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First record of the black soldier fly, *Hermetia illucens* L, 1758 (Diptera, Stratiomyidae) in central and western Senegal

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Abstract
The proven effectiveness of the larvae of the black soldier fly (*Hermetia illucens* L. 1758), in the development of organic waste but also as a replacement protein in animal feed, justifies the growing interest in this species. Despite the number of studies carried out over several decades on its dispersal across the world, datas on its exact distribution are lacking in certain areas such as Africa and non-existent in Sahel countries. This is the context in which this study aims to detect its presence in Senegal. The *H. illucens* attraction device consists of two rubber trays. The smaller one, with a capacity of 5 liters (L), was filled with 3 Kilogram (Kg) of one of the four chosen substrates and placed in another larger one, with a capacity of 12 L, filled with sand to one-fifth of its volume. On a stick, placed transversely in the middle of the large tank, perch, using a wire, stacked boxes of 7 centimeters long and 4 wide for laying support they all had been covered with a mosquito net and placed in a dark place. In this article, we report the presence of the black soldier fly in two regions of Senegal (Dakar and Kaolack) which belong to two different agro-ecological zones. Indeed, the females were attracted by the substrates on which they developed.

Keywords: dispersion, diptera, *Hermetia illucens*, new census, Senegal

Introduction
First described by Swedish naturalist Carl von Linnaeus in 1758, the black soldier fly, *Hermetia illucens* Linnaeus, 1758 (Diptera: Stratiomyidae) is a species of increasing interest worldwide. The growing interest in the soldier fly is linked on the one hand to the potential of its larvae to recycle low-value organic materials, such as household waste, agro-industrial by-products or biomass waste rich in nutrients [1-6]; on the other hand, it has the possibility for these larvae to be subsequently used as a replacement protein in animal feed [7].
Consequently, many studies have focused on the biology of the insect, including its development, its mating behavior [8, 9], the effects of diet and temperature on its development [10, 11] but also on its dispersal throughout the world. In fact, *Hermetia illucens* presents a very great flexibility of adaptation both in terms of habitats and temperatures [12].
While it is currently accepted that *H. illucens* originates from the New World, more particularly in the South of the United States [13], it is now found in different regions of the world [14, 15] It is found in habitats, presenting heterogeneous climato-geographic characteristics, distributed from temperate zones to the tropics and in the five continents [16]. There are few documented places of its presence in Africa [17] and the places where it has been recorded are almost all in very humid forest areas where there is a sub-Guinean or equatorial climate: in Réunion [18], Madagascar [19, 16], South Africa [20], Liberia, Côte d'Ivoire, Cameroon, Burundi [19], Guinea [1], Ghana and Mali [17].
It is not yet listed in the countries of the Sahelian zone [18]. Former capital of AOF (French West Africa) and hub of trade between the West African sub-region and the rest of the world for more than a century, through its ports of Dakar and Kaolack [21], Senegal could well be infested by this fly. Thus the objective of this study is to determine if the black soldier fly is present naturally in Senegal, particularly in the regions of Dakar and Kaolack.

Materials and Methods

Study sites

The study was carried out in Senegal, a country bordered to the west by the Atlantic Ocean, Mauritania to the north, Mali to the east and Guinea Bissau to the south. It lies in the far west of the African continent between 12 ° 20 'and 16 ° 40' north latitude and 11 ° 20 'and 17 ° 30' west longitude. The experiments were conducted in two phases between June and October 2020. The first was carried out from June 10 to August 10 and the second from August 20 to October 20. The period when the experiments were carried out during the rainy season during which most insects swarm the most during the year.

According to ANASIM [22] weather data (Table 1), the monthly average temperatures between June and October ranged between 26.9 °C and 29.3 °C in Dakar; 28.5 °C and 30.8 °C, in Kaolack. The maximum monthly average temperature in Dakar was recorded in October (29.3 °C); on the other hand, it was in June that the maximum monthly average temperature was recorded in Kaolack. During this same period the monthly relative humidity (RH) averages varied between 77% and 82.7% in Dakar and between 69.4% and 80.4% in Kaolack. The maximum monthly average HR was recorded in September (82.7%) in Dakar and Kaolack (Table 1).

Table 1: of monthly averages of temperature, relative humidity and precipitation between June and October 2020.

Localités	Mois	T	Tm	TM	H	PP
Dakar	Juin	30.8	26.2	37.6	60.9	41.4
	Juillet	29.2	25.5	34.3	78.3	234.46
	Aout	29	25.4	33.8	79	245.37
	Septembre	28.5	24.5	33.7	80.4	278.64
	Octobre	30.5	25.1	36.8	69.4	41.66
Kaolack	Juin	26.9	24.3	30	79.6	3.81
	Juillet	28	25.3	30.8	77.9	92.21
	Aout	28.7	26	31.3	79.6	105.41
	Septembre	28.1	24.8	31.1	82.7	246.37
	Octobre	29.3	25.4	32.6	77	33.27

The experiments were launched simultaneously in Dakar, a locality located in the west of Senegal, and in Kaolack, which is located in the center of the country. The choice of these two study sites is justified on the one hand by the fact that these two regions were, via their respective seaports, commercial exchange platforms where merchant ships from northern countries regularly served. There is therefore a good chance that these ships introduced the insect accidentally.

Equipment

Sixteen 5 L capacity bins were used as containers for the different types of substrates used. Sixteen other 12 L tanks were used as pupation places for the mature larvae.

Attraction substrates used

The substrates on which flies lay eggs in nature are very varied, but they are almost always more or less decomposed organic matter [24]. Various observations made in the field have shown the effectiveness of the following substrates: fish co-products (fish offal), peelings of fruits and vegetables, chicken droppings, contents of the rumen of cattle / sheep / goats, leftovers from meals. We opted for fish offal, fruit and vegetable scraps, poultry droppings and cracked corn because studies have already shown their strong ability to attract flies.

Substrate sampling

This waste was collected for each site, in the fish, vegetable and fruit markets; fishing docks, restaurants but also with chicken breeders for manure. These samples, once collected, were placed in plastic bins and then brought into the experimental chamber and exposed in the open air. Then the substrate was sprinkled with water from time to time to not only prevent them from drying out but also speed up decomposition.

Attraction device

The device is nothing more than an attraction unit that has been made from two rubber bins. The smaller one, with a capacity of 5 liters (L), was filled with 3 Kilogram (Kg) of substrates. This small tank was then placed in another larger one containing an egg-laying support, with a capacity of 12L, and filled with sand to one-fifth of its volume (Figure 1). After laying and larval development, the pupae were then collected and placed in incubator enclosures (Figure 3) until emergence.

Fig 1: Unit of attraction

Fig 2: *Experimental device*

Fig 3: Pupa incubator

Attraction and breeding

Four amusement units have been placed in the open and put out of reach of ants. The attraction units were permanently exposed throughout the experiment (Figure 2). Daily monitoring was carried out in order to detect, identify and count *H. illucens* larvae very quickly. Some of the larvae were removed from the substrate, then dried and packaged for another study (Figure 7). The rest was left in the substrate until they reached maturity and pupate. These pupae were then placed in incubators to obtain adults. The identification of larvae and adults of the Black Soldier Fly (*Hermetia illucens*) was done using a binocular magnifying glass and model "Optika LAB20". We also use the identification keys proposed by Oliveira *et al*. [16] and Diclaro & Kaufman [24], which in addition to the general appearance of the insect, are mainly based on the presence of two translucent windows at the level of the first segment of the abdomen in adults; and the characteristic location of body hairs in larvae.

Results

The black soldier fly, *Hermetia illucens* Linnaeus, 1758 (Diptera: Stratiomyidae), could be attracted to Dakar as well as to Kaolack by the attraction device that we developed. In addition, the females were able to lay eggs which hatched to give larvae which developed in the substrates; and a few have been successful in producing adults (Figure 4, 5).

Fig 4: Larvae of *H. illucens* in crushed maize

Fig 5: Larvae of *H. illucens* in peels

A total of 2165 larvae of the fly *H. illucens* (Linnaeus, 1758) were counted and identified at the end of the series of experiments carried out simultaneously in Dakar and Kaolack. 2156 black soldier fly larvae were obtained in Dakar against only 9 larvae in Kaolack. In Dakar, of the 100 larvae that were kept in the substrate to give rise to pupae and later adults, 58 were able to hatch in the incubators. On the other hand, 5 adults were able to emerge among the 9 pupae incubated at Kaolack.

Fig 6: *Larvae of H. illucens extracted from substrate*

Fig 7: *Adult H. illucens emerged from incubator*

Discussions

Maquart *et al* [12] presumed the presence of the soldier fly (*H. illucens*) in many African countries, notably in Senegal, thanks to images posted of members of a group of breeders devoted to the BSF ("Black Soldier Fly community ") in social networks. Our present study has just provided formal proof of the presence of *Hermetia illucens* in Senegal. Its introduction into the country could have a link with maritime traffic, as suggested by Martínez-Sánchez *et al*.[14] and Marshall *et al* [20]. Indeed, due to its geographical position and sheltering the capital of the former AOF (French West Africa), Senegal was for several decades the hub of trade between West Africa and the rest of the country of the world [21].

Its climatic adaptation in Senegal is said to be linked to the fact that in the two localities, where *H. illucens* has been attracted, the climatic conditions are similar to those of its original distribution area. According to data provided by the website historique-meteo.net, the monthly temperature averages between Dakar and Miami are almost identical, as are those between Kaolack and Austin (Capital of Texas). It was also observed during the study that larvae of the black soldier's fly (*H. illucens*) only developed in plant substrates in a state of advanced degradation. This indicates that the female was more attracted to corn and rotting peelings; and that she preferred to lay her eggs there rather than in the substrate of animal origin. This could be due to the insect's reminiscence on its preferred substrates. Oliveira *et al* [16] argue that in the continental United States, *Hermetia illucens* commonly breeds in outhouses, poorly managed compost, and poultry manure. However, Martínez-Sánchez *et al* [14] highlighted the presence of the black soldier's fly on a human corpse in the Iberian Peninsula; which proves that *H. illucens* is also capable of growing in substrates of animal origin.

Conclusion

The black soldier fly (*Hermetia illucens* L. 1758) is one of the

rare insects that are subject to industrial breeding. The objective of this study was to detect the presence of this fly in Senegal. In two regions of the country (Dakar and Kaolack), *H. illucens* could be attracted with an attracting device where it laid its eggs. The eggs hatched into larvae and the larvae then gave rise to pre-pupae which, after metamorphosis in an incubator, gave rise to adults. With this publication, we want to inform the scientific community who closely follow the distribution of this species throughout the world that *Hermetia illucens* is present in Senegal.

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