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Dirhinus giffardii (Hymenoptera: Chalcididae), parasitoid affecting Black Soldier Fly production systems in West Africa

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Abstract

Interest for insect farming is currently growing globally. Conditions in West Africa appear suitable for developing such farming systems that can benefit communities by improving livelihoods, food and feed security or sanitation. In Ghana and Mali, the Black Soldier Fly (*Hermetia illucens* Linnaeus, 1758) is being produced for waste recycling and animal feed. In a two stages process (egg and larvae production), egg production was hampered by a pupal parasitoid, *Dirhinus giffardii* Silvestri, 1913 (Hymenoptera: Chalcididae), which reduced future broodstock by almost 72%. This is the first time *D. giffardii* is reported as a parasitoid of *H. illucens* pupae and one of the first reports of parasitism in this commercially important fly species. The introduction of precautionary measures is highly recommended for the success of *H. illucens* production systems in West Africa.

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Short Communication

The Black Soldier Fly (BSF), *Hermetia illucens* Linnaeus, 1758 (Diptera: Stratiomyidae), is an insect offering biological characteristics that can benefit Low and Medium Income Countries. BSF larvae can transform low-value organic materials, such as municipal and household wastes, agro-industrial by-products or wastes into nutrient-rich biomass (Lardé, 1990; St-Hilaire *et al.,* 2007; Hem *et al*., 2008; Diener, 2010; Kalová & Borkovcová, 2010). Frass, resulting from the bioconversion process, is also a valuable by-product having value as an organic fertilizer (Choi *et al*., 2009; Green & Popa, 2012). A semi-controlled pilot-scale BSF farming system was developed in Greater Accra region (Ghana, West Africa) as a demonstration that local production of fly larvae can benefit farmers and support sustainable practices, such as animal feed production (van Huis *et al.*, 2013). Production was separated in two units subjected to natural environment conditions (Caruso *et al.,* 2013): the insectarium consisting in fly adult rearing and egg production and the larvarium for the larvae and pupae production. *Hermetia illucens* is a species well adapted to the climatic conditions of South Ghana where it has been found in rural areas (W. Berger, personal communication, June 2013). Its life cycle and breeding techniques are well described (Sheppard *et al.,* 2002; Caruso *et al.,* 2013), however application and adaptation to different environments can uncover unexpected challenges. In the case presented here, the identification of *Dirhinus giffardii* Silvestri, 1913 (Hymenoptera, Chalcididae), a parasitoid wasp originally described from Nigeria (West Africa), has been the key to understand the low emergence rate of the imagos (adult BSF) from the pupae obtained in rearing conditions (expected broodstock).

The presence of the parasitoid wasp was first noticed while adults were freely moving among BSF pupae; they simulate death when touched, which makes them easy to capture (Dresner, 1954; Narendran & Amareswara Rao, 1987). Dissection of non-emergent BSF pupae revealed the presence of parasitoid larvae and pupae (Figure 1); only one immature wasp was recorded per host pupae as reported in other species (Wang and Messing, 2004a; El-Husseini *et al.,* 2008). The species has been identified morphologically at the University of Ghana, Accra, from adults wasps captured after emergence from BSF pupae (H.E. Davis, personal communication, June 2014). To measure the incidence of the parasitoid on the BSF population, 13 randomly choosen batches containing between 90 and 3422 host pupae and produced between April and June 2014, have been sampled (a production batch is produced every 2 days in order to repopulate the broodstock). Pupae were placed in plastic containers closed by lids allowing air circulation, kept under natural temperature and humidity conditions (respectively 29.0±2.3°C and 83.7±10.9%) and batches were kept for observation during 3 to 5 weeks. During this time, BSF as well as some parasitoids emerged, and were daily removed from the containers. Non-emerged pupae were further dissected to detect the presence of unhatched parasitoids. On average, only 26.9% (SD=19.2) of the pupae turned into BSF adults emerging after 10±2 days. 52.3% (SD=17.0) pupae contained a parasitoid (emerged or not emerged) and 20.7 % (SD=12.3) died for unknown reason. The most affected batch (n=1116 pupae) contained 70.7 % of pupae parasitized by *D. giffardii* and only 8.5% of the flies emerged.

Silvestri (1913) was the first to describe this chalcidid wasp from the pupae of the fruit fly *Ceratitis anonae* Graham (Diptera: Tephritidae) collected in Nigeria. Since then, it has been introduced in many other countries as a biological control agent against tephritid flies, fruit pests of great economic importance (White & Elson-Harris, 1992; Wang & Messing, 2004c; Mohamed, 2007). *Dirhinus giffardii* can be considered as a generalist parasitoid as it can be hosted by many species of several families of Diptera (Tephritidae, Glossinidae and Muscidae) and Lepidoptera (Noctuidae) (Noyes, 2014). In line with the behaviour described by Wang and Messing (2004a), observations made in Ghana suggest that female parasitoid attacked fully formed BSF pupae. Indeed, when prepupae were isolated (placed in a container parasitoid-proof) until emergence of the imago, 98.5% of the pupae (n=1289) turned into adult flies. Some species of *Chalcis* parasitise *Stratiomyidae,* however their strategy consists in ovipositing directly into the egg or the larvae of the host (Bouček & Halstead, 1997). At the same time and on the same site in Ghana, D. *giffardii* was also found attacking housefly pupae (M. Kenis, personal communication, March 2014), which is reported as a common host for the parasitoid (Noyes 2014). However, *D. giffardii*'s reproductive strategy consists in attacking large host species in order to produce larger offspring and gain in fitness (Narendran & Amareswara Rao, 1987; Wang & Messing, 2004b), explaining the selection of *H. illucens* as host. D*irhinus giffardii*'s host selection strategy depends also on the age of its host; according to Wang and Messing (2004a) offsprings' survival rate is greater when parasiting two to three days old puparia of *Ceratitis capitata* Wiedemann (Diptera: Tephritidae). Under laboratory conditions (25-27°C; 50-60% RH), El-Husseini *et al.* (2008) found that *D. giffardii* adults live for about 19 days and a single female deposits between 13 and 58 eggs. Furthermore, the complete life cycle of *D. giffardii* (from egg to adult) takes 16 to 20 days in tropical Africa (Silvestri, 1913).

Despite the numerous studies and uses of BSF for waste bioconversion or animal feed production, parasitism has been very rarely described and litterature reported only *Trichopria sp.* (Hymenoptera: Diapriidae) as a parasitoid of the BSF (Bradley *et al.,* 1984). The pteromalid *Pachycrepoideus vindemiae* Rondani (Hymenoptera: Pteromalidae) another polyphagous parasitoid of fly pupae, is reported from BSF in the Universal Chalcidoidea database (Noyes, 2014) but the original reference does not clearly mention this host-parasitoid association (Pickens *et al.,* 1975). Interestingly, *P. vindemiae* attacked the housefly, *Musca domestica* Linnaeus (Diptera: Muscidae), at the same site in Ghana but it was not recorded on BSF (M. Kenis, personal communication, March 2014).

Figure 1. *Dirhinus giffardii* specimens collected in *Hermetia illucens* pupae in Ghana, showing different stages of development (from left to right, one adult, two pupae and two larvae).

The production of large and consistent amounts of BSF eggs is one of the main bottlenecks of sustainable and successful mass production systems, and biotic and abiotic factors affecting broodstock 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. More generally, it can be considered as a significant threat for a BSF farming system in the countries where it occurs. During the visit of another pilot farm in Mali (West Africa), the presence and strong activity of a parasitoid wasp similar to *D. giffardii* (but not formally identified) within the BSF system was also observed. Although the incidence of the wasp on overall BSF rearing system could not be assessed, it is assumed to be the main cause of the adult population decline impacting directly on the egg production results. Systems developed in Ghana and Mali are semi-controlled systems designed for Low and Medium Income Countries but they are widely exposed to environmental variations and risks (temperature changes, storms, pollution, competition, predation and parasitism). *Dirhinus giffardii* is able to impact strongly on the productivity of such a system, therefore, the introduction of precautionary measures is strongly recommended. For instance, BSF prepupae and pupae could be placed in adapted rearing structures, preventing the parasitoid wasp to enter (*i.e.* cages or trays covered with small size net mesh). Protective measure could be applied until the emergence of the imagos or until pupae vulnerability decreases. On the other hand, the interaction host-parasitoid should be further investigate in order to develop sustainable and cost-effective preventive methods to apply.

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