Integrated Management of Whitefly Pest Problems in the Middle and Near East with Special Emphasis on Biological Control

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Abstract

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Biological control is a key component for integrated management of *Bemisia tabaci*. The actual and potential roles of natural, classical and augmentative biological control are considered, and the available published records regarding natural enemies from North Africa, the Near and Middle East are summarised. Specialist and generalist natural enemies are distinguished, and the likely effects of other pest management tactics upon the two groups of natural enemies are briefly considered.

Key words: *Bemisia tabaci*, natural enemies, IPM.

Introduction

Biological Control can de defined as the action of natural enemies to control pests. In this review, three types of biological control will be considered: Natural Biological Control, the action of indigenous predators, parasitoids and diseases, which can be encouraged by various techniques known as conservation of natural enemies; Classical Biological Control, the deliberate introduction of an exotic biological control agent to control a pest, which itself is usually, but not necessarily, exotic; and Augmentative or Inundative Biological Control, the deliberate release of large numbers of a laboratory produced natural enemy to control a pest, a technique particularly useful at times when natural biological control is not present or ineffective.

Integrated pest management (IPM) provides the best combination of pest control methods so as to maximize value or profit, minimize environmental and health risks and to be sustainable. Where adequate understanding of a pest problem exists, biological control frequently emerges as a method which best meets the objectives of IPM, and therefore becomes a key component of IPM systems. The integration of biological control and other methods of IPM, including plant resistance breeding, cultural and mechanical control and minimal use of pesticides on an at-need basis should be done in a manner which does not disrupt its contribution.

Thus, in considering the management of any pest,the starting point must be the static elements which are already present or can be defined in the agro-ecosystem, before considering any active intervention to directly control a pest. As well as biological control, farmers should take advantage of resistant or tolerant varieties, cultural methods such as ploughing or irrigation to control soil pests, and rotation of crops to slow the build up of pest numbers, before considering a pest control intervention.

Natural biological control

In order to exploit natural biological control farmers need to be aware that such natural enemies are present and useful. In order to explain this to extension staff and farmers, scientists need to know and understand what are the main natural enemy groups, how and why their populations change over time, and what impact they have on pests.

The first question to ask is what known about the natural enemies of *Bemisia tabaci* (Gennadius) (Aleyrodidae) whiteflies in the subject region? From published research quite a lot is known about the situation in Egypt, Israel, Sudan and Syria, but otherwise not much has been published (Tables 1-3). Cataloguing and evaluating the natural enemies in the region should be considered a priority for future surveys and publication.

The results from Sudan are particularly interesting. (6) reports a five year study comparing the incidence of *B. tabaci* and its parasitoids in insecticide treated and untreated cotton fields. He found that *B. tabaci* developed as an early to mid season pest, but that later in the season parasitoids brought it under control. He speculates that were the whole area (the Gezira) not heavily sprayed, parasitoids would move into the crop ecosystem and build up higher levels of parasitism earlier in the season, thus keeping *B. tabaci* under effective control. Further studies were then carried out on 100 ha blocks which were left unsprayed (7). These showed that *B. tabaci* was indeed kept under satisfactory control by its natural enemies.

In contrast it was found in Israel that although *Eretmocerus mundus* and *Encarsia lutea* were the dominant natural enemies, they did not maintain adequate control of *B. tabaci* in pesticide free plots (19). Indeed in some of the plots, parasitism almost disappeared later in the season. While insecticide spray drift cannot be ruled out as a possible explanation, the local conditions including extremes of heat (perhaps mediated through a plant response) offer another.

In Egypt, Abdel-Fattah *et al.* (4) monitored parasitism rates on cotton, soya, cauliflower and tomato for a year. On cotton, they reported four peaks of parasitism between May and October (37, 73, 56 and 43% successively). Parasitism peaked on soya at 41% in June and 65% in August. Parasitism on tomato fluctuated with a maximum of 78% in May. On cauliflower parasitism was even higher with peaks of 81% in October, 84% in December and 57% in February. *Encarsia lutea* was the dominant parasitoid in summer while *Eretmocerus mundus* dominated in winter.

Studies by Abdel-Gawaad *et al.* (5) in Egypt monitored the incidence of natural enemies over two seasons on a variety of vegetable crops in the absence of insecticide applications. The concluded that a complex of parasitoids, predators and disease natural enemies "accounts for the destruction of 80% of *B. tabaci* population", of which parasitoids were most important and disease least important. They noted differences between seasons and crops, and also that natural enemy numbers built up over the season, and were greater in the second successive season. It is difficult to interpret their data further without information on the population dynamics of the whitefly itself during the study period. Exactly how to interpret what 80% destruction means in this context is not clear.

In many parts of Syria, cotton is still grown with minimal use of insecticides. Under this regime *B. tabaci* is not a major pest, and appears to be kept under natural control, suffering high parasitism due to *Eretmocerus mundus* (39). In other parts of Syria where pest control is based on heavy use of insecticides, *B. tabaci* is a major pest.

The indications are that in, at least parts of North Africa, the Near and Middle East, there are common and effective parasitoids attacking *Bemisia tabaci*. While they may not always be adequate to control the pest alone, they are sufficiently important to be able to provide a basis for IPM. The role of predators has yet to be evaluated adequately, but is also likely to be significant.

Classical biological control

Classical biological control is the deliberate introduction of an exotic biological control agent to control a pest, which itself is usually exotic.

The possibilities for use of classical biological control in the region are not very clear. The first step is to establish what natural enemies are already present, so as to evaluate the potential for introduction of exotic species. Even that first step has yet to be taken (or at least published) for many of the countries in the region. The studies which have been carried out suggest that *Eretmocerus mundus* and *Encarsia lutea* can be very common, causing high levels of parasitism in, for example, cotton in Sudan. If countries have a problem with *B. tabaci*, and these two parasitoids are missing from the indigenous fauna, then they should be considered for introduction.

In contrast, it is not so easy to suggest parasitoids to introduce if these two are already present. Many parasitoids of *B. tabaci* are already known from around the World (10), and there is considerable interest at the moment in the potential for classical biological control of *B. tabaci* and *B. argentifolia* in the USA, and various American scientists and their collaborators are introducing a variety of parasitoids from around the World. Over the next couple of years our knowledge of the parasitoids of *B. tabaci* and *B. argentifolia* will grow, and the potential for introduction of these will become clearer. It should be noted that since most of the introductions are being made against *B. argentifolia*, then their success or failure are not necessarily good indicators of likely performance against *B. tabaci*. The add on costs of evaluating these parasitoids against Old World *B. tabaci* are much less than carrying out a separate programme directed solely against *B. tabaci*, and this is a good opportunity for international collaboration.

Augmentative biological control

Augmentative or inundative biological control is the deliberate release of large numbers of a laboratory produced natural enemy to control a pest, particularly at times when natural biological control is not present or is ineffective. The indications are, that although this can be

Table 1. Summary of the published information relating to parasitoids of *Bemisia tabaci* from North Africa, the Near and Middle East*.

Family/ Species	Region	Reference	Comments
Aphelinidae			
Encarsia adriannae Lopez-Avila	Israel etc.	(32)	*E. deserticola* described from Israel is considered a synonym.
Encarsia aspidioticola (Mercet)	Turkey	(10)	A questionable record which needs clarification
Encarsia inaron (Walker)	Widespread	(32)	Widespread in southern Europe, North Africa and Asia.
E. lutea Masi	Egypt	(4)	Most important parasitoid in summer.
		(5)	Population data over two seasons; with *E. mundus* causes up to 57% parsitism.
	Israel	(19)	Together with *Encarsia lutea*, the commonest parasitoids.
	Jordan	(16)	As *Encarsia* sp.
		(34)	As *Encarsia* sp.
	Syria	(39)	Scarce parasitoid in absence of insecticides.
	Sudan	(6)	Important parasitoid, contributing to up to 77% parasitism.
Encarsia luteola Howard	Israel etc.	(32)	An American species introduced into Israel
Encarsia mineoi Viggiani	Egypt, Israel Libya, Sudan	(32)	Distribution records.
Encarsia transvena (Timberlake)	Old World Tropics	(32)	Introduced into Israel.
Encarsia sp.	Egypt	(4)	Uncommon parasitoid.
	Sudan	(6)	Different to *E. lutea*.
Eretmocerus diversiciliatus Silvestri	Sudan	(6)	
		(25)	This specific identification needs confirmation.
		(19)	This is probably also *E. mundus*.
E. mundus Mercet	Egypt	(8)	Record only (as *Eretmocerus* sp.)
		(22)	Most important parasitoid; biology described.
		(4)	An important parasitoid, dominant in winter.
		(5)	Population data over two seasons; with *E. lutea* causes up to 57% parasitism.
	Israel	(19)	Together with *Encarsia lutea*, the commonest parasitoids.
	Syria	(39)	Dominant parasitoid in absence of insecticides, causing up to 85% parasitism; activity greatly reduced by single application of insecticide.
	Sudan	(6)	Important parasitoid, contributing to up to 77% parasitism.

* Pakistan is not treated here; for information on parasitoids see Cock (9) and Mohyuddin *et al.* (29).

Table 2. Summary of the published information relatin to predatory insects attacking *Bemisia tabaci* from North Africa, the Near and Middle East.

Family/ Species	Region	Reference	Comments
Anthocoridae			
Orius albidipennis (Reuter)	Sudan	(6)	Record only.
Orius sp(p).	Egypt	(21)	
	Iraq	(1)	
Cecidomyiidae			
Aphidoletes aphidomyza (Rondani) = Phenobremia aphidivora Rubsquem	Egypt	(5)	Population data over two seasons; a common predator.
Chrysopidae			
Anisochrysa flavifrons (Brauer)	Morocco	(28)	
Chrysopa (s.l.) flava Scopoli	Morocco	(28)	
Chrysopa (s.l.) formosa Brauer	Morocco	(28)	
Chrysoperla carnea Stephens	Egypt	(15)	Also (21)
		(4)	Pupal predator.
		(5)	Population data over two seasons; a common predator.
	Israel	(24)	
	Morocco	(28)	Record only
	Syria	(39)	Commonly observed feeding.
	Sudan	(6)	Most numerous predator.
Coccinellidae			
Coccinellids	Sudan	(6)	Record only.
Coccinella undecimpunctata L.	Egypt	(4)	Larval predator.
		(5)	Population data over two seasons; a common predator.
	Syria	(39)	A common predator on cotton, but not observed to feed on *B. tabaci*.
Scymnus syriacus Mars.	Egypt	(15)	Cited in (4)
		(21)	
		(4)	Larval predator.
Miridae			
Campylomma diversicornis Reuter	Syria	(39)	Commonly observed feeding.
Deraeocoris pallens (Reuter)	Iraq	(1)	
	Israel	Sussman in (18)	
D. punctulatus (Fallen)	Syria	(39)	Commonly observed feeding.
Syrphidae			
Paragus aegyptiacus Macqart	Egypt	(4)	Larval and pupal predator in summer.
Sphaerophoria flavicauda Zett.	Egypt	(4)	Larval and pupal predator in summer.

Table 3. Summary of the published information relating to predatory mites attacking *Bemisia tabaci* from North Africa, the Near and Middle East.

Family/ Species	Region	Reference	Comments
Phytoseiidae			
Phytoseiids	Sudan	(6)	Record only.
Amblyseius aleyrodis El-Badry	Sudan	(13, 14)	
A. chilensis Dosse	Israel	(41)	
A. limonicus Garman & McGregor	Israel	(40)	
A. rubini (Swirski & Amitai)	Israel	(42)	
A. swirskii Athias-Henriot	Israel	(42)	
Eueius gossipi (El Badry) (= *Amblyseius gossipi*)	Egypt	(4) (5)	Larval predator in summer (as Amblyseius sp.). Population data over two seasons; a common predator.
E. hibisci (Chant)	Israel	(41)	
E. scutalis (El Badry)	Morocco Jordan	(26)	
Typhlodromus athiasae Porath & Swirski	Israel	(41)	
T. medanicus El Badry	Sudan	(13)	
T. occidentalis Nesbitt	Israel	(40)	
T. sudanicus El Badry	Sudan	(13)	
Stigmaeidae			
Agistemus exsertus Gonzalez	Egypt	(38)	

done using insect natural enemies, it is likely to be more cost effective using diseases of insects, such as the entomopathogenic fungi.

In fact the only pathogens known to attack whitefly are fungi - probably because fungi can penetrate the insect cuticle, whereas other pathogens need to be injected or ingested. The two pathogens considered of greatest potential are *Beauveria bassiana* and *Paecilomyces fumosoroseus* (36). Both can be mass produced on semi-synthetic media, and applied in the same way as a chemical insecticide, yet because of the use of specialised biotypes have the advantage of host specificity.

Research on the use of myco-insecticides to control whitefly in the field is now mostly at the on-farm testing stage, although the first registered products are starting to appear. Where the economics of a crop justify the costs of an intervention, then a biological insecticide would be a very useful alternative to any broad spectrum insecticide,

Effects of crop varieties on biological control

The interaction between crop varieties and natural enemies is just starting to receive attention. Of particular interest in this field is the case study which cotton provides.

The three most important pests of cotton in Sudan are cotton jassid, principally *Jacobiasca lybica* de Bergevin (Cicadellidae), cotton bollworm, *Helicoverpa armigera* (Hübner)(Noctuidae), and *B. tabaci*. Cotton jassid is actually a term used to cover a range of cicadellids, which are early season pests feeding on the leaves by sucking and causing symptoms known as hopper-burn. They are especially damaging in areas of unimodal rainfall (31) such as the Sudan Gezira. The use of hairy-leaved varieties provides a fair degree of resistance to the cotton jassid and this has been widely exploited where this pest is a problem. This is fortunate because effective indigenous natural enemies are not known - although the potential role has yet to be evaluated for generalist predators such as ants, anthocorids and coccinellids which are the dominant groups of predators in, for eaxample, Kenyan cotton (43, 44).

Trials for resistant varieties have shown that glabrous varieties are less susceptible or less attractive to *B. tabaci* [several references in Cock (9, 10)], in direct contrast with the situation for cotton jassid. Apart from the direct interaction between plant and pest, it may be that some of the observed effects are actually mediated by the interaction with natural enemies. Thus, Sippell *et al.* (35) when comparing cotton varieties of different hairiness, suggested that the smoother varieties provided improved searching conditions for *Encarsia* spp. parasitoids, leading to reduced incidence of *B. tabaci*. Natarajan (30) actually monitored parasitism rates on different cotton varieties. He found significant differences, and that glabrous leaved varieties were associated with increased parasitoid activity, and reduced incidence of *B. tabaci*. Similar observations have been reported by Miliron (27), Gerling (17) and Hulspas-Jordaan and van Lenteren (23). The whole area of interaction between plant varieties, pests and their natural enemies is one that merits considerable attention.

Other IPM measures

Many other approaches to pest control which could be incorporated into an IPM scheme have been suggested and/or tested. These are summarised in Cock (9, 10), and references listed there. The impact on natural enemies of these control methods is likely to depend partially on whether the natural enemies are specialists (feeding or parasitising only whiteflies) or generalists (feeding or parasitising a wide range of arthropods in the crop eco-system). Some control methods would favour natural enemies of one or both categories, some would discourage them, others would be neutral or difficult to predict, since they could act in either way.

Imposition of a closed season and destruction of alternative hosts is likely to adversely affect natural enemies, particularly specialists. Weeds have been condemned as a source of infestation of whitefly (3). This may well be correct, but what role might they play as sources of natural enemies which otherwise may have to move long distances to colonise a whitefly infested crop?

Straw mulch is reported to slow the rate of spread of bottle-gourd mosaic virus, perhaps because it may also encourage generalist predators. Planting crops in isolated situations, particularly upwind from infestation sources will adversely affect natural enemies as well as *B. tabaci*, unless they are maintained on another host. Barriers could act in a variety of ways. Depending upon whether the barrier excludes natural enemies or what proportion they exclude, the effects could act positively or negatively, e.g. a nylon mesh tunnel might exclude whitefly and predators, but allow the entry of parasitoids if whitefly did colonise the tunnel.

If there is a clear whitefly phenology which can be used to time the crop phenology so as to minimise colonisation, this is also likely to have an adverse effect on natural enemies, especially specialists.

Roguing will have a more or less neutral effect upon natural enemies. Rotation is likely to discourage specialist natural enemies, but depending upon the alternate crop could have a positive effect on generalist natural enemies. Trap crops are also likely to encourage the development of natural enemy populations. Indeed the action of natural enemies may be the reason the trap crop prevents the build up of natural enemy populations. Intercropping is likely to have a neutral effect upon natural enemies, but could act positively or negatively on generalists.

Deterrents and the use of neem and oils are also likely to have a neutral or negative effect on natural enemies.

Chemical insecticides are not treated in any detail here [see, for example, Matthews in Cock (9)], but note that delayed sprays, selective chemicals and carefully targeted sprays can all reduce the impact on natural enemies.

Many of these suggestions regarding the impact of other control measures on natural enemies are somewhat speculative. There is scope here for much research in the future.

Integrated pest management

The main challenge is the integration of the various possible interventions, particularly the use of chemical insecticides, with the natural biological control which can form the basis of IPM for *Bemisia tabaci*.

How can the "free" contribution by indigenous natural enemies be exploited? Biological control is compatible with many other control methods, including host plant resistance, most cultural controls, selective chemicals etc.; it is not generally compatible with broad spectrum and persistent chemical insecticides. In the case of a crop where other economically damaging pests are present, and as yet alternatives to chemical insecticides are not available, this presents a problem. Perhaps the best advice for the moment would be to delay the initiation of spraying for as long as possible, while making efforts to find alternative control methods for the other pests.

There are two schools of thought regarding the origins of the devastating outbreaks of *B. tabaci* in Sudan, both linked with the use of chemical pesticides. Abdelrahman and Munir (7) have demonstrated the potential importance of parasitism by growing cotton without insecticides, and conclude that *B. tabaci* is principally a resurgence pest caused by the elimination of parasitoids through the use of chemical insecticides. An alternative view is put forward by Dittrich *et al.* (12) to the effect that the problem is largely due to increased reproduction in response to DDT and resistance of *B. tabaci* to standard chemical insecticides, which can be solved by using new chemicals and implementing an effective resistance management programme.

As is often the case with such disagreements both views are probably correct. However, studies which show that in the absence of pesticide application, *B. tabaci* is adequately controlled by its natural enemies are more fundamental: if chemical control is not needed to control this pest then misuse of chemicals should not be an issue. On the other hand, effective control measures for the other two key pests which can be integrated with this natural biological control are therefore needed. Although the interaction between cotton varieties with hairy leaves, resistant to cotton jassids but susceptible to *B. tabaci*, needs study, the most pressing need is for a selective control strategy for *H. armigera*. This might be through introduction of exotic parasitoids (20), for example *Trichogramma pretiosum* Riley (Trichogrammatidae) into Sudan as suggested by Abdelrahman and Munir (7), by the selection and development of more effective strains of *Bacillus thuringiensis* Berliner (Bacillaceae) (11, 37), or the use of a nucleur polyhedrosis virus (2, 33, 45). Thus paradoxically, the best strategy for control of *B. tabaci* in Sudan may be the development of an effective biological control of *H. armigera*.

In conclusion, *B. tabaci* is a pest subject to a considerable degree of natural control by the action of specialist and generalist natural enemies. This is sufficient to form the basis of an IPM approach to this pest. The challenge will be to integrate control methods for other pests, so that the natural enemies of *B. tabaci* are able to continue to maintain it below the economic threshold.

الملخص

كوك، ماثيو. 1994. الإدارة المتكاملة للمشكلات التي يحدثها الذباب الأبيض في الشرقين الأوسط والأدنى مع التركيز على المكافحة الأحيائية. مجلة وقاية النبات العربية: 12 (2): 127-136

تعتبر المكافحة الأحيائية مكوناً رئيساً لبرنامج الإدارة المتكاملة للذبابة البيضاء *Bemisia tabaci*. وسيركز الباحث على الأدوار الممكنة للمكافحة الأحيائية الطبيعية والتقليدية والمتزايدة، مع تلخيص لكل السجلات المنشورة عن الأعداء الطبيعية في شمال أفريقيا والشرق الأوسط والأدنى. وسيميز الباحث بين الأعداء الطبيعية المتخصصة والعامة، وسيناقش الآثار المحتملة لطرائق الإدارة الأخرى للآفات في مجموعتي الأعداء الحيوية.

كلمات مفتاحية: *Bemisia tabaci*، أعداء حيوية، مكافحة متكاملة.

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