Dittrichia viscosa and *Rubus ulmifolius* as Reservoirs of Aphid Parasitoids (Hymenoptera: Braconidae: Aphidiinae) and the Role of Certain Coccinellid Species

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The role of the self-sown shrubs *Dittrichia viscosa* (L.) W. Greuter and *Rubus ulmifolius* Schott as reservoirs of aphid parasitoids was investigated. In the field studies conducted, *D. viscosa* grew adjacent to crops of durum wheat and barley and *R. ulmifolius* grew adjacent to cotton. The relative abundance of the parasitoids of *(a) Capitophorus inulae* (Passerini) on *D. viscosa*, *(b) Rhopalosiphum padi* (Linnaeus) on durum wheat and barley, *(c) Aphis ruborum* (Börner) on *R. ulmifolius*, and *(d) Aphis gossypii* Glover on cotton in various parts of Greece, was assessed during the years 1996–2000. In 2000, the fluctuation of parasitization of the above four aphid species was recorded and the action of the aphidophagous predators of the family Coccinellidae was studied. It was observed that *Aphidius matricariae* Haliday predominated on *C. inulae* and *R. padi* in all sampling cases. In contrast, *Lysiphlebus fabarum* (Marshall) was the dominant species parasitizing *A. ruborum* on *R. ulmifolius* and *A. gossypii* on cotton in Thessaly (central Greece) and Macedonia (northern Greece), whereas *Lysiphlebus confusus* Tremblay et Eady and *Binodoxys acalephae* (Marshall) were the dominant parasitoid species in Thrace (northern Greece). *Coccinella septempunctata* Linnaeus was the most abundant coccinellid species on durum wheat, whereas *Adonia variegata* (Goeze) predominated on cotton. However, coccinellid individuals were scarce on both *D. viscosa* and *R. ulmifolius*. The present study indicated that these two shrubs can be regarded as useful reservoirs of aphid parasitoids.
KEY WORDS: Aphidiinae; Coccinellidae; *Dittrichia viscosa*; durum wheat; barley; *Rubus ulmifolius*; cotton; parasitoid reservoir.

INTRODUCTION

Weeds contribute to the diversity of plant cover in cultivated areas (36). Some of them grow in non-crop areas: roadsides, ruderal areas, uncultivated places, fallow ground, hedges, in and around residential areas, and near ruins of old buildings (27). In such habitats, weeds are associated with several categories of insects (36) including aphids and their natural enemies (17,36,44). Weeds may harbor aphid species that could be pests on agricultural crops as well as aphid species that are considered economically unimportant (17,29,33). The latter can be parasitized by species which may disperse to the neighboring crops and parasitize a target aphid pest there (42).

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Many studies have considered the importance of various plants as reservoirs of aphid parasitoids (29,32,33,35,36,37,39,42,44). However, this role has not yet been assessed in the field with regard to adjacent cultivated plants as well as to the possible interactions of aphid parasitoids with other aphidophagous insect species.

The self-sown shrubs *Dittrichia viscosa* (L.) W. Greuter (Asteraceae) and *Rubus ulmifolius* Schott (Rosaceae) are abundant in wastelands, fallow ground, along roadsides, and near but not inside cultivated fields (6,27). Although these plants have been reported to be infested with various species of aphids (2,9) which are parasitized by aphidiines (30,38,40,43,45,46), they have not yet been studied as possible reservoirs of aphid parasitoids. The purpose of this study was to examine the importance of these two plant species as possible reservoirs of aphid parasitoids when they grow in the vicinity of cereals (mainly durum wheat) and cotton. The interactions of aphid parasitoids with aphidophagous coccinellid species was also studied. An attempt was made in the present work to establish some necessary guidelines for IPM programs.

MATERIALS AND METHODS

During the years 1996–2000 (approx. every 10 days during spring and summer), samples bearing mummified aphids were collected at random from fields of durum wheat and barley neighboring on plants of *D. viscosa* in central and southern Greece. Similarly, during 1999–2000 samples were also collected from fields of cotton in the vicinity of *R. ulmifolius* in central and northern Greece. Each sample was placed separately in a plastic bag. The bags were next brought to the laboratory where aphids were identified to species. Live aphids were preserved in 90% ethyl alcohol and 75% lactic acid, 2:1 (3). Mummies, attached on a small leaf piece each, were placed separately in small plastic boxes, which were placed inside a growth cabinet. On the lid of each box there was a circular opening covered with muslin for ventilation in order to maintain the conditions inside the boxes similar to those existing in the growth cabinet (22.5°C, 65% r.h., 16L:8D).

In spring and summer 2000, samples were taken every 10 days from two untreated fields cultivated with durum wheat and cotton located in southern (Argolis, Peloponnese) and central (Magnissia, Thessaly) Greece, respectively. The durum wheat field covered an area of 1.5 ha. At each sampling date, 60 stems, 20 cm long, were randomly collected from 60 plants (one stem per plant). The area adjacent to this field was uncultivated and bore an abundance of randomly dispersed plants of *D. viscosa.* At each sampling date, 15 shoots, 20 cm long, were collected from different plants (one shoot per plant). The cotton field covered an area of 2 ha. At each sampling date, 60 leaves were randomly collected from 30 different plants (two leaves per plant). Along one side of the cotton field there was a rural road along which plants of *R. ulmifolius* were growing densely, creating a natural hedge. At each sampling date, 15 shoots, 20 cm long, were collected from different plants (one shoot per plant). The samples were examined as above. Mean number of parasitoids was expressed per stem for durum wheat and per shoot for *R. ulmifolius.*

Sampling started with the first infestations of *D. viscosa* and *R. ulmifolius* by aphids and continued until the aphid colonies had collapsed on durum wheat and cotton.

Analysis of variance for the numbers of the parasitoids was made on transformed data ($y_{trans} = \sqrt{y + 0.5}$) and means were compared by the Tukey-Kramer (HSD) test (at P = 0.05) using the JMP statistical package (26). Each sampling date was taken as a replication.

Aphidiine parasitoids were identified using appropriate keys and descriptions: Starý

(30,34), Starý *et al.* (47), Tremblay and Eady (48), Pungerl (25), Pennacchio (23), Pennacchio and Höller (24), Mescheloff and Rosen (19–21), Kavallieratos and Lykouressis (14,15) and Kavallieratos *et al.* (17).

The monitoring of predators was achieved by a 30-min visual inspection of each plant species (durum wheat, *D. viscosa*, cotton, *R. ulmifolius*) in the field. The coccinellids found were collected with an aspirator, identified, recorded, and then released on the spot. The number of individuals in immature stages (larvae and pupae) and adults was recorded for each species. The larvae and pupae which could not be easily identified, were taken to the laboratory and reared on *Aphis fabae* Scopoli infesting artificially contaminated seedlings of *Vicia faba* L. (Fabaceae), until adult emergence.

RESULTS

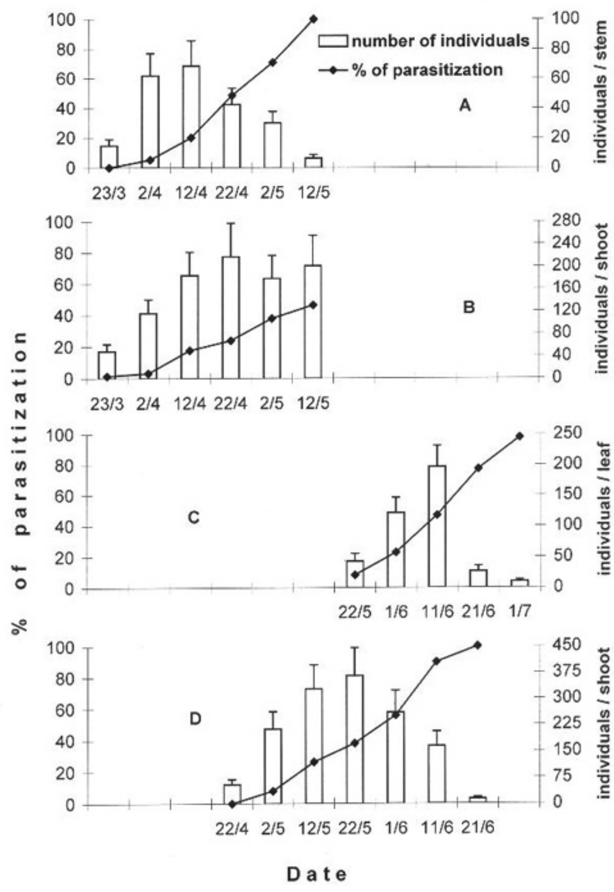

Fig. 1. Percentage of parasitization and mean (± SE) numbers of aphids (live and mummified): *Rhopalosiphum padi* on durum wheat (A), *Capitophorus inulae* on *Dittrichia viscosa* (B), *Aphis gossypii* on cotton (C) and *Aphis ruborum* on *Rubus ulmifolius* (D).

TABLE 1. Relative abundance (%) of *Capitophorus inulae* and *Rhopalosiphum padi* aphidiine parasitoids found on *Dittrichia viscosa* and cereals, respectively, in three regions (1996–2000)

Regions	Plants	Aphids	Parasitoids						Total number of specimens
			Aphidius avenae	*Aphidius colemani*	*Aphidius ervi*	*Aphidius matricariae*	*Diaeretiella rapae*	*Praon volucre*	
Attica	*Dittrichia viscosa*	*C. inulae*	–	–	–	100	–	–	312
(Central Greece)	Durum wheat	*R. padi*	–	4.26	–	71.48	21.42	2.84	845
	Barley	*R. padi*	0.97	–	1.94	74.76	22.33	–	207
Fthiotis	*Dittrichia viscosa*	*C. inulae*	–	–	–	100	–	–	502
(Central Greece)	Durum wheat	*R. padi*	–	5.26	–	82.80	11.94	–	1064
	Barley	*R. padi*	–	–	0.77	85.86	13.37	–	389
Peloponnese	*Dittrichia viscosa*	*C. inulae*	–	–	–	100	–	–	694
(Southern Greece)	Durum wheat	*R. padi*	–	14.49	–	79.08	6.42	–	1587
	Barley	*R. padi*	–	23.01	–	66.37	10.62	–	113

TABLE 2. Relative abundance (%) of *Aphis ruborum* and *Aphis gossypii* aphidiine parasitoids found on *Rubus ulmifolius* and cotton, respectively, in three regions (1999–2000)

Regions	Plants	Aphids	Parasitoids				Total number of specimens
			Lysiphlebus confusus	*Lysiphlebus fabarum*	*Binodoxys acalephae*	*Binodoxys angelicae*	
Thessaly	*Rubus ulmifolius*	*A. ruborum*	2.76	97.24	–	–	181
(Central Greece)	Cotton	*A. gossypii*	3.28	96.72	–	–	305
Macedonia	*Rubus ulmifolius*	*A. ruborum*	1.05	98.95	–	–	96
(Northern Greece)	Cotton	*A. gossypii*	0.87	99.13	–	–	230
Thrace	*Rubus ulmifolius*	*A. ruborum*	54.51	0.90	41.89	2.70	222
(Northern Greece)	Cotton	*A. gossypii*	62.82	–	37.18	–	156

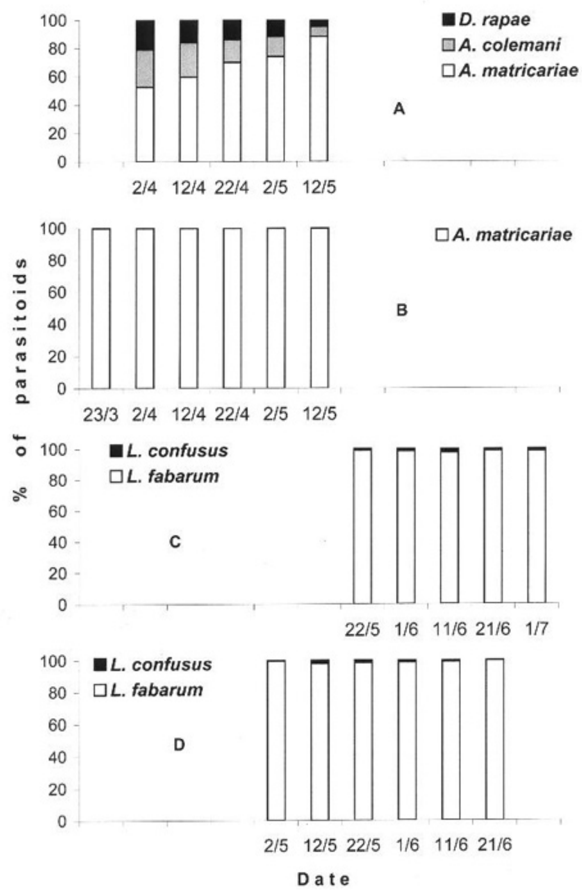

Fig. 2. Percentage of parasitoids of *Rhopalosiphum padi* on durum wheat (A), of *Capitophorus inulae* on *Dittrichia viscosa* (B), of *Aphis gossypii* on cotton (C) and of *Aphis ruborum* on *Rubus ulmifolius* (D).

The species of parasitoids found on the aphids *Capitophorus inulae* (Passerini) on *D. viscosa*, *Rhopalosiphum padi* (Linnaeus) on durum wheat and barley, *Aphis ruborum* (Börner) on *R. ulmifolius*, and *Aphis gossypii* Glover on cotton, as well as their relative abundance during the years 1996–2000, are shown in Tables 1 and 2. *C. inulae* was parasitized only by *Aphidius matricariae* Haliday, whereas the same parasitoid predominated on *R. padi* on durum wheat and barley in all experimental areas (Table 1). In contrast, *Lysiphlebus fabarum* (Marshall) was the dominant species parasitizing *A. ruborum* on *R. ulmifolius* and *A. gossypii* on cotton in Thessaly (central Greece) and Macedonia (northern Greece), whereas *Lysiphlebus confusus* Tremblay et Eady and *Binodoxys acalephae* (Marshall) were the dominant species in Thrace (northern Greece) (Table 2).

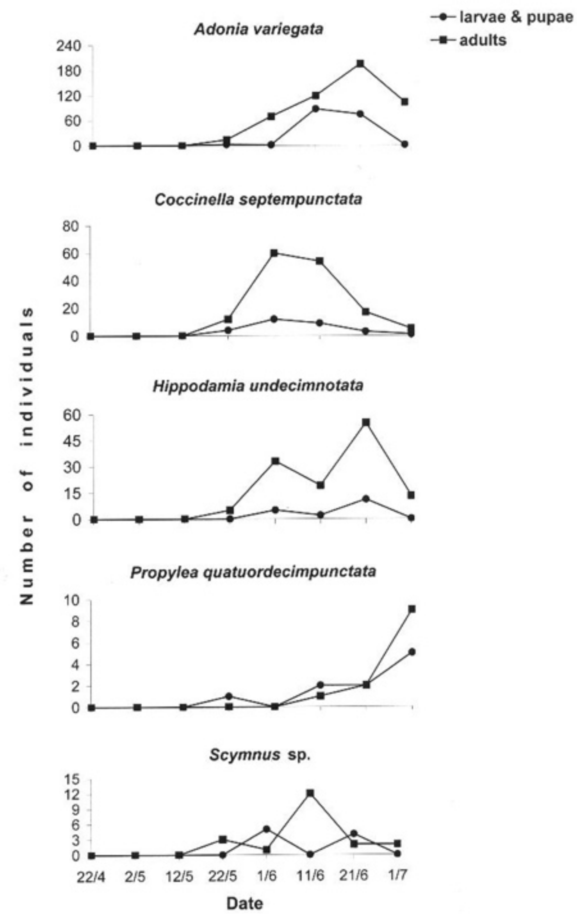

Fig. 3. Total number of individuals of coccinellid species found on *Aphis gossypii* on cotton, in a 30-minute visual inspection.

The infestation of durum wheat, *D. viscosa*, cotton and *R. ulmifolius* with aphids during the year 2000 is shown in Figure 1. Durum wheat was infested with *R. padi*, *D. viscosa* with *C. inulae*, cotton with *A. gossypii*, and *R. ulmifolius* with *A. ruborum* during the entire sampling period. All four species of aphids were found to be parasitized. *R. padi* was parasitized by *A. matricariae*, *Aphidius colemani* Viereck and *Diaeretiella rapae* (M'Intosh). *C. inulae* was parasitized by *A. matricariae*; *A. gossypii* and *A. ruborum* were both parasitized by *L. fabarum* and *L. confusus*. The percentage of parasitization and the relative abundance of aphidiines on *R. padi, C. inulae, A. gossypii* and *A. ruborum* are presented in Figures 1 and 2, respectively. ANOVA showed significant differences among the species of aphidiines parasitizing *R. padi* on durum wheat (F = 145.76; df = 2, 1077; $P<0.0001$), *A. gossypii* on cotton (F = 482.42; df = 1; 598; $P<0.0001$) and *A. ruborum* on *R. ulmifolius* (F = 172.38; df = 1; 208; $P<0.0001$). In the case of durum wheat, the mean number of *A. matricariae* ($\bar{x}$ = 7.24) individuals was significantly higher than those of *A. colemani* ($\bar{x}$ = 1.84), and *D. rapae* ($\bar{x}$ = 1.37). *C. inulae* was parasitized only by *A. matricariae*. Similarly, in the case of cotton and *R. ulmifolius*, the mean numbers of *L. fabarum* ($\bar{x}$ = 29.89 for cotton and $\bar{x}$ = 74.29 for *R. ulmifolius*) were significantly higher than those of *L. confusus* ($\bar{x}$ = 0.55 for cotton and $\bar{x}$ = 1.05 for *R. ulmifolius*).

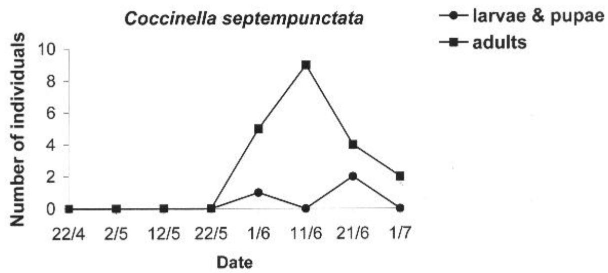

Fig. 4. Total number of individuals of coccinellid species found on *Aphis ruborum* on *Rubus ulmifolius*, in a 30-minute visual inspection.

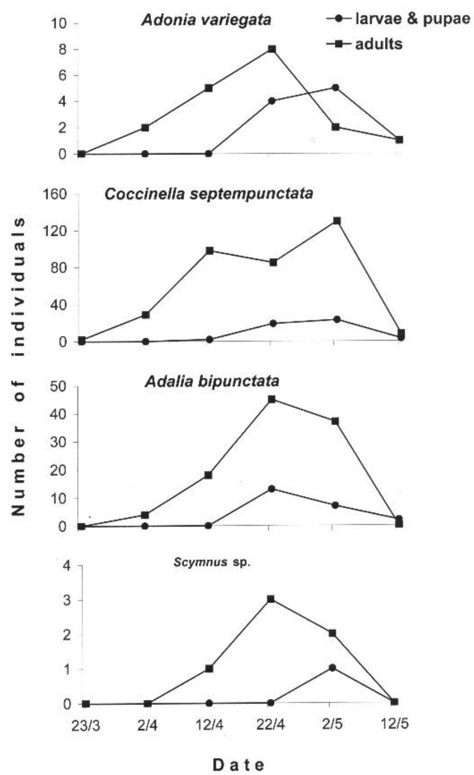

Fig. 5. Total number of individuals of coccinellid species found on *Rhopalosiphum padi* on durum wheat, in a 30-minute visual inspection.

Adonia variegata (Goeze) was the most abundant coccinellid predator of *A. gossypii* and represented 64.5% of the total number of individuals found, followed by *Coccinella septempunctata* Linnaeus (17%), *Hippodamia (Semiadalia) undecimnotata* (Schneider) (13.7%), *Scymnus* sp. (2.7%) and *Propylaea quatuordecimpunctata* (Linnaeus) (2.1%) (Fig. 3). The number of larvae and adults of each species initially increased (end of May) and subsequently decreased (end of June). Larvae of predators other than coccinellid species were also observed on *A. gossypii*, such as individuals of the genus *Syrphus* Fabricius (Diptera: Syrphidae) and of *Chrysoperla carnea* Stephens (Neuroptera: Chrysopidae). Small numbers of larvae and adults of *C. septempunctata* (Fig. 4) were the only coccinelids found on *A. ruborum*. *C. septempunctata* (71.2%) was the most abundant predator found on *R. padi*, followed by *Adalia bipunctata* (Linnaeus) (22.5%), *A. variegata* (5%) and *Scymnus* sp. (1.3%) (Fig. 5). A population increase occurred on all the aforementioned predators in the beginning of April and was followed by a decline during mid May (Fig. 5). It is noteworthy that only a few individuals of *Macrolophus* sp. (Heteroptera: Miridae), and no larvae, adults or egg-layings of any coccinellid, were ever observed on *C. inulae* during the present study.

DISCUSSION

Capitophorus inulae was parasitized by just one species (*A. matricariae*) of the genus *Aphidius* Nees. This fact has been reported in other studies as well (7,23,30,41,45,46). The predominance of *A. matricariae* on *C. inulae* and *R. padi* (Table 1, Fig. 2A,B) could be attributed to the dispersal of *A. matricariae* from *D. viscosa* to durum wheat and barley and *vice versa*. A similar dispersal could be assumed in the case of *L. fabarum* (Thessaly, Macedonia) (Table 2, Fig. 2C,D), *L. confusus* and *B. acalephae* (Thrace) (Table 2), which predominate on *A. ruborum* and *A. gossypii.* Similar observations concerning the seasonal exchange of the parasitoid populations among different crops as well as between crops and uncultivated plants infested with different aphid species have also been recorded by other researchers. Starý (31,42) stated that *Aphidius ervi* Haliday can be dispersed by *Acyrthosiphon pisum* (Harris) on lucerne to *Metopolophium dirhodum* (Walker) on barley and *vice versa*; *Aphidius picipes* (Nees) by *A. pisum* on lucerne to *M. dirhodum* on barley and *vice versa* as well as *Aphidius eadyi* Starý, González & Hall by *Acyrthosiphon pisum ononis* (Koch) on *Ononis* spp. to *A. pisum* on leguminous crops and *vice versa*. The ability of parasitoids to be transferred from one species of aphid to another on different plants has also been observed in the laboratory. Starý (35) confirmed that laboratory transfers of *L. fabarum* originating from *Aphis fabae cirsiiacanthoidis* Scopoli on *Cirsium arvense* (L.) in the field to *Aphis fabae* s. str. on *Faba vulgaris* Moench (Fabaceae) were positive. Similarly, Starý and Nèmec (44) reported that the field populations of *Praon abjectum* (Haliday) and *Trioxys angelicae* (Haliday) emerging from *Aphis sambuci* Linnaeus on *Sambucus nigra* L. (Caprifoliaceae) were successfully transferred to *A. fabae* on *F. vulgaris* in the laboratory.

During the year 2000 the percentage of parasitization of *R. padi* on durum wheat increased faster than that of *C. inulae* on *D. viscosa.* This difference may be attributed to the different behavior of aphids on the two plant species. There were enough shoots available on *D. viscosa* for the continuous proliferation of the aphid *C. inulae*, even after the time of wheat ripening. In contrast, the hardening of the ears produced unfavorable conditions for the aphids, leading them to move to other hosts. This resulted in a reduction in the number of live aphids and consequently in an increase of parasitization percentage. Similar behavior of aphids has been observed in citrus orchards (1) where the trees were not prone to infestation, due to the absence of tender shoots.

The elimination of *A. gossypii* and *A. ruborum* populations (Fig. 1C,D) could be attributed to the action of *L. fabarum,* since: *(a)* this parasitoid attacks the aphids systematically (28,35), and *(b)* it was the dominant parasitoid found on those aphids in the present study (Fig. 2C,D). The sudden increase in the percentage of *A. gossypii* parasitization on 21 June (Fig. 1C) could be attributed to the introduction of *L. fabarum* individuals emerging from *A. ruborum*, whose parasitization reached 100% on *R. ulmifolius* during the same period.

The species of predators found on *A. gossypii* and *R. padi* during the present study have also been observed in other studies. *A. variegata, C. septempunctata, P. quatuordecim-punctata, Scymnus* sp. (5,22) and *H. undecimnotata* (5,11) have been previously found on *A. gossypii*. Regarding the population composition of coccinellid predators on *A. gossypii*, Nicoli *et al.* (22) reported that in Italy *A. variegata* was the most abundant species on watermelon for two consecutive growing periods and represented 61.2% of the total predators during the first period and 87.5% during the second period. Similar figures were recorded for *A. variegata* on cotton (64.5%) during our study. Coccinellid species found on *R. padi* during the present study have also been reported as natural enemies of this aphid in previous studies (4,8,10). Hussein (10) noted that the most abundant predators of cereal aphids (*Sitobion avenae* [Fabricius], *R. padi* and *M. dirhodum*) were Coccinellidae (especially *C. septempunctata* and *A. bipunctata*), which were present throughout the entire observation period. This fact is in accordance with the high percentage of *C. septempuctata* (71.2%) and *A. bipunctata* (22.5%) observed on *R. padi* (Fig. 5) during the present study. Only a few larvae and adults of *C. septempunctata* were found on *A. ruborum*, which indicates the low significance of this predator for the specific aphid. Moreover, coccinellid species found on cotton were totally absent on vicinal *R. ulmifolius*. This indicates the preference of those predators for *A. gossypii*, which seems to be a more desirable prey than *A. ruborum.* The ability of *C. septempunctata* to feed on *A. ruborum* is supported by previous laboratory studies (18). The total absence of coccinellids in colonies of *C. inulae* on *D. viscosa,* indicates that this aphid is likely to be 'invulnerable' against those predators. The initial population increase observed for all predators and the subsequent decline (Figs. 3–5) may be attributed to respective population fluctuations of the host species (Fig. 1). However, the rapid decline of the population of *C. septempunctata* towards the end of June was more pronounced when compared with that of the other predators found on *A. gossypii*. This phenomenon may be explained by the summer diapause that has been observed for this predator in Greece and the migration of a large part of the population to hibernation sites (12).

It should be noted that the aphid *C. inulae* has a strong affinity for *D. viscosa* and *Inula conyza* D.C. (9), whereas *A. ruborum* is monoecious holocyclic on several *Rubus* species (2). Neither of these species is a crop pest. Furthermore, *D. viscosa* and *R. ulmifolius* are very common plants in uncultivated places, at roadsides and in fallow ground where they do not grow inside the crops (6,27).

Maintenance of the existing *D. viscosa* and *R. ulmifolius* plants at the edges of crop fields should be recommended in order for them to serve as reservoirs of parasitoids of aphids that infest cotton and durum wheat. Similar recommendations for the usefulness of various plants as reservoirs of aphid parasitoids as well as of other natural enemies of aphids have been proposed for other plants such as *Galium* spp. (Rubiaceae) (29), *Fraxinus excelsior* L. (Oleaceae) (32), *Urtica dioica* L. (Urticaceae) (33), *Cirsium arvense* L. (Cichoriaceae) (36), *Philadelphus coronarius* L. (Saxifragaceae) (39), *Ononis* spp. (Leguminosae) (42) and *S. nigra* (44).

The plants *D. viscosa* and *R. ulmifolius* could be considered as possible reservoirs of aphid parasitoids for other crops as well, since the species of parasitoids identified in the present study on the aphids *C. inulae (A. matricariae)* and *A. ruborum* (*L. fabarum, L. confusus, B. acalephae*, *Binodoxys angelicae* [Haliday]) are important parasitoids of a number of aphid pests in several cultivated plants (13,16,17,29,33).

The negligible predatory activity of *C. septempunctata* against *A. ruborum* on *R. ulmifolius* and the absence of predators against *C. inulae* on *D. viscosa,* may suggest that these plants are not effective as reservoirs of predators for cotton and durum wheat, respectively. However, the inability of predators to reduce the populations of *A. ruborum* and *C. inulae* contributed to the development of high numbers of parasitoids on those aphids and therefore strengthens the recommendation of these specific plants as important reservoirs of aphid parasitoids.

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