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PULSED BAITING—A NEW TECHNIQUE FOR HIGH POTENCY, SLOW ACTING RODENTICIDES

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ABSTRACT: The disadvantages of the acute, fast-acting, rodenticides are well understood by the specialist. However, despite poison-shyness and consequent short-lived, low efficacy rodent control, many users prefer "acutes" such as zinc phosphide to "first-generation" anticoagulants of the warfarin type. The techniques necessary for efficient use of the first-generation anticoagulants are often inappropriate, particularly in agriculture. High labour and bait inputs required are unacceptable and are, together with the need for area coordinated control programmes, significantly responsible for lack of widespread use of anticoagulants, even in those countries with a long history both of disastrous rodent damage to crops and rodent damage research and training centres. There are other problems, too, including widespread antithesis to prophylactic rodent control, perhaps in part due to the inherent low efficacy of acutes and the impractical nature (often leading to low efficacy) of first-generation anticoagulant baiting procedures.

The advent of a highly potent but slow-acting rodenticide molecule, brodifacoum, has allowed the development of the pulsed baiting technique. This practical technique is highly effective and offers very significant savings both in bait and labour compared to first-generation anticoagulants, with excellent levels of control. Single applications are more effective than single applications of acute toxicants. Now used in agricultural and urban control programmes, the technique is proving to be very cost-effective and highly acceptable, both to educated campaign organisers and uneducated users. The theory, development and cost-effectiveness of the technique are considered together with the experience gained from its use over more than 4 million hectares of agricultural land. Use of the technique allows for the first time practical and efficient agricultural rodent control.

INTRODUCTION

There is an increasing international awareness of the grave economic significance of vertebrate pests, especially rodents. Rodents can be associated with structural damage, growing and stored crop losses and are involved in the transmission of more than 20 disease organisms. It is usually the indirect effects of rodent damage which are most economically important. Estimates of the total cost of rodent damage are probably imprecise and conservative.

A comprehensive review of available data is, sadly, unavailable (some of the data are briefly reviewed by Dubock 1978). Nevertheless, rodentborne diseases are considered to have caused more human deaths and suffering than all the wars and revolutions ever fought (WHO 1967). Additionally, the world loss of food annually to rodents, about 11 kg per person per year for the world's population, has a value almost equivalent to the combined total Gross National Product (GNP) of the 25 poorest nations in the world (valued at US $17 billion in 1975 [FAO 1975]). In 1982 dollars this is equivalent to US $30 thousand million.

Despite the long history of rodent control (Dubock 1979) and the severity and importance of rodent depredations, rodent control is little practiced in most countries. Successful rodent control, at its simplest, can be defined as the reduction of a rodent population below the level where it causes economically important damage at a total cost less than the total benefit. Successful rodent control with toxicants, the most effective and rapid control method, can be considered to result from the application of techniques or strategy determined by the integration of a complex matrix including biological functions of man, target species, and the toxicant. It is probably the complexity of these components separately and as interacting parts which is responsible for the relative lack of effective rodent control. Simplification of the relevant control systems may be helpful in assisting and encouraging practical and economically beneficial control programmes.

Man is probably the most complex and also the most important part of the matrix. Without an understanding of the relevant principles of control, it is difficult to achieve the motivation, organisation and reinforcement of motivation at all societal levels which are essential to a successful rodent control programme. At the operational level, agricultural extension programmes can play a key role in the necessary educational function. Formal specialist education allows the demonstration of cost:benefit ratios as a result of the necessarily indirect measurement of rodent population levels and related damage. Assessment of total costs includes not only toxicant and bait but formulation, packing and distribution of bait, as well as labour costs and the cost of any accidental poisoning of domestic or wild nontarget species. These costs must compare favourably with the value, direct and indirect, of all the benefits. Different societies may well assess costs, risks and benefits differently.

The second component of the matrix is rodents. The poisoning of rodents almost always implies a need to modify the behaviour of these intelligent and adaptable animals. Usually it is necessary to cause rodents to consume the chosen toxicant. An understanding of the behaviour of different rodent species is important to optimise effective placement of the bait. In particular different species have characteristically different feeding behaviour. Rats (*Rattus norvegicus*), for example, often exhibit "neophobia" (or "new object reaction"). When new food sources or other objects are placed in their environment, they are treated very cautiously for a few days before being accepted and used regularly and without hesitation as a food source, for example. Other species, notably *Mus musculus*,

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are characteristically sporadic feeders, nibbling at food sources here and there without any particular pattern and little or no noticeable neophobia. Although the mechanism is unclear, most authorities agree that there is a social hierarchy ("gnawing-order" ?) amongst rodent populations and the resultant social interaction may affect feeding behaviour. The reproductive potential of rodent species, especially those reduced to a low level, is one of the most significant characteristics to consider as part of a control strategy.

It is convenient to characterise most of the toxicants used for rodent control, the third part of the matrix, into two broad categories: the fast-acting, acute toxicants, exemplified by zinc phosphide; and the slow-acting, chronic rodenticides. Most of the latter are blood anticoagulants which require repeated ingestion by rodents before a lethal dose is built up. Warfarin is an example. Both the acute and the "multiple-feed" chronic rodenticides have advantages and disadvantages.

a) Acute Toxicants

Until the late 1940s the acute toxicants were the only rodenticides available. They are still widely used today, and many uneducated users prefer them despite their relatively low efficacy. Rodents which succumb to acute toxicants do so quickly, usually within a few hours, and having consumed only a small amount of bait. Most uneducated users incorrectly interpret the sight of dead rodents soon after placing small amounts of bait with only low labour inputs as proving cheap and effective control. However, the symptoms of acute poisoning often cause rodents to cease feeding before ingestion of a lethal dose. These surviving animals subsequently have a learned aversion to the poison and or bait (known as "poison shyness" or "bait shyness") which may last for 3-4 months (Barnett 1948) during which time they will not eat more of the same rodenticide bait.

The effects of poison-shyness can be minimised by "prebaiting" with unpoisoned food for several days before presentation of the poisoned bait, but even with prebaiting it is difficult to consistently obtain greater than 60-70% control of rodent populations using acute toxicants (Rennison et al. 1968, Dubock and Rennison 1978). The rapid reproductive rebound of the surviving rodent populations soon compensates for the effects of poor control and so the apparently cheap acute poison treatment has to be repeated often; thus the true cost of rodent control treatment with acute poisons may be quite high. Additionally, acute toxicants are approximately equally toxic to a wide variety of animals other than rodents (see, for example, Dubock 1978). There is usually no specific antidote, nor time to administer symptomatic treatments. Accidental poisoning of man, domestic animals and beneficial wildlife increase the cost of using acute toxicants. The perceived advantages and the actual disadvantages of the acute toxicants are summarised in Table 1. In general, acute toxicants are practical to use but rather inefficient.

Table 1. Advantages and disadvantages of fast-acting, single-feed, rodenticides (acutes).

Perceived advantages	Disadvantages
Low bait	poison/bait shyness
Low labour	need for prebaiting
Immediate, visible results	poor efficacy
Cheap per kg	no selectivity
	no practical antidote
	high cost for effect

b) Chronic Toxicants

The development of what is now known as the "saturation baiting" or "sustained baiting" technique of rodent control was pioneered by O'Connor (1948) for use with dicoumarin, the first anti-coagulant rodenticide. Saturation baiting exploits the most important biological property of the anticoagulants, the slowness of the onset of symptoms of poisoning, to avoid the development of poison shyness; by the time rodents stop feeding they have already ingested a lethal dose.

The technique allows 100% control of rodent infestations without the need for prebaiting (see, for example, Rennison and Dubock 1978). Warfarin, in common with the other subsequently synthesised "first generation" (Dubock and Kaukeinen 1978) anticoagulant rodenticides, has to be ingested regularly over a "considerable number" (O'Connor 1948) of days in order to produce fatal results.

Where practical and economical the saturation baiting technique has been successfully applied, without modification, to other subsequently developed anticoagulants with similar properties to warfarin. Ideally, bait points of about 250 g each are continually replenished each 2 to 3 days so that excess bait is available until the rodents have stopped feeding. (Figure 1). Using this technique of making bait available until the rodents cease feeding on it to control populations of Norway rats with warfarin on UK farms takes about 3 weeks (95% confidence limits 9 to more than 35 days) (Drummond and Rennison 1973). The anticoagulant rodenticides have more selectivity than the acute toxicants (see, for example, Dubock 1978) and can be antidoted with vitamin K_1 in the case of accidental poisoning. Due to their slow action (days or weeks rather than hours), there is time to administer the antidote if accidental poisoning is discovered. However, the uneducated user of chronic multiple-feed rodenticides often

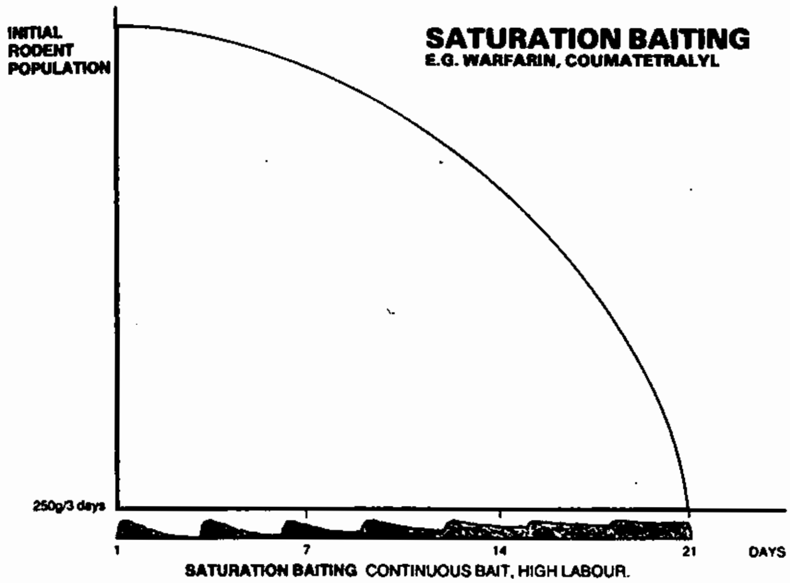

Fig. 1. Rodent population decline with time as a result of saturation baiting with multiple dose chronic toxicants.

considers them to be less than satisfactory. Large amounts of bait and labour, as well as good organisation, are prerequisites of successful rodent control with saturation baiting. These inputs are often unacceptably high, especially as control takes a long time and many rodents which die do so in places inaccessible to man and so are not seen. Thus to the uneducated user the use of saturation baiting appears expensive for the effects achieved. This is especially the case in situations where coordination is necessary but difficult to achieve and/or where the costs of bait and labour would be a significant component of the total cost of the campaign, as, for example, in many agricultural situations. Table 2 summarises the advantages and perceived disadvantages of the slow-acting, chronic rodenticides which require multiple feeds before a lethal dose is ingested. Although, if used properly, the multiple-feed chronic rodenticides are very efficient, they are rather impractical.

Table 2. Advantages and disadvantages of slow-acting, multiple-feed, rodenticides (most anticoagulants, chronic).

Advantages	Perceived disadvantages
Slow action	slow action
Selectivity	high labour
Antidote	high bait
High efficacy	high cost for effect
	slow invisible results

THE PULSED BAITING TECHNIQUE

The development of a more potent but still slow-acting anticoagulant, brodifacoum (Hadler and Shadbolt 1975, Dubock and Kaukeinen 1978), has stimulated the development of an alternative technique, pulsed baiting (Dubock 1979, 1980), which requires significantly less bait and labour than saturation baiting but is equally effective. The acute toxicity of 0.005% brodifacoum bait to rodents is such that usually only 6-7% of a rodent's daily food consumption on one day is lethal, with death after several days. Unlike warfarin, for example, there is no saving of brodifacoum toxicant if it is administered over several days. The acute oral LD_{50} of brodifacoum is the same as the sum of the daily components of the chronic LD_{50} (Dubock and Kaukeinen 1978).

Despite the potency of brodifacoum, Rennison and Dubock (1978) demonstrated that saturation baiting of Norway rat infestations with brodifacoum at 0.002%, 0.001% or 0.0005% in baits did not result in control of R. norvegicus more quickly than the use of other less potent anticoagulants. In an attempt to technically exploit the known high activity of brodifacoum, Rennison and Dubock (1978) in subsequent work placed brodifacoum (0.002%) baits for 1, 4 or 7 nights only and monitored the effect on the wild R. norvegicus populations concerned. Although 1 and 4 nights' baiting resulted in 41% and 51% control respectively, 7 nights' baiting resulted only in 68% control rather than the 100% which was expected intuitively and from laboratory results (Redfern et al. 1976). As a result, it was hypothesised that due to the high potency but slow action of brodifacoum, rats lethally feeding on baits during the first day or two of the 7-day baiting regime were continuing to feed for at least part of the rest of the period and also, more importantly, behaviourally excluding other rodents from taking a lethal dose. By the time these first feeders had become moribund or dead there was little bait left, and little time left for consumption of it by the remaining animals. Thus the incremental kill achieved by 7 nights of continual baiting compared to one night's bait placement is small. In subsequent trials, the technique was modified to compensate for this "over-kill feeding." A new technique termed "pulsed baiting" was reported (Dubock 1979, 1980) which was designed to optimise the probability of individual rodents finding the bait and consuming a lethal dose whilst minimising the possibilities of excessive bait consumption by any one rodent. In addition, by use of a number of small bait points, the ability of any one rodent to exclude other potential feeders was minimised.

THE USE OF THE PULSED BAITING TECHNIQUE FOR DENSE RODENT POPULATIONS WHERE SOCIAL INTERACTION PREVENTS ALL INDIVIDUAL RODENTS FEEDING

With most anticoagulants, including brodifacoum, the delay to death following the ingestion of a lethal dose is on average about 6 days. However, the ingestion of a lethal dose of brodifacoum bait is usually accomplished by rodents at a single feed, whereas with the multiple-feed anticoagulants 5-10 days of feeding is usually required (Dubock and Kaukeinen 1978). Figure 2 illustrates graphically the theoretical effect of applying 3 pulses or rounds of baiting, at 7 day intervals, to completely control an infestation using many small, approximately 5-10 g, bait points of 0.005% brodifacoum bait. (Unlike

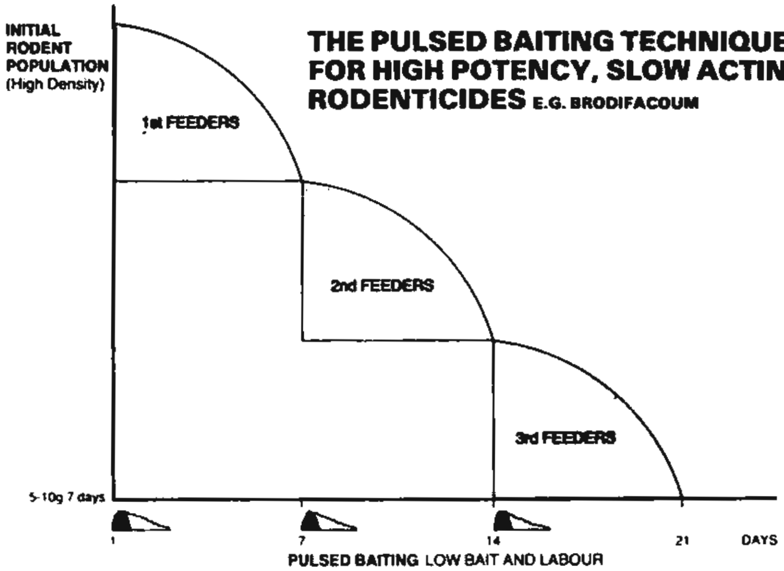

Fig. 2. Rodent population decline with time as a result of pulsed baiting with highly potent single-feed, slow-acting toxicants.

the standard saturation baiting technique, large bait points of about 250 g are not used and the baits are not continually replenished.) Due to social interactions, only some of the population (in the case depicted in Table 2, approximately 30% of the population) consume the baits laid on the first occasion. Although the bait is completely consumed after a few days, it is not replenished until 7 days later by which time the rodents which fed on the first applied baits will either be moribund, or dead, or have recovered. (It is common practice with saturation baiting to double the amount at each bait point whenever complete consumption occurs. This practice is considered wasteful of bait for pulsed baiting.) Thus, at the second pulse of baits, another section of the rodent population, which will probably include a few animals sublethally poisoned, but recovered from the first pulse, has the opportunity of feeding. Subsequently, one week later the last pulse (in the example given) is laid to complete the control by allowing the remainder of the population to feed. For the control of high-density rodent populations with pulsed baiting more, rather than larger, bait points should be laid. This has the effect of reducing the number of applications necessary before all rodents have had the opportunity of a lethal feed.

In the first pulsed baiting trials reported Dubock (1979) used the technique to control warfarin-resistant wild Norway rat (R. norvegicus) populations on Welsh farms. During the trials much of the infested areas were snow covered and too few bait points were probably laid relative to the population density. Consequently, 5-7 pulses of bait were laid using 10 g, 0.005% brodifacoum bait points at one-week intervals. The results of these trials (Table 3) showed savings of 75% of bait and 50% of labour compared to the use of standard saturation baiting technique used with first-generation anticoagulants, exemplified by warfarin, in the same situation.

Table 3. Comparison of warfarin (0.025%) saturation baiting and brodifacoum (0.005%) pulsed baiting for completely controlling one "unit of infestation" of *R. norvegicus* around farm buildings in the United Kingdom (from Dubock 1979).

Treatment	Number of applications	Bait required to control one "unit of infestation"*
brodifacoum (0.005%) 10 g loose baits	5-7	54 g
warfarin (0.025%) 250 g loose baits	9-12	202 g

*This term is explained fully in Dubock 1979.

Subsequent work in Malaysia (Dubock 1980, Khoo Chin Kok and Dubock 1981, Buckle et al. 1982) has demonstrated the effectiveness of pulsed baiting with small brodifacoum bait points in oil palm and rice. Significant savings in both bait and labour have been demonstrated using brodifacoum rather than warfarin, for the same level of control (Table 4). In oil palm 4 g brodifacoum baits were laid at 7-10 day intervals to correspond with the harvesting interval of the oil palm fruit. Thus the same labourers could be used for both tasks. Warfarin baiting with 15 g baits at the optimum 4-5 day intervals (Wood 1969) is more difficult to manage. Pulsed baiting with brodifacoum saved 75% of the bait and 50% of the labour associated with warfarin use for the same control level achieved.

Table 4. Comparison of the use of brodifacoum and warfarin wax bound baits for the same level of control of rats in Malaysia (from Dubock 1980).

Treatment	Crop	Number of applications	Total bait (kg/ha)
brodifacoum 0.003%, 4 g wax block	Rice	4	0.74
warfarin 0.05%, 15 g wax block		4	2.96
brodifacoum 0.003%, 4 g wax block	Oil palm	4	2.17
warfarin 0.05%, 15 g wax block		9	8.15

In Malaysian rice, a 7-day baiting interval was used with both warfarin and brodifacoum baiting, although one quarter of the amount of brodifacoum bait compared to warfarin bait achieved the same control of *R. argentiventer* populations. Buckle et al. (1982) also noted a tendency to poorer control of rice rats with increased replicates, (and less supervision of labourers) of the warfarin treatments. This was not observed with the brodifacoum treatments. Buckle et al. interpreted this data as suggesting that, with a 15 g, 0.05% warfarin bait and four baiting rounds at 7-day intervals, warfarin is close to the limit of its effectiveness and small errors of technique are noticeable. The effect of baiting with 5 g, 0.003% brodifacoum baits, however, is not affected by these small errors of technique which are presumed to be equivalent for the two different treatments. Buckle et al. (1982) also found that when the number of baiting rounds (pulses) was doubled and the pulse interval decreased, a relatively small increase in mortality was achieved, but with a considerable cost penalty due to greater bait and labour requirements.

Early rat damage to rice does not significantly effect yield due to later compensatory growth (Poche 1981) especially if secondary harvesting is undertaken (Buckle et al. 1979). Rat damage late in the rice crop cycle is important (Buckle et al. 1979, Poche 1981) and timing of control becomes critical. In Indonesian rice the common method of pulsed baiting with brodifacoum is to apply two baiting rounds at a one week interval a few weeks after transplanting. At this stage rat populations are very low as there is little food or cover. However, elimination of rats at this stage (when actual rat damage would be relatively unimportant) removes the focus for disastrous population build-up later in the crop cycle. A third round of brodifacoum baiting is made at the booting stage, if necessary, although often the two "prophylactic" brodifacoum baiting rounds are sufficient to give season long rat control.

Trials of various rat control methods have recently been reported by Sayed Ahmed (1981) who carried them out at the International Rice Research Institute (IRRI), Philippines. IRRI commonly encounter rat damage on 86.1% of their experimental plots with, overall, complete loss of 6.4% of all research data, rising to 20.5% loss of all research data in the worst affected areas. These losses are encountered despite regular application of recommended sustained (saturation) baiting with first-generation anti-coagulants (Sayed Ahmed 1981). Sayed Ahmed investigated the effects over two seasons rice growing of rodent control using several different methods. Saturation baiting was with coumachlor bait (0.03%) placed at the rate of 5 bait points per hectare of 50 g each checked twice a week, with double the amount being added if more than one-half of the bait was consumed. Bait stations at each place were increased as necessary and reduced when not needed, although one bait container was left at each place even if all bait was consumed.

Lethal electric rat barriers were erected on plots where this was practical; in addition, brodifacoum 0.005% baits were placed at bait stations inside the corners of each experimental plot so treated. Similar nonlethal electric barriers were also erected, and similarly brodifacoum 0.005% bait was placed in stations at the inside corners of each plot. Pulsed baiting was performed using 12 bait points per hectare with 50 g per station. These bait points were visited once a week. If the bait was completely consumed, it was replenished to 50 g at the next weekly visit. All control methods were carried out for the full length of the crop season. Two assessment methods were used by Ahmed Sayed; tiller damage and tracking tiles, before treatment, 8-9 weeks after transplanting and at maturity of the rice at 13-14 weeks after transplanting. Sayed Ahmed's results are summarised in Table 5. Sayed Ahmed concluded that the two baiting methods, pulsed baiting and saturation baiting, gave similar results and gave adequate

Table 5. Comparison of different methods of rat control in Philippine rice data for one season's control (80 days) and per hectare [mean of 4 trials; compiled from data given by Sayed Ahmed (1981)].

Method	Bait used kg/ha	Tiller damage at maturity* (%)	Rat activity index (%) at rice maturity	Total man days labour	Total cost/ha (US $)
Lethal electric rat barrier	1.8, 0.005% brodifacoum	0.9	1.7	181	1284
Pulsed baiting.	5.0, 0.005% brodifacoum	2.0	15.8	2	26
Saturation baiting	4.0, 0.03% coumachlor	1.6	18.3	4	26
Nonlethal electric rat barrier	2.7, 0.005% brodifacoum	4.1	32.5	30	268
No experimental rat control	Saturation baiting with anticoagulants (no details given)	9.3	55.8	?	

*(Note that various authors have noted that each 1% tiller damage before harvest is equivalent to 6-7% yield loss [Greaves et al. 1977, Khan and Choudry n.d.]. For example, 9.3% tiller damage just before harvest is equivalent to 9.3 x 6.5 = 60.6% yield loss.)

protection for the least cost. He also comments that the normal baiting programme may have prevented any differences between the methods showing up. In Sayed Ahmed's experiment 5 kg/ha of brodifacoum bait was used for pulsed baiting compared to 4 kg/ha of coumachlor bait for the saturation baiting. Yet it is widely recognised that brodifacoum is more acutely toxic to rodents than coumachlor (Dubock and Kaukeinen 1978, for example). It is probable that had brodifacoum been used in more, and also smaller (around 5-10 g) bait points per hectare rather than the 12 bait points per ha of 50 g each actually used, a certain amount of overconsumption of bait equivalent to overkill of individual rodents would have been prevented and less bait used to achieve control more economically.

For the saturation baiting treatment with coumachlor, 92% of the total cost was labour and only 6% was the bait. For the brodifacoum pulsed baiting, 46% of the total cost was labour and 50% of the total cost was bait (Sayed Ahmed 1981). With these costings, to have used more coumachlor bait in the saturation baiting, would not have significantly increased cost but may have increased efficacy. Similarly, to have used smaller bait points and less brodifacoum bait with the pulsed baiting technique may well have saved bait and significantly reduced costs without any sacrifice of efficacy. On the basis of other work (Dubock 1980), as much as 75% less brodifacoum bait may be necessary if the pulsed baiting technique is used than if a multiple-feed anticoagulant is used with saturation baiting. If only 1 kg/ha of brodifacoum bait was used with pulsed baiting, which is not a usually low application rate (Dubock 1980), rather than 4 kg per hectare of coumachlor bait with saturation baiting, the cost of brodifacoum treatment would have been US $ 15/ha rather than US $ 26/ha reported for both saturation baiting with coumachlor and pulsed baiting with brodifacoum. It is notable that the standard use of saturation baiting with first-generation anticoagulants at IRRI is not effective. Compared to the other treatments, significantly higher levels of rat activity and damage were noted on those plots receiving this standard treatment (no experimental rat control, 9.3% tiller damage) than on any of the treatment plots. Presumably, the experimentally used application technique was responsible for the better results achieved in Sayed Ahmed's research than in normal practice.

Further rice paddy rat control trials (Dubock 1980) in Thailand compared the effects of brodifacoum pulsed baiting with the effects of farmers' own standard rat control using zinc phosphide baiting and clubs. These trials showed that tiller damage was reduced by an amount equivalent to increasing the rice yield by 30-40% when small 10 g brodifacoum baits were applied in 3 pulses at a total application rate of 1-2 kg/ha/season (Table 6). Current rice yields in Thailand approximate to 3 te/ha/season, and the average price the farmer receives is about $US 150 te (Dr. Chatree Pitakpaivan, personal communication). The rice yield is therefore worth $US 450/ha/season to the rice farmer. Greaves et al. (1977) and Khan and Chowdry (n.d.) have reported relationships showing yield losses to be 6 or 7 times the percentage of tillers damaged just prior to harvest. Thus, the reductions of tiller damage from the two experiments summarised in Table 6 are equivalent to increases in yield of 34 to 40%, worth US$ 135-180/ha. To achieve this increase in yield required walking around the bunds of the rice field on 3 occasions and applying 10 g baits to a total of between 1 and 2 kg of bait (eg 330-660 g/ha/round) at a total cost of less than US$ 10/ha.

Table 6. Results of brodifacoum pulsed baiting in Thailand rice (from Dubock 1980).

Treatment	Total kg/ha	No of applications (rounds)	Preharvest tillers cut (%)	Reduction in damage (%)	Equivalent rice yield increase(%)
brodifacoum (0.005%) on rice. (10 g sachet)	1.65	3	1.19	84	40
farmers own (uncontrolled zinc phosphide + clubs)	-	-	7.38		
brodifacoum (0.005%) on rice (10 g sachet)	1.07	3	0.38		
brodifacoum (0.003%) (5 g wax block)	1.85	3	0.31	93	34
farmers own (uncontrolled zinc phosphide + clubs)	-	-	5.34		

Poché (personal communication) achieved excellent control of Arvicanthus niloticus at 3 different agricultural industry sites in Sudan: a flour mill covering about 4-5 hectares, an area of an experimental farm covering about 10 hectares, and a poultry shed housing about 28,000 chickens on about 5 hectares of a larger poultry farm. Live-trap census methods were used at weekly intervals at the start and then throughout the rodenticide treatments to judge effectiveness of control. Ten-to-fifteen-gram brodifacoum pelleted baits (containing 0.005% brodifacoum) were placed each week only in areas of actual rodent activity. The baits were not replenished sooner than at 7-day intervals, and only 10-15 g/point was laid, even if the previously laid bait had been completely consumed. If between one week and the next an area became "inactive," it was not baited again. At the experimental farm site baits were placed as necessary; at the flour mill site only the outsides of the buildings were baited during the first week but then baits were placed inside, too, where there were many rat signs. At the request of the management, baits were only laid outside the poultry sheds at the chicken farm, not inside.

The results of these trials are summarised in Table 7. It can be seen from these results that at the experimental farm a 95% reduction in A. niloticus population was achieved within 7 days as a result of a single bait application. Due to higher initial population density at the other sites, it took longer for all animals to have the opportunity to ingest a lethal dose. The lowest efficacy following the first pulse of bait was at the flour mill. This was due to initial placement, at the owner's request, of baits only outside the mill rather than inside where the rats were most active. The placement of bait in containers within the mill from the second pulse of baits quickly brought this population under control. However, due to lack of time, it was not possible to continue the baiting to achieve 100%. One hundred percent control was achieved within 14 days with only two pulses of baits at the other two sites. Despite very high rodent densities (in some 50 m^2 rooms at the experimental farm site more than 100 rats were actually seen before the trial commenced), only between 2-3 kg/ha of brodifacoum bait used with pulsed baiting provided effective rodent control.

The technique of pulsed baiting has also been used very effectively for urban rodent control. In trials conducted by Rodent Control Demonstration Unit, World Health Organisation/Department of Health, Burma in Rangoon, pulsed baiting with brodifacoum bait (0.005%), with 4 pulses at weekly intervals, has been compared with the use of 2.5% zinc phosphide for 3 or 4 days after 3 days prebaiting (Pe Than Htun, personal communication). The results are summarised in Table 8. With brodifacoum pulsed baiting between 91 and 93% control was recorded on the day the baits were finally removed. Animals ingesting a lethal dose of bait during the last few days before the bait was removed may well have succumbed to the poison later, but the probably increased levels of control achieved were not noted. With the zinc phosphide treatments, bait take after the 6 or 7-day treatment was used as a census bait and compared with consumption of the pretreatment prebait to provide an assessment of control success. The 86% reduction noted may therefore have included the effects of bait-shy, sublethally poisoned animals, which were not actually killed by the treatment. The 91-93% control achieved by the brodifacoum

Table 7. Summary of pulsed baiting trials with 10-15 g bait points of pelleted 0.005% brodifacoum bait at 3 sites infested with Arvicanthus niloticus in Sudan (Poché, unpublished data).

		Pretreatment	Initial bait pulse day 0	Second bait pulse day 7	Third bait pulse day 14	Day 21	Bait total (kg/ha)
Flour mill (4.3 ha)	Bait laid (kg)		4.5	4.5	2.0	-	2.8
	Trapping success (%)	45		35	5	3.3	
	Cumulative control (%)	-	-	22*	89	93	
Experimental farm (9 ha)	Bait laid (kg)		18.0	3.5	-	-	2.4
	Trapping success (%)	59	-	3	0	-	
	Cumulative control (%)	-	-	95	100	-	
Poultry farm (4.5 ha)	Bait laid (kg)		6.5	3.5	-	-	2.2
	Trapping success (%)	55		25	0	-	
	Cumulative control (%)	-	-	55	100	-	

*The first pulse of baits was laid only outside the flour mill. On day 7 the second pulse was laid outside and inside, where the infestation was worse.

Table 8. Results of WHO urban trials, Burma (Pe Than Htun, personal communication).

	Brodifacoum (0.005%) (4 pulses)	Zinc Phosphide (2.5%) (3 days prebait) 3-4 days Zn_3P_2
Structures baited	855	823
Burrows baited	16773	8170
Kg bait (total)	851	788
Dead rats recovered	2655	1231
Nontarget spp., recovered	3	7
Man hours mixing, packing, labour supervision	1467	1591
Control achieved	> 91-93%	< 86%

treatment is therefore a minimum level achieved, and the 86% recorded for zinc phosphide a maximum achieved. The results show that for the brodifacoum pulsed baited plot approximately the same total amount of bait treated twice as many rodent burrows with the same total labour requirement and with more than twice as many dead rats recovered than the use of prebaiting followed by zinc phosphide treatment.

USE OF THE PULSED BAITING TECHNIQUE FOR POPULATIONS WHERE ALL RODENTS CAN FEED ON THE FIRST AND ONLY BAIT APPLICATION

Figure 3 illustrates graphically the theoretical effect on the rodent population of a situation where all rodents have the opportunity to feed on the first pulse of baits. Such a situation occurs where the relationship between number and toxicity of bait points and number, susceptibility to the toxicant, and behaviour of individual rodents is such that no individual animal is prevented by social interaction or any other factor from ingesting a lethal dose of the first bait application. Consequently all rodents ingest a lethal dose and, on the average, all are dead about 1 week after placing the bait (Figure 3). This situation does not only occur when the rodent population is of a low density; it may also occur where the rodent population density is very high but the density of bait and its distribution is arranged so that all individuals have the opportunity for lethal ingestion of rodenticide within the same short time.

With many Microtus species the toxicity of brodifacoum bait is such that only a very small consumption is lethal. (Dubock and Kaukeinen 1978, for example.) It is a characteristic of many of these Microtine species that individuals have a very small feeding range, feeding within 10 cm of the burrow entrance, for example, in the case of Microtus socialis in wheat fields in Iraq (K.D. Taylor, personal communication), within which all potential food (or palatable rodenticide bait) is quickly discovered. The potential for quickly discovering bait also exists with the two USA pest species of apple orchards M. pinetorum and M. pennsylvanicus (Kaukeinen 1981). The realisation of this potential,

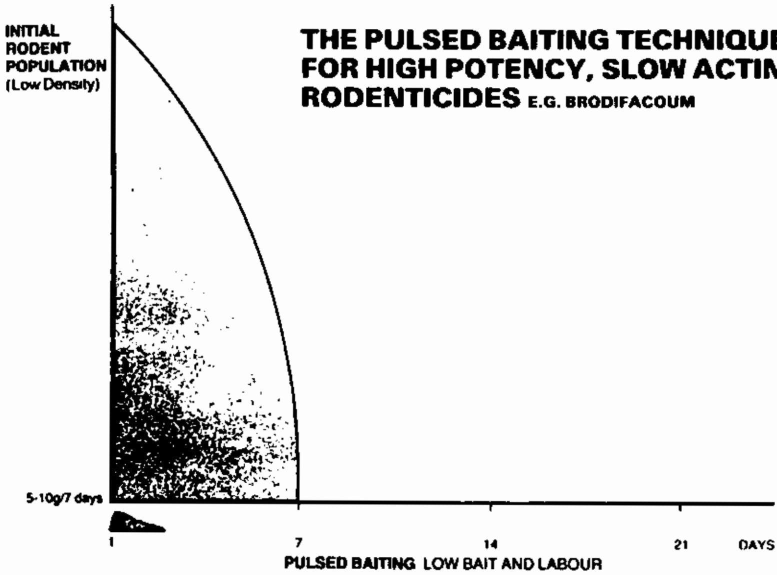

Fig. 3. Rodent population decline with time as a result of a single pulse of a potent slow-acting rodenticide where all individual rodents feed at the first pulse.

and the high potency of even 0.001% brodifacoum bait to voles, means that multiple applications of bait for vole control are unnecessary. With products less potent to voles, such as chlorophacinone or diphacinone, multiple applications of bait are required for individuals to build up a lethal dose. With 0.001% brodifacoum baits a single application, broadcast at a rate of 11 kg/ha, is sufficient to provide effective control of Microtus problems (Byers and Merson 1982). This single application can be considered as a single "pulse" of baiting with the population responding as depicted in Figure 3. In this case the wide distribution of the bait, through application by broadcasting, together with the small home range behaviour of the voles and high potency of the bait, allows all individuals to obtain a lethal dose as a result of the first and only necessary pulse of baiting (most bait has been consumed within 24 hours; Kaukeinen, personal communication), even though the density of voles may be as high as 2,718-30,000 per hectare (Byers 1978a, Walker 1975).

Experiments have also been performed in Egypt showing the efficacy of single pulse applications of 0.005% brodifacoum baits for controlling rodent infestations in citrus orchards and walled fields. In orchards an "orange census" technique was used, similar to the "apple census" technique used by Byers (1978b) for quantifying vole control methods. With the orange census technique a small section of each whole orange was removed with a sharp knife along the longitudinal axis of the orange so that any rodents feeding on the flesh of the orange had to gnaw away some of the peel leaving characteristic incisor marks. By removing all fallen fruit, placing a known number of census oranges individually on the ground at the base of the orange trees, and counting the number showing consumption one day later, an index of activity could be obtained pretreatment and at stages after treatment. In the walled field trial the rodents were living in holes at the base of a massive old mud and straw wall and feeding in the field surrounded by the wall. The "hole-blocking technique" of population census was used. The day before the census was made all rodent holes were blocked with earth. One day later all newly made holes were counted. This figure gives an index of the population equivalent to 100% before treatment starts. Subsequently, repeating the census enables changes in the population level to be monitored.

Brodifacoum (0.005%) wax block baits, each weighing approximately 20 grams, were placed at the base of perimeter trees in the orchard and in harbourage around the orchard where the rodents were living. The same type of baits were placed into holes in the wall only, in the walled field trial. (Although the rats were living in the wall and normally feeding in the surrounding fields, bait was not placed in the fields). In both cases only a single application of bait was made once the site was inspected. Application of the bait took slightly over 10 minutes per ha in the orchard. A summary of the results of these two trials are given in Tables 9 and 10. It can be seen that excellent levels of control were achieved in both trials within about 15 days of the single application of bait. Recently, Gorenzel et al. (1982) have reported similar results following single application for control of R. norvegicus in a California dairy.

A PRACTICAL RODENT CONTROL CAMPAIGN

In 1981 the pulsed baiting technique with brodifacoum baits was utilised over more than 4 million hectares of agricultural land. About 2 million hectares of this land, including villages and towns in the treatment areas, were in the Nile Delta in Egypt where more than 2,000 government agronomists were

Table 9. Rodent population reduction resulting from a single application of 2.2 kg/ha 0.005% brodifacoum bait in 20 g bait placements in a 3.6 ha Egyptian citrus orchard.

	Pretreatment census		5 days post-treatment census		10 days post-treatment census		15 days post-treatment census	
	A	B	A	B	A	B	A	B
Orange census	75	42	79	18	74	7	32	0
Reduction in rodent activity (%)	-		57		83		100	

A = number of census oranges laid
B = number of census oranges showing rodent signs the next day

Table 10. Rodent population reduction resulting from a single application of 1.6 kg/ha 0.005% brodifacoum bait in 20 g bait placements to a 2.25 ha walled field in Egypt.

	Active holes pretreatment census		Active holes 9 days post-treatment census		Active holes 14 days post-treatment census	
	A	B	A	B	A	B
Holes blocking census	-	162	-	55	-	13
Reduction in rodent activity (%)		-		66		92 (by extrapolation, 100% by 15.5 days)

instructed in the pulsed baiting technique using a 7-day interval and approximately 10-g bait points of pelleted 0.005% brodifacoum bait. The agronomists, in turn, trained agricultural labourers in the technique. Actual rates of use, effectiveness of the treatments and the application of the pulsed baiting technique were monitored as closely as was possible in such a large and practically orientated control campaign. From records of the first few hundred tonnes of brodifacoum bait used it became clear that an application rate in total of about 1-2 kg/ha was being used and that, in most cases, only 2 pulses, a week apart, were necessary for excellent control. (This compared with 10-20 kg/ha or more for first-generation anticoagulants used with saturation baiting where much more labour was also involved with mixing, packing, distribution and application of the bait.) The efficacy in practical use of the pulsed baiting technique with brodifacoum bait in Egypt was measured by K.D. Taylor et al. (personal communication), who performed pre- and posttreatment census baiting on 4 adjoining sites which together amounted to 33 hectares. Five hundred "token" baits, each containing 10 grains of whole maize, were laid before and after the rodenticide treatment. Counts of grains remaining at the token baits were made 24 hours after laying, and at each point evidence of feeding by rodents was recorded. The rodenticide treatment itself consisted of two pulses (applications) (990 g/ha in total) of the bait at a one week interval.

The trial area was divided into four sections:

1. Canal bank and well-kept orchard
2. Bank by cultivated fields
3. Canal bank and overgrown orchard
4. Cow sheds.

Species known to be present in the area were _R. rattus_, _R. norvegicus_, _A. niloticus_ and _M. musculus_. The results of this trial, measured by four methods, are given in Table 11.

The number of bait points with complete "takes" gives an indication of the confidence which can be placed on the results. In the cow shed more than 63% of the bait points laid were completely consumed by rodents. Had more grains of census bait been available, a higher initial rodent population would probably have been indicated, but it is impossible to quantify by what amount. Thus on this experiment site the initial population estimation is underestimated by an unknown amount and consequently the level of control achieved is also likely to be an underestimate. (Southern 1973 points out a similar difficulty with single-catch trap censusing of rodent populations. He recommends recensusing with more traps if over 80% trap occupancy occurs.) Conversely, on the other three experimental sites the proportion of census bait points registering complete takes is much less, and the recorded results are more likely to represent the real effects of the treatment. In these other three areas, the estimates of percentage control achieved are between 73 and 98% (mean of all assessments 91.75% control). There is little doubt that the level of control achieved of the cow shed rodent infestation was poorer than in the other areas, but perhaps not by as much as the results suggest. The poorer control was due to a relatively much higher rodent population there (mainly *R. rattus*). Most of the second application of brodifacoum was eaten and live rats suffering from the effects of brodifacoum poisoning were seen one week later. Ideally, a third and perhaps fourth application of the bait should have been made.

Table 11. Assessment of pulsed baiting (2 pulses at 7 day interval, 990 g/ha total, 0.005% brodifacoum) using four assessment methods at four Egyptian rodent infested sites.

Area (see text)	Initial baits completely taken (completes/total)	Census* method	Pretreatment census (taken/total)	Posttreatment census (taken/total)	Population reduction (%)
1		A	64/140	9/140	86
		B	24/140	1/140	96
	22/140 = 16%	C	390/1400	13/1400	98
		D	178/1400	4/1400	98
				Mean	94
2		A	45/130	12/130	73
		B	14/130	2/130	86
	27/130 = 21%	C	317/1300	37/1300	88
		D	117/1300	4/1300	97
				Mean	86
3		A	58/100	3/100	95
		B	25/100	2/100	92
	37/100 = 37%	C	482/1000	12/1000	97
		D	232/1000	9/1000	96
				Mean	95
4		A	105/130	77/130	27
		B	19/130	11/130	42
	83/130 = 64%	C	884/1300	483/1300	45
		D	176/1300	67/1300	
				Mean	44

*Census Methods: A - Token baits with take after 24 hours/token baits laid
B - Token baits with rat signs after 24 hours/token baits laid
C - Grains taken after 24 hours/grains laid
D - Grains taken, definitely rats, after 24 hours/grains laid

NB Each Token Bait Initially Comprised 10 Maize Grains

In order to determine how the pulsed baiting technique itself was being used by the agricultural labourers applying the bait, a sample of 76 villages and their surrounding fields were checked, without advance warning, by the expert staff who had trained the more than 2,000 agronomists initially, who had in turn trained the labourers who laid the bait in the village areas. The results of these spot checks are summarised in Table 12. (Note that as at some villages more than one baiting style potentially detrimental to the cost efficacy of the technique was noted; the total of the percentages is, therefore, greater than 100.)

Table 12. Application technique, analysis to optimise cost efficacy.

Technique	% of 76 villages sample
Excellent	46
Bait points unrelated to rat signs	39*
Baiting in open ground	23*
Bait points too large	21*
Scattering of bait	8*
Bait points too small	1*

*Some villages - more than one tendency

It can be seen from these results that only in 46 percent of the villages was the technique judged "excellent." The most common "fault" (39% of villages) was placing bait points without reference to rodent signs. This will tend to waste bait but is not a surprising observation; the ability to recognise rodent signs increases with practice. It is notable that in only one percent of villages were bait points judged too small, although 21 percent of villages were judged as having bait points too large, which again, would tend to waste baits by overkill feeding. This is a common tendency; with pulsed baiting it is difficult to accept that such small baits as 10 g can be effective. The tendency, especially for those people used to baiting with multiple feed anticoagulants, is to place more bait than is optimal at each place, especially if control of higher density populations is required. However, more, rather than larger, baits will give most cost effective control if the pulsed baiting technique is used with slow-acting highly potent rodenticides exemplified by brodifacoum. From the above (Tables 11 and 12) it can be seen that about 90-95% control of most infestations was probably achieved despite only 46% of villages being treated with the fully correct pulsed baiting technique. This is a good result, especially for a nonexperimental, practical and large-scale rodent control campaign, and supports the contention that the pulsed baiting technique with brodifacoum is "fool proof."

DISCUSSION AND CONCLUSIONS

The results presented above demonstrate that the pulsed baiting technique for technically exploiting high-potency, slow-acting rodenticides such as brodifacoum is effective in controlling a wide variety of rodent species in a wide variety of habitats; urban, agricultural buildings and open fields. Almost without exception the application rate which has proved most effective is 1-3 kg/ha of 0.005% bait using 5-15 g bait points and approximately 7-day baiting intervals. In almost every case control levels in excess of 90-95% control have been achieved. Even for controlling vole populations with a lower concentration bait (0.001%) approximately the same application rate is found to be effective in terms of milligrams of active ingredient per unit area. (Note, however, that at the lower concentration, higher application rate, more inert bait materials and--especially if saturation baiting is used--labour are required to apply the toxicant.)

The use of the pulsed baiting technique is safer from both a primary and secondary poisoning viewpoint than applying the same total amount of toxicant at a lower concentration and using the requisite quantity of bait for saturation baiting.

In practice, saturation baiting, even at a lower concentration of toxicant, introduces more toxicant to the environment than pulsed baiting due to difficulty of estimating rodent population levels and the need to provide excess bait continuously for a prolonged period. On the basis of Dubock (1979), for example, where 75% less brodifacoum bait was used for pulsed baiting than warfarin for saturation baiting, the brodifacoum concentration for saturation baiting would have to be reduced to 0.0012% if the total toxicant introduced to the environment was to be equivalent to pulsed baiting with 0.005% brodifacoum. At 0.0012% brodifacoum is effective for saturation baiting (Rennison and Dubock 1978) but such use carries cost penalties associated with extra inert materials and extra labour. Saturation baiting is also less practical than pulsed baiting, and tends to lead to "overkill" intoxication of rodents leading to potentially greater nontarget hazard. When baits are applied in the form of many small bait points, they are frequently completely consumed by the target animals very rapidly. The opportunity for primary poisoning by nontarget species is therefore reduced because toxic bait is not available to them for long and, anyway, is only available in very small quantities. Additionally, nontarget animals do not have the opportunity to form a "sighting-image" which, if formed, increases the probability of daily consumption of baits over a number of consecutive days. The pulsed baiting technique is designed to ensure that individual rodents ingest little more bait than is absolutely necessary for a lethal dose.

The opportunity for heavy toxicant loading of tissues at death therefore should be reduced compared to animals which consume far more than a lethal dose before death, as is probably normal for saturation baiting. This reduction of toxicant loading should reduce any problems of secondary poisoning. Similarly, animals dying as a result of consuming a lethal dose of bait several days before, as with pulsed baiting, are less likely to die with a gutfull of undigested bait than if bait was continuously available to them as with saturation baiting. This, too, will tend to reduce any hazard to predators and/or scavengers from pulsed baiting in comparison with saturation baiting.

From a practical standpoint, it is easier for labourers to apply small amounts of bait at, say, 1-2 kg/ha in 10 g bait points, than 10-20 kg/ha or more as is necessary with standard, multiple-feed, chronic rodenticides. Fewer labourers are also required. As the bait is consumed quickly there is less need for the use of impractical, large bait containers; 10 g of bait can easily be covered by leaves, or rice bran, or placed down a rodent burrow to minimize the possibilities of ingestion by nontarget animals. The weather protection function of a bait box is largely unnecessary if baits have only to remain acceptable to rodents for a few days before they are consumed.

All practical experience confirms that labourers readily take to the pulsed baiting technique. With visits necessary only once a week or so, a pulsed baiting rodent control campaign is much more easily managed and therefore more easy to coordinate than the saturation baiting system requiring more labour inputs. (In practice, many users of the rodenticidal baits, which should be used with saturation baiting for maximum effect, probably use too little bait too infrequently for the potential benefits to be obtained. For these users just changing to a more potent single-feed chronic rodenticide bait such as brodifacoum, without changing their baiting technique, will result in improved results!)

By using pulsed baiting, savings on inert bait ingredients are possible which more than compensates for the generally higher cost of the more complex high-potency molecule. Although the bait may be more expensive per kilogram than other baits, the cost for the result achieved is usually lower with brodifacoum baits and pulsed baiting than with all other toxicants and methods. Pulsed baiting cannot effectively be used with fast-acting, acute toxicants due to the development of poison-shyness in sub-lethally poisoned individual rodents; at the second and subsequent pulses of application those animals would not take the baits and good control would not be obtained. Due to lack of poison-shyness with brodifacoum baits, even single applications are usually more effective than single applications of fast-acting toxicants. These advantages of pulsed baiting with highly potent slow acting rodenticides are summarised in Table 13.

Table 13. Advantages of a single feed slow acting rodenticide used with pulsed baiting.

Advantages	
Low bait	Antidote
Low labour	Easy management
No poison shyness	Room for operator error
High efficacy	Low cost effect
Selectivity	Practical and efficient

The unique combination of practicality and efficacy the pulsed baiting technique represents has been successfully demonstrated over more than 4 million hectares. This experience possibly heralds a major role for the technique in rodent control of the future. It will be especially useful where labour motivation and cost and bait costs have, up until now, virtually precluded the possibility of economically controlling rodents.

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LITERATURE CITED

BARNETT, S.A. 1948. Preservation of grains in storage. Agricultural Studies No. 2, FAO, Rome. p. 129.

BUCKLE, A.P., F.P. ROWE, and ABDUL RAHMAN HUSIN. 1982. Field trials of warfarin and brodifacoum wax block baits for the control of the rice field rat, Rattus argentiventer in Penninsular, Malaysia. Proceedings of International Conference on Plant Protection in the Tropics, 1-4 March, 1982, Kuala Lumpur, Malaysia.

________., Y.C. YONG, and F.P. ROWE. 1979. Yield response of the rice variety improved mahsuri to simulated rat damage. Malaysian Agricultural Journal, 52:135-144.

BYERS, R.E. 1978a. Performance of rodenticides for the control of pine voles in orchards. J. Am. Soc. Hort. Sci. 103(1):65-69.

________. 1978b. Effect of orchard culture on pine vole activity. J. Am. Soc. Hort. Sci. 103(5): 625-626.

________ and M.H. MERSON. 1982. Meadow and pine vole control in 1981 field plots. In Proc. 6. East. Pine and Vole Symposium, Kearneysville, WV, 11-12 March, 1982. In press.

DRUMMOND, D.C., and B.D. RENNISON. 1973. The detection of rodent resistance to anticoagulants. Bulletin of the World Health Organisation 48:239-242.

DUBOCK, A.C. 1978. Rodent control in crop stores. Outlook on Agriculture, 9:220-224.

________. 1979. Alternative strategies for safety and efficacy of rodenticides, Fifth Session, Paper 14, pp. 1-15. Proceedings of the Fifth British Pest Control Conference, Stratford Upon Avon, UK, 26-29 September 1979.

________. 1980. The development and practical use of the novel anticoagulant rodenticide brodifacoum. Plant Prot. Bull. (Taiwan, R.O.C.) 22:223-238.

________, and D.E. KAUKEINEN. 1978. Brodifacoum (Talon™ Rodenticide) a novel concept. Proceedings Eighth Vertebrate Pest Conference, Sacramento, California, USA, pp. 127-137.

________, and B.D. RENNISON. 1978. Field evaluation of baits for poison treatments against Norway rats. Proceedings 1977 British Crop Protection Conference - Pests and Diseases, 451-459.

F.A.O. 1975. 'Ceres' 8:(1).

GREAVES, J.H., M.A. CHOUDRY, and A.A. KHAN. 1977. Pilot rodent control studies in rice fields in Sind, using five rodenticides. Agroecosystems, 3:119-130.

GORENZEL, W.P., R.E. MARSH and T.P. SALMON. 1982. Single feeding anticoagulants: Are they what they claim? Pest Control, February 1982, 32.

HADLER, M.R., and R.S. SHADBOLT. 1975. Novel 4-hydroxycoumarin anticoagulants active against resistant rats. Nature 253:275-277.

KAUKEINEN, D.E. 1982. Microtus problems and control in North America and the development of Volid rodenticide (In preparation).

KHAN, A.A., and M.A. CHOUDRY. (n.d.) Field evaluation of the newly developed rodenticides against rice field rat. Unpublished F.A.O. Report. 16pp.

KHOO CHIN KOK, and A.C. DUBOCK. 1981. Brodifacoum, a potent anticoagulant for the control of oil palm rats. Proceedings of the International Conference on 'The Oil Palm in Agriculture in the 80s', Kuala Lumpur, June 17-20, 1981.

O'CONNOR, J.A. 1948. The use of blood anticoagulants for rodent control. Research Supplement, 7:334-336.

POCHE, R.M., M.E. HAQUE, M.Y. MIAN, P. SULTANA, and M.A. KARIN. 1981. Rice yield reduction by simulated rat damage in Bangladesh. Tropical Pest Management, 27:242-246.

REDFERN, R., J.E. GILL, and M.R. HADLER. 1976. Laboratory evaluation of WBA 8119 as a rodenticide for use against warfarin-resistant and non-resistant rats and mice. Journal of Hygiene, 77:419-426.

RENNISON, B.D., and A.C. DUBOCK. 1978. Field trials of WBA 8119 (PP 581, brodifacoum*) against warfarin-resistant infestations of Rattus norvegicus. J. Hyg. Camb. 80:77-82.

___________., L.E. HAMMOND, and G.L. JONES. 1968. A comparative trial of norbormide and zinc phosphide against Rattus norvegicus on farms. Journal of Hygiene, 66:147-158.

ROSWELL, H.C., J. RITCEY and F. COX. 1979. Assessment of humaneness of vertebrate pesticides. In Proc. Can. Assoc. Lab. Animal Sci. Conv., Univ. Guelp, June 1979, 17pp.

SAYED AHMED, MD. 1981. Evaluation of rat control techniques in experimental fields of the International Rice Research Institute. MS Thesis, University of Philippines, Los Banos, 62pp.

SOUTHERN, H.N. 1973. A yardstick for measuring populations of small mammals. Mammal Review, 3:(1), 1-10.

WALKER, E.D. 1975. Mammals of the World. John Hopkins University, Volumes I & II, 3rd Edition.

WHO. 1967. "World Health" p. 1.

WOOD, B.J. 1969. Population studies on the Malaysian woodrat Rattus tiomanicus in oil palms, demonstrating an effective new control method, and assessing some other ones. "The Planter", 45:(523), 510-526.