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Net choice is key to the augmentorium technique of fruit fly sequestration and parasitoid release

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ABSTRACT

In Reunion Island, tephritid fruit flies are the main pests of fruit and vegetable crops, causing severe yield losses. Instead of the curative approach to reducing populations, this study focused on a particular sanitation technique, which forms the basis of Integrated Pest Management (IPM) in this context, using a tent-like structure called an "augmentorium" the aim of which is to contribute to controlling these pests. This structure sequesters adult flies emerging from infested fruit while allowing the parasitoids to escape, via a net placed at the top of the structure. The size of four nets was tested in the laboratory in order to include the most effective one in an augmentorium prototype adapted to the conditions of Reunion Island. The mesh finally selected (hole area 3.00 mm^2) proved to be perfectly effective with 100% sequestration of adult flies (*Ceratitis capitata*, *Bactrocera cucurbitae*, *Bactrocera zonata*). In addition, 100% of the parasitoids (*Fopius arisanus* and *Psyttalia fletcheri*) were able to escape from the cage through the mesh if they chose to do so. Farmers were enthusiastic about using the augmentorium prototype. Implications for the use of this technique in Reunion Island are discussed.

1. Introduction

Fruit Flies (Diptera, Tephritidae) are one of the most damaging groups of agricultural pests in the world (Bateman, 1972; White and Elson-Harris, 1992; Dhillon et al., 2005). A total of eight tephritid fruit fly species occur in Reunion Island, where they are considered the main pests of vegetable and fruit crops (Etienne, 1982; Quilici et al., 2005; Ryckewaert et al., 2010). Three of these species attack fruits in the plant family Cucurbitaceae: *Bactrocera cucurbitae* (Coquillett), *Dacus ciliatus* Loew and *Dacus demmerezi* Bezzi. Another fruit fly species attacks fruits in the plant family Solanaceae: *Neoceratitis cyanescens* (Bezzi). The other four species attack fruit crops (e.g., mango, *Citrus* spp.): *Bactrocera zonata* (Saunders), *Ceratitis rosa* (Karsch), *Ceratitis capitata* (Wiedemann) and *Ceratitis catoirii* Guérin-Méneville (Etienne, 1982; Quilici et al., 2005).

In cucurbit crops, the damage caused by the flies can reach 100% of the yield, and insecticides (mainly pyrethroids and organophosphates), are no longer effective (Vayssières et al., 2008). Furthermore, chemical control has some collateral and negative effects on health, biodiversity (particularly on natural enemies and pollinators) and the environment. In particular, the impact of the two most important fruit fly parasitoids imported and which established in Reunion Island, *Psyttalia fletcheri* (Silvestri) and *Fopius arisanus* (Sonan), is probably limited by insecticide applications (Quilici et al., 2004, 2005; Rousse et al., 2006).

In an IPM program, preventive measures are known to be effective against different kinds of pests (Conway, 1996; Masanza et al., 2005; Deguine et al., 2009) and especially against fruit flies (Liquido, 1991). In this respect sanitation against fruit flies is one of the key techniques for the management of their populations (Liquido, 1993; Verghese et al., 2004; Mziray et al., 2010) and forms the basis of the IPM program.

This preventive approach has been studied by USDA in Hawaii against fruit flies, especially in the last decade with the use of augmentorium[1] (Klungness et al., 2005; Jang et al., 2007). An augmentorium is a tent-like structure, placed adjacent to a cultivated field, where farmers can regularly deposit infested fruit. The augmentorium sequesters adult flies that emerge from infested fruit while allowing parasitoids to escape, thus "augmenting" their population. To do this, the augmentorium has a net placed at the top of the structure through which flies cannot escape, but parasitoids can. To implement this technique in Reunion Island, a first local prototype was recently designed (Deguine et al., 2008) (Fig. 1).

In order to address the need of local farmers, the aim of the present study was to measure the efficiency of the mesh of different nets, which may play a key role, on different species of

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[1] Augmentorium is a word derived from the Latin *augere* (to grow), *augmentor* (that which increases) and suffix −*ium* used in Latin to indicate location or place of (Klungness, 2010, personal communication).

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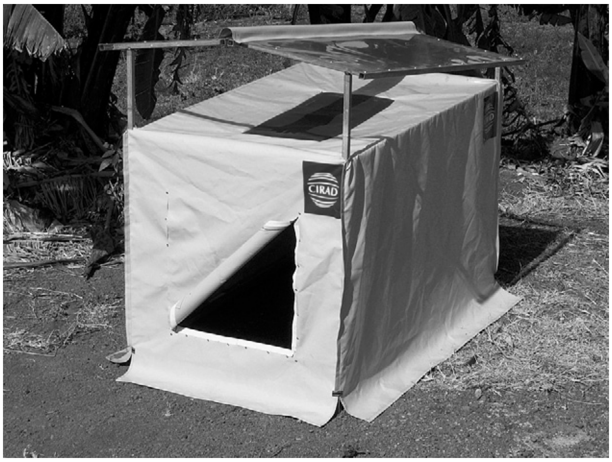

Fig. 1. Augmentorium prototype designed in Reunion Island (see the net on the top of the structure under the roof).

fruit flies (for sequestration) and different species of parasitoids (for augmentation). This study is thus a contribution to the knowledge of the efficiency of a new sanitation tool in crop protection against fruit flies. It could also be a first step in trying to use an augmentorium as a sanitation tactic for a fruit fly management program.

2. Materials and methods

The experiments were conducted in Reunion Island in the first half of 2008 in the laboratory and with the facilities of the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD) in Saint-Pierre.

2.1. Selection of a net for the augmentorium

The gauge of mesh is a key factor for effectiveness of an augmentorium (i.e. sequestration of flies and augmentation of parasitoids). Based on the availability of nets on the market in Reunion Island and differences in mesh size, three types of nets were preselected. The net used in Hawaii was added as a standard in the experiment (Table 1).

The mesh of the four types of nets was observed with a binocular microscope and photographed. The area of the mesh hole was determined by measuring its length and width using Adobe Photoshop software (CS3 version). On account of the high uniformity of the size of the mesh holes for the four tested nets, only one measurement was done.

The four types of nets were compared using 5 technical indicators: dimension of mesh (area of the mesh hole), rigidity and mechanical resistance of the mesh, availability of the mesh (local availability of the net), cost and colour (which can influence some biological parameters). The objective was to compare the 4 types of nets using these indicators. For each mesh, each indicator was marked on a scale from 1 (very bad), 2 (bad), 3 (average), 4 (good) to 5 (very good), using the Hawaiian mesh, whose efficiency was already demonstrated (Klungness et al., 2005), as the standard.

2.2. Biological material

Three species of Tephritidae (*B. cucurbitae*, *C. capitata*, *B. zonata*), routinely reared in the CIRAD laboratory, were used for the experiments. The two *Bactrocera* species were chosen because of their economic importance on vegetables and fruits respectively, *C. capitata* because it is the species whose adults are the smallest among the tephritid species of economic importance present in Reunion Island (i.e. if the adults of this species cannot pass through the mesh, all the other species of flies also could not pass). Standard rearing methods were used for all species, as described by Duyck and Quilici (2002) for *C. capitata*, Duyck et al. (2004) for *B. zonata* and Vayssières et al. (2008) for *B. cucurbitae*.

Two species of fruit fly parasitoid (*Psyttalia fletcheri* (Silvestri) and *Fopius arisanus* (Sonan)) have been imported by the Entomology Laboratory of CIRAD Reunion in the past for biological control against fruit flies (Quilici et al., 2004, 2005; Rousse et al., 2006). Parasitoids used for experiments were obtained from colonies routinely reared in the laboratory. In these colonies, depending on the parasitoid species, emerging adults were offered eggs or larvae of host-flies. The adults are maintained in a 110 cm × 60 cm × 60 cm plastic screened cage at 25 ± 2 °C, 70 ± 20% RH and a photoperiod of 12:12 (L: D) h. They were given free access to water on a moistened sponge and to a mixture of honey/agar 15% (1:1). Both species of parasitoid were used for the experiments.

2.3. Efficiency of the mesh for sequestration or escape of insects

In the laboratory, the top of circular boxes (10 cm in diameter and 8.5 cm in height) was covered with one of the four different mesh types. Each box was then placed in a larger cage in order to keep insects (flies and parasitoids) inside. Known numbers of pupae (un-parasitized or parasitized) were placed inside the boxes before the experiments and the numbers of sequestrated or escaped insects were observed.

Two types of qualitative tests were performed before the quantitative tests. First, we wanted to verify if adults of *P. fletcheri* (the biggest parasitoid of the two studied species) could escape from the boxes, with the four types of mesh. Two replications of this test were done and in each experiment, the numbers of parasitoids in the mesh box and those that had escaped into the cage were counted. Secondly, we tested the propensity of flies and parasitoids to exit from a box covered with a large mesh (6 mm × 6 mm). Two replications were done with adults of each species of fly and parasitoid.

Table 1
Characteristics of the nets.

Mesh	Manufacturer	Reference	Material	Durability index[a]	Stated size	Color	Shape
# 1	Intermas Nets, S.A. (Barcelona, Spain)	170551	glass fiber covered with PVC	4	1 mm × 1.5 mm	grey	rectangle
# 2	Phifertex Wire Products Inc. (Tuscaloosa, AL)	unknown	glass fiber covered with PVC	unknown	1.2 mm × 1.3 mm	grey	rectangle
# 3	Intermas Nets, S.A. (Barcelona, Spain)	171512	polyethylene	2	1.9 mm × 1.9 mm	green	square
# 4	Intermas Nets, S.A. (Barcelona, Spain)	174532	high-density polyethlene, treated with anti-UV additives	3	1.9 mm × 1.9 mm	green	parallelogram

[a] Durability index (which is written on the material) represents on a scale, from 0/null to 5/long, the period of time during which the net tolerates outdoor conditions.