BROWN-RICE BAIT-BAGS FOR MONITORING INSECT PEST POPULATIONS IN BAG STACKS OF MILLED RICE AS AN AID TO PEST CONTROL DECISION-MAKING

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Abstract

A major constraint to the development of decision-based pest management in food stores is the lack of accurate yet simple pest monitoring techniques. Normal spear-sampling, whilst useful for assessing the presence or absence of pests, provides no reliable measure of population density.

Earlier field trials of various trapping and sampling methods for pests in bag stacks of milled rice, conducted by NRI in collaboration with BULOG, showed that bait-bags caught insects in quantitative proportion to their population densities in the stacks, and that the best results were achieved when the bait-bags were filled with brown rice.

The brown-rice bait-bags have subsequently been tested by NRI and BULOG on 57 stacks of milled rice in operational godowns in Jakarta, and the results were calibrated against pest populations estimated by abnormally intensive spear-sampling. The results showed that, for routine sampling, three calibration lines adequately describe the relation between trap catch and population density: one for Tribolium castaneum; one for Rhyzopertha dominica; and one for all other pests. In order to estimate the density of T. castaneum to within 20% of the true mean, with 95% confidence, it would be necessary to examine 303 spear-samples from a 250t stack, requiring more than a man-week of effort and removal of about 100kg of the rice: to achieve the same accuracy with bait-bags, it is only necessary to use 18 bags, requiring just 3½h of effort, with no removal of rice or damage to sacks.

Introduction

Decision-based pest-control systems, in which control action is triggered when pest density exceeds an objective threshold, are more cost-effective and efficient than calendar systems, because they minimize unnecessary control operations and reduce the risk of economically avoidable losses. There are two constraints to the introduction of decision-based systems in grain warehouses. The first is the need for flexibility of pest-control operations: this is mainly a logistical constraint that can be overcome by changes in management procedures. The second is the requirement for a simple, yet accurate, method of pest monitoring: this has been the main technical constraint to the introduction of decision-based systems in tropical grain storage.

If the monitoring technique is not sufficiently accurate, pest control may be applied too soon or too late and is thus not fully cost-effective. Insect pest monitoring needs to be accurate in relation to the tolerances of the pest control system. The technique itself must be cost-effective: the costs of routine monitoring should be less than the benefits gained by being able to operate a threshold-sensitive strategy. Pest monitoring thus needs to be efficient in its use of materials and manpower.

One possible monitoring technique is a bait-bag - a mesh envelope containing an attractive food bait, placed in the store for a specific period. The use of such a technique, for sampling the distribution and relative abundance of storage pests, was described by Strong (1970), who tested food packets wrapped in cheesecloth in a mesh envelope of hardware cloth. Subsequently, scientists at the Pest Infestation Control Laboratory (now ADAS Central Science Laboratory, UK) developed bait-traps in which the food-bait is contained in a welded plastic-mesh envelope, in order to detect the presence of insects in a store (Anonymous, 1975; Pinniger & O'Donnell, 1978; Pinniger **et al.**, 1983).

A collaborative field trial between the Natural Resources Institute (NRI) and Badan Urusan Logistik (BULOG) in the mid-1980s compared several different sampling and trapping techniques with very intensive whole-stack sampling for monitoring pests of milled rice in bag-stacks (Hodges *et al.*, 1985). The trial showed that: many of the trapping techniques were of no use for general pest monitoring; normal spear-sampling gave very inaccurate results; but bait-bags (especially those filled with brown-rice bait) gave very good representative results with a high level of accuracy, and were quick and easy to use.

A large-scale field trial was therefore conducted on milled-rice bag-stacks to calibrate bait-bag catches against abnormally intensive spear-sampling. The inaccuracy of spear-sample analysis on single stacks was overcome by regression analysis of calibrations on many stacks, which also offered the opportunity to investigate the effects of other factors such as trapping period, age of stacks, sack size and material, pest complex, etc. The methods for placement and examination of the bait-bags were deliberately kept as simple as possible in order to test a technique that would be practicable for routine monitoring. The trial was only concerned with calibrations for beetle and moth pests: no attempt was made to quantify observations of the psocopterans (*Liposcelis* spp.) that are sometimes very abundant in S E Asian stores.

Materials and methods

The rice stacks sampled by NRI and BULOG in the field trial were all at BULOG's main godown complex (DOLOG Jaya) in Jakarta, Indonesia. The bait-bags were prepared, and the samples examined, at BULOG's research laboratory at Tambun. Preliminary analysis of the data was performed at NRI and full statistical analysis was subsequently undertaken at the Institute of Arable Crops Research, in the United Kingdom.

During the 6-month trial, 57 operational rice stacks were sampled. The stacks were chosen to represent a range of sack type, type and origin of rice, age of stack, stack volume, type of recent pest control treatment, and - most importantly - time since last fumigation (as a means of ensuring a spread of infestation levels across the calibration range). Three sets of data from stacks of imported rice in woven polypropylene sacks were subsequently found to give anomalous results compared with rice in gunny sacks and were not included in the calibration calculations: the remainder of this paper relates only to the other 54 stacks.

Each bait-bag was made from a 200 mm square of ribbed black plastic mesh[1], with just over 19 apertures/cm^2 and an aperture size of 2 mm. Each square was folded in half and heat-sealed along the side and one end. Before use, approximately 100 g of freshly-milled brown rice (measured by volume as 125-130 ml) was added to the bait-bag, and the end was closed with staples. For the trial the bait was only used once, but for routine sampling bait-bags may be re-used three times within four weeks if they are fumigated after each use.

The results of the earlier trials showed that bait-bags on the sides of stacks gave the most representative results. For conformity and ease of use, the bait-bags were therefore usually placed above the sixth layer of sacks, at shoulder height, and wedged firmly into the gaps between sacks; exceptionally, the bags were positioned above the fifth or seventh layer. The numbers of bags were related to the size of the stacks to allow for possible increased variability of pest density in larger stacks: 20 bags were used on stacks of 175-300 t or less; 24 on those of 300-450 t; and 30 on those of 450-600 t or more. The bait-bags were positioned evenly around the stack, with side:end ratios of 6:4, 7:5 and 9:6, depending on size. The bait-bags were usually left in place for seven days, but some comparative tests were made with five- and nine-day exposure periods, which showed no significant deviation from the seven-day results.

At the end of the exposure period, the bait-bags were collected into individual plastic bags and returned to the laboratory. If a bag appeared to have been damaged or disturbed, this was noted and the data from such bags were discarded if they were anomalous. At the same time, the intensive spear samples were taken with a double-tube multi-hole spear: sixty stratified samples of about 250-350 g were taken from each stack, giving a total sample of approximately 18 kg of rice. The primary stratification was by stack face: 18 sacks per side and 12 per end. The secondary stratification was by layer: 10 sacks in each layer from the bottom to the sixth. The sample sack positions within face and layer were determined by random numbers without duplication. All spear-samples were collected in separate labelled plastic bags, which were sealed immediately and returned to the laboratory. In the laboratory, the spear-samples were sieved and sorted on trays, and all insects found were identified to genus and counted.

Insects were extracted from the bait-bags by a procedure based on earlier tests (Rees, unpublished data) with known numbers of *Tribolium castaneum* (Herbst), *Sitophilus zeamais* Motschulsky and *Rhyzopertha dominica* (Fabricius). The bait-bag was first shaken twenty times, along its longitudinal axis, while still inside its plastic collection bag. It was then removed and placed on a clean white tray for about one minute, while the insects in the collection bag were tipped into a small quantity of 70% alcohol in a Petri dish. The outside of the bait-bag was then brushed with the fingers to dislodge insects clinging to the outside and shaken a further twenty times over the tray: it was then placed on a second white tray for another minute, while insects were tipped from the first tray into the Petri dish. Finally, the outside of the

1 Netlon(R) Fine Screening Mesh

bait-bag was brushed once more to dislodge any remaining insects and these were also tipped into the dish. The insects were then identified to genus and counted.

Results

The mean densities of beetle adults plus moth larvae in the stacks varied from 0.5 to 54.4 insects/kg (last fumigated 3 and 19 weeks previously, respectively), and the sampled stacks contained infestations that were fairly evenly distributed with regard to the logarithms of the densities in this range. In stacks that had been fumigated, the population densities were related to the time since fumigation, expressed by the linear regression:

$$y = 0.9444 + 0.0924x$$

where $y = \log_e(\text{no./kg} + 1)$ and x = weeks. However, there was considerable deviation from the regression, emphasizing the weaknesses of a calendar system of pest control, in which some stacks with moderately heavy infestations were not due for fumigation for another 10 weeks, whereas others were about to be fumigated but still only had fairly light infestations.

One beetle, *Tribolium* (probably exclusively *T. castaneum*), dominated the pest complex in 42 of the 54 stacks: in 35 of these, this beetle accounted for over 90% of the insects extracted from the spear-samples. *Oryzaephilus* (mainly *O. surinamensis* (Linnaeus)) was the second most abundant pest on average, but this was due to very high densities in a few stacks; it was usually associated with infestations of *Sitophilus* (mainly *S. zeamais*). Among the remaining beetles, *Rhyzopertha dominica* was abundant, but again this was due to high densities in a few stacks.

The small proportion of insects other than beetles comprised: the larvae of two moth pests, *Ephestia cautella* (Walker) and *Corcyra cephalonica* (Stainton); a predatory bug, *Xylocoris* sp.; and various parasitic wasps. The natural enemies were not, of course, included in the calibration analyses.

The data from the 54 stacks were subjected to detailed regression analyses, using linear, quadratic and exponential models, to obtain the best-fit calibration lines. This was done firstly for each of the main pests, and then for groupings of pests with similar calibrations, in order to arrive at the smallest number of separate calibrations for practical routine use.

The analyses showed that three separate calibrations were adequate for pest monitoring on milled rice in gunny sacks in BULOG's stores: (i) *Tribolium* adults; (ii) *Rhyzopertha dominica* adults; and (iii) other pests (i.e. other adult beetles plus moth larvae.

The regression analyses also investigated the possible effects of factors such as size of stack, origin of rice, time since intake, etc., on the relationship between bait-bag and spear-sample results. Except for the effect of woven polypropylene sacks of imported rice, as already noted, no other stack characteristics had sufficient differential effects on the regressions to justify subdivision of the calibrations for use in routine monitoring.

Analysis of the data for *Tribolium* adults showed that these pests were strongly attracted to the brown-rice bait-bags and that a curvilinear regression gave a better fit than a linear one. On stacks with a high density of *Tribolium* the numbers of *Tribolium* adults per bait-bag often exceeded 100, and this crowding would be expected to cause a slight but progressive reduction in the ability of the bait-bag to retain more *Tribolium* at higher densities. Since the bait-bag will have a finite carrying capacity, the theoretical form for the regression would be expected to be an exponential curve. However, within the density range experienced in this trial, the data are very well described by the simpler form of a quadratic curve through the origin. The best-fit equation is:

$$y = 0.033x + 0.0002832x^2$$

where y = no./kg and x = no./bait-bag.

The data for *Rhyzopertha dominica* adults showed that this pest is not very strongly attracted to the brown-rice bait-bags, when compared with other pest species. Nevertheless, the bait-bags always detected *R. dominica* populations at densities that were assessed by spear-sampling as 0.7 adults/kg or greater, and they also detected seven out of the eighteen lighter infestations of this species. Analysis showed that a linear regression through the origin gave a good fit to the data. The equation is:

$$y = 9.856x$$

where y = no./kg and x = no./bait-bag.

The other pests (adult beetles other than *Tribolium* and *R. dominica*, and moth larvae) were all well attracted to the bait-bags, and analysis of the data for these pests showed that a linear regression through the origin gave an adequate joint calibration for them all. The best-fit equation is:

$$y = 1.813x$$

where y = no./kg and x = no./bait-bag.

One advantage of bait-bags over spear-samples is that whereas the frequency distribution of spear-sample data fits a negative binomial distribution, because of the aggregated dispersion pattern of insects in the rice, the frequency distribution in bait-bag samples approximates to the normal distribution. The spear-sample and bait-bag data for *Tribolium* in the 54 gunny stacks were fitted to negative binomial and normal distributions, respectively. The distributions were then used to calculate the numbers of spear-samples or bait-bags that would be needed to estimate *Tribolium* populations with specified 95% confidence intervals. To achieve such intervals within ±20% of the mean would require 303 spear-samples but only 18 bait-bags. During the trial, measurements were made of the time required for each element of the procedures of spear-sampling and bait-bag trapping. From these data it has been calculated that in order to obtain this level of accuracy by spear-sampling would require 43½ man-hours of effort per stack whereas to achieve the same results by bait-bag trapping needs only 3½ man-hours. Spear-sampling at such intensity is totally impracticable; it would also damage 303 sacks and involve the loss of over 100kg of rice from the stack.

Figure 1. Calibration line for converting numbers of *Tribolium* adults per brown-rice bait-bag to numbers per kilogram of milled rice.

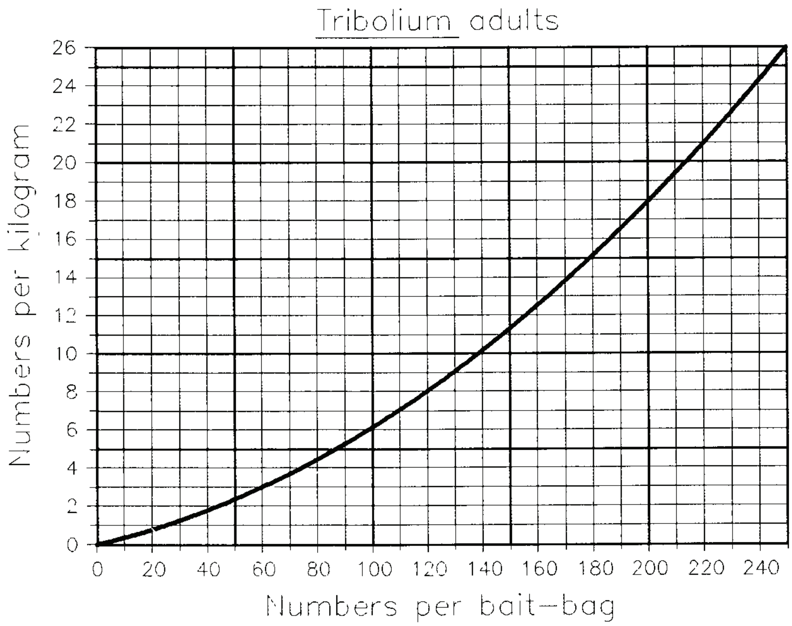


Figure 2. Calibration line for converting numbers of *Rhyzopertha dominica* adults per brown-rice bait-bag to numbers per kilogram of milled rice.

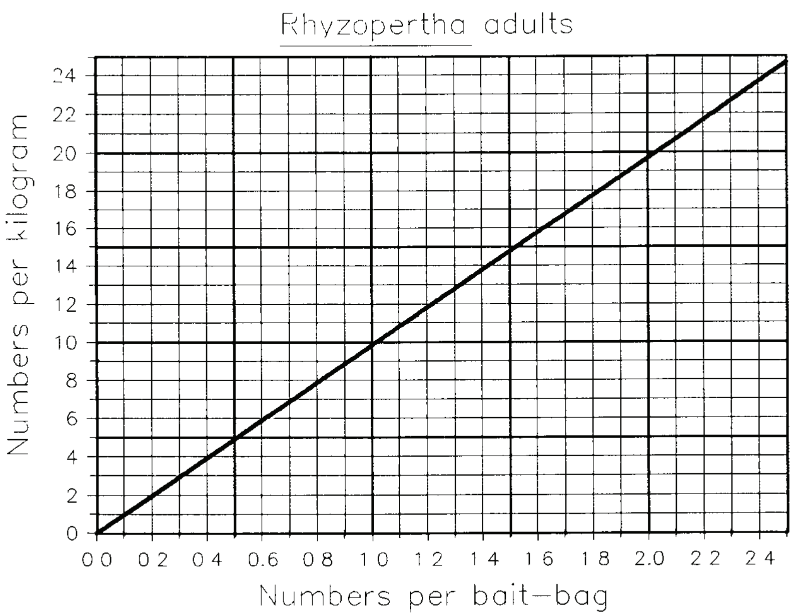
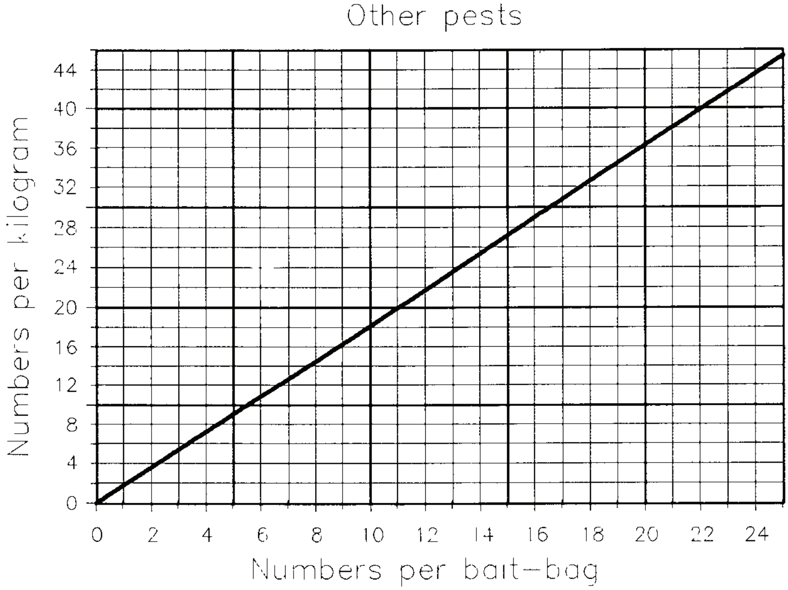


Figure 3. Calibration line for converting numbers of other pests per brown-rice bait-bag to numbers per kilogram of milled rice.



Discussion and conclusions

The calibration trial described briefly in this paper has shown that it is possible to obtain accurate estimates of pest infestation levels in milled-rice bag-stacks by the use of brown-rice bait-bags, and that the technique is simple and economical. The method is especially accurate for *Tribolium*, which is also usually the dominant pest in milled rice stores in Indonesia. For routine monitoring it is only necessary to divide the sampled insects into four groups before counting: *Tribolium*; *Rhyzopertha dominica*; other pests (adult beetles and moth larvae); and natural enemies (predatory bugs and parasitic wasps), which are not included in the analysis. The first three sets of data are used to obtain mean numbers per bait-bag, and these are then converted to numbers per kilogram of milled rice by using calibration charts (Figs 1, 2 and 3) or calibration tables.

The bait-bag technique has created an opportunity for the possible introduction of decision-based pest control in milled-rice stores. Objective economic thresholds for the pests are not yet available, but a decision system can still be introduced on the basis of an arbitrary threshold. At present, an obvious arbitrary threshold is the average infestation level at the time calendar fumigation is normally applied: about ten insects per kilogram. The use of a decision-based system could thus immediately avoid the costs of premature fumigation and reduce losses caused by overdue fumigation. In the future, further savings would be achieved by the introduction of economic thresholds based on the risks of cumulative damage before the end of the next monitoring interval.

The trial has provided a technique suitable for use with milled rice, for which brown rice was an obvious and successful bait. It should be easy to adapt the technique for use on rough rice, still using brown rice as the bait. Other commodities, such as maize, will present a greater challenge in the identification of an attractive food-bait, but it is hoped that it will prove possible to develop variants of this promising technique for use with commodities other than rice. A more detailed report of the calibration trial, including the statistical analyses of the data, is being prepared for publication.

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DES SACS DE RIZ BRUN SERVANT D'APPAT POUR LA SURVEILLANCE DES POPULATIONS DE RAVAGEURS DANS LES EMPILEMENTS DE SACS DE RIZ BLANCHI, EN TANT QUE MOYEN D'APPOINT POUR LA GESTION DE LA LUTTE CONTRE LES RAVAGEURS.

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RESUME

Une des contraintes principales au développement de la gestion raisonnée de la lutte contre les ravageurs dans les magasins de stockage provient du manque de techniques de surveillance simples mais efficaces. La récolte normale d'échantillons, bien qu'utile pour connaître la présence ou l'absence de ravageurs, ne fournit pas une mesure précise de la densité de leur population.

Des études antérieures en milieu naturel entreprises à l'aide de nombreuses méthodes de piégeage et d'échantillonnage dans des piles de sacs de riz blanchi par l'ODNRI en collaboration avec le BULOG, ont montré que les sacs-appâts capturaient les insectes dans des proportions qui sont en rapport avec la densité de leur population, et que les meilleurs résultats étaient obtenus lorsque ces sacs-appâts étaient remplis de riz brun.

La technique des sacs-appâts de riz brun a été étudiée par l'ODNRI et BULOG sur 57 piles de sacs de farine dans les entrepôts de Jakarta, et les résultats ont été étalonnés suivant les populations de ravageurs estimées par un échantillonnage intensif. Ces résultats ont montré que, pour un échantillonnage de routine, trois étalons peuvent décrire convenablement le rapport existant entre les prises piégées et la densité de la population : un pour *Tribolium castaneum;* un pour *Rhyzopertha dominica;* et un pour tous les autres ravageurs. Pour mesurer la densité de *T. castaneum* à 20 % de marge d'erreur autour de la vraie moyenne, il est nécessaire d'examiner 303 échantillons provenant d'un empilement de 250 tonnes, ce qui demande plus d'une semaine d'effort à un seul homme et le retrait d'à peu près 100 kg de riz. Pour obtenir la même précision avec les sacs-appâts, il ne faut que 18 sacs, ce qui ne demande que 3,5 heures d'effort, sans enlever de riz ni endommager les sacs.