

Review

Biological control of citrus insect pests in Turkey

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Abstract

The usage and acceptability of biological control methods are set to increase in agriculture in the future because of food safety and pesticide residue issues. Biological control implementation in Turkey started with control of cottony cushion scale *Icerya purchasi* (Homoptera: Margarodidae) through the introduction and release of *Rodolia cardinalis* (Coleoptera: Coccinellidae) in citrus plantations. Currently, the key pests of citrus, i.e. citrus mealybug (*Planococcus citri* (Homoptera: Pseudococcidae)), citrus rust mite (*Phyllocoptruta oleivora* (Acarina: Eriophyidae)) and California red scale (*Aonidiella aurantii* (Homoptera: Diaspididae)), can be suppressed by biological control, a specific acaricide and summer oil applications, respectively. As a main pest, the citrus mealybug infested area is approximately 100 000 ha in total on the East and West Mediterranean coasts of Turkey. Until now, biological control for citrus mealybug has been implemented on only 3000 ha (3.5%) of the citrus growing area. However, the small-scale nature of biological control applications in relation to the size of infested area is set to change as public awareness will lead to an increase in the area over which biological control is implemented in the future.

Keywords: Turkey, Biological control, Citrus, *Planococcus citri*, *Cryptolaemus montrouzieri*, *Leptomastix dactylopii*

Introduction

Public awareness of food safety and pesticide residue problems is set to increase the acceptability of biological control methods in agriculture in the future. Successful use of biological control in crops could be of major importance from both economic and ecological points of view. In the last few decades, significant progress has been made scientifically in biological control throughout the world but its commercial use is still limited in many crops and in many countries.

The implementation of biological control in Turkey really began with applications in citrus plantations. Citrus is a comparatively new crop for the Anatolia peninsula and, owing to the high-income potential of the crop, citrus growing practices are comparable to those used worldwide. Apart from this, there are still few other crops in Turkey in which entomophagous insects have been used to control pest insects. The reasons for this are, amongst other, an absence of technology transfer, lack of

acceptance of biological control and the trend amongst producers towards using agrochemical products – together with resistance from parts of the commercial supply chain, people who are not involved in the production process but have an important stake in marketing the crop. In practice, effective biological control may require several tactics to be combined to achieve effective pest management. Maintaining the natural balance and stability of the orchard ecosystem has, particularly in citrus plantations, provided the best opportunity for biological control to work.

History of Citrus in Turkey

It is known that the main genetic reservoir of citrus is in tropical and subtropical parts of South East Asia and India. The East Mediterranean Region has been called a second homeland for citrus. According to Ibn Avram, who lived in the twelfth century A.D., citrus was distributed by



Figure 1 The citrus growing areas of Turkey

Muslim Arabs to the Mediterranean region, throughout North Africa, the Iberian peninsula, Sicily, Cyprus, Rhodes and Crete. The first citrus plantations in the East Mediterranean, in Yafa, Haifa, Beirut and Syrian coast, were described by Evliya Çelebi, a Turkish traveller in the seventeenth century during the Ottoman Empire. During the period after the establishment of the Republic of Turkey and up to 1943, lemon was the country's only citrus crop and, as far as citrus was concerned, the country was known only for its lemon exports (M. Mühür, personal communication, 2006).

The first commercial citrus orchards were planted in the 1930s in Adana, Mersin, Hatay (Dörttyol) and Antalya (Finike) (Figure 1). During the 1950s, the major citrus crop in the Izmir region was satsuma mandarin [satsuma]; this is still the major citrus crop and has a reputation for very high quality on the world fresh citrus market. It was followed by lemons in some climatic areas and a similar expansion in production occurred with oranges, in parallel with an overall increase in areas planted with citrus. The latest citrus crop is grapefruit, whose production is now significant.

There has been a dramatic increase in the citrus growing area in Turkey over the last 30 years. In 1975 Turkey had approximately 80 000 ha of citrus plantations, and by 1998 this had increased by 10% to 87 900 ha. But by 2002 the area planted with citrus had grown to 147 650 ha, a 68% increase on the 1998 figure. The East Mediterranean Region has the largest citrus growing area in the country with 91 568 ha planted to citrus crops by 2002, representing a remarkable 68% increase in the previous 5 years. Other citrus growing regions show different growing trends over the last 30 years. In the Aegean Region the citrus growing area increased almost 100% in this period: from 8029 ha in 1975 to 16 018 ha in 2002; in the West Mediterranean Region there was an increase of about 26% in the citrus growing area, from

26 102 ha in 1975 to 33 002 ha in 2002. On a regional basis the Aegean Region still produces satsuma mandarins and the West Mediterranean Region also produces high-quality oranges. In the East Mediterranean Region, Mersin Province produces a local lemon variety, Lamas (Kütdiken), which can be kept in storage for most of the summer, and the growing area has increased 67%. In Hatay Province, the citrus crop is mainly satsuma mandarins and oranges grown in the Erzin and Dörttyol areas, which have seen a 66% increase in the area planted to citrus. The most dramatic increase recorded is for Adana province, with a 400% increase, mainly in the grapefruit growing area [1, 2].

History of Biological Control in Turkey

The first record of biological control in Turkey was during the period of the Ottoman Empire, in 1912 on Sakız island in Aegean Sea, when *Rodolia cardinalis* (Mulsant) (Coleoptera: Coccinellidae) was introduced to suppress the cottony cushion scale, *Icerya purchasi* Maskell (Homoptera: Margarodidae). The same predator was imported again in 1932 and released in the Çukurova and Aegean Regions. *R. cardinalis* adapted to Turkey successfully and could suppress the cottony cushion scale in the absence of broad spectrum pesticide usage. The second beneficial brought from abroad was a parasitoid, *Aphelinus mali* (Haldeman) (Hymenoptera: Aphelinidae), to control apple aphid, *Eriosoma lanigerum* (Hausmann) (Homoptera: Aphididae), which had also been introduced into the country. In the following years, more parasitoid species were imported from other countries: *Bracon hebetor* (Say) (Hymenoptera: Braconidae) for storage pests; *Prospaltella berlesii* Howard (Hymenoptera: Aphelinidae) for white peach scale, *Pseudaulacaspis pentagona* (Targioni-Tozzetti) (Homoptera: Diaspididae), and *Prospaltella perniciosi*

Tower for San José scale, *Quadraspidiotus perniciosus* (Comstock) (Homoptera: Diaspididae). In 1965, more beneficial insects, the predator *Cryptolaemus montrouzieri* Mulsant (Coleoptera: Coccinellidae) and the parasitoid *Leptomastix dactylopii* Howard (Hymenoptera: Encyrtidae), were imported from California for citrus mealybug, *Planococcus citri* (Risso) (Homoptera: Pseudococcidae) biological control, and these were reared in Adana (the Plant Protection Research Institute) and Antalya (the former Biological Control Institute/West Mediterranean Agricultural Research Institute).

Biological control studies have continued in the relevant departments of universities and in plant protection research institutes of the Ministry of Agriculture. Most of these studies have focused on citrus pests. Examples of recent successful biological control initiatives are the introduction of *Eretmocerus debachi* Rose & Rosen (Hymenoptera: Aphelinidae), a parasitoid of *Parabemisia myricae* (Kuwana) (Homoptera: Aleyrodidae), which was conducted by Çukurova University [3], and the introduction of *Serangium parcesetosum* Sicard (Coleoptera: Coccinellidae), a predator of *Dialeurodes citri* (Ashmead) (Homoptera: Aleyrodidae) [4], which was conducted by Adana Plant Protection Research Institute. In both cases, the natural enemies were well adapted to citrus orchards. The most recent study in citrus led to the release of the parasitoid *Cales noacki* Howard (Hymenoptera: Aphelinidae) against woolly whitefly, *Aleurothrixus floccosus* (Maskell) (Homoptera: Aleyrodidae) [5].

Turning to other crops, following earlier research on *Trichogramma evanescens* Westwood (Hymenoptera: Trichogrammatidae) for *Ostrinia nubilalis* (Hübner) (Lepidoptera: Pyralidae) control, *T. evanescens* rearing in Adana Plant Protection Research Institute was expanded to a mass-rearing level, and the Institute has been supplying it to farmers since 1996 for use on maize [6]. At Adana and Diyarbakır Plant Protection Research Institutes, studies are currently underway on the conservation and augmentation of *Trissolcus* spp., scelionid egg parasitoids of the most important wheat pest in Turkey, the Sunn pest, *Eurygaster integriceps* Puton (Heteroptera: Scutelleridae) [7].

Although these biological control initiatives are not new, more work is needed in terms of research and its practical applications in order to improve the acceptance of biological control in Turkey.

Current Status of Integrated Pest Management of Citrus Horticulture

Despite the low uptake of biological control in citrus, it is still larger than usage in other agricultural crops. This is mainly because of its successful integration with other citrus protection measures such as the use of summer oil combinations. The key pests are citrus mealybug (*P. citri*), citrus rust mite (*Phyllocoptruta oleivora*

(Ashmead); Acari: Eriophyidae) and California red scale (*Aonidiella aurantii* (Maskell); Homoptera: Diaspididae), which are suppressed by biological control, a specific acaricide and oil applications, respectively [8].

Apart from these key pests, occasional pests such as whiteflies are usually able to be controlled by natural biological control (i.e. naturally occurring natural enemies), while other scale insects, diaspids or soft scales, are suppressed by both natural enemies and summer oil applications. If the natural balance of an orchard is maintained, red spider mites do not become a problem; but if problems occur, they should be able to be controlled by natural enemies, and if these do not exert sufficient control, specific acaricides can always be used. Cottony cushion scale control by the predator *R. cardinalis* is the best-known example of biological control in citrus. The moth citrus pests, lemon flower moth (*Prays citri* Millière (Lepidoptera: Yponomeutidae)) and carob moth (*Ectomyelois ceratoniae* Zeller (Lepidoptera: Pyralidae)), were successfully controlled in Turkey by *Bacillus thuringiensis* Berliner applications. Aphids on citrus are usually controlled by natural enemies established in the orchards, although very rarely pesticide applications are needed in young plantations. A similar situation occurs with citrus leaf miner (*Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae)), with only young plantations suffering levels of infestation needing control; trees over 5 years old do not need chemicals applying. Because citrus mealybug is not a problem in young trees, the need for chemical usage for citrus leaf miner can be tolerated in the first years of citrus plantations. The other important pests occurring close to harvest-time are Mediterranean fruit fly (Medfly – *Ceratitidis capitata* (Wiedemann) (Diptera: Tephritidae)) and cicadellids. The official recommendation for controlling Medfly is bait spraying. Our personal field experience with this pest shows that under low populations, mass trapping would be a reasonable solution giving comparable control to cover spray chemical applications, which are not recommended. Cicadellids cause cosmetic damage by sucking the rind of the fruit and leaving marks. Spraying with lime is the official recommendation for their control [8].

It can be concluded from this review of plant protection measures for citrus pests in Turkey that it would be quite possible to apply biological control on a large scale in citrus plantations.

Implementation of Biological Control for Citrus Mealybug

Citrus mealybug is one of the main pests affecting all citrus varieties in Turkey. As a main pest, the citrus mealybug infests a total of approximately 100 000 ha of citrus on the East and West Mediterranean coasts of Turkey. Until now, only 3000 ha (3.5%) of the citrus growing area has been implementing biological control against the pest.

Table 1 Citrus mealybug biological control release strategies and average number of control agents released

Citrus variety	First occurrence of mealybug	<i>L. dactylopii</i>			<i>C. montrouzieri</i>		
		First release	Number of releases	Approx. no./tree	First release	Number of releases	Approx. no./tree
Lemon	End of April/ beginning of May	After 25 April	3–4	10–15	Beginning of June to beginning of July	1–2	8–10
Mandarin	May (except early varieties)	After 15 May	3–4	10–15	Beginning of June to beginning of July	1–2	8–10
Orange	End of April/ beginning of May	After 25 April	6–7	20–40	Beginning of June to beginning of July	2–3	15–20
Grapefruit	End of April/ beginning of May	After 25 April	6–8	20–40	Beginning of June to beginning of August	3–4	15–20

Citrus mealybug has a soft, oval, flat body covered with a white wax that extends into spines along the body margin. During the winter the mealybugs occupy cracks and cavities in the trunks of citrus trees. In early spring, at the end of April or beginning of May depending on temperature, they emerge from these hibernating sites. Females lay their eggs in cottony egg sacs. The egg sacs can be easily seen at the posterior end of the body, and once egg laying is complete the sacs are deposited on trunks, twigs and fruit and, in heavy infestations, on leaves. A single female can lay 300–400 eggs during her life span. Newly hatched nymphs are light yellow in colour and free from wax, but wax secretion starts just after hatching. Nymphs are mobile and seek out parts of the plant where they can attach and begin sucking on plant sap, eventually forming a colony. The damage they inflict reduces tree vigour and the honeydew they excrete causes quality decline in fruit. If a cluster of mealybugs feeds along a fruit stem, fruit drop may occur. Damage is most severe at the end of spring (end of May and beginning of June) and at the beginning of autumn (end of August and beginning of September). In the Mediterranean region, there are three or four overlapping generation per year [9].

Conservation of natural enemies is the first step in mealybug control. However, natural biological control does not always suppress the pest population sufficiently to keep it under the damage threshold level. Nonetheless, releases of *C. montrouzieri* and *L. dactylopii* have provided effective control without needing to turn to insecticides. Reducing ant populations during the growing season is one of the most important measures that increases the efficiency of biological control. Ants usually have a negative effect on parasitoid activity. The ants feed on honeydew produced by mealybugs and prevent the parasitoids from approaching them.

C. montrouzieri is a voracious feeder on citrus mealybug eggs as well as on both the larval and adult stages. Its larva resembles a mealybug but is about twice as large as the adult citrus mealybug female. Because *C. montrouzieri* does not survive the winter well, it needs to be purchased from

commercial insectaries every year. But in the summer months it can reproduce in the orchards as long as it finds enough food. The adult life span is about 2.5–3 months in the Mediterranean region. Although female *C. montrouzieri* can lay up to 300–400 eggs, the actual number depends on food quality; unless they can feed on mealybug eggs, they either do not produce eggs or produce eggs of very poor quality [10]. The adult is a small beetle with dark brown elytras and a light brown head and prothoracic shield. The critical period for controlling the mealybug population is from mid April through the summer. To avoid missing the beginning of the build up of the pest population, early spring releases are very important in orchards where citrus mealybugs were a problem in the previous year. Although the officially recommended release rate is five *C. montrouzieri* per tree (approximately equivalent to 1250 *C. montrouzieri* per hectare) in most cases, in old plantations and especially in grapefruit orchards, two to four times these numbers are usually released (at least 20 *C. montrouzieri* per tree) (Table 1). The efficiency of predation can be seen 2 or 3 weeks after releases in the empty mealybug egg sacs, in reduced mealybug colonization and in the remains of consumed mealybug colonies.

L. dactylopii is also used in biological control. This small wasp lays its eggs inside the third or older stages of the mealybug. It is exotic, and cannot survive the Mediterranean winters and thus needs to be released again each spring, like *C. montrouzieri*. Very good mealybug control is obtained from parasitization in the early growing season. The age of the mealybug population when it starts to emerge from hibernating sites, mainly third/fourth instars or adults, is very suitable for parasitism by *L. dactylopii*. Adult wasps can live about 10 days, and in this time they can parasitize 90–120 mealybugs. During the summer they can reproduce in orchards so long as there is no use of broad-spectrum insecticides. Two or three weeks after release, parasitized mealybugs can be differentiated by their hard body shape and yellowish/brownish colour, and later from the parasitoid emergence hole on one side. The

officially recommended release rate is ten parasitoids per tree but, as with *C. montrouzieri*, in old orchards and grapefruit the numbers need to be doubled, and in heavy infestations more than double the number may be needed (Table 1). In addition, early in the season when the pest population is still low (early May to mid June), two or three releases of parasitoids can be made to give the orchards continuous parasitoid activity.

Based on our field experience, Table 1 gives the starting dates, application rates/numbers and release strategies needed to achieve successful biological control.

On the basis of our field observations, broad spectrum pesticides should not be used in orchards while biological control is being implemented. If such pesticides are used, biological control agents should not be released for 30 days after spraying; if insect growth regulators are used then this period should be at least 45 days.

Major Limitations to Biological Control: A Case Study of the Citrus Mealybug

According to a questionnaire study conducted with citrus growers in the East Mediterranean Region, only 24% of growers stated that they were using biological control agents for citrus mealybug control; the rest relied mainly on chemical control. The principal reasons citrus growers gave for preferring chemical control were firstly that insecticides are effective within a short period of being applied (48% of respondents); secondly, lack of timely supply of adequate numbers of beneficials (16%), thirdly, biological control is more expensive (10%); fourthly, the beneficials were not as efficient as chemicals (5%); and lastly (5%) they have no information about biological control [11]. It was very clear that the preference for chemical control was based on rapid efficiency, but growers need also to be conscious of issues surrounding pesticide residues because of quality accreditation programmes. The supply problems have been eliminated through the high capacity of the insectarium of a commercial company, the Biological Agriculture Consulting and Engineering Co., which is able to produce the required numbers of beneficials. The company has the capacity to rear 10 million *C. montrouzieri* predators and 20 million *L. dactylopii* parasitoids annually; although the current demand for beneficials amounts to only 3 million *C. montrouzieri* and 6 million *L. dactylopii* per year. The biological control sector constantly strives to bring user costs in line with those of chemical control in order to support biological control usage. It is true that there is a lack of training among growers, among technical staff, in both the extension service and private consultancies, and in the commercial sector, which contributes to the low uptake of biological control. Successfully managing and maintaining biological control programmes needs frequent field visits by extension staff with a wide knowledge of not only plant protection but also biological control.

The low usage of beneficial insects in citrus also reflects the fact that there are very few organic farms in Turkey, and no more than 20% of the citrus growing area is under Integrated Pest Management (IPM). The rest of the citrus growing area relies on conventional plant protection methods. This indicates that there is great potential for the future expansion of biological control in citrus in Turkey.

Future Perspectives

Biological control is a promising solution for both pest problems in agriculture and environmental protection of natural ecosystems worldwide. Concern about the impact of pesticides on both human and environmental health is now firmly on public and political agendas in developed countries. There is severe pressure for all areas of agriculture and horticulture to reduce chemical use in production. Quality accreditation programmes for all agricultural products should specify IPM as the required approach for production. Biological control should be the cornerstone of an IPM programme where possible.

Increasing efforts towards biological control implementations is limited not only by growers' knowledge but also by 'middle men' in the fresh fruit sector who ultimately supply fruit to consumers. In general, the social status of citrus growers in Turkey has been quite high because of their level of education and because of their high incomes (although they no longer earn these), and they are able to access up-to-date information on citrus growing from around the world. Despite this potential for using biological control extensively in citrus production, orchard crop protection practices are largely determined by local marketing forces – traders who still tend to favour chemical usage, presumably largely for cosmetic reasons. Therefore, training of people involved in citrus marketing is a priority for making the application of biological control more widespread in citrus growing areas of Turkey – and the world. Improved knowledge amongst citrus marketing people will reflect recent consumer demand for fruit grown using biological control to appear on supermarket shelves.

Although significant economic savings can be made from an established biological control programme, one of the major reasons given for not adopting biological control within an IPM programme is the perceived risk of failure. Successfully managing and maintaining biological control of particular pests requires the presence of someone responsible with more than a rudimentary knowledge of crop protection. The adoption of biological control should be approached with the aid of expert advice and support, and a realization that some initial time and effort is required to eventually reap rewards for the whole business.

From this assessment, which has focused on citrus plantations in Turkey, it is clear that although there is

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about 30 years' history of biological control implementation in the crop, the approach is still not sufficiently widely used. However, biological control is a promising approach in view of current food safety regulations. Research in biological control is tending to increase throughout the world, and an increase in biological control implementation can be expected in parallel with a trend of increasing public awareness.

References

1. Anonymous. Agricultural Structure and Production. State Institute of Statistics, Prime Ministry of the Republic of Turkey, Ankara; 1975. 311 p.
2. Anonymous. Agricultural Structure (Production, Price, Value). State Institute of Statistics, Prime Ministry of the Republic of Turkey, Ankara; 2002. 250 p.
3. Şengonca Ç, Uygun N, Kersting U, Ulusoy R. Successful colonization of *Eretmocerus debachi* (Hym.: Aphelinidae) in the Eastern Mediterranean citrus region of Turkey. *BioControl* 1993;38(3):383–90.
4. Yiğit A, Canhilal R, Ekmekci U. Seasonal population fluctuations of *Serangium parcesetosum* (Coleoptera: Coccinellidae), a predator of citrus whitefly, *Dialeurodes citri* (Homoptera: Aleyrodidae) in Turkey's Eastern Mediterranean citrus groves. *Environmental Entomology* 2003;32(5): 1105–14.
5. Ulusoy MR, Vatanserver G, Erkılıç L, Uygun N. Studies on *Aleurothrixus floccosus* (Maskell) (Homoptera, Aleyrodidae) and its parasitoid, *Cales noacki* Howard (Hymenoptera, Aphelinidae) in the East Mediterranean Region of Turkey. *Journal of Pest Science* 2003;76(6):163–9.
6. Öztemiz S, Kornoşor S. Life table of *Trichogramma evanescens* Westwood (Hymenoptera: Trichogrammatidae) on *Ostrinia nubilalis* Hübner (Lepidoptera: Pyralidae) eggs. *Journal of Çukurova University, Faculty of Agriculture* 2004;19(3):83–92.
7. Yiğit A, Erkılıç L. Predatory insects, soldiers of biological control. *Journal of Ministry of Agriculture and Rural Affairs* 1994; (May–June) (97):16–8.
8. Aydemir M, Özkan A, Önuçar A, Yumruktepe R, Pala H, Gönen O. Integrated Pest Management Technical Instructions for Citrus Orchards. Ministry of Agriculture and Rural Affairs, Agricultural Research General Directorate, Ankara; 1997. 73 p.
9. Erkılıç L, Demirbaş H. Citrus Pests and Biological Control. Adana Plant Protection Research Institute, Adana, Turkey; 2000. 30 p.
10. Öncüer C, Bayhan N. An investigation on voracity and feeding diet of *Cryptolaemus montrozieri*. *Turkish Journal of Plant Protection* 1982;6(2):85–90.
11. Erkılıç L, Yiğit A, Karaat Ş. Questionnaire on Biological Control Practices of Citrus Pests in East Mediterranean Region. Proceedings of the IV Turkish National Congress on Biological Control, 26–29 January 1999, Adana, Turkey; 1999. p. 143–56.