

# The FAO/IAEA Interactive Spreadsheet for Design and Operation of Insect Mass Rearing Facilities

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**ABSTRACT:** An electronic spreadsheet is described which helps users to design, equip and operate facilities for the mass rearing of insects for use in insect pest control programmes integrating the Sterile Insect Technique (SIT). The spreadsheet was designed based on experience accumulated in the mass rearing of the Mediterranean fruit fly, *Ceratitidis capitata* (Wiedemann), using genetic sexing strains based on a *temperature sensitive lethal (ts/l)* mutation. The spreadsheet takes into account the biological, production, and quality control parameters of the species to be mass reared, as well as the diets and equipment required. All this information is incorporated into the spreadsheet for user-friendly calculation of the main components involved in facility design and operation. Outputs of the spreadsheet include size of the different rearing areas, rearing equipment, volumes of diet ingredients, other consumables, as well as personnel requirements. By adding cost factors to these components, the spreadsheet can estimate the costs of facility construction, equipment, and operation. All the output parameters can be easily generated by simply entering the target number of sterile insects required per week. For other insect species, the biological and production characteristics need to be defined and inputted accordingly to obtain outputs relevant to these species. This spreadsheet, available under <http://www-naweb.iaea.org/nafa/ipc/index.html>, is a powerful tool for project and facility managers as it can be used to estimate facility cost, production cost, and production projections under different rearing efficiency scenarios.

Key Words: Facility design, insect mass rearing, *Ceratitidis capitata*, Mediterranean fruit fly

## INTRODUCTION

The Sterile Insect Technique (SIT) as part of area-wide integrated pest management (AW-IPM) programmes, is a powerful insect control method that has a long history of success and is now being extended to new target species (Klassen and Curtis 2005). The SIT is based on the release of large numbers of reproductively sterile insects into a wild population of same pest species so that sterile males mate with, and impede the reproduction of, wild females (Knippling 1955). Therefore, cost effective production of insects of high quality is a key component for success. In the past, rearing facilities were often simply modifications of laboratories used originally to rear much smaller numbers of insects (Leppla and Ashley, 1978). However, currently facilities

are specifically designed, and specific requirements in terms of space, equipment, environmental conditions and procedures as well as production and quality standards (Cohen 2003, Cáceres 2002, Cáceres et al 2004, Opiyo 1999, Harrel and Gantt 1984) have been established for several insect species. The size of each facility varies with use, insect or strain to be reared, and production capacity. Final layout also depends on required equipment and expected inventory in the production system.

Currently managers, engineers, and facility operators are often faced with the challenging questions of how much land, equipment, labour and investments are required to establish a mass-rearing facility, and the complexity of these make it difficult to provide accurate and timely assessments. To address this situation, a user-friendly, Excel-based spreadsheet called "FAO/IAEA INTERACTIVE SPREADSHEET FOR DESIGNING AND OPERATING INSECT MASS REARING FACILITIES V.1.0" has been developed.

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The objective of this paper is to provide basic information about this practical model that generates information on the design and cost of mass rearing facilities. The initial model is based on data generated for the mass rearing of the Mediterranean fruit fly using genetic sexing strains based on a *temperature sensitive lethal (tsl)* mutation (Cáceres et al. 2004; Franz 2005). However, this model can calculate information for other insect species through the substitution of basic biological and production parameters for those of the desired pest species.

### BASIC CONSIDERATIONS

Facility layout inconsistencies could occur in the design of new facilities and the remodelling or redesign of existing ones. Careful planning of a facility design can have significant long-term benefits for insect production, as well as implications in terms of construction costs and future maintenance requirements. The following is an outline of the items that should be included during the planning phases of a new facility. First of all, each of the relevant biological parameters should be considered for any given species or strain. Additional components may be required, as determined by the specific location, facility size, or insect species. The main items that should be considered for the facility design phase, and which were included for the development of the spreadsheet model are:

### BIOLOGICAL PARAMETERS

Insect species

Production level required, including colony stock and number of sterile insects for release

Strain production profile and quality control specifications

Life cycle for immature and adult stages

### REARING CHARACTERISTICS

- Specifications of rearing and general type of equipment required to mass produce a specific insect species
- Equipment characteristics for each operation in the process
- Identification and size dimensions of facility components (filter rearing system, diet mixing, marking and bagging, irradiation, packing, quality, and process control laboratories)
- Flow patterns through the facility
- Type of insect diets required and specifications for nutritional and raw ingredients
- Origin of the diet components (local or imported)
- Schedule and sequence of production operations
- Forecasted volumes for each of the products (egg, larvae, pupae and adults)
- Inventory or stock volume for nutritional and raw diet ingredients and consumables
- Production schedules driven by customer orders or by inventory levels
- Overall process equipment requirements

### OPERATIONAL REQUIREMENTS

- Auxiliary areas that will be required for the facility production (clerical staff offices, maintenance, utility rooms, workshop, warehouses, shipping/receiving rooms, cafeteria/coffee break rooms, locker rooms, restrooms)

- Preliminary utility requirements, including electrical loads, compressed air, cold and hot water and, heat and A/C loads.
- Waste disposal
- Waste water treatment plant

**FACILITY ADMINISTRATION**

- Number of technicians and operators required

**SPREADSHEET STRUCTURE**

The spreadsheet was created using Microsoft® Office Excel. It uses the workbook/page- calculation Microsoft® Office Excel structure to present a series inputs/outputs related to the different aspects of the insect mass rearing process. The user of the spreadsheet will be able to input information at different levels of complexity depending on his/her own needs. Outputs are calculated based on simple formulas (Levin and Abramovich, 1992) constructed by the combination of the critical inputs involved

in the rearing process. To enter and receive information from the spreadsheet, the following basic structure has been made available:

**I. Main Menu**

The main menu contains all the options for manipulating the spreadsheet view. It is only available when the spreadsheet view is the active window (Figure 1). It contains the following main menu items.

**II. Start-up Parameter**

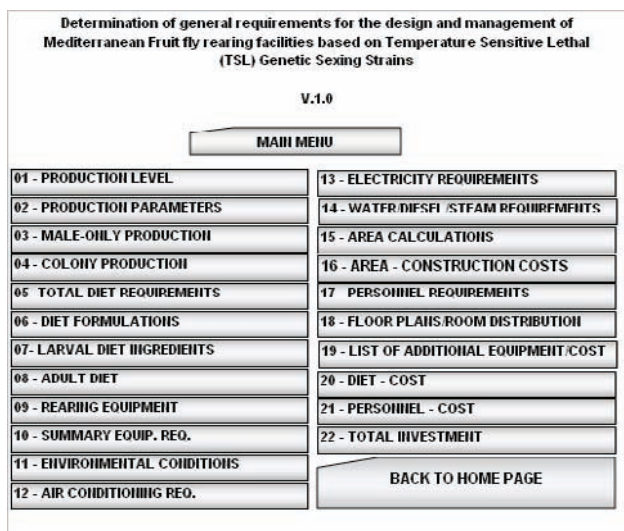
This item refers to the target number of sterile insects required per week. All the output calculations are easily generated by simply entering this information (Figure 2).

MALE ONLY PRODUCTION LEVEL (millions of pupae/week)	250
TOTAL PRODUCTION LEVEL (FLYING MALES PER WEEK)	100

**Fig 2.** Start-up parameter (target number of sterile insects required per week)

**III. Critical Inputs**

Critical inputs are the key parameters such as life cycle, production and quality control parameters of the species, types of diet, equipment and environmental conditions



**Fig 1.** Spreadsheet main menu

required. Depending on the facility location, each design variable has interrelated economic data to estimate both the required start-up capital and operational costs of the facility. Users can vary inputs and generate

many different design scenarios to address different insect strains/species, site-specific needs, and conditions for a particular production requirement. The critical inputs are:

Production parameters	
Sex ratio for release colony (females per male inside egging cages)	5
Sex ratio for second amplification (females per male inside egging cages)	4
Sex ratio for first Amplification (females per male inside egging the cages)	7
Sex ratio for filter (females per male inside egging the cages)	0.83
Efficiency brown pupae to flying males	0.750
Total of pupae produced per week (brown + white)	3.10E+08
Brown pupae recovery (%)	50
White pupae recovery (%)	25
Efficiency egg flying male (male-only)	0.1125
Efficiency egg to pupae (male-only)	0.15
Efficiency egg to pupae (colony)	0.30
Eggs per ml	25 000
Efficiency white pupae to flyer female	0.65
Pre-oviposition days	6

Fig 1. Spreadsheet main menu

#### a. Production parameters

This option contains information of the production profile and quality standards based on average data from operational facilities. It also contains information of load capacity for rearing equipment or other components. Users can modify this information according the characteristics of the strain or species in question and according to the characteristics of rearing equipment or components (Figure 3).

#### b. Diet formulation

This option allows for the introduction of specific diet components and their amounts (in %).

#### c. Environmental conditions

This option requires knowledge of the specific environmental conditions for each rearing area within the mass rearing facility. This information does not play a role in the production calculations; however, it is indispensable to define the characteristics of the environmental control equipment.

#### IV. Main Outputs

**Colony production:** Calculates the number of immature and adult stages required to maintain the colony.

**Sterile insect production:** Calculates the number of immatures and adults required to produce the target number of sterile insects.

**Larval and adult diet ingredient:** Calculates the quantity in weight or volume for each specific diet ingredient.

**Rearing equipment:** Calculates the quantity of each specific type of equipment.

**Area calculation:** Calculates the space required for each specific rearing room, considering equipment characteristics.

**Rearing staff:** Calculates the number of supervisors, technicians and operatives. Number of operative staff is calculated on the basis of the average of the number of operatives to produce one million sterile insects. Automation of some of the steps of the rearing system will affect this initial calculation.

#### V. Additional Information

These additional inputs are infrastructure data and equipment specifications that depend mainly on facility location and the strain and species in question.

**Air conditioning, heating, and electricity load:** This should be calculated by a specialist for inclusion on the equipment list. This infor-

mation is indispensable in order to calculate the cost of the facility and its operation.

**Additional equipment:** The spreadsheet provides the user with a basic list of equipment that is regularly required for rearing Mediterranean fruit fly genetic sexing strains based on the *ts/* mutation. However final calculation should take into account facility size, location and species or strain of insect in question. This information is indispensable in order to calculate the cost of the facility and its operation.

**VI. Total Investment and Rearing Cost**

This output on investment and rearing cost is illustrated in Figure 4. Rearing costs can be determined by adding the annual cost of equipment and building depreciation, per-

sonnel, diet, electricity, overheads, and other consumables and then dividing by the number of sterile insects produced per year (Figure 5).

**FINAL CONSIDERATIONS**

This spreadsheet is a powerful tool for project and facility managers. It provides managers with practical information regarding the list of items that should be considered when planning the establishment of rearing facilities of any insect species. Once facilities are established, it can also be used to estimate facility and production costs, as well as production pro-

<b>Full scale medfly mass rearing facility</b>	
Investment	
<i>Components</i>	<i>production capacity / Millions / Week</i> <b>250</b>
Production of male only flies - year	13 000 000 000
Area - m <sup>2</sup>	3 187
<b>Cost of Construction - \$</b>	<b>1 134 638</b>
<b>Cost of Equipment - \$</b>	<b>3 792 524</b>
<b>Total Investment (Cons.+ Equip.) \$</b>	<b>4 927 162</b>

**Fig 4.** Total investment calculation for a given facility size

<b>Rearing Cost</b>				
<i>production capacity / Millions / Week</i> <b>250</b>				
<i>Cost Factors</i>	<i>Amount</i>	<i>Units</i>	<i>cost per unit</i>	<i>Total Cost</i>
Depreciation - Equipment				433 362
Depreciation - building				113 464
Personnel				600 000
Diet				1 285 268
Electricity	15 385	KV / day	0.09	505 383
Water	16	m <sup>3</sup> / day	0.21	1 234
Diesel	219	liter / day	0.44	35 378
<b>Total Direct Cost</b>				<b>2 974 089</b>
Over Head	8%	of Direct Cost		237 927
Supplies	15%	of Diet cost		192 790
<b>Total Rearing Cost - \$/year</b>				<b>3 404 806</b>
<b>Rearing Cost per million of male-only sterile pupae US\$</b>				<b>262</b>

**Fig 5.** Rearing and operation facility costs.

jections under different rearing efficiency scenarios.

During the design process, it is very important that for the air conditioning (AC), heat and, electricity loads assessments a local specialist provides the required input, as the cost for these important components varies according to facility size and location. As a reference point, the model uses the production of 250 million sterile male Mediterranean fruit fly pupae per week at the “El Pino” mass rearing facility in Guatemala. The estimation and preliminary calculations of the AC system required for each specific rearing environment for fruit fly mass rearing facilities can be found in Oborny (1988). The estimation of auxiliary areas and waste water treatment plant are also not subject to automatic calculation since these areas can be standard for a given facility size. Nevertheless, the spread sheet also includes examples of sizes for each specific auxiliary area for facilities capable of producing between 100 to 250 million of male only sterile pupae per week. The spreadsheet will continue evolving, taking into account user-feedback and new technological developments for further improvement.

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