Iraqi Journal of Science, 2023, Vol. 64, No. 1, pp: 91-110
DOI: 10.24996/ijs.2023.64.1.10

ISSN: 0067-2904

A Review of Entomopathogenic Fungi of Iraq

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Received: 7/4/2022 Accepted: 24/6/2022 Published: 30/1/2023

Abstract

Insect pest management has been dominated by the use of synthetic pesticides since early 1950s. However, lately this control method is not widely accepted due to an increase in environmental awareness, food safety concerns and the increasing number of insecticide-resistant species. In Iraq, the chemical insect pest control is still a dominant control method regardless of the increased pressure to replace it gradually with environment friendly alternatives such as predators, parasitoids, nematodes and entomopathogenic fungi. In Iraq, there is an increasing volume of research that has used different genus and species of entomopathogenic fungi for controlling several agricultural pests. However, these efforts are not yet reflected in the industry. In this short review article, a detailed summary of the research that has been done with entomopathogenic fungi in Iraq since 2000 is given and a brief discussion of the potential of using entomopathogenic fungi on a large scale in Iraq, its challenges, and recommendations is presented.

Keywords: Entomopathogenic fungi, Iraq, Insect pest management, Biological control

مراجعة للفطريات الممرضة للحشرات في العراق

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الخلاصة

لقد سيطر استخدام مبيدات الآفات الاصطناعية على مكافحة الآفات الحشرية منذ أوائل الخمسينيات من القرن الماضي، ومع ذلك في الآونة الأخيرة،اصبحت طريقة المكافحة هذه مرفوضة على نطاق واسع بسبب زيادة الوعي البيئي، وتنامي المخاوف المتعلقة بسلامة الغذاء وكذلك تزايد عدد انواع الحشرات المقاومة للمبيدات الحشرية،امافي العراق فلا تزال المكافحة الكيميائية للآفات الحشرية هي طريقة المكافحة السائدة بغض النظر عن الضغط المتزايد لاستبدالها تدريجياً ببدائل صديقة للبيئة مثل المفترسات والطفيليات والديدان الخيطية والفطريات الممرضة للحشرات،مع العلم ان في العراق هنالك عدد كبير من الأبحاث التي تستخدم أنواعًا مختلفة من الفطريات الممرضة للحشرات لمكافحة العديد من الآفات الزراعية، ومع ذلك، لم تنعكس هذه الجهود بعد في مجال مكافحة الافات الحشرية على ارض الواقع، تضمنت مقالة المراجعة القصيرة هذهتقديم ملخص مفصل للبحوث التي تم إجراؤها على الفطريات الممرضة للحشرات منذ سنة 2000 في العراق ،

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وكذلك تم مناقشة امكانية استخدام الفطريات الممرضة للحشرات في العراق على نطاق واسع وتسليط الضوءعلى اهم التحديات التي تواجه ذلك وعرض بعض التوصيات لمواجهة تلك التحديات.

Introduction

Entomopathogenic fungi (EPF) are fungal species that are naturally pathogenic to insects. These fungal pathogens play a crucial role in the insect population regulation [1]. The start of this field was probably in 1835 when an Italian entomologist Agostino Bassi, announced that a fungus, that would eventually be named *Beauveria bassiana* in his honor, was transmitted among the silkworm by contact and by infected food. This silkworm disease could have given the idea of using insect infecting fungi for the control of insect pest management [2]. However, the fundamental field trial for using EPF to control insects was done by a Russian microbiologist, Elie Metchnikoff in 1888. Metchnikoff's work led to a revolution in the Biological control programs in Europe and the United States by using fungi to control insect pests [3].

Massive rise in the human population has led to more food demand [4], which was the major reason for using pesticides to control pests [5]. Since early 1950s, synthetic insecticides have been widely used to control crop pests as they showed a significant increase in crop productivity [6]. However, the abundance and unregulated use of pesticides led to the emergence of many health and environmental issues [6]. Another imperfection of using pesticides is that a large number of insecticides affect non-target arthropod species. Moreover, insects begin to develop resistance to those synthetic pesticides that led to increased pesticide dosage in every new application [7]. All these issues have forced the industry and researchers to focus on the development of alternative control methods, including many biological control agents and EPF [6].

The production of EPF for commercial purposes is not very expensive. It does not require strict storage conditions as the storage can be efficient in a wide range of humidity and temperature. Therefore, EPF is being developed and produced on mass production globally to control a wide range of agricultural pests [8]. However, in Iraq, using biological control agents to control agricultural pests is not a prior option for the farmers. Thus, hundreds of Iraqi researches have been conducted in this area. Most of these studies have been published in Arabic and are, therefore, not readable internationally, and are isolated from being invested globally. So far no local commercial products are available in the Iraqi market. Hence, it is necessary to highlight, illustrate and discuss the progress that has been done in this field in Iraq to establish a database for more focused research in local EPF species for commercial purposes.

A summary of the EPF research in Iraq since 2000 is given in this short review article. A bibliography of the published articles with their URLs has been provided a the end to increase the visibility for these articles. A list of EPF species that have been experimentally tested, with the insect pest species that were tested against, is also provided. A brief classification of these species, their sources and experimental duration are also stated. Finally, the challenges of using and developing the EPF industry in Iraq are discussed, with some recommendations to encounter these challenges.

Summary of EPF Research in Iraq

The earliest known study on EPF in Iraq was in the early 1980s. However, the real interest in this subject in Iraq started at the beginning of the 21st century. It is important to state that the collected published articles for this review represent the accessible online work since 2000. There are 128 experiments within 117 published articles that tested EPF on different

arachnids' pests. Ninety-four of these experiments were done in labs, 27 in the field and 7 in greenhouses. The most experimentally tested species was *Beauveria bassiana* (Bals. -Criv.) Vuill., (99 experiments within 88 studies) followed by *Metarhizumanisopliae* (Metchnikoff) (27 experiments within 26 studies) (Table 1).

Total 30 species were experimentally tested EPF species(Table 1). Taxonomically, they belong to 16 genera (*Beauveria, Metarhizium, Lecanicillium, Chaetomium, Isaria, Penicillium, Cladosporium, Alternaria, Aspergillus, Mucor, Paecillomyces, Trichoderma, Scytalidium, Emericella, Mycellophthora, Fusarium*), 7 orders (Hypocreales, Sordariales, Eurotiales, Capnodiales, Pleosporales, Mucorales, Helotiales), and 5 classes (Sordariomycetes, Eurotiomycetes, Dothideomycetes, Leotiomycetes, Zygomycetes). 15 of these genera belong to Division Ascomycota and just one Genus (*Mucor*) belongs to Division Mucoromycota.

In these 117 published articles, there are 26 genera and 42 species of EPF isolated from infected insects, insects cadavers, soil and sewers of the Iraqi environment (Table 2).
EPF was tested against 48 pest species (Table 1). 5 of these species belonged to class Arachnida (Orders: Ixodida and Trombidiformes), while 42 species belonged to class Insecta (Hemiptera, Lepidoptera, Coleoptera, Diptera, Blattodea, Hymenoptera, Isoptera, Orthoptera).

Table1: List of Entomopathogenic fungi species experimentally tested vs. insect pest species in Iraq and the experiment types.

EPF	Insect pest and their stages	Experiment type	Reference
***Beauveria bassiana* (Bals.-Criv.) Vuill.**	Green peach aphid*Myzuspersicae* (Sulzer) (different stages)	greenhouse	[9]
	Khapra Beetle *Trogoderma granarium* (Everts.) (eggs)	lab	[10]
	The Dust Spider Mite*Oligonychusafrasiaticus*(different stages)	lab and field	[11]
	Subterranean termite*Microcerotermesdiversus*	field	[12]
	Cotton leaf worm *Spodoptera littoralis*	field	[13]
	Black bean aphid *Aphis fabae*	lab	[14]
	House fly Musica domestica(L.)	lab	[15]
	Jasmine whitefly*Aleuroclava jasmine* (egg andnymph)	field	[16]
	Angomis grain moth *Sitotrogacerealella*(Oliver) (larvae)	lab	[17]
	Cotton leaf worm *Spodoptera littoralis*(larvae)	lab	[18]
	German cockroach *Blattel1a germanica*(L.)	lab	[19]
	Termites *Microcerotermesdiversus* (Silvestri)	lab and field	[20]
	Corn stem borer *Sesamiacretica* (Led.) (larvae)	lab and field	[21]
	Khapra beetle *Trogoderma granarium*(Everts) (larvae)	lab	[22]
	Great Moth Wax *Galleria mellonella*(L.) (larvae)	lab	[23]
	House fly *Musca domestica* (L.) (all stages)	lab	[24]
	Cowpea weevil*Callosobruchus maculatus* (Fab.) (all stages)	lab	[25]
	Potato tuber moth*Phthorimaeaoperculella*	lab and field	[26]
	Cotton leave worm*Agrotisoipsillia*	lab and field	[27]
	Whitefly *Bemisiatabaci*(nymph, adults)	field and greenhouse	[28]
	Brown banded cockroach*Supellalongipalpa*(egg, adult)	lab	[29]
	Potato tuber moth *PhthorimaeaOperculella*(SELLER) (egg, larvae, pupa)	lab	[30]

	Two spotted spider mites*Tetranychusurticae*	field	[31]
	Broad mite*Polyphagotarsonemus latus (Banks)*	field	[32]
	Wax moth *Galleria mellonella*(egg and larvae)	lab	[33]
	Black bean aphid *Aphis fabae* (Scopolli)	lab and field	[34]
	Termite*Microcerotermesdiversus*(Silvestri) (workers and soldiers)	lab	[35]
	Wax moth *Galleria mellonella*(adult)	lab	[36]
	Cotton whitefly Bemisiatabaci(nymphal stages)	greenhouse	[37]
	Citrus mealybug*Planococcuscitri*(different stages)	lab	[38]
	Onion maggot *Delia alliaria*(Fonseca)(different stages)	lab	[39]
	Onion maggot *Delia alliaria*(Fonseca)	field	[40]
	Alsdih*Triboliumcastaneum*(Herbst) (adult)	lab	[41]
	Mealy plum aphid*Hyalopterusprun*i(Geoffroy) and *Aphis pomi*(DeGree)	lab	[42]
	Moth*Ephestiacautella* (Walk.)(larvae)	lab	[43]
	Sunn pest *Eurygasterintegriceps* (Put.) (eggs) andparasitoid*Trissolcus* spp. (eggs)	lab	[44]
	Cowpea seed beetle*Callosobruchus maculatus* (Fab.) (larval stages and adult)	lab	[45]
	Tomato leafminer*Tutaabsoluta*(eggs and larval stages)	lab	[46]
	Lesser grain borer*Rhyzoperthadominica*(Fab.) (adult)	lab	[47]
	Fig Leaf Worm*Ocnerogyiaamanda*(Stgr.)	field	[48]
	Hard tickes*Boophilusmicroplus*(adult)	lab	[49]
	Rust red beetle*Triboliumcastaneum*	lab	[50]
	Sun pest*Eurygasterintegriceps*(Put)(adult)	lab	[51]
	Sun pest*Eurygasterintegriceps*(Put)(adult)	field	[52]
	Triboliumcastaneum(Herbst) (larval stages)	lab	[53]
	Potato tuber moth*PhthorimaeaOperculella*(Zeller) (all stages)	lab	[54]
	Onion maggot *Delia alliaria*(Fonseca)	field	[55]
	White scale insect *Parlatoriablanchardi*(Targ.)	lab	[56]
	Mediterranean fruit fly *Ceratitis capitata* (larvae)	lab	[57]
	Homaira insect *Batrachedraamydraula* (egg larval stages 1,5)	lab	[58]
	Khapra beetle *Trogoderma granarium*(Everts)	lab	[59]
	Rrusty flour beetle*Triboliumcastaneum*and*Rhyzoperthadominica*(Fab.) (different larval stages)	lab	[60]
	Sugar beet worm *Spodoptera exigua* (Hübner)	lab andgreenhouse	[61]
	Fig moth*EphestiaCautella*(Walk.)(all stages)	lab	[62]
	Culex quinquefasciatus(Say)(4th larval stage)	lab	[63]
	Mosquito *Culex pipienspipiens*L.(larve)	lab	[64]
	Citrus mealybug*Planococcuscitri*(Risso)	lab	[65]
	Fruit stalk borer*Oryctes*spp.	field	[66]
	Lesser pumpkin fly*Dacusciliatus*Loew (adult)	lab	[67]
	Triboliumcastaneum (Herbst) (adult)	lab	[41]
	House Fly *Musca domestica L.*(Pupa and adult)	lab	[68]
	Green peach aphid *Myzus persica* (sulzer)	lab	[69]
	Two-spotted spider mite *Tetranychusurticae* (nymph and adults)	lab	[70]

	Spodoptera littoralis (Boisd.)	greenhouse	[71]
	White fly *Bemisiatabaci* (Gennadius)(nymphs and adults)	field	[72]
	Dubas Bug*Ommatissuslybicus* (Deberg)	field	[73]
	Mole cricket *Gryllotalpa* sp.	field	[74]
	Germen cockroach *Blattella germanica* (nymphs and adults)	lab	[75]
	Moth*Ephestiacautella*(larval stages)	lab	[76]
	Angoumois moth *Sitotrogacerealella* (different stages)	lab	[77]
	Trogoderma granarium(Herbst)(larvae)	lab	[78]
	Moth Figs *Ephestiacautella* (Walk.) (eggs and larvae)	lab	[79]
	Palm dubas bug *Ommatissuslybicus* (adults)	lab	[80]
	Citrus mealybug *Planococcuscitri* (Risso)	greenhouse	[81]
	Black fly *Acaudalerodesrachipora*(Singh) (all stages)	field	[82]
	Brown Banded Cockroach *Supellalongipalpa*(F.) (different stages)	lab	[83]
	Red spider mite *Tetranychusurticae* (Koch.)	field	[84]
	Sunn pest insect *Eurygastertestudinaria* (Geofroy)	lab	[85]
	Tomato leaf minor*Tutaabsoluta*(Meyrick)	lab	[86]
	Culex Quinquefasciatus (larvae)	lab	[87]
	Corn Stem Borer *Sesamiacretica*(Led)	field	[88]
	Cuccurit fruit fly *Dacusciliatus* (Leow) and Melon Fruit fly *Dacus frontalis* (Beker)	field	[89]
	Black bean aphid *Aphis fabae* (adult)	field	[90]
	Beetle *Epilachnachrysomelina* (larvae)	lab and field	[91]
	Cowpea weevil*Callosobruchus maculatus*	lab	[92]
	Bagradahilaris(Burmeister) (nymphs and adults)	lab and field	[93]
	Green peach aphid*Myzuspersicae*(Sulzer) (adult)	lab and field	[94]
	Flour beetle Alsdih*Triboliumcastaneum* (adult)	lab	[95]
	Culex pipienspipiens	lab	[96]
Metarhizuimanisopliae	*Callosobruchus maculatus*	lab	[97]
	Corn borer *Sesamiacretica*Led.	field and lab	[98]
	House fly *Musca domestica* L. (larvae)	lab	[99]
	House fly *Musca domestica* L. (all stages)	lab	[100]
	Termite *Microcerotermesdiversus*(Silv.)	field	[101]
	Lesser grain borer*Rhyzoperthadominica*(Fab.) (adult)	lab	[47]
	Potato tuber moth*PhthorimaeaOperculella*(Zeller) (all stages)	lab	[54]
	Culex quinquefasciatus(Say)(all stages)	lab	[102]
	Mediterranean fruit fly *Ceratitis capitata* (prepupae) larvae	lab	[57]
	Cowpea beetle *Callosobruchus maculatus* Fab.	lab	[103]
	Sawtoothed grain beetle*Oryzaephilussurinamensis*L. (all stages)	lab	[104]
	Culex quinquefasciatus(Say)(4th larval stage)	lab	[63]
	Fruit stalk borer*Oryctes*spp.	field	[66]
	Chrysomyaalbiceps (Wiedeman) (larvae andadults)	lab	[105]
	Lesser grain borer *Rhyzoperthadominica*(Fab.) (all stages)	lab	[106]
	Lesser pumpkin fly*Dacusciliatus*Loew (adult)	lab	[67]
	Blow fly*Chrysomyaalbiceps*(Wiedemann) (larvae)	lab	[103]
	House Fly *Musca domestica* L.(Pupa and adult)	lab	[68]

	Mole cricket *Gryllotalpa* sp.	field	[74]
	Sunn pest insect *Eurygastertestudinaria* (Geofroy)	lab	[85]
	Dubas bug*Ommatissuslybicus*Bergevin(different stages)	lab	[108]
	Housefly Musca domestica(adult)	lab	[109]
	Culex Quinquefasciatus(egg, larvae, pupa and adult)	lab	[110]
	Aphid*Myzuspersicae, Aphis gossypii,Aphis fabae* and*Macrosiphum euphorbiae*	lab and greenhouse	[111]
	Callosobruchus maculates (Fab.) (adults)	lab	[112]
	Hard ticks*Hyalommaanatolicum*(adults)	lab	[113]
Lecanicilliummuscariu m = Verticillium lecanii (Zimm.)	Grey scale insect *Parlatoriablanchardi*	lab and field	[114]
	German cockroach *Blattella germanica* (L.)	lab	[19]
	Corn borer Sesamia*creticaLed.*	field	[98]
	Whitefly *Bemisiatabaci*(nymph, adults)	field andgreenhous e	[28]
	Potato tuber moth*Pthorimaeaoperculella*	lab and field	[26]
	Cotton leave worm*Agrotisoipsillia*	lab and field	[27]
	Rust red beetle*Triboliumcastaneum*	lab	[50]
	*Aphis craccivora*Koch(nymph and adult)	lab	[115]
	Moth*Ephestiacautella*(Walk.) (all stages)	lab	[116]
	Cucurbit fruit fly *Dacusciliatus* (Leow) and Melon fruit fly *Dacus frontalis* (Beker)	field	[89]
	Aphid*Myzuspersicae, Aphis gossypii, Aphis fabae andMacrosiphum euphorbiae*	lab and greenhouse	[111]
Chaetomium globosum	Termites*Microcerotermesdiversus*	lab	[117]
	Two-spotted spider mite *Tetranychusurticae* (nymph and adults)	lab	[70])
	Aphid*Myzuspersicae, Aphis gossypii,Aphis fabae andMacrosiphum euphorbiae*	lab and greenhouse	[111]
***Isaria fumosoroseus* (Wize)**	*Myzuspersicae*(Sulzer)(nymph and adults)	lab	[118]
***Isariajavanica* (new record)**	Mealy plum aphid*Hyalopteruspruni*(Geoffroy) and *Aphis pomi (DeGree)*	lab	[42]
Penicillium glabrum	Mealy plum aphid*Hyalopteruspruni*(Geoffroy) and *Aphis pomi*(DeGree)	lab	[42]
P.chrysogenum, P. compactum	Black bean aphid *Aphis fabae* (Scopolli)	lab and field	[34]
***Penicillium* sp.**	Termites *Microcerotermesdiversus*		[117]
	German cockroach *Blattella germanica*(L.)		[19]
	Periplaneta americana		[119]
Ulocladiumatrum. Cladosporium oxysporum	Black bean aphid *Aphis fabae* (Scopolli)	lab and field	[34]
Alternaria alternata	Terimies*Microcerotermesdiversus*	lab	[117]
	Black bean aphid *Aphis fabae*	lab	[14]
	Black bean aphid Aphis fabae (Scopolli)	lab	[34]
P. chlamydospora	White scale insect *Parlatoriablanchardi*(Targ.)	lab	[56]
	Two-spotted spider mite *Tetranychusurticae* (nymph and adults)	lab	[70]
***Alternaria* sp.**	*Periplaneta americana*	lab	[119]
Aspergillus niger, A.	Terimies*Microcerotermesdiversus*	lab	[117]

flavus, A. fumigatus			
Aspergillus candidus,A. niger, A. flavus, A. ochraceus , A. terreus	Black bean aphid *Aphis fabae*	lab	[14]
***Aspergillus* sp.**	German cockroach*Blattella germanica*(L.)	lab	[19]
A. niger	Black bean aphid *Aphis fabae* (Scopolli)	lab and field	[34]
***Aspergillus terreus, A. oryzae, A. tritici, Aspergillus* sp.**	Two-spotted spider mite *Tetranychusurticae* (nymph and adults)	lab	[70]
Aspergillus niger, A.parasiticus	Whitefly insect *Bemisiatabaci*Genn. (nymph and adult)	greenhouse	[120]
Aspergillus niger, A. fumigatus, A. fumigatus, Mucorsp.	*Periplaneta americana*	lab	[119]
Mucor* sp., *Cladosporium* sp. *Paecilomycesvariotii Trichodrema hamatum Scytalidiumlignicola	Terimies*Microcerotermesdiversus*	lab	[121]
***Trichoderma hamatum*(Rifia)**	Termites *Microcerotermesdiversus*		[117]
***Trichoderma harzianum*(Rifia)**			[10, 14, 29, 48, 73, 84, 19]
Trichoderma harzianum.	Field cricket*Gryllodessaigillatus*(nymph and adult)	lab	[122]
***Emericellavercicolla, Myceliophthora*sp.**			[14]
Fusarium solani			[20, 56]
Fusarium semitectum	Wax worm larvae *Galleria mellonella*	Lab	[123]
***Fusarium* sp.**			[14, 111]

Table 2: Entomopathogenetic fungi recorder in Iraq and their sources

Entomopathogenic fungi	Source	Reference
***Mucor* sp. *Chaetomium globosum Alternaria alternata Aspergillus niger A. flavus A. fumigatus Cladospriumsp. Paecilomycesvariotii Penicillium* sp. *Scytalidiumlignicola Trichoderma hamatum Beauveria bassiana*(different isolates)**	Cadavers and infected termites *Microcerotermesdiversus*From palm groves in Basra Governorate, Abi Al-Khasib District	[121]
	Larvae of date palm stem-borer *Jebusaeahammerschmidti*	[9,12]
	Spodoptera littoralis on potato plant	[13]
	Cadavers of sunn pest insect *Eurygastertestudinaria* (Geofroy)	[27, 28, 44, 85]
	Soil samples from fields, forests and vine yard in Duhok Governorate	[42]
	Soil samples from agro-ecosystems from Baghdad, Wasit, Diyala, Salah AL-din, Babil, Karbala, Amarah,	[124]

	DhiQar, Al-Qadisiyyah, Al-Muthanna, Dohuk, Sulaymaniyah and Erbil	
	Soil samples from palm and citrus orchards Baghdad (Koerich and Numaniyah)	[63]
	Soil samples from fields in Baghdad and citrus orchards in Kut	[67]
	Two isolates from date palm, *Phoenix dactylifera* L. leaves, and one from soil Al-Mada'in district/ Baghdad.	[73]
	Black fly *Acaudalerodesrachipora* Singh on Sidr trees	[82]
***Beauveria varroa* (first record)**	Soil samples from Gara Mountain/ Duhok	[91]
***Beauveria pseudobassiana*Rehner and Humber (first record at 2019)**	Soil samples from the hibernation site of sunn pest *Eurygasterintegriceps*Puton at Gara Mountain, Duhok	[91, 125]
***Isariajavanica* (first record)**	Soil samples from fields, forests and vine yard in Duhok Governorate	[42]
Penicillium glabrum		
Alternaria alternata, Aspergillus candidus,A. niger, A. flavus, A. ochraceus, A. terreus	Black Bean Aphid *Aphisfabae* (Scopolli)	[14]
***Emericellavercicolla, Fusarium* sp.*Myceliophthora*sp.**		
Trichoderma harzianum		
Verticillium lecanii	Whitefly *Bemisiatabaci*	[27, 28]
	Corn borer *Sesamiacretica* Led. on sorghum crop	[98]
	Soil samples from agro-ecosystems from Baghdad, Wasit, Diyala, Salah AL-din, Babil, Karbala, Amarah, DhiQar, Al-Qadisiyyah, Al-Muthanna, Dohuk, Sulaymaniyah and Erbil	[124]
Alternaria alternata, A. niger, Beauveria bassiana, Cladosporium oxysporum, Penicillium chrysogenum, P. compactum, Ulocladiumatrum	Black aphid *Aphis fabae*	[34]
P. chlamydospora		
Alternaria alternate, A. dianthicola, Cladosporium herbarum,	White scale insect *Parlatoriablanchardi*Targ. from three cites from Basra Governorate (Garmat Ali, Shatt al-Arab and the city center)	[56]
C. oxysporum, Fusarium solani, Helminthosporium*sp.*Phoma glomerata, Stemphylium* sp.,*Ulocladium*sp., *Beauveria bassiana		
***Paecilomycesfarinosus*(Holm.)**	Cadavers of sunn pest	[44]
Paecilomyceslilacinus	Soil samples from agro-ecosystems from Baghdad, Wasit, Diyala, Salah AL-din, Babil, Karbala, Amarah, DhiQar, Al-Qadisiyyah, Al-Muthanna, Dohuk, Sulaymaniyah and Erbil	[124]
***Metarhiziumanisopliae*(different strains)**	Soil samples from palm and citrus orchards from Baghdad/ Numaniyah and Basra/ Abu Khasib	[63]
	Soil samples from fields /Baghdadand citrus orchards /Kut	[67]
	Cadavers of sunn pest insect *Eurygastertestudinaria* (Geofroy)	[85]
	Corn borer *Sesamiacretica* Led. on sorghum crop	[98]
	Cadavers of *Culex quinquefasciatus* Larvae from Sewers of Al-Qadisiyah city	[110]
	Soil samples from agro-ecosystems from Baghdad, Wasit, Diyala, Salah AL-din, Babil, Karbala, Amarah, DhiQar, Al-Qadisiyyah, Al-Muthanna, Dohuk,	[124]

	Sulaymaniyah and Erbil	
Beauveria bassiana, Pithomycescharatarum, Aspergillus terreus, A. oryzae, A. tritici, Aspergillus* sp. *Alternaria alternata, Chaetomium globosum	Two-spotted spider mite on egg plant	[70]
Beauveria bassiana, Asperigllusparasiticus, A. flaves Cladosporium* sp.*Phoma glomerata	Moth *Ephestiacautella*	[76]
***Fusarium semitectum*(first record)**	Fruit stalk borer *Oryctes elegans* larvae from Basra governorate	[123]
***Fusarium* sp.**	Soil samples from agro-ecosystems from Baghdad, Wasit, Diyala, Salah AL-din, Babil, Karbala, Amarah, DhiQar, Al-Qadisiyyah, Al-Muthanna, Dohuk, Sulaymaniyah and Erbil	[124]
***Aspergillus flavus, A. niger Cunninghamellaechinulata, Emericellanidulans, Fusarium* spp., *Mucor spp., Penicillium* sp. *Rhizopus stolonifer Trichoderma* sp.*Lecanicilliumlecanii Metarhiziumanisopliae*(first record from Iraqi soil)**	Soil samples from different agro ecosystems at Duhok governorate (Alfalfa fields, different vegetables, forest of the endemic Pine *Pinus brutia*(Ten.), and soil of figs, berry, pear and walnut)	[126]
Aspergillus niger, A. parasiticus,	Cadavers and honeydew of *Bemisiatabaci*Genn	[120]
***Aspergillus niger A.fumigatus Trichoderma harzianumPenicillium* sp., *Alternaria* sp., *Mucor* sp.,*Fusarium*sp.**	Women's and obstetricians hospital and residential areas near of the hospital/ Kerbala	[119]

Sources of EPF Tested Isolates and Experimental Durations

EPF used in these studies were either isolated from infected or dead insects (Table 2) such as larvae of *Jebusaeahammerschmidti* [9, 12], *Ephestiacautella* moth [76] black flies *Acaudalerodesrachipora* [82] *Spodoptera littoralis* [13], *Aphis fabae* [34] and sunn insect *Eurygastertestudinaria* [26, 27, 28, 44, 51, 52, 85], or were isolated from agricultural soils [42, 63] and sewers [110]. Some of the used EPF were obtained from research centres or universities of other Arab countries such as Jordan [43] and Egypt [41, 99, 100]. A big portion of the used EPF was commercial formulation such as Mycotal from Koppert, Netherlands [38, 50], Naturalis from Troy- Bioscience –Arizona, USA [30, 35, 47], Biocont from Dow Agrosciemces, USA [48,7 4] (ORY-X) from Felda Agriculture, Malaysia [74, 101], Recharge from Russell IPM company, UK [89]. While most of the other used EPF were obtained from lab strains conserved either at universities or research centres in Iraq.

Experiments durations varied. Lab and greenhouse experiments ranged between 2-21 days while field experiments, in general, took a bit longer period and reached up to 14 weeks [12]. In general, all the experiments showed satisfying to excellent results in controlling pests, without any study indicating a failure in their outcomes.

The Status of Using EPF in Iraq, its Challenges, and Recommendations

There is an increased demand for safe, eco-friendly products globally, and using EPF and other biological control products to control agricultural pests that fulfils this demand [4].

These products reduce pesticide use, minimize the negative impact of their use on the environment and guarantee farmers safety while maintaining crop production [6, 127]. In many countries, an entire industry has developed to produce, disseminate and aid in the adoption of natural enemies use [7, 8, 9]. This came up with a new generation of growers who are more concerned about pesticide use, its potential non-target effects, and other environmental and health issues. Supported by the government legislation and rules that provide the foundation for regulation of the introducing and applying natural enemies of insects as biological control agents [127]. In Iraq, despite all the above-listed work that has been done in this area, no local commercial products have emerged from this effort. Many challenges are faced in the establishment of this industry in Iraq. There is not enough awareness among the public and farmers towards the side effects of using chemical pesticides to control pests. Thus, increasing farmers' awareness of the environment and health issues associated with using chemical pesticides, could be a good starting point. Financial investment in research to develop this industry and the commercial interests are absent. Therefore, a long-term government support is required to support more focused research in Universities, research centres and the Ministry of Agriculture. Changing the chemical culture that Iraqi farmers and governments approaching for decades needs a genuine change in government attitude in controlling agriculture pests. Led by emphasizing the importance of preserving these species for the environment in education, especially in the faculties of agriculture and media, is needed. Following that proper technology is provided to support this approach, proper legislation is needed to implement rules and regulations that organise the importing, breeding, transporting and applying of these organisms. Also, there is a need for International cooperation represented by transporting experience and providing essential support techniques.

Conclusion

There is a global movement toward replacing chemical pesticides with eco-friendly controlling pest methods and Iraq has to follow this movement. Although the volume of research that has been done by Iraqi researchers to investigate and test the applicability of using different organisms such as EPF to control agricultural pests, there is no satisfying progress in this field yet. There is a dire need for more focused research, necessary technology, successful marketing, farmers' awareness, international cooperation and government support to achieve this goal.

Conflict of interest

The author declared no conflict of interest to this review article.

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