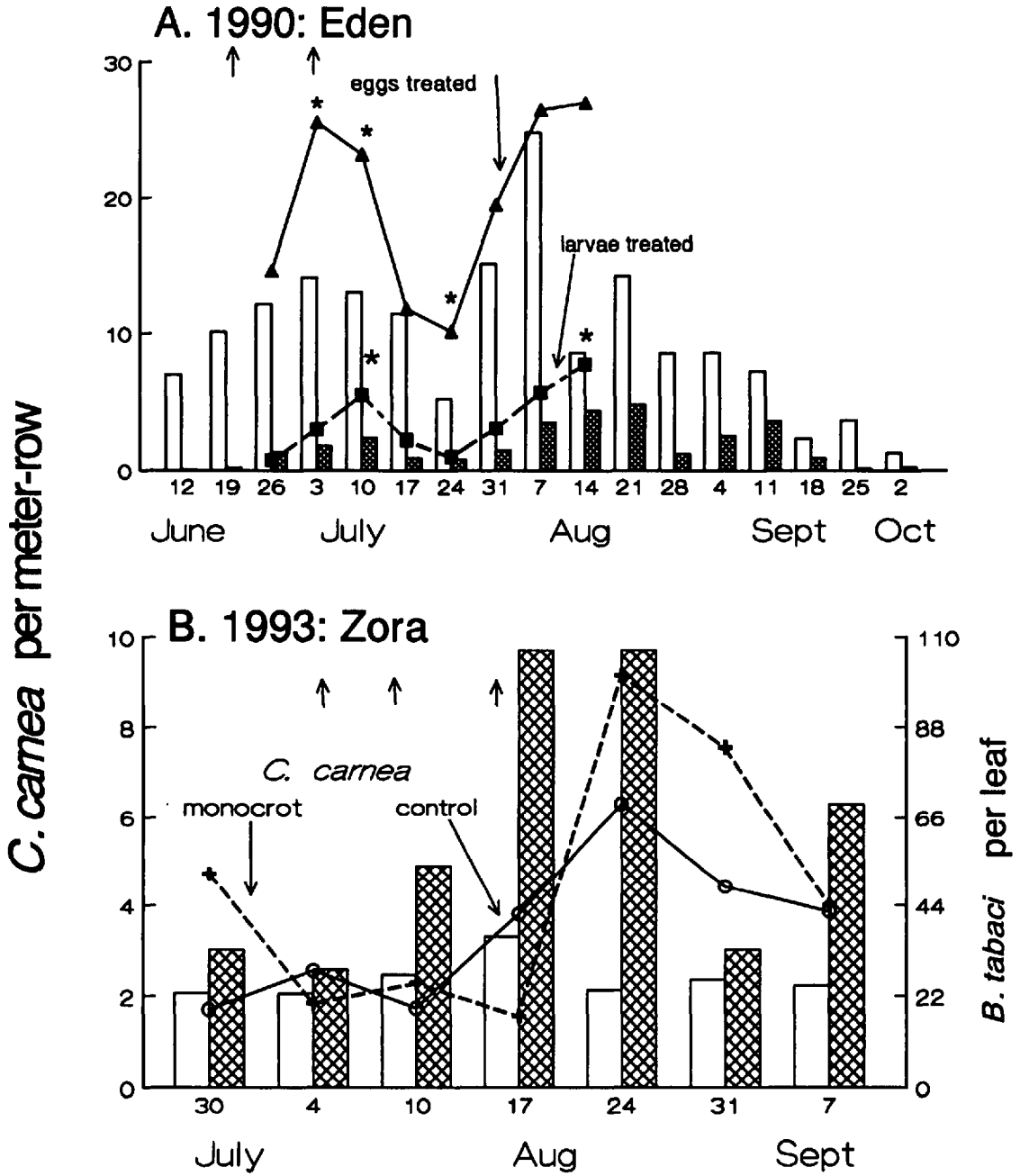


Fig. 5. Effect of monocrotophos treatments on populations *C. carnea* (A) in the Eden farm during 1990 (bars are the untreated control populations for eggs [□] and larvae [□] of *C. carnea*), (B) in Zora in 1993 (bars are the untreated [□] and treated [□] populations of *B. tabaci*). Arrows indicate insecticide treatments, stars indicate significant differences between treatments at the 5% level.

in Zora 1993. With $\approx 7-8$ plants per meter, this amounts to a maximum of 1 larva per 1 or 2 plants. However, as noted, the number of whitefly immatures consumed per day by *C. carnea* larvae does not exceed 25 or ≈ 500 during their 20-d development from egg to pupa. If we take into account that the presence of a leaf bearing a number of whiteflies usually indicates the existence of ad-

ditional infested leaves on the same plant (Gerling et al. 1980), it is evident that 1 *C. carnea* larva or less per plant cannot act as an efficacious whitefly controlling agent during pest outbreak periods. However, because it is a predator of whiteflies, it contributes to whitefly suppression and could augment the prevention of outbreaks during low whitefly populations.

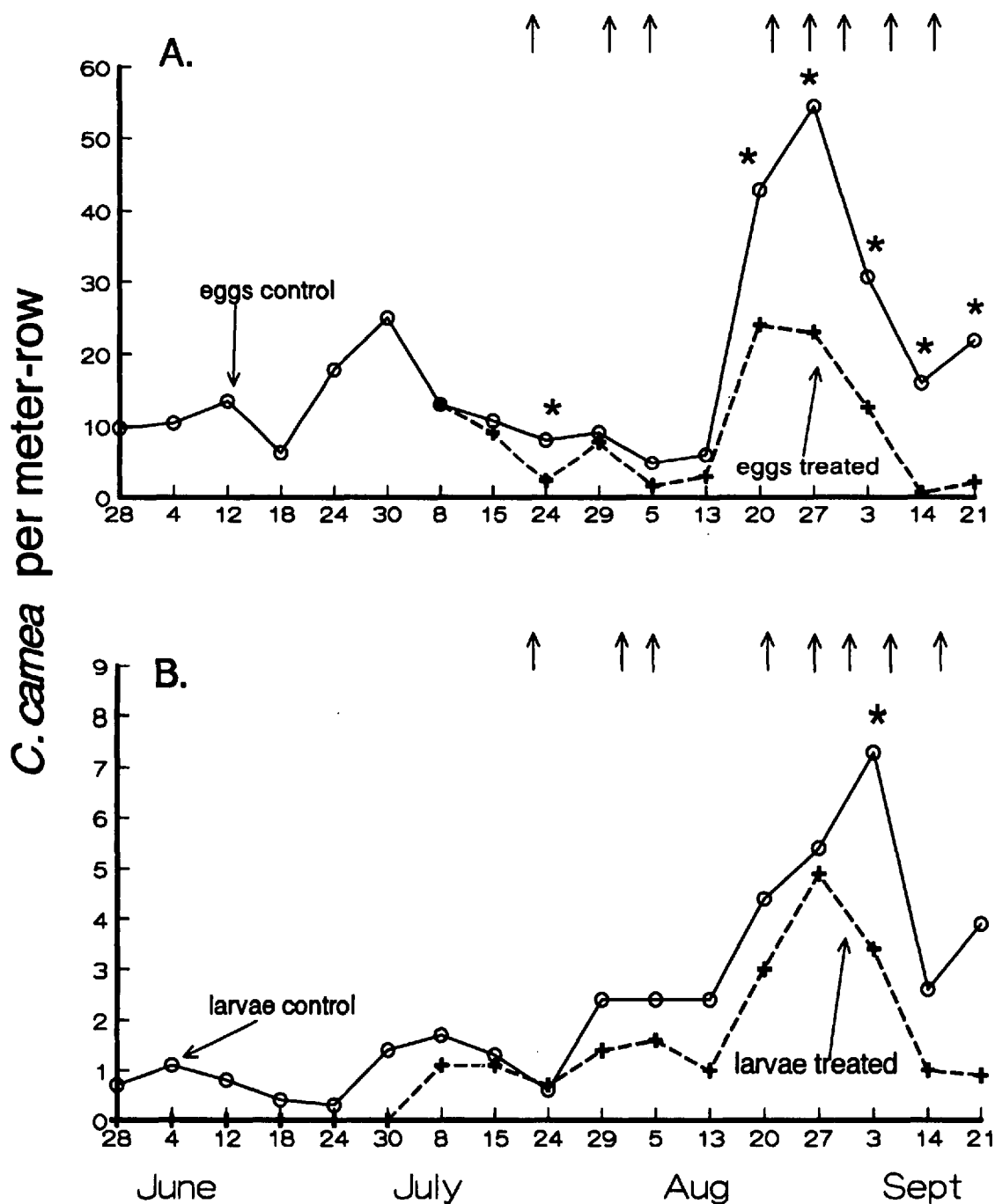


Fig. 6. Effect of commercial insecticide treatments on populations of *C. carnea* in Maale Gilboa during 1992. (A) Eggs. (B) Larvae. Arrows indicate insecticide treatments, stars indicate significant differences between treatments at the 5% level.

Our data support the statement made by Milbrath et al. (1993) that although many predators may be assumed to have a very broad range of food selection, in reality their choice is limited by both dietary needs and behavior. Although *C. carnea* occurs throughout the cotton season in all cotton fields, and it can consume *Bemisia* immatures, nutritional deficiency, the number of whitefly nymphs

consumed per day, and the preference for other prey may play an important role in reducing its importance as a predator of *Bemisia*.

In Eden 1990, *C. carnea* egg populations rose significantly 1–2 wk after treatment with monocrotophos (Fig. 5A). The oviposition pattern followed closely that of the untreated control, but at a much higher rate. It is possible that the use of monocro-

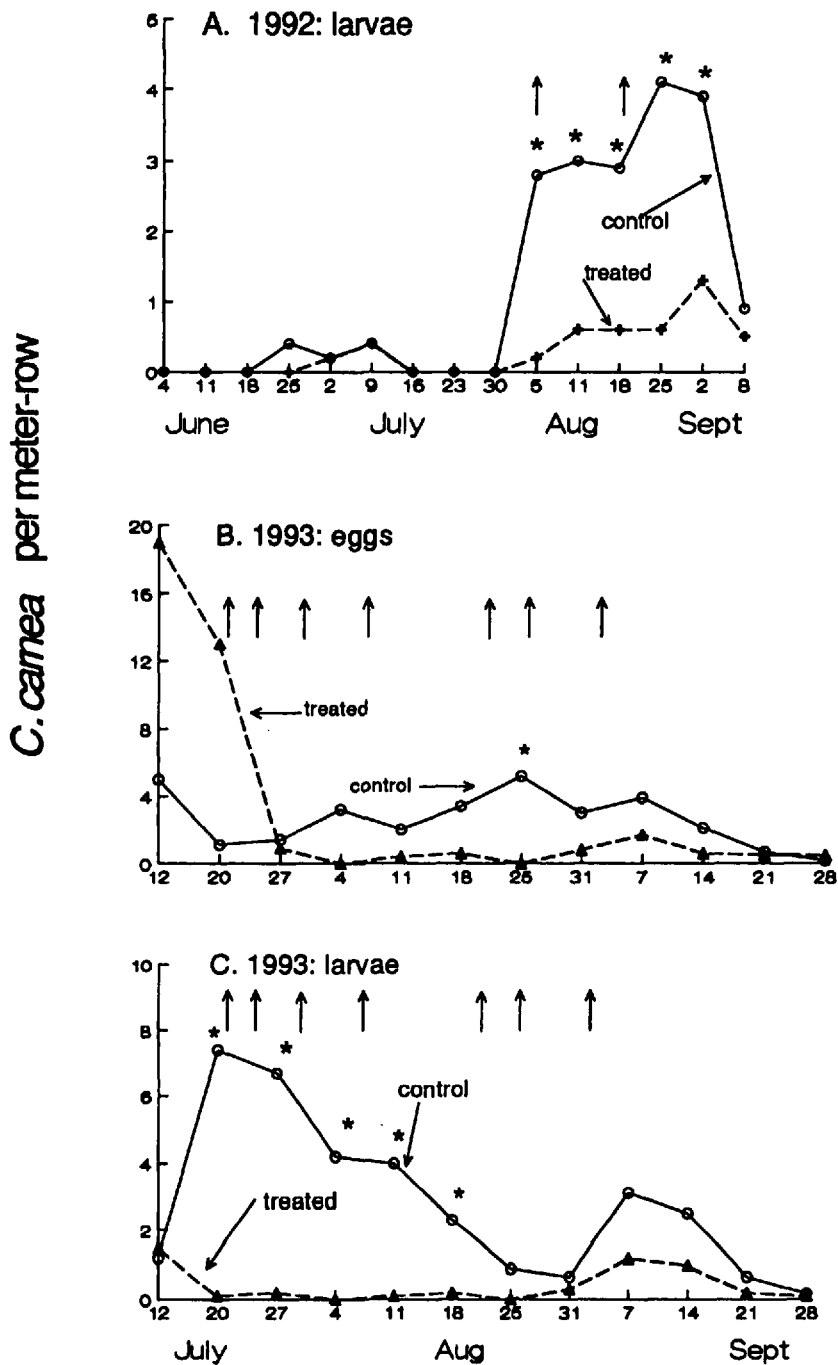


Fig. 7. Effect of commercial insecticide treatments on the populations of *C. carnea* in Zora. (A) Effect on larval populations during 1992, (B) and (C) effects on egg and larval populations respectively, during 1993. Arrows indicate insecticide treatments, stars indicate significant differences between treatments at the 5% level.

tophos did not diminish the numbers of the adults either through direct toxic effects or through effects on the larvae, or that the insecticide had a direct or indirect stimulating effect on the number of eggs that adult *C. carnea* will lay.

The observed rise in oviposition was followed by a significant rise in larval populations, which de-

clined again shortly afterward (Fig. 5A). This decline was possibly the result of the lack of sufficient food for the developing larvae. Lack of food might also have been the cause for the discrepancy between the egg population levels and that of the larvae that generally was observed. The results of our sampling, during which all plant parts were

inspected thoroughly, and in which very few potential prey were found, also support this hypothesis. A gap between egg and larval populations had already been observed by Whitcomb and Bell (1964) and Wilson and Gutierrez (1980) who speculated that this was caused by immature larval mortality, possibly the result of intraguild predation. Recently, Rosenheim et al. (1993) showed that, indeed, intraguild predation may account for some of the gap between egg and larval populations. Although such predation might also have occurred early in the season in the fields that we studied, it could not have accounted for the gap later on, because at that time *C. carnea* was the only predator present in the field in appreciable numbers (Lazare 1994).

An examination of Fig. 2 and of Table 1 may illustrate the complexity of the situation. The population peaks for *C. carnea* occurred each year at a different part of the season, in Maale Gilboa 1992 (regular) they occurred in August, when practically no other predators existed, and in Maale Gilboa 1993 in early July, when *Orius* spp. and other predators were still present (Lazare 1994). However, the index of survival (i.e., the percentage of nymphs that made it to the 4th instar, out of the egg population) for the 2 yr was similar (Table 1), indicating approximately equal mortality both with and without predators. Yet, a much higher correlation between egg and larval populations was shown for both years during the end of the season, when other predators were rare or absent, than for the first 10 wk when other predators abounded. This may point to the possible importance of mortality factors that were more intense in the first part of the season.

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