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Developing and Validating Sequential Sampling Plans for Integrated Pest Management on Stored Products

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Abstract

This short communication intends to present some references on development and validation of sequential sampling plans to estimate pest density or classifying infestation levels with reference to an action/economic threshold for integrated pest management on stored products.

Sequential sampling plans were developed and validated for *Cryptolestes ferrugineus* (Stephens)*, Prostephanus truncatus* (Horn), *Sitophilus zeamais* Motschulsky, *S. oryzae* (L.) and *Lasioderma serricorne* (F.) infesting stored wheat, maize, rice, pet food or tobacco.

The methods used were Wald's sequential probability ratio test (SPRT), Green's fixed precision sampling, fixed binomial sampling plan and/or Iwao's confidence interval method.

The firsts experiments, data were obtained from product samples but since 2003 the absolute samples were replaced by records obtained from traps (baited with pheromone or/and food lure).

Only one Tobacco Company used economic thresholds, the other industries or the storekeepers applied an empirical action threshold (AT).

Some studies considered that further work is needed to improve the management decision support. Other studies gave information about accuracy of the sampling program, helped the managers to make decisions and reduce the infestation levels to values far below injury.

Keywords: Stored-product; Sequential sampling plan; Sitophilus; Prostephanus; Cryptolestes

Sequential Sampling Plans for IPM on Stored Products

The tendency to manage insects in stored products is the replacement chemical control measures by cost-effective nonchemical alternatives. Integrated Pest management (IPM) is an approach to pest control that uses cost-benefit analysis in making decisions [1]. IPM programs include the study of factors regulating insect distribution and abundance [2] and sampling to make inferences about insect populations.

A good IPM must balance the cost of a sampling program with higher profit of reducing pest infestation [3]. Sampling methods as absolute sampling is very expensive and in countries where the manpower is costly is usually replaced by traps. Relative sampling (sampling using traps) costs less but is still expensive, because usually traps need to be replaced either because they are consumables or damaged.

The first step of sampling is predicting mean variance to determine the number of samples needed [2,3]. The implementation of a sampling program must attach a threshold of the economic injury level, the limit from that the insect density causes the reduction of the market value of the product and the needs to make a decision of using control measures. This threshold should be obtain based on cost-benefit analysis but often the industry use a threshold based on their empirical experience.

After collecting a sort of data it is possible to develop sequential sampling plans. Sequential sampling is a statistical procedure with the profit that the sample size is not fixed and is based on a limited number of observations that give us the information if more samples must be taken or not. Usually this procedure reduces, in the majority of the events, to half the number of samples required by the traditional sampling. Only if the results are uncertainty we take more samples.

Sequential sampling plans were developed for five of the most important key-pests on stored products. *Prostephanus truncatus* (Horn) is a very important pest of cereals and in Africa is the pest of major importance of farm-stored maize and dried cassava [4]. *Sitophilus zeamais* Motschulsky and *S. oryzae* (L.) are the two most common primary key-pests of whole cereal grain. The undamaged hull of paddy is the best barrier to this pests attack [5]. *Cryptolestes ferrugineus* (Stephens) is one of the most common secondary pests of slight broken cereals and cereal products. *Lasioderma serricorne* (F.) is the most serious insect pest of stored tobacco, chocolate and cocoa beans [4-8].

The first study on development and evaluation of sequential sampling plans for a stored-product insect was carried out by Subramanyam et al. [9]. It was based on complete counts and the presence/absence of *Cryptolestes ferrugineus* (Stephens), infesting farm-stored wheat, in 0.5 kg grain samples with a fixed level of precision for classifying the insect infestation level. The authors reported when the proportion of infested samples are closed to the Action Threshold a larger number of samples must be taken to arrive to a decision.

Meikle et al. [10] conducted a trial on rural maize stores in Benin and using the data developed a sequential sampling plan for negative

binomial distribution (Wald's sequential probability ratio test, SPRT) to determine pest status for *Prostephanus truncatus* (Horn) and *Sitophilus zeamais* Motschulsky. The results showed the lower and upper thresholds for both species were adequate [0.2 and 1.0 for *P. truncatus* per ear (k=0.2 and alpha=beta=0.1); 10 and 20 for *S. zeamais* per ear (k=1.0 and i alpha=beta=0.1)]. The authors considered besides the promising results further work would be needed to improve the management decision support.

Toews et al. [11] used traps for the first time instead absolute samples to develop three sequential sampling methods for estimating *Sitophilus oryzae* (L.) density, by Green's fixed precision sampling, classifying infestation levels, by SPRT, and determination the proportion of sample units infested with at least *t* insects by fixed binomial sampling plan. To get data the authors sampled eight pet stores during six months and using 30 traps. The results showed that fewer samples were needed for estimating high densities and more samples should be taken when the population were low. From SPRT stop lines a minimum of nine traps was required for classifying infestation level and ASN showed for classifying 0,001-1 infested traps 10-52 traps need to be observed, where the pic of 52 traps happen when the proportion of infested samples was close to the action threshold. The binomial plan with 20, 25 and 30 traps showed the probability of not taking action [action threshold (AT) of 50%] was more than 40%.

Carvalho et al. [6] developed sequential sampling plan for classifying the pest status of *Lasioderma serricorne* (F.) based on complete counts from insects caught in 26 sex pheromone traps in a cigarette factory. *L. serricorne* (F.) is the most serious pest in stored tobacco. As the adult population follows the negative binomial distribution, a sequential sampling plan was developed using the sequential probability ratio test (SPRT). The sampling plan was implemented to assist management decision-making based on the economic threshold of 5 insects/trap/week determined by the Tobacco Company. Using SPRT, managers could make decisions reducing in 73% of traps, using only seven traps, with a minimum risk of incorrect assessment. The pattern of the trap catches helped to redesign traps location, placing traps in a grid pattern in order to cover all the available space and near walls where meaningfully more insects were caught.

The same authors [8] transferred the knowledge when faced with high cigarette beetle infestation at cigarette factory in Cape Verde islands. Sampling plan was carried out using pheromone traps (started with nine traps and increased to 13 traps) and data obtained were used to develop sequential sampling plans for classifying pest status using SPRT and Iwao's confidence interval method. The main purpose was to help the manager to decide whether or not need to implement control measures, with a minimum risk of error using few sampling units. The industry together with the authors agreed to use an empirical action threshold of 10 insects/week/trap. The results shown that, using SPRT or Iwao's methods, managers can make decisions using six and 13 traps, respectively, with a minimum risk of incorrect assessment. After three years of applying sampling methods the infestation was suppressed to densities far below the AT [7].

Carvalho et al. [12] developed and validated a fixed precision enumerative sequential sampling plan, using Green's fixed precisions sampling plan and the Resampling Validation of Sampling Plan, for the key pests *Sitophilus* spp. in the rice industry in Portugal. 25 pitfall traps baited with food grade oil and pheromone specific for weevils were placed inside the rice mill and the empirical AT of 0.5 *Sitophilus* spp was used. 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.

Insects associated to stored-products are one of the major causes of quantitative and qualitative losses, either in raw or processed food. Preventing economic losses by insect pests is important from post-harvest to consumer. Carvalho et al. [13] confirmed that a sufficed implementation of a sampling program in one rice industry in Portugal was reflected in the significant decrease of the number of rejected package units of polished rice from 126 ton in June 2006 to 0.5 ton in June 2009.

A good pest management must balance the cost of sampling programs for monitoring insects and the benefit of reducing infestations by increasing profit. Two ways of reducing cost must be attained: by reducing the charge of the sampling program and/or increasing the trade product available because suppressing pests. Sequential sampling plans is generally less expensive because fewer samples were needed for estimating high densities and sample size only increases the closer is the AT. To get more accurate and realistic results, the empirical action thresholds must be replaced by well documented economic thresholds to help managers to decide with a probably of error below 25%. Additional research should be very productive in finding economic thresholds for the most import key-pests of stored-products based on trap catches. Integration of pest management methods by starting with sampling and decision-making to treat only when and where is needed must be the commonest decision to protect stored-products in the future.

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