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Natural enemies associated with some economic pests in Egyptian agro-ecosystems

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Abstract

No doubt, there are changes in insect pest problems facing the farmers in the newly reclaimed land as well as in the old valley in Egypt due to different reasons, e.g., pesticide misuse and pest resistance, secondary pest outbreaks, absence or inefficient presence of natural enemies, and climate changes. Since the 1990s, the Ministry of Agriculture and Land Reclamation emphasizes to spread the philosophy of integrated pest management (IPM) among the farmers to utilize all suitable means, techniques, and approaches for maintaining pest population levels below those causing economic losses. Among these means is understanding the role of natural enemies in the agro-ecosystem to preserve and encourage their presence and enhance their role in suppressing pest populations as a main factor among the IPM strategies. Thus, it is of essential need to know more about the existing natural enemies associated with the key pests of the economic crops representing different agro-ecosystems in Egypt to develop a successful utilization of biological control agents within the frame of such IPM programs. Thus, it was found necessary to update their recent status as natural resources in various agro-ecosystems. These data are considered a review article eagerly needed for strategies of IPM of serious insect and mite pests in Egypt. The role of the biological control agents, mainly parasitoids and predators in different economic crops, is highlighted.

Background

The intensification of land reclamation for agriculture in Egypt in the last four decades is continuing to meet the needs of the growing human population in the country. Such agricultural development requires contribution of all related agricultural sciences, especially those of plant protection. No doubt, there are changes in insect pest problems facing the farmers in the newly reclaimed land as well as in the old valley due to different reasons, e.g., pesticide misuse and pest resistance, secondary pest outbreaks, climate changes, and absence or inefficient presence of natural enemies. Since the 1990s, the Ministry of Agriculture and Land Reclamation emphasizes the philosophy of integrated pest management (IPM) among the farmers to utilize the suitable means, techniques, and approaches for maintaining pest population levels below economic losses. Among these means is understanding the role of natural enemies in the agro-ecosystem to preserve and encourage their presence and enhance their role in suppressing pest populations as a cornerstone within the IPM strategies. Thus, it is of essential need to know more about the existing natural enemies associated with the key pests attacking economic crops representing different agro-ecosystems in Egypt to develop a successful utilization of biological control agents within the frame of IPM programs.

The various biocontrol agents recorded in the unpublished list titled "List of natural enemies of various insect pests recorded in Egypt" by Tawfik and Awadallah (1992) and the survey followed by Tawfik (2002) are mentioned here apart from their actual validity and efficiency against their prey/host species in the environment. El-Husseini (2015) shed light on the most important effective native and introduced parasitoid and predatory species of main economic insect pests in Egypt. Thus, it was found necessary to update their more recent status as natural resources in various agro-ecosystems.

The presented data could be considered a review article eagerly needed for integrated control of serious insect and mite pests in Egypt.

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Investigated agro-ecosystems

Field crops

Cotton fields

The cotton leafworm, *Spodoptera littoralis* (Boisd.) (Noctuidae), and the bollworms, especially the pink bollworm, *Pectinophora gossypiella* Saund. (Gelechiidae), and the spiny bollworm, *Earias insulana* Boisd. (Noctuidae), may be, fairly, considered the most injurious pests in cotton fields in Egypt (Hafez et al. 1969).

From extensive samples of all immature forms of the cotton leaf worm collected by Hafez et al. (1976) from cotton fields in all Egyptian Governorates, the main parasitoid species secured were the braconid parasitoids, *Chelonus inanitus* (L.), *Apanteles ruficrus* (Haliday), and *Microplitis rufiventris* Kok.; the ichneumonid *Zele chlorophthalma* (Nees); and the tachinids *Exorista larvarum* (L.) and *Strobliomyia aegyptia* Vill., emerged from the host larvae and pupae. No parasitoids emerged from the host eggs. *Trichogramma evanescens* West. and *T. minutum* Riley were reported earlier by Kamal (1951) as parasitoids of *S. littoralis* eggs on cotton. As an evaluation, it seems that, nowadays, the parasitoid complex of *S. littoralis* does not play an efficient role in controlling the population of this pest in Egypt, as it was used in the earlier years. Before the excessive use of pesticides, parasitoids used to cause as high as 75% mortality among the collected leaf worm populations of the winter brood and approximately 32% during the summer months (Kamal 1951). The deterioration of parasitism rate is, most probably, attributed to the widespread use of chemical pesticides, particularly in cotton fields, which receive about 70% of the total amount of pesticide applications, used for pest control in all cultivated crops combined (El-Heneidy et al. 2015). The most important feature in the pattern of parasitism upon the larvae of *S. littoralis* is represented by the change of the leading species from the two tachinnids *E. larvarum* and *S. aegyptia* in the past to the abovementioned braconid parasitoids (Hassanein et al. 1985). Recently, the high host fraction of parasitism is caused by *M. rufiventris* (25–82%), followed by *C. inanitus* (32–53%), and the lowest by the ichneumonid *Z. chlorophthalma* which is found in extremely low densities.

The bollworms *P. gossypiella* and *E. insulana* are the most injurious pests in cotton; the former is distributed all over the country, while the latter is more common in Upper Egypt. As for *P. gossypiella*, the hymenopterous parasitoids *Exeristes roborator* Fabr. (Ichneumonidae), *Chelonus sulcatus* Nees, *Bracon brevicornis* Wesm., and *Apanteles platyedrae* Wlk. (Braconidae) and the pyemotid mite *Pyemotes herfsi* Oud. were reported also, by Hafez et al. (1969). *E. roborator* is distributed in both Lower and Middle Egypt, as there is no evidence of its occurrence south in the Governorates of Upper Egypt. It has 6–15 generations/year, in comparison to about 6 generations of the pink bollworm. The fourth generation of *P. gossypiella* which dominates almost all the month of September is highly parasitized, while its sixth generation, which appears in November, extends for about 4 months during which the majority of larvae enters into diapause from October to just before the host breaks its resting period in April/May. Thus, the newly emerged parasitoid females deposit their eggs on the diapausing bollworm larvae within dry bolls where the parasitoid progeny develops during spring on these larvae. The rate of parasitism by *E. roborator* on *P. gossypiella* was relatively low (9.7% at the maximum), and its active period on this host during cotton season in the field was relatively short (1–2 months/year). It attacks only the full-grown larvae in dry bolls; its direct effect on the host is rather restricted, and its role is to affect the population of the host of the subsequent season but not to prevent the direct injury which occurs in the green bolls. Other parasitoids, i.e., *C. sulcatus*, *A. platyedrae*, and *B. brevicornis*, have the same role, but they are less abundant. The first parasitoid, *C. sulcatus*, is found all over Egypt, increases in September, just after harvesting cotton, and its activity continues during October and early November. The second one, *A. platyedrae*, is more distributed in Upper Egypt than in Lower Egypt. The parasitic mite, *P. herfsi*, distributes in all cotton-growing Governorates where it attacks resting larvae of the pink bollworm in dry bolls or within infested seeds by the end of the season. It plays an important role in reducing populations of this pest; 84% parasitism was reported for this active biocontrol agent (Farrag 1976). Metwally and Shenouda (1976) stated that no more than 6% of the active larvae of *P. gossypiella*, found on cotton squares, flowers, and bolls, died, mostly by factors other than the parasitoids and predators. About 96% of the diapausing larvae were killed, during the resting period by the aforementioned parasitoids. These agents, as shown above, play their role at the end of the season and thus do not prevent the direct injury that occurs in the green bolls during the season. For this reason, efforts have been directed towards introducing egg or egg-larval parasitoids capable to do the job or towards augmentation of endemic egg-larval parasitoids, as *C. sulcata.*

No accurate information is published, hitherto, concerning the role played by the indigenous natural enemies against the spiny bollworm, *E. insulana*. A survey was conducted by Eid (1992) to shed light on this aspect and showed that this pest is not suffering from the endemic parasitoids, which are of very rare occurrence and represented, mostly, by the egg parasitoid *T. evanescens* West. and an unidentified egg-larval parasitoid belonging to the genus *Chelonus*, which reproduce parthenogenetically. The American cotton bollworm, *Helicoverpa armigera* Hübner (Noctuidae), is accidentally distributed

as it is under effective control by several parasitic species, i.e., the braconids *A. ruficrus*, *B. brevicornis*, and *M. rufiventris*; the ichneumonids *Barylypa humeralis* Brann., *B. rufa* Holargon, and *Campoplex xanthostoma* Grav.; an encyrtid polyembryonic parasitoid *Copidosoma* sp.; and the tachinids *E. larvarum* and *S. aegyptia* (Final report of the Egyptian project on natural enemies of *H. armigera* in Egypt).

Through an American-Egyptian collaboration project titled "Cotton IPM with emphasis on biological control of bollworms" carried out between 1991 and 1994 directed by El-Heneidy, the role of some exotic parasitoid species, the egg parasitoid *Trichogrammatoidea bactrae* (N.) and the two larval parasitoids *Goniozus legneri* Gordh and *G. pakmanus* (G. Gordh & Ellington), in controlling the pink bollworm was evaluated. Mass rearing and releases of these parasitoids took place in two Governorates (Kafr El-Sheikh and Sharkia). Through an Egyptian Histological arthritis severity in recipientproject entitled "Evaluation of exotic parasitoids against the pink bollworm (PBW) *P. gossypiella* in cotton," carried out between 1997 and 2000, percentage of infestation with PBW on cotton plants declined by 36 and 55% (El-Heneidy and Abdel-Hafez 2001). The first two parasitoids have been well established and became already available in the Egyptian agro-ecosystems. Some researchers have made significant contributions to the aspect of biological control of cotton bollworms by parasitoids: Abd El-Hafez et al. (2002), Mesbah et al. (2003), El-Heneidy et al. (2004), and Hend et al. (2016), as already several mass-rearing units, governmental and private, for *Trichogramma* spp. have been established and distributed in most of the cotton regions in the country, as well as El-Husseini et al. (2008a), who successfully applied *T. evanescens* for controlling pink and spiny bollworms in fields of organic cotton production in Egypt.

A suggestion was reported by El-Husseini et al. (2000) to leave stripes of clover (15–20 m wide) for seed production between cotton fields each 50 or 100 m. These stripes served in attracting large populations of different beneficial insects mostly *Orius* spp., especially during clover flowering period, and became the source from which they moved by clover dryness to the adjacent cotton fields (mid-May/June) on each side performing a successful suppression of all cotton pests during this period.

Agrotis ipsilon Rott. (Lepidoptera: Agrotidae) is the most abundant species of cutworm seedlings in Egypt, and it is relatively considered one of the most injurious pests of cotton seedlings. A survey carried out by El-Heneidy and Hassanein (1987) showed two endoparasitoids, *Apanteles ruficrus* Hal. and *Meteorus rubens* Nees, found attacking larvae of this pest. However, percentages of parasitism were not high, reaching a maximum of (27.7%), and *M. rubens* appeared more active than *A. ruficrus.*

The cotton whitefly, *Bemisia tabaci* (Genn.), has recently developed to a rather serious pest on several crops including cotton because of the expansion in application of organic pesticides, especially pyrethroids, presumably leading to change in the natural balance between pests and their natural enemies. A survey carried out in cotton fields during 1983–1984 exhibited three parasitoid species attacking *B. tabaci*, *Prospaltella lutae* Masi, *Eretmocerus mundus* Mercet, and *Encarsia artenopae* Masi. *E. mundus* appeared very active, playing a main regulating factor of population of this pest in cotton fields (Hafez et al. 1978–1979), where (46%) parasitism was recorded in Lower Egypt and (59–71%) in Upper Egypt. A high rate of parasitism (98%) was also reported for this parasitoid against the pest on *Lantana camara* Linnaeus, which was unexposed to pesticide treatment. In 1984/1985, the average rate of parasitism decreased to 7.9–33.8% on larvae and 44.2–60.6% on pupae of *B. tabaci* because of the intensive use of pesticides in cotton fields.

The cotton aphid, *Aphis gossypii* Glover, became more abundant with recent intensive applications of insecticides. The parasitoid species found associated with this pest in cotton fields are still unstudied, most probably due to their uncommon existence. Two species, one belonging to the genus *Aphelinus* and the other to *Aphidius*, were reported (Abul-Nasr and El-Nahal 1963).

Many predatory species exist in cotton fields where they play an important role against most of the pests attacking this crop (El-Heneidy et al. 1996, 1997). This group of predators consists of the dermapteran, *Labidura riparia* Pallas; the hemipterans, *Onocephalus pilicornis* H.S. (Reduviidae), *Orius albidipennis* Reut., and *O. laevigatus* Fieb. (Anthocoridae); and the neuropterans, *Chrysoperla carnea* (Steph), (Chrysopidae) and *Helicomiitus festivus* Ramb. (Ascalapidae); the coleopterans, *Calosoma chlorostictcum* De Geer (Carabidae), *Chilomenes vicina* Muls, *Coccinella undecimpunctata* L., *C. septempunctata* L., *Scynmus interruptus* Goeze and *Scymnus syriacus* Mars. (Coccinellidae), and *Paederus alfierii* Kock. (Staphylinidae); the dipterans, *Phenobremia aphidivora* Rubs (Cecidomyiidae), *Paragus aegyptius* Macq., and *Sphaerophoria flavicauda* Zett. (Syrphidae); and lastly, the phytoseiid mite *Amblyseius gossipi* El-Badry. Among these agents, the most common are *L. riparia* against larvae and pupae of lepidopterous pests; the anthocorids against egg masses of *S. littoralis*; the chrysopids against aphids, whitefly, and mites; and *Am. gossipi* against eggs and larvae of the whitefly. Based on 28S rDNA, Gamila et al. (2016), molecularly, identified five coccinellid species from field crops at Giza region, i.e., *Coccinella undecimpunctata*, *C. septempunctata*, *Cydonia vicina isis*, *C. vicina nilotica*, and *Hippodamia variegata.*

Since the 1990s, the applied IPM program in cotton fields depends mainly on avoiding pesticide use against the early- and middle-season cotton pests (the sucking insects and *S. littoralis*) to conserve and enhance the role of parasitoids and predators that migrate from the clover fields to the cotton fields (by May and June). Use of pesticides is only recommended in case of exceeding the economic threshold of the infestation rate with bollworms (3–5%).

Corn fields

The most detailed work on the insect fauna of corn fields was that carried out in Giza by Tawfik et al. (1974). Their studies showed that corn fields are inhabited by representatives of 66 families from 14 orders. About 40 of these species have been recorded as corn feeders. Among them, the three corn borers *Sesamia cretica* Led., *Chilo agamemnon* Bles, and *Ostrinia nubilalis* (Hb.) and the aphid species *Macrosiphum (=Sitobion) avenae* F., *Rhopalosiphum padi* L., and *R. maidis* Fitch. are considered the major pests of corn plants in Egypt. Sometimes, and in some areas, the cotton leafworm *S. littoralis*, the greasy cutworm *A. ipsilon*, and the mole cricket *Gryllotalpa gryllotalpa* L. could be destructive to these plants. However, the pest status in corn fields is associated with the existence of 42 beneficial species which play efficiently, as biological control agents, against these pests. Aphids are controlled by several predaceous species, such as the nymphs and adults of the anthocorids *Orius albidipennis* Fieb. and *O. laevigatus* Fieb. (the former is more common than the latter); adults of the staphylinid *Paederus alfierii* Kock.; larvae and adults of the coccinellids *Cydonia (=Chilomenes) vicina* var. *isis* Cr. and *var. nilotica* Muls, *Coccinella undecimpunctata* L., *Scymnus interruptus*, and *S. syriacus*; larvae of the syrphids *Syrphus corollae* Fabre, *Sphaerophoria flavicauda* Zett, and *Paragus aegyptium* Macq.; and larvae of the octhiphilid *Leucopis puncticornus aphidivora* Rond. Aphids, on corn, are parasitized by the braconid species *Aphidius sonchi* Marsh and *Praon flavinoda* Hal.

In Egypt, the three corn borers represent the most serious pest species of corn plants that cause high damages. Egg masses and newly hatched larvae of the aforementioned corn borers, and other lepidopterous pests, are subject to attacks by the anthocorids, the coccinellids, and the rove beetles mentioned above. However, coccinellids prefer aphids than lepidopterous pests, while syrphids are more restricted to aphids and are less frequently distributed. An anthocorid, namely, *Blastostethus piceus pallescens* Poppius, an accidentally introduced species, is commonly found attacking the larvae of *Pyroderces simplex* Wlsm. on the ears. Tawfik and El-Sherif (1969) found that larvae of *P. simplex* feed during the early stages on young leaves, silk, and pollen grains of maize but old larvae bore into the kernels inducing serious damage to the ears. A braconid wasp belongs to the genus *Psychotria* was found frequently parasitizing these larvae. This parasitoid plays together with the aforementioned anthocorid predators an important role in controlling the population of this pest.

A group of parasitoids consists of *Platytelenomus hylas* Nixon, *Conomorium eremita* Foerster, and *T. evanescens* present in the fauna of corn plants; the first is specific egg parasitoid on *S. cretica*, the second parasitizes pupae of the same pest, and the third is well known as egg parasitoid of most lepidopterous pests but prefers eggs of *C. agamemnon* and *O. nubilalis* more than *S. cretica.* Economic importance of the egg parasitoid *P. hylas* on the eggs of *S. cretica* was assessed in Egypt, by Hafez et al. (1979) during the period 1968–1971. It was found that in most cases, almost all natural mortality of the borer eggs was caused through parasitism by *P. hylas.* Rate of parasitism starts very low at the beginning of the season, during April and May, and reaches a peak of accumulated parasitism late in the season during September and October when the parasitoid starts to hibernate within the host eggs. During the 4 years of work, the highest rates of parasitism ranged between 92 and 95% in autumn. At certain localities, these rates reached 100% during August–October. El-Heneidy and Hassanein (1992) recorded the gregarious braconid parasitoid, *Meteorus rubens* Nees, for the first time in Egypt, on larvae of *S. cretica* in maize fields at Giza Governorate.

Mass production and release of *T. evanescens* induced efficient control of *C. agamemnon* in corn, rice, and sugarcane fields and is one of the successfully achieved programs for using biological control agents in Egypt (El-Heneidy et al. 1991).

Faunal work in corn fields at Mansoura Governorate, carried out by Ragab (1988), showed most of the beneficial species mentioned above, in addition to the dermapteran, *Diaperasticus erythrocephalus* (Olivier) (Forficulidae), as first recorded species predaceous upon aphids, egg masses, and young larvae of corn borers. This forficulid was studied by Tawfik et al. (1995), and their observations revealed its predaceous and phytophagous feeding habits. On the other hand, Lutfallah and Kares (1988–89) reported the braconid *Bracon brevicornis* (Wesm.) as a larval parasitoid of *O. nubilalis* and *C. agamemnon*, in addition to most of the predators mentioned above. *B. brevicornis* was also recorded, as an efficient parasitoid, on the hibernated larvae of corn borers in dry corn stalks during winter (Abd El-Gawad 2000).

A survey on the soil inhabiting predaceous arthropods of *Sesamia* pupae in sorghum fields, carried out by Temerak (1978–1979), included many predators, i.e., *Labidura riparia* Pallas and *Labia minor* L. (Dermaptera; Labiduridae), and the coleopterans, *Agrypnus notodonta*

Latr. and *Drasterius binaculatus* Ros(Elateridae); *Paederus alfierii*, *Philonthus misor* Rossi, *Ph. turbidus* Er., and *Scopaeus debilis* Koch (Staphylinidae); and *Gonocephalus* sp. and *Opatrum punculatus* Braull (Tenebrionidae), and the true spiders *Lycosa ferox* Lucas., *L. urbana* apo, *Paradosa ventrix* Lucas (Lycosidae), and *Paradosa* sp. (Areneidae). Corn plants are good shelters for many harmful and beneficial insects, during adverse environmental conditions. Small aggregations of *C. undecimpunctata* adults were observed by Tawfik et al. (1974) during May hidden at the bases of leaves when climatic conditions were unsuitable for aphids' existence.

In the applied IPM program in maize fields, the present recommendation of the Ministry of Agriculture refers to delaying the sowing date to be between mid-May to mid-June, to avoid the high infestation by the first generation (exit from the hibernation) of *S. cretica* to the corn plants. This undoubtedly can help the natural enemies' conservation in this agro-ecosystem.

Cereal fields

Cereal plants (wheat and barley) are attacked by few numbers of pests; the most injurious are aphids. El-Heneidy and Attia (1988–1989) reported five aphid species: *Schizaphis graminum* (Rond), *Sitobion avenae* F., *Rhopalosiphum maidis* F., *R. padi* (L.), and *Diuraphis noxia* Mord. as main pests of wheat plants in Beni Suef and Fayoum Governorates. High rates of infestation occur during March. Two hymenopterous species, *Diaeretiella rapae* M. and *Aphidius* spp. (Fam. Braconidae), were found parasitizing these aphid species. Percentages of parasitism reported were low, ranging between 6 and 9%. The authors reported that the aphidophagous predators, *C. undecimpunctata*, *Scymnus* spp., *Ch. carnea*, *P. alfierii*, and true spiders, increased gradually towards the end of the season and peaked during April. Dominant occurrence of *C. undecimpunctata* was quite clear during the season. In Giza and Kafr El-Sheikh, Ibrahim and Amal (1991a) recorded the primary parasitoids, *Aphidius matricariae* Hal., *A. uzbekistanicus* Luz., and *Praon gallicum* Hal., associated with *Sitobion avenae* F.; *A. matricariae* was the most dominant one. These parasitoids were subjected to be attacked by four secondary parasitoids namely, *Alloxysta* sp., *Phaenoglypha* sp. (Cynipidae), *Asaphas* sp., and *Pachyneuron* sp. (Pteromalidae). Ibrahim (1990) previously reported these primary and secondary parasitoids for the aphid *S. graminum* in wheat. Five syrphid species were secured, i.e., *Metasyrphus* (=*Syrphus*) *corollae* Fabr., *Lasiophthious* (=*Scaeva*) *albomaculata* Macq., *Sphaerophoria flavicauda* Zett., *Xanthogramma aegyptium* Weid., and *Paragus aegyptius* Macq. This group proved as the first dominant aphidophagous predators. There were the coccinellids, *C. undecimpunctata* and *Chilomenes vicina* var. *isis* and var. *nilotica*; the first species was the highest in abundance, and the chrysopid, *C. carnea*, occupied the lowest status among all the collected predators (Ibrahim and Amal 1991b). El-Heneidy et al. (2001b) published an extensive survey of the primary and secondary parasitoid species on key wheat aphid species in most of the wheat cultivations in Egypt (12 Governorates), which covers most of those reported by other authors including the Aphidiidae *A. matricariae* Haliday, *A. colemani* Viereck, and *D. rapae*. Mc'Intosh, *Paron necans* Mackauer, *Ephedrus persicae* Haliday, and *Trioxys* sp.; the Aphilinidae *Aphelinus albipodus* Hayat & Fatima and the secondary parasitoids; the cynipid *Alloxysta* (Chalcidididae); the pteromalids (*Asaphes* and *Pachyneuron*); and the encyrtids *Aphidencyrtus* sp., Megaspilidae, and *Dendrocerus* (=*Lygocerus*) sp. They found that the aphidiids and the aphelinids were represented by 96.3 and 3.2%, respectively. The genus *Aphidius* (*A. matricariae* and *A. colemani*) predominated slightly over the other genera of Aphidiidae (35.5%), followed by *Diaeretiella* (34.4%). *D. rapae* was followed by *P. necans* (25.6%). The cynipids were the most dominant secondary parasitoid species (78.1%), followed by the chalcids (9.7%). Obtained data showed that the total percentage of hyperparasitism all over the country (12 Governorates) reached 21.2%. Native *Aphelinus* sp. which emerged from cereal aphid species, collected from Egyptian wheat fields, was identified as *Aphelinus albipodus* Hayat and Fatima (Adly 2008).

On barley, Ibrahim (1990) recorded four aphid species, i.e., *S. graminum*, *R. maidis*, *R. padi*, and *S. avenae*, parasitized by the three hymenopterans, *A. matricariae*, *P. gallicum*, and *A. uzbekistanicus*. These primary parasitoids were found playing an important role against the aforementioned aphids, especially by the end of March, when *A. matricariae* was the most efficient species (60–64% parasitism), while the least efficacy was reported for *P. gallicum* (27–25%). However, the primary parasitoids were attacked by the four secondary ones previously mentioned in the case of wheat fields, added to them a fifth one namely *Dendrocereus* sp. (Megaspilidae). *Alloxysta* sp. was the most predominant hyperparasitoid as in wheat fields. Same occurrence of the abovementioned predators on wheat was reported for barley.

A comprehensive work was given by El-Heneidy and Adly (2012) as a review article concerning aphid parasitoid species infesting cereal crops and their weeds in Egypt. They indicated their seasonal abundance as well as their economic thresholds and efficiency of insecticides against their natural enemies and recorded the primary and secondary parasitoids and predators which were recognized in Egypt.

Recently, Neveen et al. (2017) reported 11 aphidiine parasitoid species, belonging to six genera (*Aphidius* Nees, *Binodoxys* Mackauer, *Diaeretiella* Starý, *Ephedrus*

Haliday, *Lysiphlebus* Foerster, and *Praon* Haliday) from three aphid species [*Rhopalosiphum maidis* (Fitch), *Rhopalosiphum padi* (L.), and *Sitobium avenae* (F.)], feeding on four cereal plants (*Avena sativa* L., *Hordeum vulgare* L., *Triticum aestivum* L., and *Zea mays* L.) in Egypt. They provided a key, indicating the tritrophic (parasitoid-aphid-plant) associations of the recorded aphidiines and their distribution in the target area. Among the emerged parasitoids, *Aphidius ervi* Haliday was a new record for the fauna of Egypt. *Aphidius transcaspicus* Telenga and *Binodoxys angelicae* (Haliday) were reported for the first time to be associated with aphids infesting cereals in Egypt.

Rice fields

In Egypt, rice is subjected to infestation by several species of pests among which the most common are the blood worm *Chironomus* sp., maggots of the tabanid *Atylotus agrestis* (Wied.), and the rice stem borer *Chilo agamemnon* Bles. By several practices towards the first pest, it became possible to get very satisfactory cultural control results. *A. agrestis* could be found in enormous numbers in the field, particularly when livestock manure is used for fertilization. Level of infestation becomes lower in early-planted fields and in less susceptible varieties to infestation. No biological control agents are reported, hitherto, for both pests. The rice stem borer *C. agamemnon* is considered the most destructive to rice plants. Estimated losses in rice yield in Egypt due to this pest range between 3 and 7%. These losses differ considerably according to variety, date of sowing, locality, and rate of nitrogen fertilization (Sherif et al. 2005).

There are many natural enemies, which play an important role against rice pests, especially *C. agamemnon* (Tantawy; personal communication). There are two species of true spiders; one belongs to the genus *Lycosa* (Fam. Lycosidae) and the other is *Areneus inustus* (Fam. Araneidae), both predating on moths of the rice stem borer, the cotton leaf worm, and the rice butterfly. Some predaceous insects are also found in the rice fields feeding vigorously on eggs and young larvae of these insects. Among these predators are *Reduvius pallipes* (Reduviidae), the staphylinid *Paederus alfierii* Koch., and some anthocorids. It appears, also, that the egg parasitoid *T. evanescens* West. plays a promising role against the stem borer, especially late in the season (time of the fourth generation of this pest). Consequently, a natural range of parasitism (95.5–96.2%) was recorded (Sherif et al. 2005). Accordingly, it was recommended, in the first symposium of the Egyptian Society of Biological Control of Pests (ESBCP) that was held in Cairo in February 1992, not to undertake any insecticidal application in rice fields, except when degree of infestation with the rice stem borer exceeds the economic threshold <) 7%(. In the frame of the IPM program in rice fields, utilization of *T. evanescens* through inundative releases has been highly recommended in case of high infestation with the pest.

Sugarcane fields

A survey of the insect fauna of sugarcane fields in Upper Egypt referred to 13 insect genera as sugarcane feeders (Ezzat and Atries 1967). These are *Aiolopsis* and *Locusta* (Acrididae), *Labia* (Dermaptera), *Phyllodromia* (Blattidae), *Geotomus* (Cydnidae), *Empoasca* and *Exitianus* (Jassidae), *Tropidocephala* (Delphacidae), *Chilo* (Grambidae), *Pelopidus* (Hesperiidae), *Leucania* (Noctuidae), *Dorylus* (Formicidae), and *Pentondon* (Scaraebidae). The authors mentioned that although the apparent serious damage to sugarcane in Egypt is mainly due to the lepidopterous sugarcane and corn borer *Chilo agamemnon* Bles., all other pests in the aforementioned genera had different degrees of importance. However, the fauna included a considerable number of useful insects providing the bright aspect of the picture. The most reliable species in this beneficial group are concentrated in the orders Hemiptera, Neuroptera, Diptera, Hymenoptera, and Coleoptera. From Hemiptera, the anthocorid *Orius* sp.? *niger* is known as predator on insect eggs, mites, small insects, and aphids. Two reduviids, *Oncocephalus notatus* Klug and *Pirates sterpitans rufipennis* Lucas, were also reported as bloodsuckers of other insects. In Neuroptera, *Chrysopa vulgaris (=Chrysoperla carnea)* Steph. and *Cueta variegata* Klug were recorded. The former species is also known as predaceous on the sugarcane mealybug, *Saccharicoccus sacchari* Ckll., and other pests. Among Diptera, two syrphids were recorded, *Syritta spinigera* Loew and *Syrphus corollae* F., which are known to be predaceous upon aphids and nymphs of other homopterous insects. Also, the sarcophagid *Sarcophaga rapax* Walk. was recorded; it plays a role in controlling the sugarcane moth borer, *Diatraea saccharalis* Fabricius. Among the Hymenoptera, members of family Ichneumonidae include *Diplazon laetorius* Fabr. and *Barylypa humeralis* Branus (L.P.); the first is known as a parasitoid of syrphids and the second of Lepidoptera. A single parasitic species was reported for either Encyrtidae or Trichogrmmatidae, i.e., *Homalitylioidae* and *T. evanescens*, respectively. Since the 1980s, great efforts have been carried out by the Ministry of Agriculture to utilize this parasitoid *T. evanescens* against *C. agamemnon* in sugarcane fields by mass rearing and inundative releases of the parasitoid through 14 mass-rearing units, covering all the sugarcane areas (300,000 feddans = 120,000 ha) (El-Samea and Saadia 2002). Through the implementation of this program, the infestation with *C. agamemnon* in sugarcane fields was reduced successfully from 17 to > 3% in almost all the sugarcane fields. In the above authors' list, other hymenopterous species of known beneficial role are present, i.e., *Myzine arabica* Guer. (Scoliidae) that

works as ectoparasitoid on larvae of Scarabidae; *Chrysis* sp. (Chrysididae) parasitizes certain caterpillars; *Eumenes maxillosa* F. (Eumenidae), *Ammophila tyedi* Guill., *Liris praetermissa* Rich, *Phillanthus triangulum abdelkader* Luc., and *Sceliphron sprifex* L. (Sphecidae) feeders on collected young lepidopterous larvae; and *Paracyphononyx ruficrus* Klug and *Pompilus* sp. (Pompilidae) known as predators of spiders. Among the Coleoptera, the coccinelids *Chilomenes vicina* Muls, *C. undecimpunctata*, and *Scymnus syriacus* (Goeze) are well known as predators in sugarcane fields in different parts of the world. The authors mentioned that the first coccinellid attacks different young insects; the second mainly attacks the mealybugs *S. sacchari* and *Symicoccus bonsis*, while the third feeds on coleopterous pests. The two staphylinids, *Paederus alfierii* Koch and *Philonthus longicornis*, were also reported; the first is a well-known predator of insect eggs and young larvae or nymphs or insect pest, and the latter most probably feeds on insect stages inhabiting the soil, e.g., pupae of *Chilo.* Five carabids, *Calosoma levantinus leavistriatus* Schatz., *Broscus punctatus* Dej., *Calosoma rugosum chlorostictum* Klug., *Microlestes* sp., and *Tachys lucasi* Duv., were included in the list. Their activity is restricted in feeding on various stages of insects inhabiting soil.

From the aforementioned data, it becomes obvious that the insect fauna in sugarcane fields in Upper Egypt includes numerous insect groups, few of which are causing some damage and the rest of other groups forming a complex of species of possible benefit. No pesticide treatments are carried out in sugarcane fields, and thus, some kind of conservation of biocontrol agents is taking place. However, the most destructive species in these fields consist mainly of the borer *C. agamemnon* and partially the mealy-bug *S. sacchari.* The former pest is now controlled by inundative releases of the egg parasitoid, *T. evanescens*, and the populations of the latter pest are associated with a newly recorded predator, *Diaperasticus erythrocephalus* (Olivier) (Dermeptera; Forficulidae), found by Ragab (1988) in Lower Egypt (Dakahlia Governorate). El-Serwy (2002) stated that the red-striped soft scale, *Pulvinaria tenuivalvata* (Newstead) (Hemiptera: Coccidae), on sugarcane is parasitized by *Coccophagus semicircularis* (Foerster) (Aphelinidae); *Metaphycus flavus* (Howard), *Microterys* sp., and *Microterys nietenri* (Motschulsky); *Diversinervus elegans* Silvestri (Encyrtidae); and *Pachyneuron muscarum* (Linnaeus) (Pteromalidae). The highest rate of parasitism upon females of this pest at El-Aiat (Giza Governorate) reached 90, 77.3, and 75% in late October, mid-November, and early January. The corresponding rates at Atfieh at the same Governorate were 56, 60.7, and 58.3% and attained the highest rate of 78% by late January. On nymphs, the rates were 40.6, 98.7, and 100% by late November, December, and January, respectively, and attained the highest rate of 78% by late January.

On the other hand, seven predators, *Scymnus glivifrons* Muls. and *Stethorus punctillum* Wiese (Coccinellidae), *Phaleria* sp. (Tenebrionidae), *Ch. carnea*. (Chrysopidae), *Orius laevigatus* (Fiebe) (Anthocoridae), *Anatrachyntis rileyi* (Walsingham) (Cosomopterigidae), and an unidentified ceccidomyiid, were found associated with this pest at the same location. Also, four predaceous mites, *Amblyseius swirski* Athias–Henroit and *Typhlodromus pelargonicus* (Phytoseiidae), *Agistemus exsertus* Gonzalez (Stigmaeidae), and *Anystus* sp. (Anystidae), were recorded (Karam and Sanaa 1992).

Clover fields

Egyptian clover, *Trifolium alexandrinum* L., is the principal forage crop in Egypt, and thus, no chemical control applications against pests take place on it. In a survey of insect fauna of this crop carried out by Tawfik et al. (1976b) at Giza, 35 species of parasitoids and predators were recorded. These agents are undoubtedly protected. The predators are as follows: *Orius* spp. (Anthocoridae); *Deraecoris punctulaus* (Miridae); *Geocoris megacephalus* (Lygaeidae); *Ch. carnea* (Chrysopidae); *Bembidion* sp. (Carabidae), *Paederus alfierii* Koch., *Platystethus degener*, *Carpelimus* sp., and *Tachyperu* sp. (Staphylinidae); *Coccinella undecimpunctata* L., *C. septempunctata* L., *Cydonia vicina* var. *nilotica*, and *Scymnus interruptus* (Coccinellidae); *Anoplius infuscatus* Goeze (Pompilidae); *Vespa orientalis*, *Polistes gallica* (Vespidae), and *Platypalpus* (Empidae); and *Syrphus corollae* Fabr., *Sphaerophoria flavicauda* Zett., *Xanthogramma aegyptium* Wied., and *Paragus aegyptius* Macq. (Syrphidae). The commonly occurring predators are *C.carnea*, *P. alfierii*, *C. undecimpunctata*, and *S. corollae*, while the occasionally occurring ones are *Orius* spp., *S. interruptus*, *S. flavicauda*, *Xanthgramma aegyptium*, *Paragas aegyptius*, and *Platypalpus* sp.

Parasitoid species found in clover fields, at Giza, were the ichneumonids *Diplazon* sp., *Grelis* sp., *Casinaria* sp., *Mythobia* (*Angitia*) sp., *Barylypa rufa*, and *Bathyplectes curculionis* Thoms.; the braconids *M. rufiventris*, *Apanteles* sp., *Opius* sp., and *Zele chlorophthalma* Nees; the pteromalids *Habrocytus sequester* Walk. and *Pteromalus puparum* L.; and the tachinid *E. larvarum.* The most known species are *B. rufa*, the larval pupal parasitoid of *S. littoralis*; *B. curculionis*, the larval parasitoid of *Hypera brunneipennis* Boh.; *M. rufiventris, E. larvarum* and *Z. chlorophthalma*; the larval parasitoids of *S. littoralis*; and *Pteromalus puparum* L., the pupal parasitoid of *Pieris rapae.* The role played by other parasitoids is still unknown. Kolaib et al. (1980) recorded the parasitoids *M. rufiventris*, *Z. chlorophthalma*, and *Zele* sp. near *Zele nigricrnis*, *C. inanitus*, *Barlypa* spp., and *S. aegyptia* and two unidentified tachinids on the cotton leafworm in clover fields at Alexandria. Boraei (1993) gave the first

record of *Microctonus* sp. on the Egyptian alfalfa weevil (*Hypera brunneipennis* Boh.) in Egypt. Higher levels of parasitism were observed when larvae were dissected during the years of 1992 and 1993 showing 20 and 44% parasitism, respectively, with an overall mean of 40%. According to the above information, it seems that clover fields are very good habitats for numerous biological control agents that distribute safely in these fields far from any chemical control application. Strip harvesting of clover in these fields, undoubtedly, conserves and encourages propagation and the role played by these agents in various agro-ecosystems (El-Husseini et al. 2000).

Horticultural crops

Vegetable crops

From the extensive samples collected from vegetable crop fields in Upper and Lower Egypt by Hassanein et al. (1985), 12 species of well-known lepidopterous pests and their parasitoids were recorded. On tomato, *S. littoralis*, *Phthorimaea operculella*, *H. armigera*, and *Autographa* sp. were the main insect pests. On the first pest, the parasitoid species *M. rufiventris* and *S. aegyptia* were recorded. *Bracon instabilis* Marshal (L.P.) and *Apanteles litae operculellae* Nixon were secured from *P. operculella*, while the parasitoids *E. larvarum* and *Apanteles* sp. were found associated with *H. armigera.* On potato, *P. operculella* was the most destructive pest, where the three parasitoids *Apanteles litae* var. *operculellae* Nixon, *Bracon instabilis* Marshal, and *Diadegma mollipum* Hlmgrn were found parasitizing the pest. Cabbage was severely attacked by *S. littoralis*, *S. exiga*, *Autographa* spp. *Pieris rapae*, *Helulla undalis* Fabr., and *Plutella xylostella* Linnacus. On this crop, *S. littoralis* was found attacked by five parasitic species: *M. rufiventris*, *Ch. inanitus*, *Z. chlorophthalma*, *S. aegyptia*, and *Meteorus gyrator* Thunberd. *P. puparum* and *Brachymeria femorata* Panz. were encountered on *P. rapae. Apanteles ruficrus* Hal. and *Apanteles* sp. were found parasitic on *Autographa* sp., while *M. rufiventris* emerged from *S. exigua* only in Upper Egypt. The authors for *P. xylostella* reported no parasitic species, but Abbas and Hassanein (1989) found it attacked by the ichneumonid *Hyposoter ebeninus* Grav. Samples collected by Hassanein et al. (1985) from eggplant fields showed also a high infestation with *P. operculella* and low infestation with *A. ipsilon*, *Euzophora osseatella* Tr., and *H. armigera.* No *D. molliplum* nor *B. instabilis* were recorded on *P. operculella*, while *A. ruficrus* was sometimes found parasitizing *A. ipsilon.* Jew's mallow was found attacked by *S. littoralis*, *S. exigua*, *H. armigera*, and *A. ipsilon. M. rufiventris*, *Z. chlorophthalma*, *M. gyrator*, and *S. aegyptia* parasitized the first pest. Beans were infested by *S. littoralis*, *S. exigua*, *Autographa* sp., and *Cosmolyce baeticus* L. Mainly, *M. rufiventris* and partly *S. aegyptia* were the common parasitoids of *S. littoralis* on the two mentioned crops. *A. ruficrus* was reported for *C. baeticus*, and *M. rufiventris* was less frequent on *S. exigua.* No parasitoids attacked *Autographa* spp. on mallow and beans. Cowpea plants suffered from infestations by *S. littoralis*, *S. exigua*, and *A. ipsilon* that were parasitized by *M. rufiventris*, *S. aegyptia*, and *M. gyrator. M. gyrator* parasitized only *S. littoralis.* Okra was severely attacked by *S. littoralis*, *E. insulana*, and *Autographa* spp. where no parasitoids were secured from the two latter pests, while few parasitoid individuals (*M. rufiventris*, *M. gyrator*, *Z. chlorophthalma*, and *S. egyptia*) were recorded on *S. littoralis.* Eid (1992) reported that *E. insulana* on okra plants was very poorly parasitized by unidentified egg-larval parasitoid belonging to the genus *Chelonus.* Hassanein et al. (1985) found four lepidopterous pests infesting Egyptian Mallow, i.e., *S. littoralis*, *Autographa* sp., *H. armigera*, and *Vanessa cardui*. No parasitoids emerged from the last two pests, while *S. aegyptia* was secured from *S. littoralis*, and *Apanteles* sp. from *Autographa* sp. *S. littoralis* on artichoke was seen parasitized by the tachinid *S. aegyptia*, and *Autographa* sp. on cauliflower by the baraconid *A. ruficrus.* El-Husseini et al. (2006a) studied the parasitoid *Trissulcus basalis* Wollaston, as an important egg parasitoid on eggs of the green stinkbug *Nezara viridual* (L.) in okra fields in El Beheira Governorate, where its parasitism rate reached 90–100%. In a newly reclaimed Egyptian land, Meabed et al. (2011) applied successful releases of *T. evanescsens* in potato fields to suppress the infestation by the potato tuber moth, *P. operculella*. On the basis of the aforementioned observations, it appeared that among the 12 lepidopterous pests attacking vegetable crops, the most destructive ones were *S. littoralis* and *P. operculella.* On the other hand, the most common parasitoid was *M. rufiventris*, followed descendingly by *S. aegyptia*, *M. gyrator*, *B. instabilis*, and lastly *Z. chlorophthalma.*

Ibrahim and Fayad (1983) surveyed the aphids attacking vegetable crops and their associated parasitoid species. They reported an unidentified species from the family Braconidae as a parasitoid of *Aphis craccivora* Koch and *Acyrothosiphon pesui* on French beans and the aphidiid *Diaeretiella rapae* Mc'Intosh parasitizing *Brevicoryne brassicae* L. on cabbage, cauliflower, turnip, and radish. Kolaib (1991) reported the rate of parasitism caused by the latter parasitoid on the cabbage aphid, as well as the rate of hyperparasitism on *D. rapae* in Menofia Governorate. The former rate reached a mean of 96.4% during December, referring to the high efficacy of the primary parasitoid *D. rapae.* Rate of hyperparasitism peaked on January (91%) through the secondary parasitoids, *Pachyneuron aphidis* Bouche and *Alloxysta* sp. Hassanein et al. (1993) found the braconid *Opius nitidulator* (Nees) parasitizing the full grown larvae of *Pegomia*

mixta Villenouva, the important dipteran pest of sugar beet in Egypt.

El-Agamy et al. (1994) found two trichogrammatid parasitoid species attacking eggs of the lepidopterous pests infesting *Monothochaeta nigra* Blood and Krugger and the gregarious larval parasitoid *Tetrastichus* sp. (Hymenoptera: Eulophidae). Percentage of parasitism reported for the first parasitoid ranged between 10.1 and 15.5%, while that of the second one was 3.7 and 5.3%. Leaf-mining insects and their parasitoids need thorough investigations. There are plenty of species which are not recorded yet. However, Metwally (1991) recorded four parasitoids on *Liriomyza trifolii* attacking cowpea. Those were *Halticoptera circulus* Walker, *Anagyrus* sp., *Chrysonotomyi* sp., and *Hemiptarsenas zilahisbessi*. The highest rate of parasitism (33.9%) occurred in mid-October.

Recently, Askar and El Husseini (2016) recorded the ichneumonid *Sinophorus xanthostomus* (Gravenhorst) parasitizing *Artogia* (*Pieris*) *rapae* L. in cabbage fields at El Beheira Governorate. They also recorded the eulophid parasitoid *Tetrastichus galactopus* (Ratzeburg) as a hyperparasitoid on *S. xanthostomus* in *P. rapae*. Furthermore, Askar and El Husseini (2016) studied the dispersal of *P. puparum* and *T. evanescens* parasitizing *A. rapae* at El Beheira Governorate.

The whitefly *Bemisia tabaci* Genn. may be fairly considered one of the major insect pests on a wide range of vegetable crops, especially Cucurbitaceae, Solanaceae, and Crucifereae, since this pest is a vector of serious virus diseases. It appears that biological control with its known natural enemies does not represent, solely, a sufficient control measure (Hafez et al. 1978–1979).

In 2009, the South American tomato leaf miner *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) was detected as an invasive neotropical pest in Egypt. It is one of the most destructive insect pests of tomato that threats yield production. Preliminary survey of its indigenous parasitoid species in Egypt revealed the records of *Trichogramma* spp. on eggs and the larval parasitoids *Necremnus artynes* (Walker) on L2 and L3 and *Bracon* (=*Habrobracon*) *nigricans* on mature larvae in both open fields and greenhouses during spring and summer tomato plantations (Zappala et al. 2013).

Fruit crops

Orchard plant pests Natural enemies associated with orchard plant pests are numerous and mostly efficient, but they did not receive considerable investigations compared with those reported on pests of the field crops. Orchards represent more stable agro-ecosystems, and thus, efforts directed towards biological control of their pests would be a more successful control measure. The present status of natural enemies in these agro-ecosystems that referred recently is restricted to pests infesting the most economic fruit crops.

Citrus orchards Citrus represents one of the most important fruit crops in Egypt, as well as it is one of the best competitors in the world. That is why great care is paid nowadays to citrus orchards from the standpoint of horticultural procedures and pest control. Citrus plants are infested with different pests of which scale insects, e.g., the California red scale, *Aonidiella aurantii* Mask., and the purple scale, *Lepidosaphes beckii (*Newm.), are now the most destructive. In the past, the black scale *Chrysomphalus ficus* Ashmed was the most common pest species on citrus, but now, it is under the control of many biocontrol agents, especially the encyrtid endoparasitoid *Habrolepis pascuorum* Mercet. which is widely spread all the months of the year. Tawfik et al. (1970) recorded this parasitoid among other parasitoids of the same pests, i.e., *Aphytis chrysomphali* Mercet (Aphelinidae) and *Aphychus flavus* Howard (Encyrtidae). The role of the former species had drastically declined, possibly due to competition and replacement by *H. pascuorum.* The latter parasitoid was reported earlier as parasitic on *Coccus hesperidum* Linneaus, *Eriococcus orgenseni*, *Pulvinaria iceryi*, and *Saissetia oleae* Bern and later was observed by Tawfik et al. (1970) through very small numbers restricted to only few and localized samples collected from citrus. It was stated by Abul-Nasr and El-Nahal (1963) that the citrus mealybug *Planococcus citri* Risso is kept under control by the two encyrtid parasitoids, *Anagyrus pseudococci* Gir. and *Leptomastidea* sp. In a more recent investigation, Morsi (1999) stated that *C. ficus* Ashm. is attacked in Beni-Suef Governorate by the parasitoids *Aphytis citrinus* Comp., *A. chrysomphalli*, *A. lingnanensis*, *Encarsia* sp., *Marrietta exitiosa* Comp. (Aphelinidae), and *H. pascuorum* (Encyrtidae). On the other hand, Hekal and Sakr (2001) reported the aphelinid parasitoid, *Aphytis holoxanthus* Debach, as a new record attacking the same scale insect. They added that this parasitoid was accidentally entered from Israel to Egypt during the beginning of the 1980s, causing the gradual scarcity of *C. ficus* and the entire displacement of *A. chrysomphali*. In a survey of the natural enemies of scale insects on citrus, Mahmoud (1981) studied their status in association with the most common scales, *A. aurantii* Mask. and *L. beckii.* For the former pest, an *Aphytis* sp. was reported as the most important ectoparasitoid on adult females. The increase in its population density during winter resulted in an obvious decrease in that of its pest. Another primary endoparasitoid, *Habrolepis aspidisti* Compere, was also recorded, being more abundant during summer than in winter. A hyperparasitoid, *Aspidiophagus* sp. was found attacking the

aforementioned primary parasitoids but was not of a common occurrence.

On sour orange, Morsi (1999) recorded the parasitoids *Aphytis melinus* Debach and *Coccophagoids* sp. (Aphelinidae) and *Habrolepis aspidioti* Comp. & Ann. (Encyrtidae) on the same scale insect at Beni-Suef Governorate. On the other hand, only one species, i.e., *Aphytis lepidosaphes* (Comper) was found by Mahmoud (1981) parasitic on pre-adult and adult females of *L. beckii* Newn whose population was greatly suppressed due to the active role played by this parasitoid, especially during February and March. In summer, this role was affected badly due to the attacks of a secondary parasitoid, namely *Marietta exitosa* Compere (Aphelinidae).

El-Husseini et al. (1994) studied the seasonal fluctuations of *A. lepidosaphes* parasitizing *L. beckii* during the two seasons (1985/1987) in citrus plantations which were kept free from any chemical application. The first season was characterized by a relatively higher rate of parasitism (54.4%) than the second season (23.4%). The maximum rate of parasitism (46.0%) took place in May during the second season. Nymphs and females of *L. beckii* seemed to be more favorable for the parasitoid than males. The average values of annual fluctuations were 1.404 and 2.768 for the first and second seasons, respectively.

An outbreak of the citrus leaf miner *Phylocnistis citrella* Stainton was recorded in the 1994 season in almost all citrus orchards all over Egypt. It was a minor pest infesting citrus trees since the 1980s. A survey of the parasitoid species of *P. citrella* was carried out by Tawfik et al. (1996), which resulted in seven hymenopterous species. Identified parasitoids showed four eulophid species, *Cirrospillus pictus* (Nees), *Ratzoburgiola incompleta* Boucck., and *Sympiesis* sp. The other two species were *Prigalio* sp. and *Baryscapus* sp. Lamia; Abo Abdalla (2015) recorded four hymenopterous parasitoid species: *Cirrospilus* sp., *Zagrammosoma* sp., *Pnigalio* sp., and *Baryscapus* sp. (family Eulophidae) parasitizing *Cirrospillus pictus* in Alexandria, Egypt. The species *Cirrospilus* sp. was the dominant one through the 2 years of study (2012 and 2013).

A group of predators was found associated with the scale insects on citrus. Among the predaceous insects, the two coccinellids, *Chilochorus bipustulatus* L. and *Scymnus syriacus* March, were reported by Tawfik et al. (1970) (for *C. ficus*) and Mahmoud (1981) for *A. aurantii* and *L. beckii*. The former predator was considered by both authors as the most efficient. Metwally et al. (1999) at Kafr El-Sheikh Governorate (northern Egypt) studied seasonal abundance of the coccinellid predator, *Clitostethus arcuatus* (Rossi). This predator accounted 41.9% of the total number of predators found associated with the citrus whitefly *Dialeurodes citri* (Ashm.) on citrus trees, where a mean number of the predator reached 15 individuals/80 double net-strokes, as described.

Hamed and Saad (1989) observed the coccinellid *Rodolia cardinalis* Mulsant adapting its known feeding habit from *Icerya purchasi* Mask. to *I. aegyptiaca* (Douglas) on the same crop as previously mentioned by Tawfik et al. (1970) and Mahmoud (1981). *Chrysopa* was also recorded as a predator during larval stage on crawlers of these pests. Tawfik et al. (1970) included the two predators *Pharoscymnus varis* Kirsch (Coccinellidae) and *Cybocephalus flavipes* Reitt. (Nitidulidae) which were not reported later by Mahmoud (1981) who found the phlaeothripid *Haplothrips cahirensis* (Tryb) as a predator upon different stages of *L. beckii* and *A. aurantii* during the period from March to October. The anthocorid *Cardiostethus nazarenus* Reui. was also reported by Tawfik et al. (1976a) as a predator of *L. beckii* on citrus.

Morsi (1999) surveyed the natural enemies of the scale insects on citrus trees at Beni-Suef Governorate and found the insect predators *Scymnus includens* Kirsch, *S. subasciatus jumperi* Mots, *S. syriacus* Marsuel, *Stethorus puncutellum* Weise (Coccinellidae), *Chrysoperla carnea* Steph. (Chrysopidae), and predaceous mites *Euseins scutalis* Athias–Henriot and *Proctolaelaps orientalis* Nasr attacking *A. aurantii* on baladi orange and *Scymnus syriacus*, *Chilocorus bipustulatus* L., *Exochomus nigromaculatus* Goeze, *Pharoscymnus varius*, *Rodolia cardinalis* Muls, and *C. carnea* attacking *C. ficus* on mandarin.

Several predaceous mites exist on citrus trees playing an active role against scale insects. Mahmoud (1981) reported a eupalopsellid mite *Eupalopsellus oleratus* Gomma. as a predator on eggs and crawlers of *L. beckii* and *A. aurantii.* Zaher (1986) recorded nine species of mites feeding on scale insects in Egypt. Those were *Agistemus exsertus* Gonzalez. (Stigmaeidae) on *C. ficus* and *L. bekii*, *Neophyllobius magniferus* Zaher & Gomaa. (Neophyllobiidae) (on *C. ficus*), *Saniosulus nudus* Summers. (Eupalopsellidae) on *L. beckii* and *L. tableyi*, *Eupalosellus olearius* Zaher & Gomaa. (Eupalopsellidae) on *L. ulmi*, *Cheletogenes ornatus* Canestrini & Fanzago, *Hemicheyletia backeri* Ehara. (Cheyletidae) on different scale insects, *Typhlodromus magniferans* Zaher & El-Brallosy, and *Amblyseius gossipi* El-Badry. (Phytoseiidae) on *C. ficus*. The same author found the cunaxid mite, *Cunax capreolus*, and the phytoseiid mite, *Typhlodromus magnifera*, feeding on the phytophagous mite, *Eutetranychus orientalis*, on citrus.

Morsi (1999) recorded *Agistemus excertus* Gonz., *Blattiscus tarsalis* Berlese (Ascidae), and *Tydeus californicus* Banks (Stigmaeiidae) as predaceous mites against *C. ficus*, *Euseins cutalis* Athias-Henriot, and *Proctolaclaps orientalis* Nasr on *A. aurantii* on citrus at Beni-Suef Governorate. Zaher (1986) had observed the phytoseiid mite *Amblyseius gossipi* attacking whiteflies. Rakha and El-Naggar (1993) studied the relationship between

predaceous mites and citrus pests in two different localities in Egypt, Qalyobia (Nile Valley) and Beheira (Coastal lands). The phytoseiid mite *E. scutalis* was the most commonly encountered predator associated with phytophagous mites and whiteflies, while the predatory cheyletid mite *Cheletogenes ornatus* Canestrini and Fanzogo was the most abundant species associated with scale insects. Recently, El-Husseini et al. (2011) recorded *Crosidura* sp. (Insectivora: Soricidae) as a key predator suppressing naturally the populations of the scarabaeid hairy rose shafer *Tropinota squalida* Scop. in the desert agro-ecosystem in deciduous fruit orchards.

Olive orchards Olive is one of the important economical crops in Egypt. Olive trees are attacked by insect pests that affect quality and quantity of the yield. On olive trees, populations of the fruit fly, *Bacteracera (Dacus) oleae* Gamel are suppressed by the braconid parasitoid, *Opius concolor* Szepl. (Ajjan 1962), and those of the olive scale insect *Parasaissetia oleae* by the pteromalid parasitoid *Sautellistea cyanea* Mols. (Hosny et al. 1966). The two stem borers, *Phlocotribus scarabaeides* Bern. and *Zeuzera pyrina* L. are parasitized by two pteromalids, *Cheiropochus quadrum* and *Rhaphitelus maculatus*, and two unidentified species belonging to the genera *Euplemus* and *Eurytoma* (Ismail et al. 1988). The shot-hole borer *Scolytus amaygdali* (Coleoptera: Scolytidae) of olive trees is parasitized during its larval stage by seven hymenopterous parasitoids, i.e., *Cerocephala cornigera*, *Cheiropachus quadrum*, *Rhaphites maculatus* (Pteromalidae), *Cephalonoma* sp. (Bethylidae), *Eupelmus* sp. (Eupelmidae), *Eurytoma* sp. (Eurytomidae), and *Leptomastix trunctellus* (Encyrtidae) (Ismail et al. 1988). In most recent studies, El-Khawas et al. (2000) presented a detail record concerning parasitoids on common olive pests in Egypt, in Alexandria, Fayoum, and North Sinai Governorates. *Opius concolor* Szeph. (Braconidae), *Prigalio agraules* Walker (Eulophidae), *Eupelmus* sp. and *Macroneara* sp. (Eurytomidae), *Eurytoma martelli* Masi and *Eurytoma* sp. (Eurytomidae), and *Cryptoprymna latipes* Ronaldi (Pteromalidae) were reported on larvae of *Bacterocera* (*Dacus) oleae*, and *Prays oleae* Bern that feed on leaves, flower buds, and fruits was subject to attack by *Apanteles* sp. and *Bracon* sp. (Braconidae), while the Jasmine moth, *Palipta unionalis* Hb., that feeds on buds was parasitized by *Apanteles syleptae* F. (Braconidae) and *Brachymeria aegyptiaca* Masi (Chalcididae). The armored scale insect *Leucaspis riccae* Targ was attacked by *Aphytis* sp., while the California red scale *A. aurantii* by *Marietta* sp. (Aphelinidae) and *Habrolepis* sp. (Encyrtidae). A recent survey on parasitoids of *B. oleae* carried out by El-Heneidy et al. (2001b) in Alexandria and El-Fayoum Governorates included eight hymenopterous parasitoids namely *Cyroptyx latipes* R., *Cyroptyx* sp., *Eupelmus* sp., *Eurytoma* sp., *Eurytoma martelli*, *Macroneura* sp., *Prigalio agraules* W., and *Opius concolor* S. The first seven species were recorded for the first time in Egypt. The eighth parasitoid species was recorded in the fresh fruits, while only six were recorded from the fallen fruits. All species were recorded during the period from July to November. Mean percentages of parasitism reached 38.9 and 10.8% by the two species; *O. concolor* and *P. agraules*, respectively.

Auphyllura phillyreae (Homoptera: Psyllidae) destroys the flower buds through feeding and secreting wax materials on them. In Egypt, this pest was parasitized by the two primary parasitoids *Catolaccus crassiceps* (Pteromalidae) and *Psyllophaga* sp. (Encyrtidae) and the secondary ones *Pachyneuron* sp., *P. muscarum*, and *P. formusum* (Braconidae) (Nada 1994).

The most recent studies concerning survey of important pests attacking olive trees and their associated natural enemies were carried out by El-Basha (2002) in Ismailia Governorate. In this survey, many hymenopterous parasitoids were reported for six olive pests, i.e., *Psyttalia (Opius) concolor* Szepl (Braconidae) on *Bactrocera oleae* (Diptera: Tephritidae), *Psyllaephagus euphyllura* (Encyrtidae), *Marietta picta* Andre (Aphelinidae) and *Pachyneuron muscarum* (L) (Pteromalidae) on *Euphyllura straminea* (Homoptera: Aphalaridae), *Aphytis* sp. (Aphelinidae), *Habrolepis* sp. (Encyrtidae) and *Marietta picta* (Andre) (Aphelinidae) on *Aspidiotus hedera* (Homoptera: Diaspididae), *Aphytis* sp. (Aphelinidae) on *Parlatoria oleae* (Homoptera: Diaspididae), *Apanteles* sp. (Braconidae), *Bracon* sp. (Braconidae) and *Trichogramma* sp. (Trichogrammitidae) on *Prays oleae* (Lepidoptera: Hyponomeutidae), and *Apanteles sylepta* F. (Braconidae) and *B. aegyptiaca* (Chalcididae) on *P. unionalis* (Lepidoptera: Pyralidae). These pests were found also associated with the three predators *Chrysoperla carnea*, *Syrphus corollae*, and *Scymnus* sp.

Nasr et al. (2002) recorded *Apanteles xanthostigmus* Hal. and *A. sylepta* F., (Braconidae), *Xanthopimpla punctata* Fr. (Ichneumonidae), and *Brachymeria* spp. (Chalcididae) on the olive leafmoth *P. unionalis* and *A. xanthostigmus* and *Opius concolor* Szepl. (Braconidae), *Tetrastichus amythestinus* Ratz. (Eulophidae), and *Hockeria bispinosa* Walker and *Chalcis modesta* Masi. (Chalcididae) on the olive moth *Prays oleae* Bern in olive groves at Giza and Alexandria. Hegazi et al. (2005) recorded three trichogrammatid species, *T. cacociae*, *T. bourrachae*, and *T. cardubensis*, parasitizing eggs of the olive pests *P. unionalis* and *P. oleae* in olive orchards, located in the western desert in Egypt.

Other orchard crops

One of the most destructive pests in orchards is the tephritid Mediterranean fruit fly *Ceratitis capitata*

(Wied.) that infests many kinds of fruits, e.g., citrus, apricot, peach, guava, mango, and apples. Serious damage is restricted to citrus, apricot, peach, and guava. Sarhan (1981) reported the pupal parasitoids of this pest species, being the chalcid *Euchalicidia caryobori* Hanna and the pteromalids *Pachycrepoides vindemia* (Rodani) and *Spalangia gemina* Boucek. The rate of parasitism reported for these parasitoids seemed to be low as it does not exceed 9%, and thus, their role in suppressing the populations of the pest is rather limited. On the other hand, its pupae were found attacked in the soil and under the fallen infested fruits by the earwig *Labidura riparia* and spiders. No parasitoids were recorded on other stages of *C. capitata.* El-Minshawy et al. (1999) recorded the peach fruit fly *Bactrocera zonata* (Saunders) as a new exotic pest of several fruits such as mango, guava, peach, apricot, fig, and citrus in Egypt. El-Husseini et al. (2008a) recorded the chalcidid *Dirhinus gifardii* (Silvestri) parasitizing the pupae of *B. zonata* under guava trees in El Kanater region.

Ibrahim (1994) reported *Ephedrus persicae* Forgatt, *A. matricariae*, *D. rapae*, and *Praon volucre* Hal. as efficient parasitoids of the aphids *Myzus persicae* (Sulz.), *Aphis gossypii* (Glov.), and *Aphis pomi* De Geer on apple trees at Giza Governorate. Parasitism rates of 12.5, 24.6, and 28.7% were reported for the parasitoids mentioned above. Both *E. persicae* and *A. matricariae* were the dominant and highly effective species against the aphids *M. persice* and *A. gossypii.* Rates of 35.9 and 34.1% of the total percentage of parasitism were found. Ibrahim and Amal (1993) reported the aphid *Hyalopterus pruni* (Geoff) as a dominant pest on peach leaves in Egypt. They found the parasitoids *Aphidius colemani* Vier and *A. picipes* (Neas) attacking it, representing a maximum percentage of (64.5%) parasitism that recorded in May. Efficient parasitoids of pomegranate pests were the two chalcids *B. aegyptiaca* (Awadallah et al. 1970) and *B. brevicornis* (Hosny et al. 1966) on pupae of the pomegranate butterfly *Deudorix livia* Klug. and *T. evanescens* on eggs of the same pest (Awadallah et al. 1970).

It is noteworthy to mention in this article that the aphelinid *Aphelinus mali* Hald., which was introduced to Egypt from the UK in 1934 to control the woolly apple aphid *Eriosoma lanigera* Hausm (Kamal 1951), has been well established and showed very successful results about controlling the pest in many regions in Egypt.

Shoukry et al. (1997) recorded three parasitoid species attacking the honeydew moth *Cryptoblabes gnidiella* (Mille) that infests mango in Ismailia Governorate. These parasitoids were the egg-larval braconid wasp *Phamerotoma ocularis*, the ichneumonid wasp *Diadegma aegyptiacum* on larvae, and the chalcidid wasp *B. aegyptiaca* on pupae. The highest percentages of parasitism reported for these parasitoids were 32.6, 42.2, and 69.2% in May and August, respectively, in 1993, and 44.2, 51.3, and 55.5% in May and June, 1994. The same pest is also subjected to the attacks by the predator *Blaptostethus piceus* Fieber *var. pallescens* (Hemiptera: Anthocoridae) that plays an important role in suppressing its population in mango orchards. Also, on mango, Morsi (1999) found that the scale insect *Aulacaspis tubercularis* Newst was attacked by the parasitoids *Aphytis* sp., *Aspidiotiphagus citrinus* Craw (Aphelinidae), *Encarsia* sp., *Haprolepis aspidioti*, *H. obscura* Comp. & Ann., and *Metaphycus* sp. (*flavus* Howard) (Encyrtidae) and an unidentified encyrtid sp. and the insect predators *Chilocorus bipusculatus* L., *Exochomus nigromaculatus* Coccinillid, *S. syriacus*, *S. puncutellum*, and *C. carnea*, and the predaceous mites *Cheletogenus ornatus* Can. & Fan. (Cheyletidae), *E. scutalis*, *Kleemannia pulmosus* Oudem. (Amerosidae), and *Tydeus californicus* Banks (Stigmaeiidae).

Marwa et al. (2012) studied the parasitism on larvae of the date palm fruits *Cadra* (*Ephestia*) *cautella* (Walker) on dried stored fruits by the braconid ectoparasitoid *Habrobracon hebetor* Say. The estimated parasitism rate on eggs of *C. cautella* ranged between 9.5 and 46.3% by the three different *Trichogramma* spp. (*T. bourorachea*, *T. evanescens*, and *T. cacoceciae*).

Youssif et al. (2014a, b) recorded the two new predatory species *Chrysemosa jeanneli* (Navas 1914) (Neuroptera: Chrysopidae) and *Wesmaelius navas* (Andreu, 1911) (Neuroptera: Hemerobiidae) for the first time in Egypt, on apricot and peach trees associated with the aphid *Hyalopterus pruni* (Geoffroy) at El-Khattara district, Sharkia Governorate, Egypt, in years 2010 and 2011.

Ornamental crops

Pests of ornamental plants were also investigated from the standpoint of their natural enemies. On buddlia, *Aphis verbasci* is commonly distributed as a dominant pest throughout the year. Azab et al. (1965) recorded many insect predators feeding actively on *A. verbasci*, being *C. undecimpunctata*, *Leucopis puncticornis*, and *Phaenobremia aphidivora* (=*Aphidoletes aphidimyza*). In their studies on the insect fauna of the ornamental tree *Ficus nitida*, Tawfik (1967) and Maha et al. (2013) reported an unidentified hymenopterous parasitoid belonging to the genus *Pleurotropis* (Eulophidae) for the larvae of thrips, *Gynaikothrips ficorum* Marchal (Phlaeothripidae). The same authors also stated that this pest was attacked by the two anthocorid bugs *Montandoniella moraguesi* Put. and *Orius albidipennis* Reut., the chrysopid *Chrysopa vulgaris* (=*Chrysoperla carnea*), the termatophylid bug *Termatophylum insigni* Reut., and the predaceous mite *Adactylidium* sp. (Pyemotidae, now Acarophaenacidae). *Adactylidium* sp. was identified by Zaher and Kandeed (Zaher 1986) as *Adactylidium*

gynaikothripsi. El-Husseini et al. (2006b) studied the biology and incidence of eulophid *Pediobius thysanopterus* Burks parasitizing *G. ficorum* on *F. nitida* trees. *Aphis nerii* infesting the ornamental tree *Nerium oleander* was found by Ismail and Swailem (1971) as a favorable prey of the predators *Ch. carnea*, *C. undecimpunctata*, *Scymnus* sp., and some syrphids. Rashad (1975) recorded population densities of the mealybug *Ferrisia virigata* (Cockerell) (Pseudoccidae) and its natural enemies on *Acalypha macrophylla* in Giza. For this pest, two hymenopterous parasitoids, namely, *Leptomastix* sp. (Encyrtidae) and *Tetrastichus principiae* (Eulophidae), and five predaceous spp., *Scymnus includens*, *Cryptolaemus montrouzieri*, *Chrysoperla carnea*, *Sympherobius amicus* Navas. (Neuroptera), and *Hyperaspis vincigurrae* Capra (Coccinellidae), were reported. Swailem et al. (1976) recorded the encyrtid parasitoid *Habrolepis* sp. on *Lindigaspis rossi* (Diaspididae) that infests *F. nitida* and *Jasminum pubscens*. Hegazi and Moursi (1983) recorded the two hymenopterous parasitoids *Antisrophoplex conthurnatus* (Masi) (Tormydae) and *Pronotalia* sp. (Eulophidae) on the capsule fly *Acanthiophilus helianthi* Rossi infesting safflower. Ragab (1991) found the eggs of the green bug *Nezara viridula* L. parasitized by the scelionid species, *Microphanurus basalis*, *Stromatum flovum* Villers (Cerambycidae) is considered an important stem borer on casuarina trees; Khalafallah (1988–89) found it parasitized by *Scleroderma ephippium* (Saunders) (Hymenoptera: Bethylidae). Most natural enemies attacking pests of other orchard and ornamental plants are still in need of further investigations. Mousa et al. (2001) reported that among the 60 ornamentals and aromatic host plants of the pink hibiscus mealy bug, *Maconellicoccus hirsutus* (Green), the most injurious mealy bug species occurring in Egypt, sampled from different Egyptian regions in year 2000, 66.3% were found parasitized. The survey revealed the presence of eight primary and four secondary parasitoid species. The primary parasitoid species were *Allotropa* sp. near *mecrida* (Walker) (Platygastridae); *Gyranusoidea indica* Shafee, Alam and Agarwal; *Leptomastidea abnormis* (Girault); *Leptomastix algirica* Trjapitzin, *Leptomastix* sp.; *Anagyrus kamali* Moursi; and *Anagyrus* sp. and *Clausenia* sp. (all Encyrtidae), while the secondary species were *Chartocerus* sp. (Signiphoridae), *Marietta* sp. (Aphelinidae), *Pachyneuron* sp. (Pteromalidae), and *Prochilonerus bolivari* Mercet (Encyrtidae). Gonzalez et al. (2003) reported that although the ornamental hibiscus host plants were found abundantly in Egypt, Spain, and Morocco but pink hibiscus mealybug (PHMB) *M. hirsutus* was found only in Egypt and among its several parasitoids recovered, the platygastrid gregarious parasitoid species *Allotropa* sp. near *mercida* (Walker) was by far the most abundant one attacking PHMB in Egypt.

Through the studies of Priesner and Hosny (1940), El-Nahal et al. (1976), Abdel-Fattah et al. (1984), Awadallah et al. (1999), and Abd-Rabou (1998, 1999a, 1999b, 2000, 2001a, 2001b) more than 40 parasitoid species were recorded on the whiteflies, soft and armored scale insects, and mealy bugs on the ornamental plants and some horticulture crops in different Egyptian agro-ecosystems. The most common genera of the recorded parasitoid species were *Aphelinus*, *Aphytis*, *Encarsia*, *Eretomocerus*, *Encyrtus*, *Coccophagous*, *Pteroptrix*, and *Marietta* spp.

Naturally occurring entomopathogenic microorganisms in Egyptian ecosystems did not receive any attention from the entomologists until 1954 when Prof. Abul Nasr got interested in controlling the cotton leaf worm *S. littoralis* by its nuclear polyhydrosis virus. Although a large spectrum of these agents is available, most species are still unknown, and taxonomic and biological knowledge of the studied agents are fragmentary. Most attention that took place early was paid towards the entomopathogenic bacterium *Bacillus thuringiensis* revealing various varieties or subspecies, e.g., *thuringiensis* from *S. littoralis* (Abdellah and Abul Nasr 1970), *P. gossypiella* (Farrag 1979), and *E. insulana* (Abul-Nasr et al. 1978-1979). For fungi, Sewify (1997) reported some information concerning occurrence and pathogenicity of certain economic important species, e.g., *Beauveria bassiana*, *Metahrizium anisopliae*, *Verticillium lecanii*, and *Entomophthora* sp. The susceptibility of different insect pests to these fungi was investigated by the same author, i.e., *Bemesia tabaci*, *Myzus persicae*, and *Aphis gossypii* to *V. lecanii*; *B. tabci*, *Cassida vittata*, *Zeuzera pyrina*, and *Sesamia critica* to *B. bassiana*; and *Z. pyrina*, *Locusta migratoria*, *C. vittata*, *S. littoralis*, *P. gossypiella*, and *E. insulana* to *M. anisopliae*. Nematodes had also received considerable attention from Egyptian specialists, especially towards species infesting economic plants, while entomopathogenic species were less investigated (El-Kifl et al. 1970). Atwa (1999) reported *M. anisopliae* infecting important insect pests in Egypt, i.e., *Z. pyrina*, with two strains of *Steinernema carpocapsae* (EGB2), *Steinernema* sp. (EGB20), and two *Heterorhabdities bacteriophora* (EGB13), *H. indicus* (EBN 16). Those of *Pieris brassicae* and *S. littoralis* were *Steinernema* sp. (EGB20), *H. bacteriophora* (EGB13), and *H. indicus* (EBN16).

Since the polyhydrosis virus of the cotton leaf worm was recorded by Abul-Nasr et al. (1978-1979), many investigations were carried out to investigate the importance of these biological control agents in Egyptian agro-ecosystem. Among these investigations was that of Abol-Ela et al. (1988) who shed light on the different strains of this virus in the cotton leaf worm. Khamiss et al. (1999) recorded the Egyptian isolates of S. *littoralis*

granulovirus from cotton fields in Egypt. Fèdière et al. (1999), here also, was the first to isolate densovirus and picornavirus from natural field populations of the same pest in Egypt. Actually, the densonucleosis virus was first recorded in Egypt from the cotton leaf worm by Fediere et al. (1995). It was found necessary to have a future publication concerning exclusively all reported entomopathogenic microorganisms infecting insect pests commonly distributed in Egyptian agro-ecosystems.

Conclusions

The above data represent an overview and documented status of the most common natural enemies of major and economic insect pests in important Egyptian agro-ecosystems. These will undoubtedly help in planning any strategy needed for integrated pest management in the most important economic crops in Egypt.

First, we are looking forward towards a conservation strategy that embraces preservation and maintenance, rational utilization, and enhancement of the natural biological control agents in these agro-ecosystems. Secondly, the survey reported in this review article will shed light on the parasitoid–predator complex of each pest within which special consideration will be given to the most active agents. These agents should be preserved in the environment, during the course of agricultural practices, or utilized if possible in periodic colonization. Thirdly, this may help in the cases which require introductions of exotic natural enemies eagerly needed to control harmful pests with inactive endemic agents.

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All datasets are presented in the main manuscript.

Authors' contributions

All authors read and approved the final manuscript.

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