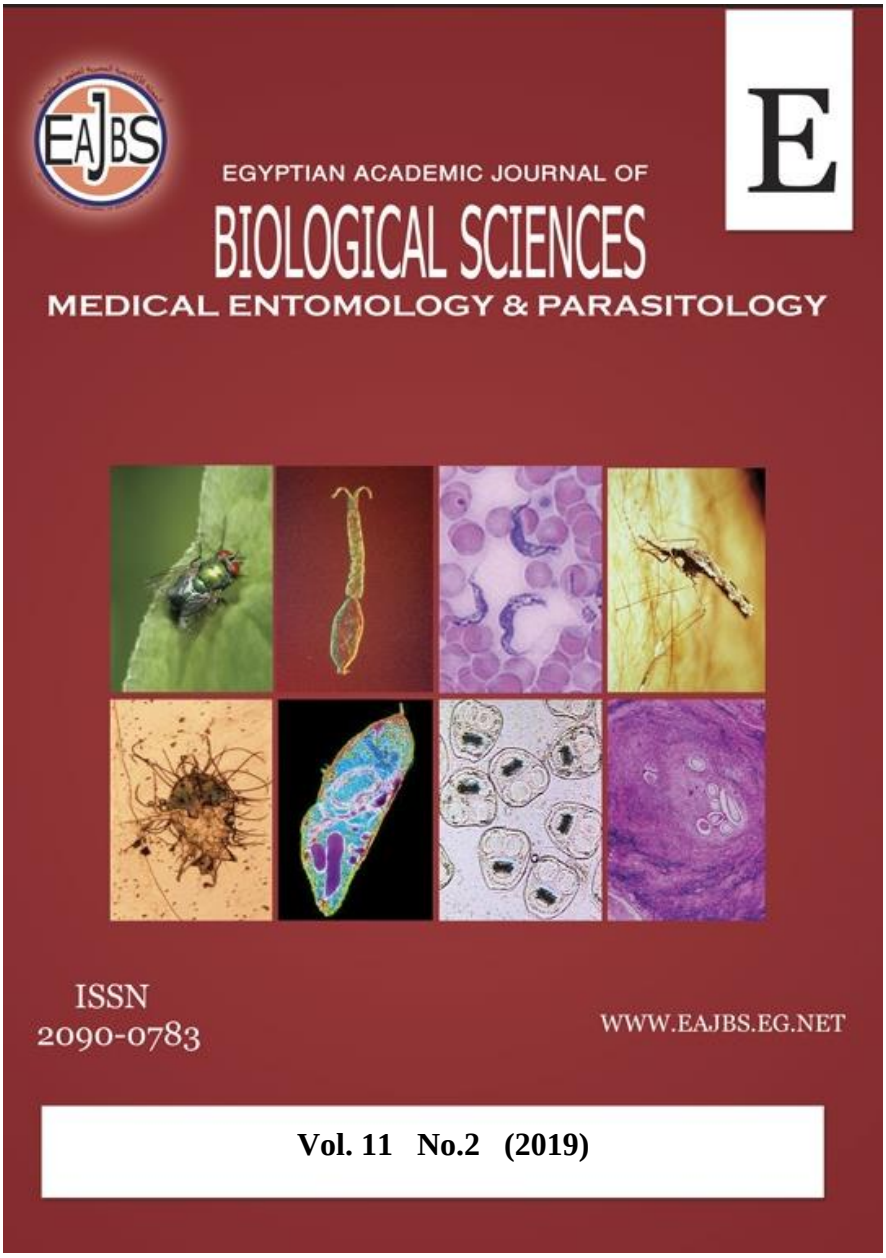

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A Brief Review of Myiasis with Special Notes on the Blow Flies' Producing Myiasis (F.: Calliphoridae)

Eslam M. Hosni*; Mohamed A. Kenawy; Mohamed G. Nasser, Sara A. Al-Ashaal and Magda H. Rady

Department of Entomology, Faculty of Science, Ain Shams University, Abbassia, Cairo 11566, Egypt

E-mail: iobek@sci.asu.edu.eg

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ABSTRACT

One of the most interesting and sophisticated relations that seen in nature is myiasis which represents the relation between these tiny small larvae of Diptera and another living creature where these larvae feed on its tissues. Several previous works discussed the issue of myiasis from different aspects. In this work, a brief and comprehensive review of myiasis including classification of its types, classification of dipterous larvae that cause it and special notes on family Calliphoridae and its role in causing myiasis.

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INTRODUCTION

In nature, the relationships among living organisms are very complicated. Significant observations and continuous surveillance allow us to understand this complexity. One of these relations is the association between flies and targeted vertebrate hosts. Although the apparent difficulty, the association could simply be either detrimental or beneficial (Hall and Wall, 1995).

Earlier in 1815, Kirby and Spence were the first to use the term "scholechiasis" to describe the animal diseases caused by insect larvae. Then in 1840, Hope conceived a new term "Myiasis" which defines the invasion of human and animal bodies with dipterous larvae and referred the terms "scholechiasis" and "canthariasis" to the disease caused by larvae of Lepidoptera and Coleoptera, respectively (Hall and Wall, 1995). Later, De la Torre-Bueno (1937) indicated, in Glossary of Entomology, that myiasis is "The disease or injury caused by the attack of dipterous larvae". Zumpt (1965), gave the practical and accurate definition of term myiasis as " The infestation of live human and vertebrate animals with dipterous larvae, which, at least/or for a certain period, feed on the host's dead or living tissue, liquid body-substances, or ingested food".

Myiasis is considered a neglected disease with great economic impacts on animals and humans (Hall *et al.*, 2016). From ancient times till recent days myiasis causing flies occupied Holarctic and Holotropic regions. The power of this widespread is referred to a wide variety of hosts from wild and domestic animals and even humans (Francesconia and Lupi, 2012). Myiasis is widespread throughout the world especially the tropical regions. It usually occurs in both domestic and wild animals and incidentally in humans under certain conditions (Hall and Wall, 1995 and Hassona *et al*., 2014).

In animals, the odor of infected wounds, decayed organic matters, urine, and feces attract gravid fly females to lay their eggs. Then the voracious larvae consume necrotic tissues and pervade healthy ones producing deep injury (Zumpt, 1965). In humans, although the infestation is rare; about 165 cases of human myiasis were reported from 1914 till 2014 (Sing and Sing, 2015). The predisposing factors like low socioeconomic status, poor hygiene, mental regardless patients without care and drug addicts increase the disease incidence. Moreover, the pathogenicity of myiasis is asymptomatic and may lead to death due to septicemia and toxemia (Singh and Singh, 2015).

This review is objected at providing information related to the types of myiasis and its causing flies. Due to the economic and health impacts of this injury to both animals and humans, efforts have to be intensified toward control of such fly pests.

MATERIALS AND METHODS

A review of the available published and unpublished reports on miyasis and flies producing such condition was performed on PubMed and Research Gate documents and internet-based articles. In addition, several related web pages were accessed. A total of 28 articles were included in this review.

RESULTS AND DISCUSSION

Classification of Myiasis:

Two main ways for myiasis classification: (1) The **Anatomical way** (Table 1) which is based on infested parts of the host's body. It was first proposed by bishop in 1922 and modified by James in 1947 then by Zumpt in 1965 (Gour *et al.*, 2017) and (2) The **Ecological (Biological or Parasitological)** way (Table 2) according to the host-parasite relationship or level of dependence between dipterous larvae and hosts (Zumpt, 1965 and Hall and Wall, 1995). The former classification gives a short cut to identify the accused fly species, but the later one portrays the biology of the fly and permits understanding the evolution of myiasis habit (Hall and Wall, 1995).

Table 1: Anatomical classification of Myiasis; after Hall and wall (1995)

Bishopp 1922	James 1947	Zumpt 1965
01. Bloodsucking	01. Bloodsucking	01. Sanguinivorous
02. Tissue-destroying 03. Subdermal migratory	02. Furuncular 03. Creeping 04. Traumatic/wound 05. Anal/vaginal	02. Dermal/subdermal
04. An infestation of the head passages	06. Nose, mouth, sinuses 07. Aural 08. Ocular	03. Nasopharyngeal
05. Intestinal/urogenital	09. Enteric 10. Anal/vaginal	04. Intestinal
	11. Bladder, urinary passages 12. Anal/vaginal	05. Urogenital

Table 2: Biological (Parasitological or Ecological) classification of myiasis, after Hall and Wall (2016)

Classification	Description
Obligatory (Specific)	Parasitic maggots depend on the live host for a time to complete their life cycle.
Facultative (Semi-specific)	Parasitic larvae develop on either living or decayed organic matters under three levels..
01. Primary	The larvae are free-living and able to initiate myiasis.
02. Secondary.	The Larvae are unable to initiate myiasis and parasitize as a secondary species.
03. Tertiary	The larvae which parasitize the host near its death..
Pseudo-myiasis (Accidental or false myiasis)	The free-living nonparasitic larvae are accidentally affecting the host.

Biological (Ecological or Parasitological) Classification of Myiasis:

The causing flies are classified into three categories:

01. The **obligatory or specific myiasis producers** which develop only on live hosts (Zumpt, 1965 and Hall and Wall, 1995). Such flies select various host organs or tissues in which they deposit eggs or larvae. Examples of such flies are *Wöhlfartia magnifica* and *W. vigil* (Flesh flies), *Oestrus ovis* (Sheep bot fly), *Hypoderma bovis* (Warble fly),*Gasterophilus intestinalis* (Horse bot fly), *Cochliomyia hominivorax* (New-world screwworm) and *Chrysomya bezziana* (Old-world screw-worm) and *Dermatobia hominis* (Human bot fly or the Torsalo) (Kenawy, 2008).
02. The **facultative or semi-specific myiasis producers** (opportunistic) which develop on both living and decayed organic matters under three levels: primary wherein the larvae are able to initiate myiasis or secondary and tertiary when the host becomes near the death (James, 1947). Flies attack filthy infected wounds, stimulated by the odor and do not attack clean wounds or intact skin. Examples of these flies are *Calliphora* spp. (Bluebottle flies) and *Lucilia* spp. (Greenbottle flies), *Sarcophaga* spp. (Flesh flies), *Piophila casei* (Cheese skipper) and *Tubifera tenax* (Rat-tailed maggot) (Kenawy, 2008).
03. The **pseudo- or accidental myiasis produces** are those free-living nonparasitic larvae that are accidentally swallowed (Zumpt, 1965). Flies of family Muscidae are common in causing such false myiasis (Nagakura *et al.,* 1991).

Anatomical Classification of Myiasis:

01. **Sanguinivorous Myiasis:** This term concerning dipterous larvae with voracious behavior towards blood. They are ectoparasitic and able to initiate obligatory myiasis. *Chrysomya bezziana* and *Auchmeromyia luteola* (Congo floor maggot) (Calliphoridae) and *Dermatobia hominis* (Oestridae) are sanguinivorous fly larvae (Zumpt, 1965).
02. **Cutaneous (Wound, Traumatic, Dermal or Sub-dermal) Myiasis:** is the most frequent type of myiasis (Visciarelli *et al.,* 2007). In this condition, obligatory myiasis dipterous larvae feed on animal tissue (epidermis and dermis layers) causing wounds. These wounds or trauma, either caused by insects or others, attract other obligatory or facultative parasites to cause myiasis (Zumpt, 1965). Flies of families Calliphoridae and Sarcophagidae like

Cochliomyia hominivorax, *Lucilia sericata*, and *Wohlfahrtia magnifica* could produce dermal and wound myiasis (Gour *et al.*, 2017).

03. **Furuncular (Warble) Myiasis:** is considered a type of cutaneous myiasis and occurs after penetration of the healthy skin by dipterous larvae causing furuncular lesion or nodes. The furuncular lesion is a nodule with a central pore that exudates a purulent fluid after larval infestation. The number of maggots in the furuncular nodes varies according to fly species (Francesconia and Lupi, 2012). The erythematous lesion, pruritus, movement sensation, hyperpigmentation, fluid leak from nodes and night pain are reported as symptoms of furuncular myiasis (Mahal and Sperling, 2012). The number of lesions and their distribution patterns are fly species-dependent. *Cordylobia anthropophaga*, *Dermatobia hominis*, *Wohlfahrtia vigil*, *Wohlfahrtia magnifica*, and *Cuterebra* sp. are common agents of furuncular myiasis (Robbins and Khachemoune, 2010).
04. **Migratory (Creeping) Myiasis**: occurs when the maggots start to migrate for a distant in the host skin and burrow in it causing obvious migratory lesions. This migration produces ulcerated epithelium and causes inflammation in dermis layer. The larvae then diagnosed in the fibrous cystic sinus tract in dermis layer (Gour *et al.*, 2017). *Hypoderma bovis* (Cattle bot fly) and *Gasterophilus intestinalis* (Horse bot fly) are common agents of migratory or creeping myiasis. Unintentionally, humans could be infested by cattle and horse bot flies but, the larvae are unable to complete their life cycle in human skin (Royce *et al*., 1999).
05. **Cavity Myiasis:** is an infestation of body cavities by dipterous larvae. This type usually receives its name from the anatomical region affected (Francesconia and Lupi, 2012).
06. **Ocular (Ophthalmic) Myiasis:** occurs due to the infestation of host eyes by dipterous larvae. Eye infestation could be internal, external or in the orbital part. Ophthalmo-myiasis interna occurs when the infestation including the anterior and posterior segment of the eyeball (Jakobs *et al*., 1997). In Ophthalmo-myiasis externa, the infestation is restricted to superficial ocular tissues. Red eyes, eye pain, and vision loss are described as symptoms of Ocular myiasis (Anane and Hssine, 2010). *Chrysomya bezziana*, *Dermatobia hominis*, *Lucilia* spp. and *Cuterbera* spp. are the common agents of ocular myiasis (Francesconia and Lupi, 2012).
07. **Oral Myiasis:** was first described by Laurence (1909). The incidence of oral myiasis is associated with poor oral hygiene, alcoholism, mental disability and other clinical forms like oral trauma and gingival diseases (Hassona *et al*., 2014). Also, people whose mouth remains open for a long time are susceptible to Oral myiasis (Sharma *et al.*, 2008). Swelling of mouth, lips and gingival was reported as symptoms of Oral myiasis. The reported species are *Chrysomya bezziana*, *Cochliomyia hominivorax*, *Musca domestica*, *Wohlfahrtia magnifica* and *Calliphora vicina* (Hassona *et al*., 2014).
08. **Aural (Otom) Myiasis:** includes the infestation of the ear by dipterous larvae. Female flies oviposit eggs or larvae around the aural cavity (Uzun *et al.*, 2004). Symptoms vary from itching, inflammation of auditory canal, aural pain to otorrhea and bleeding. The most common species that cause aural myiasis are *Chrysomya bezziana*, *Chrysomya megacephala*, *Cochliomyia*

hominivorax and *Wohlfahrtia magnifica* (Francesconia and Lupi, 2012).

09. **Nasal Myiasis:** occurs when female flies deposit their larvae in the nasal cavity while the host is sleeping. In a study about 252 peoples older than 50 yrs. were suffering from nasal myiasis (Francesconia and Lupi, 2012). Low socioeconomic status and poor hygiene are predisposing factors of larval invasion (Francesconia and Lupi, 2012). Nasal pain, movement sensation, anosmia, nasal discharge, and nasal bleeding are common signs of nasal myiasis (Tsang and Lee, 2009). *Chrysomya bezziana*, *Cochliomyia hominivorax*, *Oestrus ovis*, *Lucilia sericata*, *Wohlfahrtia magnifica Drosophila melanogaster* and *Cephalopina titillator* (Camel bot fly) are the main agents of nasal myiasis (Francesconia and Lupi, 2012).
10. **Intestinal (Enteric) Myiasis:** is widespread in animals rather than humans where the alimentary tract of the mammals from pharynx to anus harbors larvae. Symptoms vary from asymptomatic cases to nausea, vomiting, abdominal pain and rectal bleeding (Karabiber *et al.,* 2010). *Gasterophilus intestinalis* is the common maggot causing enteric myiasis (Singh and Singh, 2015).
11. **Urinogenital Myiasis:** is the infestation of urinogenital area of the host by dipterous larvae. The most common symptoms are lumbar pain, ureteric obstruction, and dysuria. The causing flies are *Wohlfahrtia magnifica*, *Sarcophaga haemorrhoidalis*, *Fannia canicularis* and *Sarcophaga carnaria* (Francesconia and Lupi, 2012).
12. **Cerebral Myiasis:** is rare, fatal, and survival rates are low (Terterov *et al.,* 2010). Species of *Hypoderma bovis* and *Hypoderma lineatum* were discriminated to cause cerebral myiasis (Francesconia and Lupi, 2012).

Calliphoridae and Other Dipterous Families as Myiasis Producing Agents:

Order Diptera (Tru flies) currently includes more than 150,000 described species in 10,000 genera and about150 families (Pape and Thompson, 2010). About thirteen families of this order compress all myiasis causing flies. These are Calliphoridae, Oestridae, Sarcophagidae, Muscidae, Gastrophilidae, Phoridae, Drosophilidae, Psychodidae, Stratiomydae, Scenopinidae, Syrphidae, Piophilidae and Dryomyzidae (Singh and Singh, 2015) of which three families are the major ones: The first one is family Oestridae which contains 151 species in 28 genera. All species are obligate parasites in their larval stages. The second family is Sarcophagidae with 2000 species in 400 genera and the third family is Calliphoridae (Hall and Wall, 1995). About 80 species of Sarcophagidae and Calliphoridae have been recorded to cause myiasis (Hall and Wall, 1995).

Calliphoridae (blow flies, carrion flies, bluebottles, greenbottles, cluster flies) (Table 3) is one of the most common and interesting families of Diptera. It is classified into 6 subfamilies with 150 genera and about 1000 species. Calliphorid flies are characterized by their metallic bodies with blue and green color, while some species are dull. The members of this family are performing several environmental services including, but not limited to decomposing of dead animal bodies and pollination (Shafqat *et al*., 2016). On the other hand, several species of the family have medical and veterinary importance (Stevens, 2003).

Table 3: Prominent myiasis causing species of family Calliphoridae; after Francesconia and Lupi (2012)

Species	**Parameters**	**Status Description**
Cochliomyia hominivorax (New-World Screwworm)	Distribution	Through tropical and temperate zones of US, Caribbean and Latin America.
	Classification	Obligatory wound myiasis.
	Hosts	Mammals.
	Human Myiasis	Cause human wound myiasis and destroy the underlying tissues because of the screw-like feeding fashion of maggots.
Chrysomya bezziana (Old-world Screwworm)	Distribution	Prefers tropical and subtropical climates and widespread throughout tropical Africa, Middle East region, Indian sub-continent, from south-east Asia to China, and from the Philippines to Papua New Guinea.
	Classification	Obligatory wound myiasis.
	Hosts	Sheep and human.
	Human Myiasis	Human wound myiasis cases were reported in a poor region in Africa and Indian sub-continent.
Chrysomya megacephala	Distribution	Has a worldwide distribution especially in Oriental and Australasian regions.
	Classification	Facultative wound myiasis.
	Hosts	Decomposing flesh and feces.
	Human Myiasis	Wound and aural myiasis. Has forensic importance.
Chrysomya albiceps and *Chrysomya rufifacies*	Distribution	Native species in Australia.
	Classification	Facultative wound myiasis flies.
	Hosts	Primary and secondary myiases in humans and other animals.
	Human Myiasis	Wound and Nasal myiasis. Has forensic importance.
Auchmeromyia senegalensis (Congo floor maggot)	Distribution	Mainly distributed in Sub-Saharan Africa.
	Classification	Sanguinivorous myiasis.
	Hosts	Mammals.
	Human Myiasis	Suck human blood.
Lucilia serricata and *Lucilia cuprina*	Distribution	*Lucilia serricata* in North America and Europe and *Lucilia cuprina* in South Africa and Australia.
	Classification	Facultative wound myiasis.
	Hosts	Prefer dead tissue of sheep and sometimes feed on living tissue.
	Human Myiasis	Facultative wound myiasis.
Calliphora sp.	Distribution	Has a worldwide distribution.
	Classification	Facultative myiasis.
	Hosts	Decomposing flesh of carrions
	Human Myiasis	*Calliphora vicina* is primary invader causing oral, aural, nasal, intestinal, urinogenital and wound myiasis. *Calliphora hilli* cause ocular myiasis.
Cordylobia anthropophaga (Tumbu fly)	Distribution	Sub-Saharan Africa and Portugal..
	Classification	Obligatory cutaneous myiasis
	Hosts	Wild mammals and domestic animals
	Human Myiasis	Furuncular myiasis
Cordylobia rodhaini (Lund's fly)	Distribution	Tropical Africa especially in humid forests..
	Classification	Obligatory cutaneous myiasis.
	Hosts	Forest mammals particularly rodents.
	Human Myiasis	Occasionally cause furuncular myiasis
Phormia regina and *Protophormia terranovae*	Distribution	The northern area of Tropic cancer.
	Classification	Facultative wound myiasis.
	Hosts	Decomposing flesh and *Protophormia terranovae* is a serious parasite of cattle, sheep, and reindeer
	Human Myiasis	*Phormia regina* is facultative wound myiasis and has forensic importance.

Conclusion

The way is still so far for getting a complete understanding of myiasis relation and extensive investigations are needed in this direction. This work forms a small step in gathering the data of myiasis causing flies especially those belonging to family Calliphorida.

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ARABIC SUMMARY

مراجعه موجزه وشامله لظاهره التدويد مع القاء الضوء علي الذباب النافخ والتابع لعائله الخوتعيات

إسلام محمد حسني؛ محمد أمين قناوي؛ محمد جمال الدين ناصر؛ ماجده حسن راضي
قسم غلم الحشرات – كلية العلوم – جامعة عين شمس، العباسيه، القاهره 11566، مصر

تعتبر ظاهره التدويد واحدة من العلاقات الأكثرتعقيدا و إثارة للاهتمام في الطبيعه. وذلك لطبيعه العلاقه المركبه بين طرفين ؛الاول هو يرقات الذباب والطرف الاخر هو الانسجه الحيه التي تتغذي عليها من العائل الحي. وقد ناقشت العديد من الابحاث العلميه السابقة ظاهره التدويد من جوانب مختلفة. ويعد هذا العمل مراجعة موجزة وشاملة لظاهره التدويد بما في ذلك الاقسام والانواع المختلفه لتلك الظاهره وكذلك ، تصنيف يرقات الخوتعيات من رتبه ثنائيات الاجنحه و المسببه لظاهره التدويد.