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Insect population distribution and density estimates in a large rice mill in Portugal – A pilot study

Maria Otília Carvalho [a,*], Alexandra Faro [b], Bhadriraju Subramanyam [c]

[a] Instituto de Investigação Cientifica Tropical, IICT-Biotrop Centre, Polo Mendes Ferrao, Apartado 3014, 1301-901 Lisbon, Portugal
[b] Núcleo de Investigação e Formação Contínua em Segurança e Qualidade Alimentar, Instituto Superior de Ciências da Saúde Sul, Portugal
[c] Department of Grain Science and Industry, Kansas State University, Manhattan, KS 66506, USA

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ABSTRACT

The objectives of this study were to characterize the spatial distribution of the most abundant insect species identified in the rice plant, optimize the sampling program, develop and validate a fixed-precision enumerative sequential sampling plan for the key pests *Sitophilus* spp. in the rice industry in Portugal. Experiments were carried out from September 2005 to July 2007, using 25 pitfall traps baited with food grade oil and pheromone specific for *Sitophilus* spp. The traps were observed weekly and the insects were identified and counted. Several species were found but *Sitophilus zeamais* and *Sitophilus oryzae* were the most abundant (90% of the total) followed by *Tribolium castaneum*. Taylor's power law parameters, from the regression of log variance versus log mean, suggest an aggregated distribution for *Sitophilus* spp. and *T. castaneum*. A fixed-precision sequential sampling plan was developed for *Sitophilus* spp., using Green's fixed precisions sampling plan and the Resampling Validation of Sampling Plan, with an action threshold of 0.5 *Sitophilus* spp. The sampling plan was designed to provide precision levels of 0.20, 0.25 (for pest management purposes), 0.30 and 0.35. The current sample size raised a precision of 0.30, and an increase of the number of traps to 37 would be needed to achieve the desirable precision of 0.25. This fixed-precision sequential sampling plan for *Sitophilus* spp. populations in rice is demonstrated to be a useful tool in IPM tactics at rice facilities.

1. Introduction

Portugal is a major rice consumer among the European Union countries. The annual per capita consumption of rice in Portugal is 15 kg, 2.5 times higher than in Spain, which is the second largest consumer of rice in the EU. About 2000 rice farmers and eight rice processors in Portugal annually produce 129,000 metric tons (MT) of *japonica* rice and 26,000 metric tons of *indica* rice, primarily in three main regions: Mondego (36,000 MT of *japonica* rice); Tejo (49,000 MT of *japonica* rice and 6500 MT of *indica* rice) and Sado Valley (43,400 MT of *japonica* rice and 19,500 MT of *indica* rice). In Portugal rice is a seasonal crop; planting takes place in April and is harvested near the end of August. As a consequence, the maintenance of paddy and milled rice quality is very important for availability year-round. The demand by the consumer for better quality rice has increased, resulting in a need for review of all aspects of rice production from breeding to agronomic practices and storage.

Paddy rice in storage is subject to infestation by stored-product insects which can contribute to qualitative and quantitative losses. While a great amount of research has been conducted on insect pests in wheat storage (Smallman and Loschiavo, 1952; Subramanyam et al., 2005; Toews et al., 2006; Campbell et al., 2010a, 2010b), little information is available on stored-product insects in facilities where rice is milled and packaged. Mills are ideal habitats for stored-product insect pests. These insects become of economic significance because of year-round warm temperatures and constant availability of food resources that allows for continuous breeding (Smallman and Loschiavo, 1952). Under an IPM strategy, management of insects in mills is important in order to produce wholesome and unadulterated products (milled rice). Recommended IPM practices in mills include inbound inspection of raw materials (paddy rice), sanitation, exclusion, stock rotation, use of residual insecticides in non-food areas, and well-timed use of whole-facility treatments with heat or fumigants. Research in wheat flour mills has shown that managing insect infestations in mill environments is difficult because of their continuous operation (24 h a day 7 days a week); inadequate inbound inspection of materials, ineffective sanitation

* Corresponding author. Tel.: +351 21 361 72 47; fax: +351 21 361 72 48.
E-mail addresses: motiliac@iict.pt, motiliac@netcabo.pt (M.O. Carvalho).

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and exclusion practices (Subramanyam et al., 2005), and improper timing of pest management interventions (Toews et al., 2006). Insects also infest structures and equipment in areas that are difficult to access (Campbell et al., 2010a, 2010b) resulting in reservoirs of pests that can reinfest product after control measures have been implemented.

The rice industry in the European Union is currently facing serious problems related to insect contamination due to the restrictions placed on the use of chemical pesticides. Some grain protectants that were historically used on rice have been removed from the EU market due to insecticide resistance or through regulatory action. An example is the organophosphate insecticide malathion, once extensively used in pest management programs in stored grains, but now largely discontinued in many countries. Although consumers express preferences for residue-free food products, the rice storage industry must occasionally use insecticides to maintain quality and prevent economic damage. In addition, in many countries insects are developing resistance to insecticides, including the fumigant phosphine (Price and Mills, 1988; Zettler and Cuperus, 1990; Chaudhry, 1999). Thus, the implementation of an IPM program assists in minimizing the use of pesticides and targets when they are most needed.

The lack of information on insects in rice mills, especially in Portugal, prompted us to conduct a two-year study to understand the populations of insect species found and to determine the optimal number of traps (the "sample size") needed for the estimation of species density in this rice milling plant. This information can then be used to achieve effective control in the most efficient manner. The advantage of sequential sampling is to optimize sample size required for decision making and therefore save time and money and minimize the error of ineffective control measures. Therefore it is important to validate the sampling plan to determine actual error rates for IPM tactics, as conducted for this facility, in a similar way in other rice plants.

2. Materials and methods

2.1. Rice plant environment

This study was conducted in a 30-year-old rice facility that belongs to a producer association in the Tejo Valley region of central Portugal. This particular facility has a storage capacity of 23,000 tons for paddy (using corrugated metal bins) and 1000 m^2 warehouse space for storage of packaged milled rice. The facility processes 17.500 MT of rice annually of varieties such as Ariete (*japonica*) and Jasmine (*indica*). Paddy rice received at the rice mill usually comes directly from the field at harvest and is dried to 13–14% moisture and stored in corrugated metal bins until processing occurs.

The rice processing plant structure has a total area of 2000 m^2 divided into three main areas: reception, factory and packaging (Fig. 1). The *reception area* is for rice receival, inspection and determination of quality attributes of the rice. The *factory* is where stored paddy rice is brought in, cleaned, processed and polished. This typically includes de-stoning machinery, sifters, sieves for classifying contaminants, roller stands, brown rice separators, rice polishers, and processed white rice classifying sieves. In the *packaging area* the milled rice is packaged, labelled, and stacked on pallets. This area also contains a laboratory where rice samples are examined and stored for final product quality purposes.

2.2. Insect sampling experimental design

Adult stages of insects associated with stored rice were sampled with commercial floor traps continuously from 9 September 2005 to 29 June 2007. From 9 September 2005 to 15 September 2006, 25 Stogard® Beetle Trap (Dome design) baited with food based oil (Trécé Inc., Adair, OK, USA), were used to capture insects present and to monitor residual populations of the key pests. From 15 September 2006 to 29 June 2007, these traps were replaced by 25 PC Floor Traps baited with Sitophilure, the synthetic *Sitophilus* spp. male aggregation pheromone lure (Insects Ltd, Westfield, IN, USA).

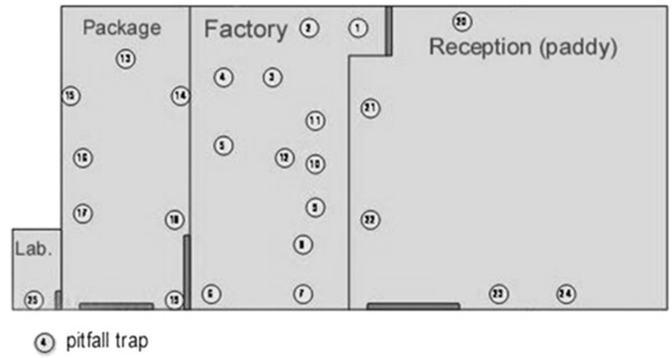

Fig. 1. Layout of the rice mill showing trap locations. 1) De-stoning machine; 2) sifter; 3–4) sieves for classifying contaminants; 5) storage deposit; 6–19) floor close to door; 7) roller stands; 8) brown rice separator; 9–10–11) rice polishers; 12) white rice classifying sieves; 13–17) package lines; 18) floor; 20) big bags with broken rice; 21–22) paddy receiving area; 23–24) cyclones (aspirators); 25) rice mill laboratory to house retainer samples.

The traps were placed at various positions around the rice mill and the majority of these devices were located close to the machinery to follow the relationship between steps in rice processing and insect infestation (Fig. 1). Traps were checked weekly and the insects collected were placed in a plastic bottle and brought to the laboratory for species identification and counting. Pheromone lures in traps were replaced monthly.

2.3. Characterizing spatial distribution of insects

Taylor's power law regression was applied to each data set and used to classify the spatial distribution of *Tribolium castaneum* (Herbst) and *Sitophilus* spp. in order to develop a sequential sampling plan for *Sitophilus* spp. To classify the spatial distribution of *T. castaneum* a total of 82 data sets were collected data was used in the Taylor's model. To develop sequential sampling plans for *Sitophilus*, from a total of 86 data sets collected, two groups of counts were randomly selected: 71 data sets we used for estimation of the Taylor's power law parameters, to classify the spatial pattern and to be used in Green's plan; and 15 data sets for validation with Resampling for Validation of Sampling Plans (Naranjo and Hutchison, 1997).

Taylor's power law is a regression used to model the relationship between mean ($\bar{x}$) and variance (s^2) and was applied for *Sitophilus* spp. and for *T. castaneum*. The most common relationship is: $s^2 = A\bar{x}^b$, where b is the slope and A was determined by taking the antilog of the intercept a from regression analysis. Sample means and sample variances were transformed logarithmically. The intercept coefficient is a scaling factor related to sample size and b is a constant depending on insect behaviour: $b = 1$, $b > 1$ and $b < 1$ indicates random, aggregated or uniform dispersions, respectively (Davis, 1994).

Once the model is validated for a particular ecosystem, we can predict the variance of a set of counts, based on the known mean density, and design a sampling plan to obtain estimates of specified precision (Krebs, 1999).