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Dirhinus giffardii (Hymenoptera, Chalcididae), affecting Black Soldier Fly (*Hermetia illucens*) (Diptera, Stratiomyidae) production systems in Tanzania, review on its hosts and notes on its worldwide repartition

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Abstract. – *Dirhinus giffardii* (Hymenoptera, Chalcididae), a parasitoïd described from Nigeria and used as a biological control agent against tephritid flies, was recorded to attack Black Soldier Fly (BSF) pupae. It can be found in more than 20 countries across the globe and may pose significant non-target risks to other primary fruit fly parasitoids, and could even harm endemic Diptera diversity. Its presence in a BSF production system can lead to a drastic reduction in pupae hatching rates and therefore can represent a real constrain. Its occurrence is recorded for the first time from a Black Soldier Fly production system in coastal Tanzania, it was also collected in Kenya, South-Africa, Thailand and Malaysia. Representing a threat for this commercially important species, a list of countries where this wasp is known to occur is provided in the present communication along with a list of all known host.

Résumé. – ***Dirhinius giffardi* (Hymenoptera, Chalcididae) affectant un site de production de Mouche-soldat noire (*Hermetia illucens*) (Diptera, Stratiomyidae) en Tanzanie, liste de ses hôtes et notes sur sa répartition mondiale**. *Dirhinus giffardii* (Hymenoptera, Chalcididae), une guêpe parasitoïde décrite du Nigéria et utilisée comme agent de lutte biologique contre les mouches Tephritidae, est connue pour s'attaquer aux pupes de mouches-soldats noires. Elle est présente dans plus de 20 pays, et peut représenter une menace sérieuse envers les autres parasitoïdes de mouches de fruit, et la faune de certains Diptères endémiques. Sa présence dans un système de production de BSF peut réduire considérablement le taux d'émergence des pupes, représentant une réelle contrainte. Sa présence est signalée pour la première fois dans un site de production de mouches-soldats noires sur la côte tanzanienne, et sa présence est attestée au Kenya, Afrique du Sud, Thaïlande et Malaisie. Étant une menace pour cette espèce d'intérêt commercial, une liste des pays où cette guêpe est connue est présentée, ainsi qu'une liste de ses hôtes.

Keywords. – Chalcid wasp, biological control, *Hermetia illucens*, biodiversity, parasitoid wasp.

The Black Soldier Fly, *Hermetia illucens* (Linnaeus, 1758) (Diptera, Stratiomyidae), appears to be one of the best candidates due to its high feed conversion rates, for farmed insects as feed (Kenis *et al.*, 2014; Stamer *et al.*, 2014; Oonincx *et al* 2015; Tromberlin *et al.*, 2015; Henry *et al.*, 2015). The fly does not feed during the adult stage, and cannot transmit nor carry diseases. It provides an excellent bioconversion of the substrate (Oonincx *et al.*, 2015) and can be used in upcycling organic materials (Newton *et al.*, 2005; Diener *et al.*, 2011). Acting as a waste remediation service, the Black Soldier Fly can contribute to organic waste remediation, poverty alleviation —by creating local employment— and create a local, soon-to-be affordable feedstuff for aquaculture, poultry and livestock productions. However, scaling up the production to make it price-competitive is still a challenge, one of the main constraints being consistent eggs production (Pastor *et al.,* 2015; Rumpold & Schlüter, 2013).

No disease or pathogen affecting the production systems have yet been identified, and while it is known that the presence of BSF reduces bacterial activity in the substrate (Liu *et al.*, 2008), inhibits and controls the oviposition and development of *Musca domestica* (Sheppard, 1983; Bradley & Sheppard, 1984), pupation is a sensitive development stage. So far, three

parasitoidic wasps are known to feed on the Black Soldier Fly pupae. The first one belongs to the genus *Trichopria* Ashmead, 1893 (Hymenoptera, Diapriidae) and was recorded from the USA (state of Georgia) (Bradley *et al.*, 1984). It was also observed in Indonesia (Caruso *et al.*, 2013). Unfortunately, in both cases, specimens were not identified to a species level. The second species, *Eniacomorpha hermetiae* Delvare, 2019, a recently described Chalcidid wasp, was recorded from pupae in Kenya and Ghana (Delvare *et al.*, 2019). The third species, *Dirhinus giffardii* Silvestri, 1914 (Hymenoptera: Chalcididae) was identified in 2015 affecting the pupal development in BSF production systems in Ghana and Mali (West Africa) (Devic & Maquart, 2015). *D. giffardii* is a solitary parasitoid attacking young host pupae (2-3 day old) when they enter to the pharate stage (for details on development stages see Barros-Cordeiro *et al.*, 2014). However, they never parasite pupae older than 8 days old (Dresner, 1954, on Tephritid flies, but also confirmed in Ghana for *H. illucens* from our observations). *D. giffardii* can strongly impact the emergence of Black Soldier Fly pupae, causing a reduction of up to 70.7 % of the production, and decreasing hatching rates to only 8.5% (Devic & Maquart, 2015).

According to Silvestri (1914), the life cycle of *D. giffardii* (from egg to adult) takes 16 to 20 days in tropical Africa. The wasp larvae feed externally on its host (the pupae) but is present inside the puparium. The adults measure between 3-4 mm long, and can feigned death for periods of up to 2 minutes if they are disturbed (Dresner, 1954) making them easy to collect. El-Husseini *et al.* (2008) estimated that adults live for about 19 days and that a single female could lay between 13 and 58 eggs.

The species was described from Nigeria in 1914, and thought to be initially an exclusive predator of Tephritid flies (Fruit flies). The descriptor, Filippo Silvestri —an Italian entomologist— took live samples and introduced them in Italy in 1915 to be used against the expansion of fruit flies. Since then, this parasitoidic wasp has been introduced in many other countries as a biological control agent against tephritid flies. It was introduced in Oceania/Pacific Islands: Australia (Queensland and Lord Howe Island) (Snowball *et al.*, 1962), Hawaii, Fiji, Micronesia (Herting, 1978); in Africa: Egypt (El-Husseini *et al.*, 2008), Ghana, Mali (Devic & Maquart, 2015), Tunisia, Malawi (Yu *et al.*, 2017), Madagascar (Raoelijaona, 2005), Reunion Island (Étienne, 1973; Vayssières *et al.*, 2001), Cap Verde Islands (Fry, 1987); Americas: Mexico, Costa-Rica, Puerto-Rico, Republica Dominica, Trinidad and Tobago, Colombia, Peru, Bolivia (Arias & Delvare, 2003), USA (Yu *et al.*, 2017); Asia: Pakistan (Muhammad *et al.*, 2014; Ahmad *et al.*, 1975), India (Kapoor, 1993), China (Yu *et al.*, 2017) and Europe: Italy, Israel (Wang & Messing, 2004b). The worldwide distribution is presented in fig. 1.

Material examined. – *Dirhinus giffardii*. Label data verbatim: "TANZANIA, Bagamoyo, 6°27'52.2"S 38°51'54.8"E, 27/VII/2017, breed out of *Hermetia illucens* pupae *Willems J. leg*.", 8 ♀, 9 ♂; "SOUTH-AFRICA, Western Cape, Table Mountain National Park, II/2015", 6 ♀, 2 ♂; "KENYA, Nairobi, Malaise trap, VI/2015", 2 ♂; "THAILAND, Prachinburi province, Nam Sai Farms, hand-picked, 21/II/2018, *Maquart P. O. leg*.", 4 ♂, 2 ♀; "MALAYSIA, near Kuala Lumpur, III/2018, *Devic E. leg*.", 1♂, 2 ♀. All specimens are deposited in the collection of the Iziko South African Museum in Cape Town, South-Africa (SAMC).

Résultats

In February 2015, eight specimens of *D. giffardii* were collected in the Table Mountain National Park, in the vicinity of Cape Town (fig. 2) attesting its presence in South Africa. The same year, two specimens were also collected in Kenya (Nairobi), suggesting its presence in this East African country. In January 2017, a Black Soldier Fly production system based in Tanzania (Pwani province, Bagamoyo Town: 6°27'56.7"S 38°51'56.4"E) saw the emergence rate of its pupae dropped. After a careful examination, it appeared that *D. giffardii* was present in the breeding boxes and developing inside the puparium of the BSF. Located near an open

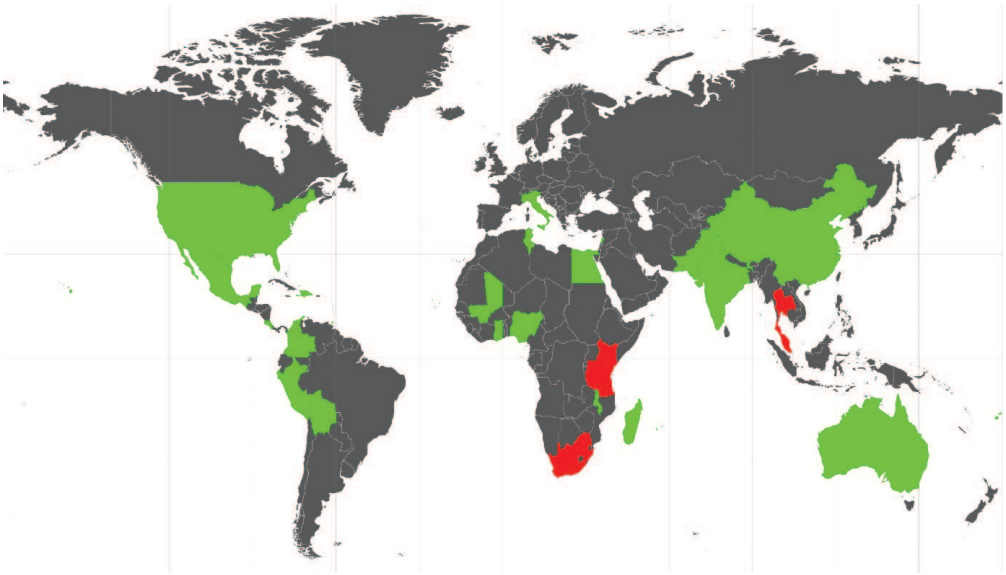

Fig. 1. – Distribution map of *Dirhinus giffardii* Silvestri (green: known location; red: new countries reported in this article).

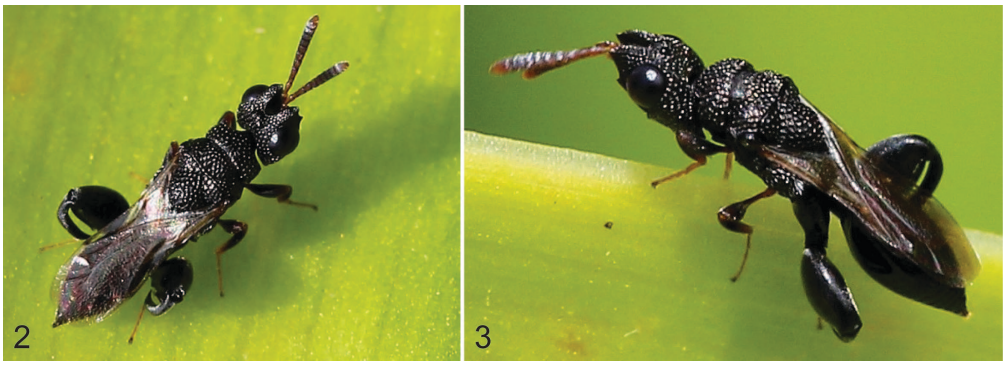

Fig. 2-3. – *Dirhinus giffardii* Silvestri resting on a leaf, in the Table Mountain National Park, Cape Town, South-Africa. Cliché courtesy of Lynette Rudman.

dumpsite, a wild population of Black Soldier Fly —along with housefly— has settled nearby, which might have encouraged the presence of the parasitoid. More recently (February 2018), the wasp was also found in Eastern Thailand (Prachinburi province), and some specimens were collected from a Black Soldier Fly-producing system in Malaysia. After examination, all the specimens belonged to *Dirhinus giffardii.* For details on their collections, see the *examined material* section.

Discussion

Primarily used against Tephritid fly —a commercially important pest for fruit production— this wasp develops on a wide host spectrum, from Diptera (16 species from three families) to Hymenoptera (five species). The list of known hosts is given in table I. It was suggested by Wang & Messing (2004a) that *D. giffardii*, because of its nature of facultative hyperparasitism, may pose significant non-target risks to other primary fruit fly parasitoids, and could even harm endemic fly's biodiversity.

Table I. – List of known hosts of *Dirhinus giffardii* Silvestri.

Order	Family	Species	Reference
Diptera	Stratiomyidae	*Hermetia illucens* (Linnaeus, 1758)	Devic & Maquart, 2015
	Muscidae	*Musca domestica* Linnaeus, 1758	Herting, 1978
	Tephritidae	*Anastrepha obliqua* (Macquart, 1835)	Yu *et al.*, 2017
		A. suspense Loew, 1862	Yu *et al.*, 2017
		Bactrocera zonata (Saunders, 1841)	El-Husseini *et al.*, 2008; Mohamed, 2007
		B. oleae (Rossi, 1790)	Stibick, 2004
		B. passiflorae (Froggatt, 1911)	Yu *et al.*, 2017
		B. ciliates Loew, 1862	Ahmad *et al*., 1975; Stibick, 2004
		B. tryoni (Froggatt, 1897)	Snowball *et al.*, 1962
		Ceratitis capitata (Wiedemann, 1824)	Silvestri 1914; Wang & Messing, 2004a; Étienne, 1973; Stibick, 2004
		C. malgassa Munro, 1939	Raoelijaona, 2005
		C. rosa Karsch, 1887	Étienne, 1973; Stibick, 2004
		Dacus ciliates Loew, 1862	Vayssières *et al.*, 2001
		D. frontalis Becker, 1922	Fry, 1987 ; Stibick, 2004
		Paradalapsis cyanescens Bezzi, 1924	Stibick, 2004
		Toxotrypana curvicauda Gerstaecker, 1860	Yu *et al.*, 2017
Hymenoptera	Braconidae	*Fopius vandenboschi* (Fullaway, 1952)	Dresner, 1954
		F. arisanus (Sonan, 1932)	Wang & Messing, 2004a
		Diachasmimorpha longicaudata (Ashmead, 1905)	Wang & Messing, 2004a
		D. tryoni (Cameron, 1911)	Wang & Messing, 2004a
		Psyttalia incise Silvestri, 1916	Wang & Messing, 2004a

The production of large and consistent amounts of BSF eggs is one of the main bottlenecks for a sustainable and successful mass production systems, and biotic and abiotic factors affecting brood stock husbandry are yet to be fully understood (Gobbi, 2012). In the case reported here, the parasitoid *D. giffardii* represents an additional constraint to egg production. It can be considered as a significant threat for a BSF farming system in the countries where it occurs. The list of countries is probably heavily underestimated, and it is most likely, that the wasp occurs —at the very least— in all nearby countries of the ones listed above, and can be found in all tropical and equatorial regions. The precautionary measures indicated in Devic & Maquart (2015) (*i.e.* protecting the early stages of the pupae using a mesh <1 mm) can help minimizing the stress caused by the presence of this wasp on the BSF pupae.

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