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A REVIEW OF BRODIFACOUM EFFICACY IN THE U.S. AND WORLDWIDE

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INTRODUCTION

It was just over 10 years ago with the paper by Hadler and Shadbolt (1975) that a series of novel anticoagulants, which included brodifacoum, was announced. Today, after a decade of brodifacoum study and experience, the value of this compound in vertebrate pest management, particularly in rodent control, can scarcely be questioned. In order to most effectively build upon this experience, a thorough review of the literature for the period of 1975 to 1985 was undertaken to also include much unpublished information available to the authors.

Undoubtedly to a greater extent than any other new vertebrate pesticide, brodifacoum has been the subject of extensive testing and development around the world. This research has included much original work by scientists within ICI since 1975 with the acquisition of rights to brodifacoum and related compounds, in the areas of efficacy, toxicity, hazard determinations, formulation development, and new application techniques. Supporting open, responsible research and publication in the scientific literature, ICI has provided brodifacoum samples to, and maintained close liaison with, various government, university, and other research groups in the United States, England, and elsewhere. These efforts and resulting publications in recognized journals and proceedings have served to stimulate, coordinate, and add to the rapidly growing body of scientific knowledge about this compound. Laboratory characterizations led to field trials, and the confidence and results derived from such testing allowed in due course for registrations of brodifacoum as a vertebrate toxicant in many countries. Then other but equally valuable data sets could emerge for documentation. These are concerned with the practical experience with a chemical tool in actual large-scale use.

A number of conferences or symposia have also been convened or sponsored by ICI to supplement the few regular symposia on the subject, and to provide an open forum on vertebrate pest management, including discussions of brodifacoum research findings. Examples are an International Public Health Seminar, in Surrey, England, in 1979; a symposium entitled "The Organization and Practice of Vertebrate Pest Control," held in Hampshire, United Kingdom, in 1982 (Buckle 1983); and a conference, Rodent Control in the Tropics, held in London in 1983 (McDonald 1983). Proper concern and attention have been given by ICI and other researchers to determining environmental and nontarget animal impact of brodifacoum use (Kaukeinen, 1982, 1984b; Hegdal et al. 1984; Godfrey 1985). As with all available vertebrate pest toxicants, brodifacoum can be toxic to other organisms if misused or accidently ingested. Formulation developments and new application techniques, to be later discussed, can reduce hazard and improve selectivity by taking advantage of brodifacoum's unique properties.

The discovery of brodifacoum in England as first published in 1975 (Hadler and Shadbolt) was quickly followed by reports concerning its characterization and promise in the area of rodent control. While initial reports concerning a "new development in rodent control" were concerned with difenacoum, a related compound in the Hadler series, published work on brodifacoum in England by Hadler and the staff of the UK Ministry of Agriculture, Fisheries and Food soon followed (Redfern et al. 1976, Rowe and Bradfield 1976, Anon. 1978). These studies characterized the properties of brodifacoum against those most predominant of rodent pests, the commensal species Rattus norvegicus, Rattus rattus, and Mus musculus. Research began soon after in the United States and elsewhere on these and other species. Such work, including further commensal studies from MAFF, such as Rowe et al. (1978), was the subject of an extensive review by Dubock and Kaukeinen (1978). That first major review of brodifacoum encompassed 25 species, involved work in 14 countries, and contained 38 references.

Additional reviews or general articles that summarized brodifacoum's characteristics or that touched upon further findings soon followed (e.g., Hadler 1979, Dubock 1980, Anon. 1981b, Hone and Mulligan 1982, Renapurkar and Kamath 1982, Meehan 1984, Lund 1985); however, these were not comprehensive, prompting the current review. Prior reviews did indicate the basic properties of the compound, which are now generally familiar, and provided a framework for an update.

PROPERTIES OF BRODIFACOUM RODENTICIDE

1. Same mode of action and antidote as other anticoagulants.

2. Highly active against a broad spectrum of pest species.

3. Efficacious with limited feedings, including against rodents resistant to other anticoagulant rodenticides.

4. Palatable, active, stable and otherwise amenable to conventional incorporation in baits.

This review is organized in a fashion similar to the above listing, first covering brodifacoum activity, formulation development, and palatability in the laboratory, followed by efficacy in both the laboratory and field worldwide within specific pest problem areas for both commensal and agricultural species. A concluding section includes areas for further developments of brodifacoum formulations.

The present review encompasses some 62 pest species, 37 countries, and over 200 published references on brodifacoum efficacy. Published papers reviewed were as determined from review of the existing pest rodent bibliographies (described in Kaukeinen 1986), from a search of ICI-PPD's HARVEST database in the United Kingdom, utilization of the United States' on-line DIALOG system for access to various literature databases, and from searches of personal reprint files and those of associates. Copies of all referenced papers were obtained. This review has also provided an opportunity to include reference to considerable new data and information produced by ICI, or that from elsewhere as kindly provided to the authors, which have not yet been published. The United States has been the scene of principal technical developments of brodifacoum formulations and early registrations for brodifacoum. Also, the States have seen considerable experimental work on their considerable and often unique agricultural problems with noncommensal pest rodent species. Therefore, and in deference to the principal audience of these proceedings, a review of brodifacoum efficacy information for the United States will constitute a separate section.

REGISTRATION HISTORY

Beginning in 1978, and following regulatory authority review of both published and unpublished findings, brodifacoum began to receive registrations around the world for rodent control. Initially registered in Indonesia and then the United Kingdom that same year, registration in the United States followed in 1979. Brodifacoum is currently registered in over 40 countries in the form of over 100 separate registrations covering different formulations or product forms. ICI has applied for registrations in a further 50 countries, based on in-house, cooperator, and independent research data.

GEOGRAPHIC DISTRIBUTION OF BRODIFACOUM RESEARCH AND EXPERIENCE

Table 1 arranges published references from this review by origin where this criteria is of importance, as in reference to local species and problems, according to a standard convention which comprises 11 world divisions. Appendix 1 gives further information on countries and research areas represented. Brodifacoum efficacy research within the European, South Asian and North American regions has predominated. Although brodifacoum is currently undergoing development and registration as well in regions less represented, the lack of publications for some areas generally follows that noted in a similar analysis of some 20,000 citations relative to general pest rodent biology and control, as published over a 25-year period (Kaukeinen 1986). Exceptions to this distribution for brodifacoum efficacy references from this review are a relatively greater contribution from South Asia and a relatively reduced contribution from Europe than would otherwise be expected (perhaps due in part to the unfortunate recent curtailment of pest rodent research at the United Kingdom Ministry of Agriculture). For the most part, information given in this review and the details in the appendices indicate that some information on the use of brodifacoum as a rodenticide exists in reported form for most world areas, species, and problem situations.

Table 1. Published brodifacoum references from this review arranged by geographic region.

Region	Number	Percent
Europe	30	17
Middle East	3	2
Africa	9	5
South Asia	42	24
Far East	15	8
S. E. Asia	17	9
Oceania	7	4
North America	49	27
Central America	2	1
Caribbean	0	0
South America	6	3
Totals	180*	100

* Some papers counted in more than one category.

COMPARABLE MODE OF ACTION AND ANTIDOTE TO OTHER ANTICOAGULANTS

Considerable pharmacological and other research has documented that brodifacoum has a mechanism of action which is comparable to warfarin and other anticoagulants. This subject is beyond the scope of an efficacy review, but recent examples of brodifacoum pharmacology research are Bachman and Sullivan (1983) and Breckenridge et al. (1985). Vitamin K1, as with other anticoagulants, is an effective antidote. Also, as with other anticoagulants and in spite of brodifacoum's potency to target species, there is a delay to death of normally 4 to 10 days or more. A test with albino Norway rats (ICI, unpubl.) involved intubation of a group of 14 rats with 27 mg/kg, or 100 times an LD50. This resulted in 100% kill with an average day of death of 5.5 (range 3 to 7 days), which is comparable to the time to death seen with lab administration of low doses. The delay to death with some pest species, such as up to 20 to 30 days with Mus (e.g., Lund 1981), can result in misleading study results if brodifacoum test protocols do not ensure an adequate observation period after toxicant exposure.

HIGHLY ACTIVE/REDUCED RODENTICIDE REQUIREMENTS

The activity of brodifacoum has been investigated in the laboratory by many researchers, and is summarized in Appendices 2 to 6. These appendices include reference to species strain or source as such differences can be important. For example, Hoque (1983a) noted that R. r. mindanensis from the Philippines showed 1.7 times greater tolerance to warfarin than the same subspecies from Indonesia. Also, where appropriate, these appendices cite the bait formulation tested. Variations in mortality to brodifacoum as observed in these and other studies may result in part from differences in vitamin K content of baits offered, or from other physiological or pharmacological effects after anticoagulant intake as produced by different diets themselves (Colvin and Wang 1974). Also, rodents that may have been recently exposed to sublethal doses of other toxicants, such as zinc phosphide, may subsequently respond differently to anticoagulants such as brodifacoum (Bhardwaj and Prakash 1984).

Appendix 2 lists available acute LD50 figures, Appendix 3 reports subacute LC50 information, Appendix 4 gives lethal feeding periods, and Appendix 5 notes restricted feeding trial results. The LD50 values reported in Appendix 2 encompass 12 genera of rodents, generally of worldwide pest status, and show LD50 values of less than 1 mg/kg against these pests in all cases. For the two lagomorph species as given, LD50s are less than 0.5 mg/kg; the marsupial species represented has an LD50 of 0.2 mg/kg. The variations seen in LD50 values for the same or similar species with brodifacoum (or as noted in the literature for nearly all rodenticides) may be attributable to animal source or strain differences, or result from different experimental approaches and preparations (e.g., see Ashton et al. 1986).

One means to assess the potency of an anticoagulant is to compare LD50 and LC50 values as derived for the same species. For example, warfarin has a high LD50 but a low LC50 value, and is generally considered the least potent of the anticoagulants. Brodifacoum is at the opposite end of the range in the comparability of its LD50 and LC50 values. Thus, it can be noted from Appendix 3, which lists subacute LC50 values, that repeating brodifacoum exposure on successive days until death does not normally decrease the total dose of brodifacoum required to kill in an acute LD50 test. For example, with Bandicota bengalensis and R. norvegicus, The cumulative 4- or 5-day divided dose for an LC50 closely approximates the LD50 as given in Appendix 2.

Only 2 species in Appendix 3 show a lower total for divided daily doses from LC50 derivations as compared to their LD50: Cricetulus and Mus. Fortunately, Cricetulus is a pest in only limited and localized areas. The greater tolerance to all anticoagulants, including brodifacoum, as seen with Mus, can be partially explained by the fact that all available anticoagulants and the new second-generation anticoagulant materials, were developed from basic screening on the Norway rat and therefore are particularly suited to field use against this species. Generally poor efficacy with first-generation anticoagulants against house mice is well known to the extent of precluding their use for this species in some areas. As Appendices 2 to 5 indicate, brodifacoum retains good efficacy against M. musculus, particularly at 50-ppm active concentration in baits.

Regarding lethal feeding period (LFP) data, Appendix 4 suggests that most pest rodent species can be killed with limited exposure to brodifacoum. Six rodent species have LFP98 values reported of less than 4 days, and 2 species have values of less than 11 days. Only Acomys, of species reported, has a high LFP corresponding to its tolerance of anticoagulants in general.

Appendix 5 gives restricted, no-choice feeding exposures of generally 1 to 4 days, further illustrating the reduced need for rodenticidal exposure with brodifacoum. With 50-ppm bait (0.005%) and a 1-day exposure, test groups of 28 species show 100% mortality. Most of the remaining 18 species or subspecies as represented showed either control of 80% or better in a 1-day exposure to 50-ppm brodifacoum, or (particularly with some gerbil and hamster species) 80 to 100% kill after 2 to 3 days of exposure. Appendix 6 gives further verification of broad spectrum pest efficacy and limited bait requirements with the results of just 6- or 12-hr exposures to 7 nonfasted rodent species giving high levels of control.

EFFICACY ON RODENTS RESISTANT TO OTHER ANTICOAGULANTS

Resistance in rodents to warfarin and other first-generation anticoagulants during the past 20 years has been ably reviewed by others (e.g., Greaves 1985). Brodifacoum retains efficacy against resistant Norway rats as reflected in Hadler's "resistance factor" comparisons as given in Table 2 (from Hadler and Shadbolt 1975, Dubock and Kaukeinen 1978).

Table 2. Rattus norvegicus resistance factors of anticoagulants.

Anticoagulant	Prothrombin ED50 Wistar (mg/kg)	Prothrombin ED50 Homozygous (mg/kg)	Resistance factor (ratio)
brodifacoum	0.08	0.10	1.3
difenacoum	0.17	0.32	1.9
coumatetralyl	0.31	4.4	14.2
chlorophaconone	0.22	>20.0	>90.9
diphacinone	0.22	>50.0	>227.3
warfarin (S-)	0.30	>50.0	>166.7

Lab test data against warfarin-resistant strains of the three common commensal species are included in Appendices 2, 3 and 5. Appendix 5 shows that a 1-day feed on 5-ppm brodifacoum was insufficient against resistant house mice, but that 50-ppm bait gave 90% in a 1-day no-choice feed and 100% after a 3-day feed. Only some Canadian resistant mouse strains (Siddiqi and Blaine 1982a) showed lowered efficacy, at 75% kill with a limited 3-day exposure to 50-ppm bait. For warfarin-resistant Norway rats, a 1-day exposure to only 10-ppm brodifacoum bait gave 100% kill. With warfarin-resistant roof rats, 20-ppm bait gave 80% control in 2 days, whereas 50 ppm gave 100% mortality. Further verification of brodifacoum efficacy on warfarin-resistant strains is given in Rowe and Bradfield (1976), Rennison and Dubock (1978), and Myllymaki (1986). Field trials of brodifacoum against difenacoum-resistant Norway rats in England (Greaves et al. 1982) reported less efficacy against this population than expected for warfarin-susceptible rats. However, these trials were conducted with 20-ppm brodifacoum, whereas 50 ppm is the recommended active concentration for control of commensal species (as well as for most agricultural rodent pests). In some countries, such as Denmark and England, regular anticoagulant susceptibility surveys utilizing laboratory techniques from field captures have continued from prior baseline years through the advent of new anticoagulants, such as difenacoum, bromadiolone, and brodifacoum. Findings suggest a limited resistance to difenacoum, and resistance of a more practical significance to bromadiolone, but there have not been reports of rodent survival with 50-ppm brodifacoum (e.g., Lund 1984b, Lund and Lodal 1986) when challenged in standard laboratory resistance screening tests such as recommended by the World Health Organization (Anon. 1982c).

BRODIFACOUM PALATABILITY AND FORMULATION DEVELOPMENT

The rodenticidal properties of a material such as brodifacoum would be of limited value if the active at normal bait strength caused significant taste rejection in baits such that lethal doses would not be ingested. The innate taste of anticoagulants rodenticides is certainly of less importance than with fast-acting acute materials, because of generally lower active concentrations in anticoagulant baits, and due to the delay to death which does not normally result in bait discrimination (or general changes in dietary habits due to poisoning symptoms) for at least 2 or 3 days.

It may be an oversimplification to attribute the normally excellent acceptability of anticoagulant baits to a conclusion that levels of active ingredient in the normal range of 10 to 250 ppm are completely undetectable by rodents. Bentley and Larthe (1959) showed clear differences in the acceptability of several first-generation anticoagulants at normal use concentrations. For example, it was noted that diphacinone showed less acceptance at the same active concentration than warfarin with R. norvegicus, whereas the reverse preference was found for R. rattus. With brodifacoum, work exemplified by Redfern et al. (1976) with the three commensal species comparing poisoned versus unpoisoned bait consumption found brodifacoum baits somewhat less acceptable than the plain bait base with house mice at 20 and 50 ppm, although both concentrations gave complete kills.

While relative acceptability of brodifacoum-treated versus untreated diets in the literature is generally about equal, variations exist and may possibly be due not only to possible "taste" of the active ingredient, but also to noncomparable test diets in experimental studies. An example would be a blank bait not treated with the same solvents or diluents as the treated bait. In much of the published literature, it is unclear how diets were prepared. In addition, some bait bases may be more effective at "masking" toxicant taste qualities.

Major factors in determining the palatability of a rodenticidal bait are the nature and quality of the ingredients. In much of the world in areas where efficacious rodenticides are needed, expertise in bait development and formulation procedures may be insufficient to safely produce an optimum material with consistently high quality. Brodifacoum in technical and concentrate form requires handling precautions that precludes the "mixing in a pan" approach familiar to users of some other rodenticide concentrate products which may have been available.

It has therefore been necessary to improve the consistency of performance of brodifacoum against pest rodents and to control safety aspects in formulating brodifacoum baits. In some cases, because of special local needs, specific brodifacoum formulations have been developed with ICI assistance for local production. However, ICI has concentrated much internal research effort in developing optimum formulations with novel characteristics that can be commercially produced within the confines of approved contractors for widespread distribution. Formulations developed include the 50-ppm TALON, KLERAT or HAVOC pellet, the 50-ppm TALON or KLERAT wax block, the 30-ppm MATIKUS wax block, and the 10-ppm VOLID pellet. These formulations form the core of the product range in a variety of shapes, colors and sizes according to local preferences, and are exported by ICI to many countries. The ICI formulations have characteristics providing considerable shelf stability (2 years or more), moisture-resistance in the field, and are subject to rigorous quality control assuring consistency from batch to batch. As these registered trade names refer to specific, proprietary ICI formulations, they should not be used to refer to brodifacoum baits made locally by non-ICI personnel (e.g., for research purposes), as the only similarity to ICI baits may be in strength of active.

Appendix 7 gives results of standard acceptability studies of principal ICI formulations with 14 species. Percent acceptance levels of 30 to 80% with generally 90 to 100% kill of test groups were achieved after 3- or 4-day choice exposure versus an attractive blank bait. The ICI pellets are highly acceptable even to agricultural pest species (e.g., lab studies in the USSR showed good palatability of TALON pellets with the great gerbil, Rhombomys opimus, versus corn (Anon. 1980 rept. to ICI). For increased moisture and mold resistance, or to provide a larger "unit feed" appropriate to some baiting strategies (for example, in agriculture), the ICI wax block formulation is useful and highly attractive, even to Mus and microtines not normally expected to accept paraffinized baits (Appendix 7, also Myllymaki 1986, Lund and Lodal 1986). In special circumstances, the wax block formulation may be at advantage in being more difficult for poultry or wild birds to accidentally consume.

NEW BAITING STRATEGIES

Brodifacoum baits can be utilized in the field as for conventional first-generation anticoagulants in sustained baiting approaches. The greater cost that toxicants represent in relation to labor for many control situations, and the great potency of brodifacoum itself, have led to the development of "pulsed baiting". This has been ably described by Dubock (1982, 1984b) and also verified in the field as reported by Richards (1983) and others, including the authors of many of the examples used in the following section and several citations from Appendices 8 and 9. Briefly, the application method involves the placement of many small bait placements throughout the infested area. Baits are allowed to be entirely consumed and rodents which fed allowed to die before rebaiting (pulse) is conducted. When such baiting, limited in total quantity but increased in distribution, is conducted at intervals of 1 to 4 weeks, successive "waves" of rodents are poisoned and the total bait requirements are reduced. Trials comparing the older, "sustained" baiting approaches with pulsed baiting have supported these advantages of the latter technique (e.g., Mo and Liang 1984, Hoque and Olivida 1986).

Although pulsed bait methodologies are still undergoing study and refinement (e.g., Richards and Husin 1985), the pulsed baiting method as presently verified has great merit at present, being particularly useful in agricultural or village-wide rodent control campaigns. The method does require coordinated planning and organization to be successful, and must incorporate efforts for more extended monitoring and allowance for rebaiting. The method is especially suited to a compound such as brodifacoum which, although toxic in a single feeding, does not produce poison shyness and so can remain effective after repeated applications. In reducing the total amounts of rodenticide applied, pulsed baiting also reduces potential hazard to those nontarget animals which might directly consume the bait. And as Dubock (1984b) reports, pulsed baiting also reduces the toxic residues in target rodents over that produced from sustained baiting, and so may offer less hazard to potential secondary feeders, such as birds of prey.

VERTEBRATE PEST PROBLEM AREAS

Problems with commensal vertebrate pests in villages and cities are essentially universal, as are agricultural pest attacks to stored crops and commodities, damage to structures, and losses in crops and in domestic animal production. No fewer than 25 separate rodent problem areas have related brodifacoum efficacy work represented in the materials upon which this review was based. It is not possible to discuss each area and all relevant literature in detail within the confines of this review. Accordingly, only a few major areas representative of the diversity of pest problems and the corresponding utility of brodifacoum will be covered through the use of selected examples from the literature. Further details and a listing of reviewed published efficacy trials, as well as much unpublished work, are contained in the appendices, and in the U.S. efficacy section to follow.

COMMENSAL PEST FIELD EFFICACY TRIALS

Urban Rodent Control

City trials have generally been conducted by government authorities or representatives responsible for rodent control, frequently with the objective of reducing rodents as known or potential disease vectors. Urban pest species generally include any or all of the three main commensal species, R. norvegicus, R. rattus, and M. musculus.

Sao Paulo, Brazil, is a city of some 12 million people, containing pockets of makeshift habitations termed "favelas" heavily infested with commensal species. A smaller favela with a population of about 300 people in 56 dwellings was the subject of a brodifacoum trial (Richards 1986a). Two 50-ppm brodifacoum blocks were applied in each room, inside active burrows where possible. Two applications at a 14-day interval gave a rodent activity reduction of 98% utilizing tracking patches. Aleppo, Syria, is a city of some 1.3 million people. Richards (1986a) reports the organizing of the city into 12 districts, each further divided into 12 zones, allowing each zone to be baited by project staff in 1 day and a complete district in every 4 weeks. Six baiting teams were involved and a pilot project involved premise inspection and baiting in active areas with brodifacoum pellets or blocks. Evaluation teams used tracking patches before and after treatment to determine rat activity. Use of brodifacoum in the test district resulted in 92% reduction of activity 12 days after the second bait application.

Brodifacoum trials in Zhuo Xian, Hebei Province, China (a city of 50,000 people), are reviewed by Richards (1986). The city was divided into 10 areas for the trial. Some 474 technicians were trained and worked under the supervision of 49 technical leaders, with more than 2,000 additional persons in the city assisting in baiting, collecting and disposing of dead rats and distribution of baiting information. Talon was baited inside structures at the rate of 10 to 50g per room in 2 to 5-g covered piles and at two intervals of 5 days. Three independent census methods showed an average reduction of rodents of about 90% after treatment.

Trials with brodifacoum in a town of 18,000 persons were conducted in Hlegu, Burma. Rodent control teams incorporating governmental health staff conducted thorough surveys of dwellings. Wax brodifacoum baits of 25-g each were placed in active burrows for B. bengalensis. Additional blocks were placed in bait stations inside homes to control other species (R. rattus, R. exulans, M. musculus and Suncus murinus). Census baiting before and after treatment showed that 73% of houses had initial infestations. Only 1.5% of homes showed any signs of rodent activity after the treatment (Richards 1986a).

Village and Farm Structures

Small towns, villages, and housing clusters (such as in farming areas) may often experience rodent problems, especially of a seasonal nature, when rodents find less alternate food in surrounding croplands or other habitat and then invade structures to establish a commensal existence. Trials to establish the efficacy of a rodenticide in such circumstances are difficult without an organizational infrastructure present to facilitate a systematic, consistent, thorough and area-wide treatment for rodents. Such research can best give meaningful results when pest immigration and movement effects can be reduced.

Trials in village housing clusters in Bangladesh (Bruggers and Valvano 1981, Rahman and Brooks 1982) evaluated 50-ppm brodifacoum baits during the monsoon season when rodents had deserted plowed fields for higher, inhabited areas. Tracking tiles were placed before and after treatment, and concluding snap-trapping was conducted. Of the compounds tested, brodifacoum gave consistently greater reduction in animal activity in each of the three housing clusters in the evaluations, producing an overall reduction of R. rattus, M. musculus, and S. murinus of 97% from initial activity levels. Baiting rodents around structures was judged easier and more effective than baiting in adjacent field crop situations, and it was recommended to do large-scale village baiting programs during the monsoon season to reduce rodent populations to nondestructive levels by the onset of the dry-season cropping period.

Similar village-level work in Vietnam is reported by Richards (1986a,b). Mai Xa cooperative had a population of about 2,400 persons and 660 dwellings within a mosaic of gardens, rice fields, and canals. Baiting was conducted in February after harvest and before the next rice planting. Much movement of rats, predominantly R. r. molliculus, from fields to dwellings was recorded. An organization for baiting was created and 50-ppm brodifacoum wax blocks each weighing 5 g were applied in active village areas. The approximate rate was 15 baits per house, 400 baits per ha garden and 100 baits per ha in adjacent rice fields. Two applications at intervals of 14 days gave a 95% reduction in rodent activity. Subsequent damage estimates to rice showed a significant protective effect from the village treatment.

AGRICULTURAL PEST RODENT FIELD EFFICACY TRIALS

The introduction in recent years of high-yielding, improved quality grain and other crop varieties has resulted in significant commitments to the production of these crops in many countries, both for self-sufficiency and for export. Such crops are often extremely vulnerable to rodent damage at certain crop stages. Rodent control in crop situations under the conditions and needs of modern agriculture is shifting to area- and crop-wide organizational pest management strategies in some countries, relying less on the initiative of individual farmers and growers. New control materials such as brodifacoum and associated new application techniques, such as pulsed baiting, have received considerable interest and evaluation under this new impetus.

Rodenticide evaluation techniques in crop situations as utilized in the subsequent section describing brodifacoum field work have been the subject of previous reviews (e.g., Buckle and Rennison 1986), and such methodologies will not be reviewed here. Suffice it to say that the potential for pest rodent movement and test plot immigration, uneven pest distribution within fields, uneven crop density or attractiveness, crop stage and seasonal effects on infestations, and the laborious needs of most crop damage assessment or pest activity measurements in crops can be listed as some of the difficulties inherent in such work. Particularly important goals are to develop and utilize techniques which allow for ongoing monitoring efforts to determine optimum timing and duration of control efforts, and those which can demonstrate cost benefits of control and the economic threshold of damage. Most of the evaluation examples as described below and in Appendices 9, 11, and 12 also included trials of other anticoagulant or acute rodenticides. The clear superiority of brodifacoum, often when applied at lower rates, over other materials can be readily determined by a review of the citations given in the following section and corresponding appendices.

Rice

Rice in Malaysia is the second most important crop (after rubber) and, as elsewhere in much of the southeast Asian area, R. argentiventer is the principal pest, causing 2 to 10% yearly damage (Buckle et al. 1985). Following laboratory evaluations. brodifacoum wax blocks of 50 ppm weighing 5 or 15 grams were applied in Malaysian rice fields under different experimental regimes (Lam 1980, Buckle and Rowe 1981, Buckle et al. 1982). Baiting began before transplanting and effectiveness was measured by the use of census baits applied before and after treatment. The larger blocks gave the best activity reduction (87%) when applied twice a week for 4 weeks. Using the 5 g-blocks, applications weekly for 4 weeks gave 80% reduction, far better than could be achieved with conventional anticoagulants (warfarin) at considerable savings of bait and labor. Other work in Malaysian rice fields (Majid and Chye 1984) found a local 30-ppm brodifacoum wax block product weighing 4 g to also be effective within an overall control strategy.

In the Philippines, initial laboratory studies with brodifacoum and Rattus species infesting rice were described in Anon. (1977). Subsequently, sustained baiting and weekly baiting in the field were compared utilizing 50-ppm brodifacoum in rice bait or wax blocks. Yield losses were reduced by both techniques but the weekly baiting was judged more economical to use (Hoque and Olivida 1986). Philippine trials with 5-g brodifacoum wax blocks at 50 ppm during the wet season in lowland rice involved an application of 1.24 to 1.71 kg/ha. Damage was significantly reduced and the crop yield was 42% greater than expected (R. Brown, pers. comm. 1985).

In trials of brodifacoum in rice fields in Venezuela, one report (Williams and Vega 1984) concerns Portuguesa State where Holochilus was found to predominate. A 24-ha nonirrigated study area was selected and rodents live-trapped before treatment and trapped again after treatment. Rice was 50 to 60 cm in height at the time of the evaluation and was receiving rodent damage. About 2,000 bait stations were established on dikes and around edges of the study area. Stations were each filled with 30 g of brodifacoum bait, giving a rate of 2.5 kg/ha. Stations were checked regularly and replenished as necessary. Consumption had reached near-zero levels by the ninth day of treatment and stations were removed. Eight days later, posttreatment trapping was initiated until heavy rains prevented further work. A reduction of 89% in rodent captures from initial levels was recorded. A companion report (Williams and Pereira 1984) from Venezuela describes research in another area, this one irrigated and with two Sigmodon spp. accounting for 75% of initial captures, with the remainder Holochilus. A 30-ha site received 900 stations as described previously. Treatment lasted for 7 days and final trapping revealed 100% reduced activity, as no rodents could be recovered. Observations extended until harvest and no damage to the rice from any residual population was observed.

Sugarcane

A thorough review of rodent problems in sugarcane and evaluations of damage and rodenticide efficacy, including for brodifacoum, is presented by Hampson (1984). It is noted that some 100 countries with a total of about 13 million ha of cane provide 60% of the world's sugar needs annually. Losses from rodents in the range of 10 to 30% are reported common. The crop is a difficult one for baiting and damage evaluations once canes become grown and nearly inpenetrable, although many techniques involving crop borders and in-crop transects are described. Bait application strategies to be recommended vary with the area, economics, and pest species present, but theoretical calculations suggest that a yield increase of less than 0.5% can justify rodent control. The susceptibility of a principal cane pest, Sigmodon, to brodifacoum (Gill and Redfern 1980) combined with the properties of brodifacoum, suggest that the compound has much promise for use in cane in the Americas, and will allow for reductions in baiting quantities and intervals needed for rodent control in sugarcane. Hampson reports a trial of brodifacoum in Mexican sugarcane, principally against Sigmodon, in which a trapping index was reduced from 38% capture to zero, 7 days after a single application of 3 kg/ha of 50-ppm brodifacoum bait. In Nicaragua, this species was also reduced in cane following aerial application of 4 kg/ha of 50-ppm brodifacoum bait, based on trapping results before and after treatment. Similar work in Mexican cane is also reported by Humbert (1983) in which only brodifacoum baits of those materials tested reduced trap success posttreatment to zero levels.

In the Far East and Pacific area, trials in cane in Australia involved aerial broadcast of 50-ppm brodifacoum baits against R. sordidus (previously R. conatus). A rate of 1.68 kg/ha appeared more effective than a 0.84 kg/ha rate, and suggested an anticoagulant such as brodifacoum might be a suitable replacement for the more hazardous acute products in general use (Hitchcock et al. 1983).

Oil Palm

Considerable evaluations of brodifacoum baits, principally involving 30 or 50-ppm wax block formulations of 4 to 20 g, have been undertaken in Malaysia (Khoo 1979, 1980, 1984; Khoo and Dubock 1981), where this major crop suffers about 5% damage yearly equivalent to M$ 115 million based on 1981 prices. The principal pest species is R. tiomanicus. Trapping or other census methods are difficult in this crop because of the arboreal nature of the environment, which may even necessitate baiting in crowns of trees. The initial trials reported involved 13-g brodifacoum blocks of 30 ppm which were placed at the base of each palm according to different schedules of application. Eight rounds at 3 to 4-day intervals with a total application of 7.5 kg/ha gave 78% reduction in activity as determined from fruit damage surveys and bait-take observations. A similar baiting interval carried for 5 rounds (total 5.1 kg/ha) gave 85% control, and 7-day baiting intervals and 2 rounds (2.3 kg/ha) gave 83% control. Four rounds at 7-day intervals used 5.7 kg/ha and gave 97% reduction. Even a 10-day baiting interval with 3 rounds (5.0 kg/ha) gave 72% control with brodifacoum. These authors also report the successful use of

4-g 30-ppm brodifacoum wax baits placed at the base of every palm in the grid planting system. Taken baits were replaced every 7 to 10 days for 4 weeks for a total application of 2.0 kg/ha. Damage assessments and bait takes revealed a 71% reduced activity at considerable savings in bait and labor over other materials tested. Interval (pulsed) baiting was considered highly suitable for this crop.

Fruit Orchards

Fruit orchard damage by rodents occurs in temperate areas in North America, Europe, Africa, Asia, and the Nordic countries, and has been the subject of extensive research efforts. Examinations over the years comparing cultural, mechanical, and chemical control generally have concluded that few alternatives exist to the use of rodenticidal baits, and that baits are generally more economical and preferred by growers, whether used alone or within an integrated management system. Microtines are especially important orchard pests in northern latitudes. In Canada, Bouchard (1978, 1979) found that 9 kg/ha of 50-ppm brodifacoum applied in apple orchards resulted in a 73% vole reduction. In another Canadian study, brodifacoum was considered efficacious in orchard trials when applied in special bait stations which would provide continued opportunities for voles to feed beneath snow cover (Siddiqi 1982, Siddiqi et al. 1983b). While the economy, practicality and effectiveness of bait station use in orchards has not been sufficiently verified in actual use, the approach has merit for areas subject to heavy snows, and also reduces opportunities for accidental feedings by other animals. Myllymaki (1984) suggests application to Finnish orchards after snowfall and directly to vole breathing holes (perhaps in paper or plastic sachets to help protect the bait) to allow feeding and to provide similar protection against nontarget animals. Baiting with brodifacoum in vole burrows in orchards in the Soviet Union resulted in 97% control (Khryanina 1981).

The 10-ppm ICI VOLID pelletized formulation has been found surprisingly efficacious against *Microtus*, not only in North America but also in Denmark (Lund 1984a) and in Finland (Myllymaki 1984) where it was also judged sufficiently effective against *Arvicola*, a species normally difficult to control with prepared baits. Multiple-feeding, older anticoagulants have been rejected in Scandinavia due to lack of efficacy (Myllymaki 1984).

RODENT THREAT TO INSULAR FAUNA

Old world rodents have become established within many endemic insular faunas, endangering native birds and mammals alike. Proposals have been made to "eradicate" commensal rodents from such islands utilizing rodenticides, especially to protect nesting seabirds, but this approach has been seldom attempted. Vertebrate toxicants generally lack specificity, and no available rodenticides are entirely pest rodent-specific. Selectivity can be enhanced with special formulations and application strategies. Good results have been obtained with brodifacoum in insular situations against pest rodents where other small mammals were absent. Brodifacoum was one of two rodenticides evaluated to remove rats from islands in New Zealand. Wax blocks and a specially prepared paste of brodifacoum (rodenticidal forms not readily taken by birds) successfully removed rats on three of four islands (Moors 1984). Successful experiences on the Galapagos Islands with Talon for rat control have also been reported (Coulter et al. 1982).

BRODIFACOUM DEVELOPMENT AND EFFICACY RESULTS IN THE UNITED STATES

Much of the early research in determining and verifying the characteristics of brodifacoum was conducted in the United States, including efficacy to warfarin- and pival-resistant Norway rats (Dubock and Kaukeinen 1978) and warfarin- and diphacinone-resistant roof rats (Ecke and Lewellan 1979) in the laboratory. Table 3 gives additional unpublished U.S. data on warfarin-resistant Norway rats and house mice.

Table 3. Efficacy of Talon to warfarin-resistant rats and mice in the laboratory.

Treatment	Concentration	Length of feeding	Average dose (mg/kg)	Kill
HOUSE MICE				
Warfarin	250 ppm	no-choice 21 days	970.4	8/29
Talon	50 ppm	choice 3 days	12.9	10/10
NORWAY RATS				
Warfarin	60 ppm	no-choice 6 days	NA	0/20
Talon	50 ppm	choice 3 days	3.5	19/20*

* one nonfeeder survived (from S. Frantz, pers. comm., June 1977).

COMMENSAL RODENT TRIALS

The experimental use permit allowed by the U.S. Environmental Protection Agency (EPA) for 20,000 pounds of 50-ppm brodifacoum in the pelletized formulation TALON, generated over 235 trials around the United States with commensal rodents in a variety of industrial, residential, commercial, and agricultural situations (Anon. 1979b, Kaukeinen 1979a). The pest control industry and the National Pest Control Association in the United States were instrumental in these field characterizations, providing verification of product utility. Nearly 75% of respondents considered their trial results with TALON as producing "good" to "excellent" results, even though the material was often evaluated only on problem accounts. Appendix 10 lists representative data for those additional 35 ICI-conducted commensal TALON trials in cities, villages, and farms as submitted to EPA as product performance data for the three U.S. commensal species in support of TALON and WEATHERBLOK registrations. These trials were conducted according to standardized protocols as described by Kaukeinen (1979b). Since the U.S. registrations for brodifacoum rodenticidal formulations, over 12 million pounds of these products have been sold in the U.S.

In the United States, published reports of urban trials with brodifacoum are noted for Cleveland, Ohio (Marsh 1979); Chicago, Illinois (Anon. 1982a, Ashton and Jackson 1979); New York City (McClelland 1979); Trenton, New Jersey (Anon. 1982a); Lincoln, Nebraska (Anon. 1979c); and as reported in appendix 10, for a city sewer trial in Ohio and a business building trial in Colorado. Most urban trials involved outside baiting in burrows around structures. Field trials against roof rats in a warfarin- and diphacinone-resistance area of Saratoga, California (Ecke et al. 1979), utilized baiting with 50-ppm paraffin brodifacoum blocks on utility poles, giving effective control.

During the period 1972 to 1982, warfarin-resistance was determined from field-collected rat samples from federally funded cities by the Bowling Green, Ohio, and the Troy, New York, Resistance Testing Laboratories, and recommendations made for cities to discontinue use of anticoagulants when resistance reached levels of 10% or more in the samples tested. Rat sample incidence of resistance in Chicago at 75% or more left the city without a ready control alternative, and the Chicago rat population exploded during the period 1975 to 1981. Blocks designated by various criteria as infested increased from 40% in 1975 to 93% in 1980. Initial trials in the Chicago resistance areas were successful (Ashton and Jackson 1979). Following the adoption and use of TALON rodenticide by the City of Chicago, overall infestation rates were reduced to less than 2% and rat bites were reduced 64% during the period 1980 to 1984 (T. Howard, pers. comm. 1985). Today, most U.S. city rodent control projects are using brodifacoum baits on a regular basis.

Unpublished data from representative farm trials with brodifacoum in the United States are included in Appendix 10. These trials generally involved the use of bait stations or burrow stuffing. A trial at a ranch near Pendleton, Oregon, is discussed in Anon. (1979c). A rat and mouse infestation among stored crops and livestock was treated with bait stations containing 50-ppm brodifacoum pellets and produced a 95 to 100% reduction in activity. Trials in poultry houses against Norway rats first determined as warfarin resistant in the laboratory were carried out near Raleigh, North Carolina. Brodifacoum pelletized bait applied in bait stations inside and within active burrows and stations outside of four poultry houses resulted in an average reduction in rodent activity of 85 to 99% (Apperson et al. 1981). Bait exposure in a California dairy farm building resulted in 92% control of Norway rats (Gorenzel 1982).

AGRICULTURAL RODENT TRIALS

Orchards

The development of brodifacoum for *Microtus* control in apple orchards in North America was initially involved with research of the 50-ppm pellets (see Appendix 11). Subsequent developments involved the creation of a new, 10-ppm pelletized formulation, VOLID (Kaukeinen 1984), especially regarding the properties of the ICI pelletized 10-ppm VOLID formulation. Appendix 12 gives results of ICI, cooperator, and independent researcher results with VOLID against *Microtus* species. Good results were generally obtained from hand baiting at rates as low as 2 kg/ha of 10-ppm material. Broadcast rates at 5 to 15 kg/ha also gave effective control, even of the more fossorial species such as *M. pinetorum*. Broadcast trials generally involved the use of tractor-mounted seeder or fertilizer spreaders, and handbait trials at affected trees were in runway systems, with bait covered with wood, stone or ceramic slabs, can lids, or portions of roofing paper. In the United States, large-scale experimental use in eastern orchards during 1979 to 1982 produced extensive efficacy data as illustrated by Appendix 12. However, hazard evaluations accompanying some orchard vole efficacy studies gave equivocal results in determining effect levels to populations of nontarget animals, particularly raptors such as screech owls (Kaukeinen 1982, Hegdal et al. 1984). Currently, VOLID research and development for U.S. orchard use against *Microtus* is continuing, and is the subject of a recent additional experimental permit submitted by ICI for the U.S. Fish and Wildlife Service to better allow evaluation of environmental effects in orchards. VOLID use in other crop situations, for example in artichokes in California, is also promising. Work by the University of California during 1984-85 found the VOLID formulation gave 90% control of California voles in 2 days (Marsh and Tunberg 1985).

Forestry

Trials of 10-ppm VOLID in Christmas tree plantations of Scotch pines in upper Michigan showed good efficacy against *M. pennsylvanicus* (Haigh and Jackson, pers. comm. 1980). Two 1-A plots each contained about 1,200 trees. One plot was treated with VOLID at 15 lb/A and the other plot left untreated. The treated plot showed 100% reduction in activity after the hand application, whereas the untreated plot showed 33% of trees with fresh damage. Reinspection at 10 mo after treatment showed fresh damage in the treated plot at 8.5% compared with 26.5% in the untreated. Lab evaluations (see Appendices 2 and 5) also show brodifacoum exhibited good efficacy against gophers and Peromyscus species which can also constitute significant forestry pests in the United States.

Nut Trees

Nut tree crops, such as walnuts and almonds, are often severely damaged by pest rodents. Experimental trials with TALON pellets in a California walnut orchard involved baiting 460 Spermophilus beecheyi burrows. Only 10% of bait remained after 48 hrs and all disappeared within 5 days. Census observations revealed an 88% reduction in squirrel activity from the treatment. Gophers (Thomomys bottae) infesting an almond orchard in California were controlled in experimental trials in which tunnel systems in treated plots were baited with 30-g placements using a hand probe. Although the soil was not ideal for burrow baiting and the probe use caused some tunnel collapse, it was still possible to show a 74% reduction in gopher activity 32 days after treatment.

Grassland/Rangeland

Grazed land in the western United States is often subject to intensive ground squirrel populations, causing much reduction of forage quantity and quality. Brodifacoum has been experimentally tested in the United States in the laboratory or in the field against six species of Spermophilus (Citellus), in the states of California, Montana, Wyoming, New Mexico, Washington, Oregon, and elsewhere. Brodifacoum formulations tested against ground squirrels in the United States involved either TALON pellets or an ICI oat groats 50-ppm bait (see Appendix 11).

In California, Marsh (pers. comm. 1982) conducted field trials in Tulare County which indicated 90% or better control of S. beecheyi fisheri following 6 lb/swath/A aerial treatment with 100-ppm oat groats or with hand baiting with 50-ppm oat groats at 12 lb/A. Brodifacoum so applied was judged equal to or superior to conventional 1080 baiting at the same rate. In an extensive evaluation of brodifacoum control of ground squirrels in pasture, the U.S. Fish and Wildlife Service and the Montana Department of Agriculture in 1981 conducted trials with S. richardsonii. Three 1-ha plots (each surrounded by 250-m buffer strips which were also treated) were treated at either 1.56, 2.38 or 1.68 lb/A with 50-ppm brodifacoum oat groats bait. Oats were placed near burrows at 16 to 19 g-quantities, and control plots received a blank, unpoisoned oats bait. Control was measured by three methods. Recovery of the 22 squirrels from each plot which had been fitted with radio-telemetry transmitters revealed a 98% kill. A trapping index comparing pre- and posttreatment trapping indicated 99% reduction, and a more formal CMR trap study indicated a 97% population reduction (Matschke, pers. comm. 1982).

In general, brodifacoum has been evaluated against most genera of agricultural pest rodents in the United States. Efficacy has been superior to other materials tested when applied at the same or lower rates and concentrations of bait.

NEW RESEARCH AREAS AND FUTURE DEVELOPMENTS

Brodifacoum has principally been incorporated into grain-based baits for various trials and registrations around the world, including many innovative bait formulations. The characteristics of the compound have also stimulated the development of alternative application approaches. Anticoagulant liquid or water baits have been utilized for many years. Water baits containing brodifacoum have been proposed and tested in India by Soni and Prakash (1984b, 1985). Laboratory trials against Meriones, Tatera and Rattus species with 50-ppm water-based liquid bait gave 83.80 and 90% kill, respectively, after 24 hr exposure. Extending exposure to 48 or 72 hr gave 100% kill. Liquid brodifacoum baits have also been developed in Taiwan (Ku 1984), where the waterer is placed inside a feeding station allowing only rodent entry.

Tracking powders are another conventional form of rodenticide for which developments incorporating brodifacoum have been made. Dubock and Kaukeinen (1978) report initial work with brodifacoum tracking dusts as developed by Davis and Moran. Dubock (1979b) reports potential use of brodifacoum tracking powder with an artificial burrow-building machine for control of Cricetus in Hungary. Brodifacoum tracking powders were also made and tested against suspected warfarin-resistant house mice in Finland (Myllymaki 1986), and gave 92% kill in the laboratory.

A more novel form of contact rodenticide involves the development of a paste or gel which, as with tracking powders, is ingested by the pest species while grooming. A research newsletter from New Zealand (1981a) notes that 0.015% brodifacoum paste baits were evaluated there for rabbit control and were judged as effective as 0.025% 1080 paste. For use against rodents, a brodifacoum paste made of edible fat was described by Davis (1983) for house mouse control. Use of a 0.01% paste for rat control in New Zealand is described by Moors (1984).

A contact rodenticidal device specifically developed for house mouse control with brodifacoum has been described by Gibson and Barratt (1979), Gibson (1982), and Morris et al. (1984). The device consists of wicks containing brodifacoum which are enclosed within a protective tube housing. As mice enter and traverse the tube, the brodifacoum is taken up on their fur and later groomed off. The device offers advantages over baits for house mouse control in many situations. A commercial version is currently undergoing trials in the United Kingdom and will be the subject of future publications (Proc. 7th British Pest Control Conference, in prep., 1986).

It is possible to create rodenticides with advantages for specific situations through formulation research and development. The inclusion of safening agents and protective colorants, olfactory stimulants (including pheromones) and other materials are being investigated. The addition of emetics (as rodents are normally unable to vomit) may provide an additional safety factor for nontarget animals. However, as with all additives and chemical modifications, resulting baits must still retain their attractiveness and efficacy to the target species.

SUMMARY AND CONCLUSIONS

As noted in this review, brodifacoum has been successfully evaluated against most small mammal pests which plague mankind around the world, and in a variety of both commensal and agricultural situations. Brodifacoum offers reduced rodenticide requirements to lower costs and hazard, and makes new baiting strategies, such as pulsed baiting, practical for large-scale use. Broad spectrum activity enables effective control with mixed-species infestations and against those normally tolerant of other anticoagulants, such as house mice. As developed as a material for use against warfarin-resistant commensal rodents, brodifacoum has retained its ability to give effective control in urban and other problem situations where first-generation anticoagulants have previously been extensively used. Brodifacoum has the same mode of action and has the same antidote (vitamin K) as other anticoagulants, providing the advantages of delayed action in the pest species as well as assurances for successful antidoting for the user and domestic animals. Brodifacoum is a palatable and stable compound, which has been successfully incorporated into various baits, contact toxicants, and control devices.

The discovery of new candidate rodenticides is a combination of intent and serendipity. Not until at least preliminary laboratory and field characterizations are in hand, are the immutable laws and interrelationships of chemistry and biology sufficiently unfolded to reveal what imperfections toward its intended use the new molecule possesses. There has never been, nor is there likely ever to be, a "perfect rodenticide." Somewhere within the broad profile for each vertebrate control compound--including specificity, mode of action and antidote, acceptability to the pest, stability, formulating characteristics, and cost of synthesis and development--will be unknowns and limitations. Brodifacoum's proximity to a near uniformly excellent profile as a rodenticide has stimulated great interest and effort to make it work for man's benefit in a variety of ways against vertebrate pests during the past decade. In achieving its present successful status worldwide, brodifacoum promises to show continued momentum toward further popularity and future developments.

REFERENCES

ANON. 1976. Assessment of PP581 in Wild Norway and Ricefield Rats, Vert. Damage Control Research in Agric., USFWS, Denver Wildlife Research Center, USAID, Annual Report. p. 12.

ANON. 1977. Toxicity of Commercial Rodenticides to Agricultural Rodents in Developing Countries, Vert. Damage Control Research and Agriculture, USFWS, Denver Wildlife Research Center, USAID, Annual Report. pp. 37-39.

ANON. 1978. Brodifacoum, A New Anticoagulant Rodenticide for the Control of Rats and Mice, UK Ministry of Agriculture, Fish and Food, Pest Infest. Control Lab., Tech. Circular 36. 4 pp.

ANON. 1979a. Controlling Rodents in Deepwater Rice; Field Testing for Rodenticides in Deep Water Rice (Bangladesh), Vert. Damage Control Research and Agriculture, USFWS, Denver Wildlife Research Center, USAID, Annual Report. pp. 25-26.

ANON. 1979b. TALON™ - A New Rodenticide, U.S. National Pest Control Assoc., ESPC 06335, Tech. Rel. 4 pp.

ANON. 1979c. TALON® Field Trials Show Promise, Pest Control Technology 7(2):19-23.

ANON. 1981a. A Gnawing Problem (Egypt, 1981). Middle East 79:40.

ANON. 1981b. KLERAT -- A Single Feed Rodenticide. World Crops 33(4):89.

ANON. 1981c. Research News (New Zealand, Brodifacoum). Counterpest (Suppl.) 5.

ANON. 1982a. How Urban "Pied Pipers" are Taking on the Rats. American City and County Magazine, April. pp. 45-46.

ANON. 1982b. Instructions for Determining the Susceptibility or Resistance of Rodents to Anticoagulant Rodenticides. WHO/VBC/82843.

ANON. 1983. Rats on the Run--A New Generation of Rodenticides. West African Farming, May/June. pp. 40-41.

ANON. 1985. Effective Rodent Control Saves Transvaal Poultry Farmers Thousands of Rands. Pluimvee Bulletin (S. Africa), May. pp. 255-256.

APPERSON, C. S., O. T. SANDERS, and D. E. KAUKEINEN. 1981. Laboratory and Field Trials of the Rodenticide Brodifacoum Against Warfarin-Resistant Norway Rats. Pesticide Science 12(6):662-668.

ASHTON, A. D., and W. B. JACKSON. 1979. Field Testing of Rodenticides in a Resistant-Rat Area of Chicago. Pest Control 47:14.

ASHTON, A. D., W. B. JACKSON, and H. PETERS. 1986. Comparative Evaluation of LD_{50} Values for Various Anticoagulant Rodenticides. In: Proc. Symp. Control Mammal Pests (C. G. J. Richards and T. Y. Ku, Eds.), 4 Intl. Theriol. Cong., Edmonton, Canada. Tropical Pest Management (In press).

BACHMAN, K. A., and T. J. SULLIVAN. 1983. Dispositional and Pharmacodynamic Characteristics of Brodifacoum in Warfarin-Sensitive Rats. Pharmacology 27:281-288.

BAJOMI, D. 1984. Hungarian Experiences with "TALON-B" Containing Brodifacoum. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 163-179.

BALASUBRAMANDYAM, M., M. J. CHRISTOPHER, and K. R. PURUSHOTHAM. 1984. Laboratory Trials of 3 Anticoagulant Rodenticides (Warfarin, Bromadiolone, Brodifacoum) for Use Against the Indian Field Mouse *Mus booguda* Gray. J. Hygiene 93(3):575-578.

BALASUBRAMANDYAM, M., M. J. CHRISTOPHER, and K. R. PURUSHOTHAM. 1985. Laboratory Evaluation of Anticoagulant Treated Baits (Warfarin, Bromadiolone, Brodifacoum) Against Indian Field Mouse Mus booguda Gray. Proc. Indian Academy of Science, Animal Sciences 94(2):93-98.

BENTLEY, E. W., and Y. LARTHE. 1959. The Comparative Rodenticidal Efficacy of Five Anticoagulants. J. Hygiene 57(2):135-149.

BHARDWAJ, D., and I. PRAKASH. 1984. Efficacy of Three Anticoagulant Rodenticides (Brodifacoum, Coumatetralyl, Warfarin) for the Control of Poison Shy Rattus rattus. In: Proc. 11th Vert. Pest Conf. (D. O. Clark, Ed.), Sacramento, CA. pp. 82-84.

BOUCHARD, C. 1978. Control of Meadow Voles in Apple Orchards (in French). Canada Pesticide Research Report. pp. 70-71.

BOUCHARD, C. 1979. Control of Field Mice (Microtus pennsylvanicus) in Apple Orchards (in French). Canada Pesticide Research Report. p. 7.

BRADFIELD, A. A. G., and J. E. GILL. 1984. Laboratory Trials of Five Rodenticides (Warfarin, Difenacoum, Brodifacoum, Calciferol, Zinc Phosphide) for the Control of Mesocricetus auratus. J. Hygiene 93(2): 389-394.

BRECKINRIDGE, A. M. et al. 1985. A Study of the Relationship Between the Pharmacokinetics and the Pharmacodynamics of the 4-hydroxycoumarin Anticoagulants Warfarin, Difenacoum and Brodifacoum in the Rabbit. British J. Pharmacol. 84:81-91.

BROOKS, J. E., P. T. HTUN, and H. NAING. 1980. The Susceptibility of Bandicota bengalensis from Rangoon, Burma to Several Anticoagulant Rodenticides. J. Hygiene 84:127-135.

BROOKS, J. E. et al. 1979. Laboratory Evaluations of Rodenticides for Use Against South-East Asian (Burma) Commensal Small Mammals. WHO/VBC 79.720, 15 pp.

BRUGGERS, R. L. (Ed.). 1980. Rodent Control in Wheatfields (Bangladesh). Vert. Damage Control Research in Agric., USFWS, Denver Wildlife Research Center, USAID, Annual Report. pp. 19-25.

BRUGGERS, R. L., and A. VALVANO (Eds.). 1981. Anticoagulant Rodenticide Studies; Comparative Field Trials of Two Rodenticides in Village Housing Clusters (Bangladesh). Vert. Damage Control Research in Agric., USFWS, Denver Wildlife Research Center, USAID, Annual Report. pp. 22-29.

BRUGGERS, R. L., and A. VALVANO (Eds.). 1982. Comparative Field Trials of Two Rodenticides in Wheat-fields (Bangladesh). Vert. Damage Control Research in Agric. USFWS, Denver Wildlife Research Center, USAID, Annual Report. pp. 20-24.

BRUGGERS, R. L., and A. VALVANO (Eds.). 1983. Operation OSKER (Bangladesh), Vert. Damage Control Research and Agriculture, USFWS, Denver Wildlife Research Center, USAID, Annual Report. pp. 42-46.

BUCKLE, A. P. 1983. The Organization and Practice of Vertebrate Pest Control, Elvetham Hall, Hampshire, August-Sept. 1982 (Review). Tropical Pest Management 29(1):72-76.

BUCKLE, A. P., and B. D. RENNISON. A Review of Methods for Measuring and Evaluating the Losses Caused in Rice and Other Crops by Rodents. In: Proc. Symp. Control Mammal Pests (C. G. J. Richards and T. Y. Ku, Eds.). 4. Intl. Theriol. Cong., Edmonton, Canada; Tropical Pest Management (In press).

BUCKLE, A. P., and F. P. ROWE. 1981. Rice Field Rat Project, Malaysia, Technical Report 1977-1980. Dept. Agric. Malaysia and Cent. Overseas Pest Res., London. 99 pp.

BUCKLE, A. P., F. P. ROWE, and A. R. HUSIN. 1982. Laboratory Evaluation of the Anticoagulants Coumatetralyl and Brodifacoum Against Rattus argentiventer in Peninsular Malaysia. Tropical Pest Management 28(2):126-130.

BUCKLE, A. P., F. P. ROWE, and A. R. HUSIN. 1984. Field Trials of Warfarin and Brodifacoum Wax Block Baits for the Control of the Rice Field Rat, Rattus argentiventer, in Peninsular Malaysia. Tropical Pest Management 30(1):51-58.

BUCKLE, A. P., Y. C. YONG, and A. R. HUSIN. 1985. Damage by Rats to Rice in South-East Asia with Special Reference to an Integrated Management Scheme Proposed for Peninsular Malaysia. In: Proc. 3 Intl. Theriol. Cong. (A. Myllymaki, Ed.), Helsinki, Finland; Acta Zool. Fennica 173, Vol. 5, p. 139.

BYERS, R. E. 1977. Pine Vole Control Research in Virginia. Proc. 1. Eastern Pine and Meadow Vole Symposium, Winchester, VA, March 10-11. p. 89.

BYERS, R. E. 1978a. Cultural and Toxicant Control of Pine and Meadow Voles in Apple Orchards. Hort Science 13(3):365.

BYERS, R. E. 1978b. Performance of Rodenticides for the Control of Pine Voles in Orchards. J. American Society Horticultural Science 103(1):65-69.

BYERS, R. E. 1978c. Pine Vole Control Studies in Virginia--1977. Proc. 2. Eastern Pine and Meadow Vole Symposium, Beltsville, MD, February 23-24. p. 62.

BYERS, R. E. 1979a. Meadow Vole Control Using Anticoagulant Baits. HortScience 14(1):44-45.

BYERS, R. E. 1979b. Results of Pine Vole Control Studies in 1978 (Virginia). Proc. 3. Eastern Pine and Meadow Vole Symposium, New Paltz, NY. p. 77.

BYERS, R. E. 1980. Pine Vole Control in 1979 Field Plots (Virginia). Proc. 4. Eastern Pine and Meadow Vole Symposium, Hendersonville, NC. p. 68.

BYERS, R. E. 1981. Pine Vole Control With Anticoagulant Baits in Apple Orchards. J. American Society Horticultural Science 106(1):101-105.

BYERS, R. E. 1983. Economics of Microtus Control in Eastern US Orchards. Proc. 7. Eastern Pine and Meadow Vole Symposium, Harpers Ferry, WV. p. 1.

BYERS, R. E. 1984. Economics of Microtus Control in Eastern US Orchards. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England; ICI-PPD. pp. 297-302.

BYERS, R. E., and M. H. MERSON. 1981. Meadow and Pine Vole Control in 1980 Field Plots (Virginia). Proc. 5. Eastern Pine and Meadow Vole Symposium, Gettysburg, PA. p. 7.

BYERS, R. E., and M. H. MERSON. 1982a. Current Improvements in Baiting Pine and Meadow Voles. In: Proc. 10 Vert. Pest Conf. (R. E. Marsh, Ed.), Monterey, CA. pp. 139-142.

BYERS, R. E., and M. H. MERSON. 1982b. Effect of Pellet Size and Packaged Commercial Baits for the Control of Pine Voles. Proc. 6. Eastern Pine and Meadow Vole Symposium Ferry, Harpers Ferry, WV. p. 22.

CHMELA, J., and V. P. RUPES. 1983. Testing the Efficiency of the Rodenticide Brodifacoum on Norway Rats and House Mice. Vesnick Ceskoslovenske Spolecnosti Zoologicke 47(1):6-12.
CHMELA, J., M. DUB, and V. RUPES. 1985. Testing the Efficacy of VOLID Rodenticide (in Czech.). Agrochemia 25(5):155-158.
CHOPRA, G., and V. R. PARSHAD. 1985. Efficacy of 4 Anticoagulants (Brodifacoum, Bromadiolone, Coumatetralyl, Warfarin) in Controlling the House Rat Rattus rattus. Indian J. Agricultural Sciences 55(2):125-128.
COLVIN, H. W., and W. L. WANG. 1974. Toxic Effects of Warfarin in Rats Fed Different Diets. Toxicology and Applied Pharmacology 28:337-348.
CONWAY, J. A. 1984. The Use of Brodifacoum Formulations for Rodent Control Treatments Against Bandicota bengalensis in Food Godowns in Bagladesh. Tropical Stored Products Information 47:10-14.
COULTER, M. et al. 1982. Experiments on the Effectiveness of TALON Controlling Populations of Black Rats (Rattus rattus) in Galapagos Island Ecuador. Annual Report, Darwin Research Station, Guayaquil. 9 pp.
DAVIS, R. A. 1983. Edible Fat As A Carrier for Contact Rodenticides. International Pest Control 25 (2):46-47.
DENG, Z., and C. WANG. 1984. Rodent Control in China. In: Proc. 11 Vert. Pest Conf. (D. O. Clark, Ed.), Sacramento, CA. pp. 47-53.
DUBOCK, A. C. 1978. Rodent Control in Crop Stores. Outlook on Agriculture 9(5):220-224.
DUBOCK, A. C. 1979a. Alternate Strategies for Safety and Efficacy of Rodenticides. In: Proc. 5 British Pest Control Conf., Stratford-Upon-Avon. Session 5, Paper 14. 15 pp.
DUBOCK, A. C. 1979b. Rodent Control in Hungary. Anglo-Hungarian Plant Protection Symposium, Cambridge, England. 28 pp.
DUBOCK, A. C. 1980. The Development and Practical Use of the Novel Anticoagulant Rodenticide Brodifacoum. Plant Protection Bulletin, Plant Protection Society, Republic of China (Taiwan) 22 (2):223-238.
DUBOCK, A. C. 1982. Pulsed Baiting--A New Technique for High Potency, Slow-Acting Rodenticides. In: Proc. 10 Vert. Pest Conf. (R. E. Marsh, Ed.), Proc. 10 Vert. Pest Conf., Monterey, CA. pp. 123-136.
DUBOCK, A. C. 1984a. Economic Benefits of Vertebrate Pest Control. In. Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 316-326.
DUBOCK, A. C. 1984b. Pulsed Baiting--A New Technique for High Potency, Slow Acting Rodenticides. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 106-142.
DUBOCK, A. C., and D. E. KAUKEINEN. 1978. Brodifacoum (TALON Rodenticide), a Novel Concept. In: Proc. 8 Vert. Pest Conf. (W. E. Howard, Ed.), Sacramento, CA. pp. 127-137.
ECKE, D. H., and L. L. LEWALLEN. 1979. Susceptibility of Anticoagulant Resistant Roof Rats (Rattus rattus) to TALON . California Vector Views 26(7/8):66-69.
ECKE, D. H., M. A. DENNIS, and M. GODFREY. 1979. Testing 0.005% Brodifacoum Against Roof Rats (Rattus rattus) in Saratoga, California. J. Environmental Health 42(3):128-129.
GIBSON, J. A., and P. B. BARRATT. 1979. The Constant Need to Improve Pest Control Techniques and Standards. In: Proc. 5, British Pest Control Conf., Stratford-Upon-Avon, England; Session 7, Paper 20. 6 pp.
GIBSON, J. A. 1982. Field Trials of a Contact Rodenticide Device for Control of House Mice Mus musculus. International Pest Control 24(2):38-40.
GILL, J. E., and R. REDFERN. 1979. Laboratory Tests of Seven Rodenticides (Warfarin, Coumatetralyl, Difenacoum, Brodifacoum, Bromadiolone, Calciferol, Zinc Phosphide) for the Control of Mastomys natalensis. J. of Hygiene 83(2):345-352.
GILL, J. E., and R. REDFERN. 1980. Laboratory Trials of Seven Rodenticides (Warfarin, Coumatetralyl, Difenacoum, Brodifacoum, Bromadiolone, Calciferol, Zinc Phosphide) for Use Against the Cotton Rat Sigmodon hispidus. J. Hygiene 85(3):443-450.
GILL, J. E., and R. REDFERN. 1983. Laboratory Tests of Seven Rodenticides for the Control of Meriones shawi (Warfarin, Coumatetralyl, Difenacoum, Brodifacoum, Bromadiolone, Calciferol, Zinc Phosphide). J. Hygiene 91(2):351-357.
GODFREY, M. E. R. 1985. Non-target and Secondary Poisoning Hazards of "Second Generation" Anticoagulants. In: Proc. 3. Intl. Theriol. Cong. (A. Myllymaki, Ed.), Helsinki, Finland. Acta Zoologica Fennica 173 No. 5, p. 209.
GODFREY, M. E. R., and C. P. LYMAN. 1980. Preliminary Dosing Trials of a New Anticoagulant, Brodifacoum, as a Toxicant for the Rabbit, Oryctolagus cuniculus (L.). New Zealand J. Experimental Agriculture 8(1):1-6.
GODFREY, M. E. R., T. C. REID, and H. J. F. McALLUM. 1981. The Oral Toxicity of Brodifacoum to Rabbits. New Zealand J. Experimental Agriculture 9:23-25.
GORENZEL, W. P., R. E. MARSH, and T. P. SALMON. 1982. Single Feeding Anticoagulants--Are They What They Claim? Pest Control 50(2):32.
GOSNEY, J. 1981. ICI's New Rodenticide Kills After One Feed. Intl. Agric. Develop., July/August. pp. 22-23.
GREAVES, K. J. 1985. The Present Status of Resistance to Anticoagulants. In: Proc. 3. Intl. Theriol. Cong. (A. Myllymaki, Ed.), Helsinki Finland; Acta Zoologica Fennica 173, no. 5, p. 159.
GREAVES, J. H., D. S. SHEPHERD, and R. QUY. 1982. Field Trials of Second Generation Anticoagulants (Brodifacoum, Bromadiolone) Against Difenacoum Resistant Norway Rat Rattus norvegicus Populations. J. Hygiene 89(2):295-301.
HADLER, M. R. 1979. Brodifacoum--A Potent New Rodenticide. In: Proc. 5. British Pest Control Conf., Stratford-Upon-Avon; Session 5, Paper 13. 8 pp.
HADLER, M. R., and R. S. SHADBOLT. 1975. Novel 4-Hydroxycoumarin Anticoagulants Active Against Resistant Rats. Nature 253:275-277.

HAMPSON, S. J. 1984. A Review of Rodent Damage to Sugarcane with Criteria for the Use of Rodenticides. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 227-251.
HAN, K. J., and S. BOSE. 1980. Some Studies (Warfarin, Brodifacoum Trials) on Mammalian Pests in Cocoa Planted Under Coconuts (Malaysia). Planter (Kuala Lumpur) 56:273-283.
HEGDAL, P. L., B. A. COLVIN, and R. W. BLASKIEWICZ. 1984. Field Evaluation of Secondary Hazards to Barn Owl (Tyto alba) and Screech Owls (Otus asio) Associated with Brodifacoum Baits Used for Rodent Control. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 647-662.
HITCHCOCK, B. E., R. E. KERKWYCK, and M. A. HETHERINGTON. 1983. Evaluation of Some Anticoagulant Rodenticide in Queensland Cane Fields. Proc. Australian Society of Sugar Technologists. 6 pp.
HONE, J., and H. MULLIGAN. 1982. Brodifacoum. In: Vertebrate Pesticides. Science Bulletin 89, Dept. Agric. NSW, Australia. pp. 3-5.
HOPPE, A. 1979. Biennial Report 1977/78--Pest Rodent Research Lab, Morocco. (in French). Ministry of Agriculture, Marrakech. 55 pp.
HOPPE, A. H., and A. KRAMBIAS. 1984. Efficacy of Three Anticoagulant Rodenticides (Brodifacoum, Difenacoum, Bromadiolone) Against Rattus rattus fugivorus. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 336-339.
HOQUE, M. 1981. Rat Control in Pineapple. Crop Protection News (Philippines) 2:14-15.
HOQUE, M. M. 1983a. Development of an Anticoagulant Resistance Monitoring Program for Philippine Rats. Philippine Agriculture (Los Banos) 66(1):36-46.
HOQUE, M. M. 1983b. Rat Control in Coconut-Pineapple Intercrop. Philippine Agriculture (Los Banos) 66(1):82-89.
HOQUE, M. M., and J. L. OLIVIDA. 1986. Comparison of Baiting Methods for Ricefield Rats in the Philippines. In: Proc. Symp. Control Mammal Pests, 4 (C. G. J. Richards and T. Y. Ku Eds.), Intl. Theriol. Cong., Edmonton, Canada, Tropical Pest Management (in press).
HTUN, P. T., W. W. MULLER, and H. NAING. 1984. Paired Rodent Control Field Trials with Zinc Phosphide and Brodifacoum in Rangoon, Burma. WHO/VBC/84.902. 14 pp.
HUMBERT, R. P. 1983. Control of Rodents - New Rodenticide Gives Excellent Results in Sugarcane Fields (in Spanish). Agricultura de las Americas, Dec. pp. 6-7, 26-27.
INDRARTO, N. 1984. Five-Year Rat Control Programme in Indonesia. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 475-485.
JACKSON, W. B. et al. 1985. Present Status of Rodent Resistance to Warfarin in the United States. In: Proc. 3. Intl. Theriol. Cong. (A. Myllymaki, Ed.), Helsinki, Finland; Acta Zoologica Fennica 173 no. 5. p. 163.
JAIN, U., Y. SAXENA, and J. P. NAG. 1982. Laboratory Evaluation of Brodifacoum, A New Anticoagulant Rodenticide Against Rattus rattus. Pestology 6(3):21-22.
KADHIM, A. H., K. T. MUHSEN, and A. M. MUSTAFA. 1984. Field Trials of the Anticoagulant KLERAT (Brodifacoum) for Control of the Norway Rat, Rattus norvegicus Berk., in Baghdad. JBS 15(2):1-6.
KALOTAS, Z., and Z. KALOTAS. 1984. The Oral Toxicity of the Rodenticide "VOLID" to the Field Vole (Microtus arvalis palo.) and the Hamster (Cricetus cricetus L.) (in Hungarian). Novenyvedelem 20 (11):484-488.
KARASEVA, E. V., Y. G. CHERNUKHA, and E. V. STRIKHANOVA. 1984. Natural Focus of Leptospirosis in the Ricefields of Krasnodar Krai - SFSR USSR and the Ways (Rotindan, Brodifacoum) for its Sanitation (in Russian). Zh. Mikrobiol. Epidemiol. Immunobiol. (3):58-62.
KAUKEINEN, D. E. 1977. Development of PP581 Rodenticide by ICI-United States, Inc. Proc. 1. Eastern Pine and Meadow Vole Symposium, Winchester, VA. p. 105.
KAUKEINEN, D. E. 1978. Status of PP581 (VOLAK) Rodenticide Development. Proc. 2. Eastern Pine and Meadow Vole Symposium, Beltsville, MD. p. 101.
KAUKEINEN, D. 1979a. Experimental Rodenticide (TALON) Passes Lab Tests; Moving to Field Trials in Industry. Pest Control 47(1):19-21, 46.
KAUKEINEN, D. E. 1979b. Field Methods for Census Taking of Commensal Rodents in Rodenticidal Evaluations. ASTM STP 680. pp. 68-83.
KAUKEINEN, D. E. 1979c. Vole Control with VOLAK Rodenticide. In: Proc. 3 Eastern Pine and Meadow Vole Symposium, New Paltz, NY. pp. 77-81.
KAUKEINEN, D. E. 1982. A Review of the Secondary Poisoning Hazard to Wildlife from the Use of Anticoagulant Rodenticides. In: Proc. 10 Vert. Pest. Conf. (R. E. Marsh, Ed.), Monterey, CA. pp. 151-158. (Also published in Pest Management 1(11):10, 12-14; 1(12):16, 18-19, 1982).
KAUKEINEN, D. E. 1984. Microtus Problems and Control in North America and the Development of VOLID® Rodenticide. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 589-618.
KAUKEINEN, D. E. 1984b. Potential Non-Target Effects from the Use of Vertebrate Toxicants. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 619-629.
KAUKEINEN, D. E. 1986. Management of Harmful Rodents: Published Literature Sources. In: Proc. Symp. Control Mammal Pests. (C. G. J. Richards and T. Y. Ku, Eds.), 4 Intl. Theriol. Cong. Edmonton, Canada; Tropical Pest Management (in press).
KHAN, A. A. 1981. Field Trial of Some Rodenticides (Brodifacoum, Zinc Phosphide, Vacor, Thallium Sulfate) Against the Collared Pika Ochotona rufescens in Apple Orchards (Pakistan). International Pest Control 23(1):12-13.
KHAN, A. A., and W. R. SMYTHE. 1980. The Problem of Pika (Ochotona rufescens) Control (Brodifacoum, Vacor, Thallium Sulfate) in Baluchistan Pakistan. In: Proc. 9. Vert. Pest Conf. (J. P. Clark, Ed.), Fresno, CA. pp. 130-134.
KHAN, A. A., S. AHMED, and M. A. CHOUDRY. 1984. Comparative Evaluation of Brodifacoum and Bromadiolone Against Field Rats in Wheat and Paddy Crops. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England; ICI-PPD. pp. 363-379.

KHOO CHIN KOK. 1979. Developing an Agricultural Rodenticide. Proc. Intl. Public Health Seminar, England; ICI-PPD. paper 22. 9 pp.
KHOO CHIN KOK. 1980. "Pulsed Baiting" with Brodifacoum Baits to Control Oil Palm Rats in Malaysia. Selangor Planters Association Annual Report/Journal 198:42-46.
KHOO CHIN KOK. 1984. The Practice of Rodent Control in Malaysian Plantation Crops. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England; ICI-PPD. pp. 209-226.
KHOO CHIN KOK and A. C. DUBOCK. 1981. Brodifacoum, A Potent Anticoagulant Rodenticide for the Control of Oil Palm Rats. Proc. Intl. Conf. Oil Palm in Agriculture in '80s, Kuala Lampur; Paper AP15. 18 pp.
KHRYANINA, R. A. 1981. Results of Rodenticide Testing (in Russian). Zaschita Rastenii (10):31.
KU, T. Y. 1984. Distribution and Population Fluctuations of Field Rodents and Their Control in Taiwan. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England; ICI-PPD. pp. 487-519.
LANTING, F. O., F. L. ANDRES, and R. B. RANDON. 1981. Efficacy of Brodifacoum Baits Against Rodents in Storage Areas (Philippines). Intl. Rice Research Institute Newsletter 6(5):21-22.
LAM YUET-MING. 1978. Brodifacoum--A New Rodenticide Against the Rice Field Rat, Rattus argentiventer. Malaysian Plant Protection Society Newsletter 2(3):3-4.
LAMB YUET-MING. 1980. Laboratory Evaluation of Brodifacoum for Use Against the Rice Field Rat, Rattus argentiventer (Robinson & Kloss). Malaysian Agricultural J. 52(4):1-7.
LUND, M. 1981. Comparative Effect of the Three Rodenticides Warfarin, Difenacoum and Brodifacoum on Eight Rodent Species in Short Feeding Periods. J. Hygiene 87(1):101-108.
LUND, M. 1982. Rat Control. In: Danish Pest Infestation Laboratory Annual Report for 1981. pp. 58-61.
LUND, M. 1983. Rat Control. In: Danish Pest Infestation Laboratory Annual Report for 1982. pp. 89-101.
LUND, M. 1984a. Control of Mice and Voles (Brodifacoum). In: Danish Pest Infest. Lab. Ann. Rept. 1983. pp. 70-72.
LUND, M. 1984b. Resistance to the Second-Generation Aticoagulant Rodenticides (Difenacoum, Bromadiolone). In: Proc. 11. Vert. Pest. Conf. (D. O. Clark, Ed.), Sacramento, CA. pp. 89-94.
LUND, M. 1985. The "Second Generation" Anticoagulants: A Review. In: Proc. 3 Intl. Theriol. Cong. (A. Myllymaki, Ed.), Helsinki, Finland; Acta Zool. Fennica 173, Vol. 5, p. 149.
LUND, M., and J. LODAL. 1984. Current Work at the Danish Pest Infestation Laboratory, Vertebrate Department. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England; ICI-PPD. pp. 253-264.
LUND, M., and J. LODAL. 1986. Rodent Research. In: Danish Pest Infest. Lab. Ann. Rept. 1985. pp. 74-83.
MAHMOUD, W., and R. REDFERN. 1981. The Response of the Egyptian Spiny Mouse (Acomys cahirinus) and Two Other Species of Commensal Rodents to Anticoagulant Rodenticides (Rattus rattus, Rattus norvegicus; Warfarin, Difenacoum, Brodifacoum). J. Hygiene 86(3):329-334.
MAJID, T. B., and O. S. CHYE. 1984. The Organization and Practice of Rice Field Rat Control in Malaysia. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 465-473.
MARSH, B. T. 1979. Cleveland Tests Rodenticides (TALON, Zinc Phosphide). J. Environmental Health 42 (3):131-132.
MARSH, R. E., and A. D. TUNBERG. 1984. Research on Meadow Mouse (Microtus californicus) Biology and Its Control Relative to Artichoke Production. Univ. Calif., Davis, Progress Rept. No. 1. 105 pp.
MARSH, R. E., and A. D. TUNBERG. 1985. Research on Meadow Mouse (Microtus californicus) Biology and Its Control Relative to Artichoke Production. Univ. Calif., Davis, Progress Rept. No. 2. 118 pp.
MATHUR, R. P., and I. PRAKASH. 1980a. Acceptability and Toxicity of Six Anticoagulants to the Palm Squirrel (Funambulus pennanti Wroughton). Zeitschrift Angew. Zool. 67:477-482.
MATHUR, R. P., and I. PRAKASH. 1980b. Laboratory Evaluation of Anticoagulant-Treated Baits (Warfarin, Fumarin, Chlorophacinone, Brodifacoum) For Control of the Northern Palm Squirrel Funambulus pennanti. J. Hygiene 85(3):421-426.
MATHUR, R. P., and I. PRAKASH. 1981. Evaluation of Brodifacoum Against Tatera indica, Meriones hurrianae and Rattus rattus. J. Hygiene 87(2):179-184.
MATHUR, R. P., and I. PRAKASH. 1984a. Comparative Efficacy of Some Anticoagulant Rodenticides Against Indian Rodents. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 381-393.
MATHUR, R. P., and I. PRAKASH. 1984b. Field Trials of Brodifacoum, Chlorophacinone and Coumatetralyl Against Desert Rodents in India. Tropical Pest Management 30(1):59-61.
MATHUR, R. P., and I. PRAKASH. 1984c. Reduction in Population of Indian Desert Rodents with Anticoagulant Rodenticides. Proc. Indian Academy of Science, Animal Sciences 93(6):585-589.
McCLELLAND, R. 1979. TALON Trial Successful in NYC Infestations. Pest Control Technology, Vol. 7, August.
McDONALD, D. 1983. Rodent Control in the Tropics. International Pest Control, May/June.
MEEHAN, A. P. 1984. Brodifacoum. In: Rats and Mice--Their Biology and Control. Rentokil Limited, Sussex UK. pp. 205-208.
MERSON, M. H., and R. E. BYERS. 1983. Results of 1982 Rodenticide Field Tests (Virginia). Proc. 7. Eastern Pine and Meadow Vole Symposium, Harpers Ferry, WV. p. 13.
MEYLAN, A. 1985. Control of Small Mammals in Specialty Crops (Orchards, Grapes) (in French). Revue Suisse Vitic. Arboric. Hort. 17:64-65.
MITCHELL, G. C., and A. VALVANO (Eds.). 1984. Rodent Control (KLERAT blocks, TALON Pellets) in the Maldives, Indian Ocean. Vert. Damage Control Research in Agric., USFWS, Denver Wildlife Research Center, USAID Annual Report. pp. 41-44.

MO, G., and L. GUOGENG. 1984. An Experimental Comparison of Poisoning Rats by Using Intermittent and Saturated Doses of Brodifacoum (in Chinese). Acta Theriologica Sinica 4(1):79-80.
MOORS, P. J. 1984. Eradication Campaigns Against Rattus norvegicus on the Noises Islands, New Zealand, Using Brodifacoum and 1080. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 395-412.
MORRIS, K. D., R. D. PROCTOR, and D. E. KAUKEINEN. 1984. Design and Evaluation Criteria for Development of Toxic Wicks for Rodent Control. In: ASTM STP817 (D. E. Kaukeinen, Ed.). pp. 165-182.
MUHR, A. C. 1984. Practical Experience with Difenacoum and Brodifacoum in the Pest Control Servicing Business in Switzerland. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 329-333.
MYLLYMAKI, A. 1984. Efficacy of a Number of Toxic Baits and Baiting Against the Voles, Microtus agrestis and Arvicola terrestris. In: Proc. 11. Vert. Pest Conf. (D. O. Clark, Ed.), Sacramento, CA. pp. 38-46.
MYLLYMAKI, A. 1986. Efficacy of Anticoagulants and Flupropadine on Wild Strains of the Finnish Mouse, (Mus musculus L.). In: Proc. 2. Symp. Recent Advances Rodent Control, Kuwait. Feb., 1985 (in press).
NIKODEMUSZ, E., and G. NECHAY. 1982. The Common Vole (Microtus arvalis Pall. 1758) in the Laboratory. 2. Evaluation of Rodenticides. Zool. Jb. Anat. 107:306-318.
NIKODEMUSZ, E., G. NECHAY, and R. IMRE. 1980. The Toxicity of Brodifacoum on Hamsters (Cricetus cricetus L.), Field Voles (Microtus arvalis Pall.), Hares (Lepus europeus L.) and Pheasants Phasianus colchicus L.) (in Hungarian). Novenyvedelem 16(12):608-611.
O'CONNOR, B. P. 1979. Vertebrate Pest Control in New Zealand. Proc. Intl. Public Health Seminar. ICI-PPD, England, UK. paper 24. 5 pp.
PAGANO, R., and J. McANINCH. 1983. The Efficacy of Several Broadcast Rodenticides in the Mid-Hudson Valley, New York. Proc. 7. Eastern Pine and Meadow Vole Symposium, Harpers Ferry, WV. p. 25.
PARSHAD, V. R., N. AHMAD, and G. CHOPRA. 1985. Laboratory and Field Evaluation of Brodifacoum for Rodent Control. International Biodeterioration 21(2):107-112.
POCHE, R. M. et al. 1980. Rodent Control in Wheat Fields. Bangladesh Agricultural Research Institute, Tech. Rept. 10. 17 pp.
RAHMAN, S. A. M., and J. E. BROOKS. 1982. Comparative Field Trials of Two Rodenticides in Small Farm Housing Clusters. Bangladesh Agric. Res. Inst., Vert. Pest Sect., Tech. Rept. No. 14.
RAI, R. S., P. IAL, and P. K. SRIVASTAVA. 1984. Efficacy of Brodifacoum Against House Rat (Rattus rattus). CAZRI (Jodhpur), ICAR Rodent Newsletter 8(1-4):16.
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. J. Hygiene 77:419-426.
RENAPURKAR, D. M., and V. R. KAMATH. 1982. Laboratory Evaluation of Brodifacoum, A New Anticoagulant Rodenticide. Bulletin Haffkine Institute (India) 10(1):17-20.
RENNISON, B. D., and A. C. DUBOCK. 1978. Field Trials of WBA 8119 (PP581, Brodifacoum Against Warfarin Resistant Infestations of Rattus norvegicus. J. Hygiene 80(1):77-82.
RICHARDS, C. G. J. 1983. Cost-Effective Use of High Potency Anticoagulant Rodenticides. In: Proc. 6. British Control Conf., Cambridge, England; Session 5, Paper 12. 11 pp.
RICHARDS, C. G. J. 1986. Cost Effective Approaches to Large-Scale Rodent Control Programmes. In: Proc. 2. Symp. Recent Advances Rodent Control. Kuwait, 2-6 Feb. 1985 (in press).
RICHARDS, C. G. J. 1986. Approaches to Small-Holder Rodent Control. In: Proc. 12 Vert. Pest Conf., March 4-6, 1986, San Diego, CA. (in press).
RICHARDS, C. G. J., and L. W. HUSIN. 1985. Toward the Optimal Use of Anticoagulant Rodenticides. In: Proc. 3. Intl. Theriol. Cong. (A. Myllymaki, Ed.), Helsinki Finland. Acta Zool. Fennica 173, Vol. 5. p. 155.
RICHMOND, M. E., and P. N. MILLER. 1980. Field Evaluation of Candidate Rodenticides (New York). Proc. 4. Eastern Pine and Meadow Vole Symposium, Hendersonville, NC. p. 78.
ROTHERT, H. 1985. New Anticoagulants and Acute Poisons Against Brown Rats and House Mice (Difenacoum, Brodifacoum, Bromadiolone, Bromethalin, Flocoumafen) (in German). Praktishe Schaedlingsbekaempf. 37(8):165-169.
ROWE, F. P., and A. BRADFIELD. 1976. Trials of the Anticoagulant Rodenticide WBA8119 Against Confined Colonies of Warfarin-Resistant House Mice (Mus musculus L.). J. Hygiene 77:427-431.
ROWE, F. P., T. SWINNEY, and C. PLANT. 1978. Field Trials of Brodifacoum (WBA 8119) Against the House Mouse Mus musculus. J. Hygiene 81(2):197-202.
SAXENA, Y., and R. K. SHARMA. 1981. Laboratory Evaluation of Brodifacoum (TALON) Bait Against Indian Desert Gerbil, Meriones hurrianae Jerdon. Pestology 5(4):22-23.
SAXENA, Y., and R. K. SHARMA. 1982. Relative Susceptibility of Zinc Phosphide and Brodifacoum Baits to Funambulus pennanti. Bulletin of Grain Technology 20(1):43-46.
SAXENA, Y., and R. K. SHARMA. 1984. Efficacy of Brodifacoum (TALON) Bait Against Three Rodent Species (Meriones hurrianae, Rattus rattus and Funambulus pennanti. In: Proc. 11. Vert. Pest Conf. (D. O. Clark, Ed.), Sacramento, CA. pp. 101-102.
SHIEN, T. T. 1981. The Experimental Report on the Toxicity of the New Anticoagulant Rodenticide KLERAT. Taiwan Sugar J. 28(3):92-95.
SIDDIQI, Z. 1982. Meadow Voles--Enemy in the Grass. Proc. Ontario Horticulture Conference. pp. 117-120.
SIDDIQI, Z., and W. D. BLAINE. 1982a. Anticoagulant Resistance in House Mice in Toronto, Canada. Pest Management 1(14):10, 12-14. (Also in Environmental Health Review 26(2):49-51, 1982)
SIDDIQI, Z., and W. D. BLAINE. 1982b. Long-Term Vole Control in Ontario Apple Orchards. Proc. 6. Eastern Pine and Meadow Vole Symposium, Harpers Ferry, WV. p. 12.
SIDDIQI, Z., W. W. D. BLAINE, and S. TAYLOR. 1983a. Long-Term Vole Control in Ontario Apple Orchards. Proc. 7. Eastern Pine and Meadow Vole Symposium, Harpers Ferry, WV. p. 44.
SIDDIQI, Z., W. D. BLAINE, and S. TAYLOR. 1983b. Meadow Vole Control in Ontario Apple Orchards. Proc. 1. Eastern Animal Damage Control Meeting, Cornell University, New York. pp. 207-208.

SIDDIQI, Z., W. D. BLAINE, and S. TAYLOR. 1983c. Single Feeding Anticoagulants. Pest Control 51(7): 36, 41.
SONI, B. K. 1981. Efficacy of WBA 8119 (Brodifacoum) to Indian Rodents. Rodent Newsletter 5(4):28-29.
SONI, B. K., and I. PRAKASH. 1981. Laboratory Evaluation of WBA 8119 (Brodifacoum) Against Gerbillus gleadowi Murray. Pestology 5(9):23-24.
SONI, B. K., and I. PRAKASH. 1983. Evaluation of Brodifacoum (WBA8119) Against the Northern Palm Squirrel, (Funambulus pennanti). CAZRI (Jodhpur), ICAR Rodent Newsletter 7(3):10.
SONI, B. K., and I. PRAKASH. 1984a. Efficacy of Brodifacoum Against the House Mouse Mus musculus. Pesticides (Bombay) 18(7):15-17.
SONI, B. K., and I. PRAKASH. 1984b. Efficacy of Liquid Brodifacoum (PP581) Against Two Gerbils and House Rat. CAZRI (Jodhpur), ICAR Rodent Newsletter 8(1-4):1-2.
SONI, B. K., and I. PRAKASH. 1984c. Evaluation of Brodifacoum for the Control of Rattus meltada and Golunda ellioti. Indian J. Plant Protection 12(1).
SONI, B. K., and I. PRAKASH. 1985. Evaluation of Liquid Brodifacoum Against Gerbils and Rats. Pestology 9(1):21-24.
SONI, B. K., A. P. JAIN, and G. R. SONI. 1984. Trials of Wax-Blocks of Brodifacoum (WBA8119) Against Desert Rodents. CAZRI (Jodhpur), ICAR Rodent Newsletter 8(1-4):10-11.
SONI, B. K., B. D. RANA, and A. P. JAIN. 1985. Field Trials of Some Rodenticides (Aluminum Phosphide, Brodifacoum, Bromadiolone) to Control Rodents in Various Crop Fields of Western Rajasthan Desert. Pestology 9(1):25-27.
STEBLEIN, P. F., P. N. MILLER, and M. E. RICHMOND. 1983. Efficacy of Spring Broadcast Rodenticides in the Hudson Valley, New York. Proc. 7. Eastern Pine and Meadow Vole Symposium, Harpers Ferry, WV. p. 19.
SULTANA, P., et al. 1981. Comparative Toxicity of Several Anticoagulant Rodenticides to Bandicota Bengalensis. Bangladesh Agriculture Research Institute, Vertebrate Pest Section, Technical Report No. 13. 5 pp.
TANTAWY OMAR, M. 1984. The National Rat Control Campaign in Egypt. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 443-458.
TAYLOR, K. D. 1983. Practical Considerations in Large Scale Rodent Control with Special Reference to the Situation in Egypt. In: Proc. 1. Symp. Recent Advances in Rodent Control, Kuwait, 1982. pp. 64-70.
TONGTAVEE, K. 1980. Efficacy Tests of Different Rodenticides on Some Species of Rats in Thailand. In: Proc. 9 Vert. Pest Conf. (J. P. Clark, Ed.), Monterey, CA. pp. 143-145.
TONGTAVEE, K. 1984. Experience with Brodifacoum in Laboratory and Field Conditions in Thailand. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 357-362.
TONGTAVEE, K. et al. 1986. The Safety and Efficacy of Brodifacoum ("KLERAT" Wax Blocks) and Zinc Phosphide for Rodent Control in Thailand. In: Proc. Symp. Control Mammal Pests (C. G. J. Richards and T. Y. Ku, Eds.), 4. Intl. Theriol. Cong., Edmonton, Canada. Tropical Pest Management (in press).
VANUROVA, E. 1980. Evaluation of Rodenticide Approved for Use in Czechoslovakia and Proposed New Products. Agrochemia (3):84-85.
WANG, C., and Z. DENG. 1984. Rodent Control in China. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 512-531.
WANG, P. Y. 1978. Effects of Brodifacoum on Five Taiwan Rodent Species and Warfarin Tolerance Testing with Sugarcane Rodents, Bandicota Nemorivaga and Rattus losea (in Chinese). Taiwan Sugar Research Institute Report. p. 363.
WANG, P. Y. 1981. Effectiveness of New Anticoagulant Rodenticide Brodifacoum for the Control of Wild Rats in Sugarcane Fields (in Chinese). Report of Taiwan Sugar Research Institute (94):33-40.
WANG, P. Y. 1982. Control of Wild Rats (KLERAT, Glyzophrol). Taiwan Sugar Journal 29(1):28.
WILLIAMS, J. M. 1984. Rabbit Control Strategies Using Anticoagulants, in New Zealand. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 543-552.
WILLIAMS, J. O., and E. M. PEREIRA. 1984a. Brodifacoum as a Rodenticide to Control Rodent Damage in Rice Fields in Venezuela: II. Calaboza, State of Guarico. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 347-351.
WILLIAMS, J. O., and C. VEGA. 1984b. Brodifacoum as a Rodenticide to Control Rodent Damage in Rice Fields in Venezuela: I. State of Portuguesa. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 341-345.
WOLF, Y. 1980. Report on Field Trials for the Evaluation of the Efficacy of the Rodenticide Brodifacoum for the Control of Rodents on Farms. Israel Ministry of Agriculture, Plant Protection Department Report. pp. 2-5.
YOUNG, R. S. 1979. Pine Vole Control 1978-1979 Experiment (West Virginia). Proc. 3. Eastern Pine and Meadow Vole Symposium, New Paltz, NY. p. 60.
YOUNG, R. S. 1980. Update of Pine Vole Research at the Kearneysville Experiment Farm (West Virginia). Proc. 4. Eastern Pine and Meadow Vole Symposium, Hendersonville, NC. p. 66.
YOUNG, R. S. 1981. Pine Vole Activity Results for 1979-1980 Toxicant Applications (West Virginia). Proc. 5. Eastern Pine and Meadow Vole Symposium, Gettysburg, PA. March 4-5. p. 15.

APPENDIX 1. Brodifacoum efficacy by region and country

Region and country	Reference	Pest research area covered
Europe		
Cyprus	Hoppe & Krambias 1984	Lab Work, General Ag. & Commensal, Rattus spp.
Czechoslovakia	Chemla & Rupes 1983	Lab and Field Trials, Commensals
	Chemia, Dub. & Rupes 1985	General Microtine, Alfalfa
	Vanurova 1980	General Microtine, Alfalfa
Denmark	Lund 1981, 1982, 1983, 1984a, 1984b	Microtine Lab and Field, Commensal
	Lund & Lodal 1984	Microtine Lab and Field, Commensal
England	Anon. 1978	Lab and Field Trials, Commensals
	Bradfield & Gill 1984	Lab Trials, Introduced Hamsters
	Gibson 1982	House Mouse Field Trials
	Greaves, Shepherd & Quy 1982	Field Trials Resistance - Commensals
	Redfern, Gill & Hadler 1967	Lab Resistant Study, Commensals
	Rennison & Dubock 1978	Field Trials Resistant Commensals
	Richards & Husin 1985	Commensal Field Trials
	Rowe & Bradfield 1976	Lab Field Trials, Mice
	Rowe, Swinney & Plant 1978	Field Trials, Mice
Finland	Millymaki 1984	Lab and Field Trials, Voles
	Millymaki 1986	Lab Studies, Mice
Germany	Rothert 1985	General Considerations, Commensals
Hungary	Bajomi 1984	Field Trials Ag. and Industrial, Commensal
	Dubock 1979	Lab and Field Trials Commensal & Ag. (Microtines and Hamsters)
	Kalotas & Kalotas 1984	Lab Work, Voles and Hamsters
	Nikodemusz & Nechay 1982	Microtus Lab Work
	Nikodemusz, Nechay and Imre 1980	Lab Work, Voles, Hamsters, Hares
Switzerland	Meylan 1985	Microtus Control Materials
	Muhr 1984	Commensal Field Experiences
USSR	Karaseva, Chernukha & Strikhanova 1984	Field Trials in Rice, Vector Control
	Khryanina 1981	Lab and Field Trials - Commensals
Middle East		
Iraq	Kadhim, Muhsen & Mustafa 1984	Urban Commensal Field Trials
Israel	Wolf 1980	Commensal Field Trials - Poultry Farms
Syria	Richards 1986	Urban Commensal Trials
Africa		
General	Anon. 1981a	Country-wide Field Use and Training
	Anon. 1983	General Characteristics
	Gill & Redfern 1979, 1983	Mastomys, Meriones Lab Studies
Egypt	Anon. 1981	Country-wide Field Use and Training
	Mahmoud & Redfern 1981	Acomys and Commensal Lab Studies
	Tantawy Omar 1984	General and Agricultural Trials
	Taylor 1983	Agricultural and Commensal Field Trials
Morocco	Hoppe 1979	Lab Work, Mariones
South Africa	Anon. 1985	Field Use, Poultry Houses
South Asia		
Bangladesh	Anon. 1979a, Bruggers, 1980, Bruggers & Valvano, 1981, 1982, 1983	Ricefield Rat Trials, Crop and Village
	Conway 1984	Bandicoot Rats, Crop Stores
	Mitchell & Valvano 1984a	Lab Trials, Ag. Species
	Poche 1980	Wheat Field Trials
	Rahman & Brooks 1982	Farm and Village Commensal Trials
	Sultana 1981	Bandicoot Rat Lab Work
Burma	Brooks 1979	Lab Evaluation Urban Species
	Brooks, Htun & Naing 1980	Lab Trials Bandicoot Rats
	Htun, Muller, & Naing 1984	Field Trials Urban Species
	Richards 1986	Field Trials Urban Review
India	Balasubramandyam, Christopher & Purushotham 1984, 1985	Lab Tests, Mus
	Bhardwaj & Prakash 1984	Lab Trials, Rattus rattus
	Chopra & Parshad 1985	Field Trials Commensal Rats
	Jain, Saxena & Nag 1982	Lab Trials Rattus rattus
	Mathur & Prakash 1980ab	Lab Trials, Squirrel Ag. Pest
	Mathur & Prakash 1981, 1984a	Lab Evaluation, Ag. & Commensal Species
	Mathur & Prakash 1984b, 1984c	Desert Grassland Field Trials, Meriones and Other Spp.
	Parshad, Ahmad & Chopra 1985	Lab and Field Trials, Agricultural Species
	Rai, lal & Srivastava 1984	Commensal Rat Trials
	Renapurkar & Kamath 1982	Lab Trials, Commensal & Ag. Spp.
	Saxena & Sharma 1981	Lab Evaluation, Meriones
	Saxena & Sharma 1982	Lab Trials, Squirrel Ag. Pest
	Saxena & Sharma 1982	Lab Trials, Three Ag. Spp.
	Soni, 1981	Lab Trials, Three Ag. Spp.

South Asia (cont'd)		
	Soni & Prakash 1981	Lab Trials, Gerbillus
	Soni & Prakash 1983	Lab Trials, Squirrel Ag. Pests
	Soni & Prakash 1984abc	Lab Trials, Commensals
	Soni & Prakash 1985	Lab Evaluation, Three Species Gerbils, One Rat
	Soni, Jain & Soni 1984	Lab Trials, Commensal & Ag. Species
	Soni, Rana & Jain 1985	Crop Field Trials
Pakistan	Khan 1981	Orchard Field Trials, Pikas
	Khan & Smythe 1980	General Trials, Pikas
	Khan, Ahmed & Choudry 1984	Wheat and Rice Field Trials
Maldives	Mitchell & Valvano 1984	General Trials
Far East		
China	Deng Zhi & Wang Chengxin 1984	General Commensal and Ag., 7 Spp. Lab and Field Data
	Mo & Liang 1984	Commensal Trials
	Richards 1985	Review Urban Trials
	Wang Chengxin & Deng Zhi 1984	Results General Lab and Field Commensal and Ag. Trials
China (Taiwan)	Ku 1984	General Commensal and Ag., Field Use Island-wide
	Dubock 1980	General Review Lab and Field Trials
	Shien Tay Tseng 1981	Lab and Field Trials, Ag. Crops
	Wang 1978, 1981, 1982	Lab and Cane Field Trials, 5 Species
Philippines	Hoque 1981	Field Pineapple Trials
	Hoque 1983a	Coconut/Pineapple Intercrop Field Trial
	Hoque 1983b	Resistant Studies, Commensals
	Hoque 1986	Field Trials, Baiting Techniques
	Lanting, Andres & Randon 1981	Commensal Field Trials
South East Asia		
Indonesia	Indrarato 1984	General Ag. and Rice Trials
Malaysia	Buckle & Rowe 1981	Lab and Rice Field Rat Trials
	Buckle, Rowe & Husin 1984	Ricefield Rat Field Trials
	Buckle, Yong & Husin 1985	Ricefield Rat Field Trials
	Han & Bose 1980	Field Trials, Cocoa
	Khoo Chin Kok 1979, 1980	Oil Palm Field Trials
	Khoo Chin Kok 1984	Rat and Squirrel Ag. Field Trials
	Khoo Chin Kok & Dubock 1981	Oil Palm Field Trials
	Lam Yuet Ming 1978, 1980	Ricefield Rat Trials
	Majid & Chye 1984	Ricefield Rat Trials
Thailand	Dubock 1984	Ricefield Rat Trials
	Tongtavee 1984, 1986	Lab, Rice and Other Field Trials
	Tongtavee 1980	Commensal and Ag. Species, Lab Trials
Vietnam	Richards 1986	Village Field Trials
Oceania		
Australia	Hitchcock, Kerkwyck & Hetherington 1983	Rat Field Trials, Cane
	Anon. 1981c	Rabbit Field Trials, Islands
	Godfrey & Lyman 1980	Lab Trials Rabbits
	Godfrey, Reid & McAllum 1981	Lab Trials Rabbits
	Moors 1984	Rat Trials, Islands
	O'Connor 1979	Rabbit, Rat and Possum Field Trials
	Williams 1984	Rabbit Field Trials
North America		
Canada	Bouchard 1978, 1979	Orchard Vole Field Trials
	Siddiqi 1982	Orchard Field Trials, Voles
	Siddiqi & Blaine 1982b	Orchard Field Trials, Voles
	Siddiqi & Blaine 1982a	Lab Resistance Study, Mus
	Siddiqi, Blaine, & Taylor 1983c	Lab Resistance Study, Mus
	Siddiqi, Blaine, & Taylor 1983ab	Orchard Field Trials Voles
United States	Anon. 1979c, 1982b	Urban Commensal Field Trials
	Apperson, Sanders, & Kaukeinen 1981	Lab, Field Rat Resistance Trials
	Ashton & Jackson 1979	Urban Trials, Commensal Resistant
	Byers 1977, 1978a, 1978b, 1978c, 1979a, 1979b, 1980, 1981, 1983, 1984	Lab and Field Research, Orchard Voles
	Byers & Merson 1981, 1982a, 1982b	Lab and Field Research, Orchard Voles
	Ecke & Lewallen 1979	Lab Resistance, Rattus rattus
	Ecke, Dennis & Godfrey 1979	Field Trials Urban Rattus rattus
	Gorenzel, Marsh & Salmon 1982	Commensal Field Trials, Farm
	Jackson et al. 1985	Resistance Status
	Kaukeinen 1979a, 1979b	Urban Commensal Field Trials
	Kaukeinen 1977, 1978, 1984	Lab, Orchard Field Vole Trials
	Marsh 1979	Urban Rat Trial
	Marsh & Tunberg 1984, 1985	Lab & Field Research Artichokes, Voles
	McClelland 1979	Urban Commensal Trial
	Merson & Byers 1983	Orchard Vole Field Trial
	Pagano & McAninch 1983	Orchard Vole Field Trial
	Richmond & Miller 1980	Orchard Vole Field Trial

North America (cont'd)

	Steblein, Miller & Richmond 1983	Orchard Vole Field Trial
	Young 1979, 1980, 1981	Orchard Vole Field Trial
Mexico	Gill & Redfern 1980	Lab Work, *Sigmodon*
	Hampson 1984	Cane Field Trials
	Humbert 1983	Cane Field Trials
Central America		
General	Gill & Redfern 1980	Lab Work, *Sigmodon*
Nicaragua	Hampson 1984	Cane Field Trials
South America		
General	Gill & Redfern 1980	Lab Work, *Sigmodon*
Argentina	Humbert 1983	Cane Field Trials
Brazil	Richards 1986	Urban Commensal Trials
Ecuador	Coulter 1982	Island *Rattus* Control
Venezuela	Williams & Peieira 1984	Rice Field Trials, *Sigmodon*
	Williams & Vega 1984	Rice Field Trials, *Holochilus*

APPENDIX 2. Vertebrate pest acute LD50 values, brodifacoum (determined by intubation unless noted).

Species	Strain/source	LD50	Reference
Bandicota bengalensis	Bangladesh	0.20 (0.14-0.28)[a]	Sultana et al. 1981
Citellus columbianus	US	Male 0.168 (0.138-0.206) Female 0.180 (0.143-0.226)	Matschke, Pers. Comm.
Citellus dauricus	China	0.093	Deng Zhi & Wang Chengxin 1984
Citellus richardsonii	US	0.13 (0.063-0.188)	Pallister & Baril, Pers. Comm.
Cricetulus triton	China	0.86	Deng Zhi & Wang Chengxin 1984
Cricetus cricetus	Hungary	0.33[b]	Nikodemusz, Nechay & Imre 1980
Lepus europaeus	Hungary	0.15[b]	Nikodemusz, Nechay & Imre 1980
Meriones hurrianae	India	0.083 (0.05-0.13)	Mathur & Prakash 1981
Meriones unguiculatus	China	0.002-0.003	Deng Zhi & Wang Chengxin 1984
Mesocricetus auratus	Domestic	0.56	Dubock & Kaukeinen 1978
Microtus arvalis	Hungary	0.22[b]	Nikodemusz, Nechay & Imre 1980; Nikodemusz & Nechay 1982
Microtus pinetorum	US	0.36 (0.22-0.59)	Byers 1978
Microtus pennsylvanicus	US	0.72 (0.53-0.98)	Byers 1978
Mus musculus	LAC Grey China	Male 0.40 (0.30-0.63) 0.85	Redfern, Gill & Hadler 1976 Deng Zhi & Wang Chengxin 1984
Myospalax fontanieri	China	0.44	Deng Zhi, Pers. Comm.
Ochotona curzoniae	China	0.14	Deng Zhi & Wang Chengxin 1984
Oryctolagus cuniculus	New Zealand	0.20 (0.15-0.28)	Godfrey, Reid & McAllum 1981
Rattus argentiventer	Malaysia	0.18 (0.15-0.22)	Lam Yuet Ming 1978
Rattus flavipectus	China	0.39	Deng Zhi & Wang Chengxin 1984
Rattus norvegicus	Wistar US Wild China Wild	Male 0.26 (0.20-0.37) Female 0.22 0.32	Redfern, Gill & Hadler 1976 Dubock & Kaukeinen 1978 Deng Zhi & Wang Chengxin 1984
Rattus rattus	US	Male 0.73 (0.55-0.91) Female 0.65 (0.40-0.90)	Dubock & Kaukeinen 1978
R. r. rufescens	India	0.77 (0.40-1.28)	Mathur & Prakash 1981

Rattus rattus mindansis	Philippines	Male 0.28 Female 0.30	Dubock & Kaukeinen 1978
Rattus tiomanicus	Malaysia	0.33	Khoo Chin Kok 1980
Tatera indica	India	0.10 (0.08-0.17)	Mathur & Prakash 1981
Trichosurus vulpecula	New Zealand	0.2	Bell, Pers. Comm.

a Feeding Protocol
b ALD (approximate lethal dose)

APPENDIX 3. Vertebrate pest sub-acute LC50 values, brodifacoum (determined by intubation unless noted).

Species	Source/strain	LC50	x Days	Reference
Bandicota bengalensis	Bangladesh	0.18 (0.56-1.16)[a]	4	Sultana, et al. 1981
Cricetulus triton	China	0.11	3	Deng Zhi & Wang Chengxin 1984
Mus musculus	Grey LAC China Wild	0.035 (0.021-0.050) 0.099	5 5	Dubock & Kaukeinen 1978 Deng Zhi & Wang Chengxin 1984
Oryctolagus cuniculus	New Zealand Wild	0.22 (0.15-0.31) 0.16 (0.12-0.21)	3 5	Godfrey, Reid & McAllum 1981
Rattus flavipectus	China	0.07	5	Deng Zhi & Wang Chengxin 1984
Rattus norvegicus	Wistar Wistar China Wild UK Resistant	Male 0.06 (0.04-0.08) Female 0.05 0.07 Male 0.05	5 5 5 5	Redfern, Gill & Hadler 1976 Dubock & Kaukeinen 1978 Deng Zhi & Wang Chengxin 1984 Dubock & Kaukeinen 1978

a feeding protocol

APPENDIX 4. Vertebrate pest lethal feeding period (days), brodifacoum.

Species	Source/strain	Form	Conc.%	LFP50 (days)	LFP98 (days)	Reference
Acomys cahirinus	Egypt	Oatmeal	0.002	0.88	291.4	Mahmoud & Redfern 1981
Bandicota bengalensis	Burma	Fish meal, rice, corn, peanuts	0.001	1.12 (0.87-1.44)	3.26 (2.02-5.25)	Brooks, Htun, & Naing 1980
Funambulus pennanti	India	Millet	0.005	1.1 (0.7-2.0)	--	Mathur & Prakash 1984a
Meriones hurrianae	India	Millet	0.002 0.005	0.79 (0.50-1.26) 0.74 (0.36-1.55)	2.52 (1.55-4.18) 2.23 (1.26-4.17)	Mathur & Prakash 1981
Mastomys natalensis	Africa	Oatmeal	0.002	1.9 (0.8-1.5)	3.6 (2.7-7.0)	Gill & Redfern 1979
Meriones shawi			0.005	4.8 (4.0-5.3)	10.3 (8.1-18.1)	Gill & Redfern 1983
Mus musculus bactrianus	India	Millet, oil	0.002 0.005	1.52 (1.03-2.24) 1.26 (1.18-1.35)	8.32 (3.9-17.8) 7.25 (5.76-9.12)	Soni & Prakash 1984a
Rattus rattus	India	Millet	0.002 0.005	0.76 (0.40-1.51) 0.68 (0.38-1.23)	3.02 (1.35-6.76) 2.76 (1.59-4.79)	Mathur & Prakash 1981
Sigmodon hispidus			0.002	0.9 (0.6-1.2)	3.3 (2.4-7.1)	Gill & Redfern 1980
Tatera indica	India	Millet	0.002 0.005	0.69 (0.32-1.48) 0.64 (0.32-1.39)	2.34 (1.10-5.0) 2.10 (1.25-4.16)	Mathur & Prakash 1981

APPENDIX 5. Vertebrate pest restricted feeding periods - brodifacoum (no-choice exposure in diet).

Species	Source/ strain	Form.	Conc. (%)	Days given	Mortality no.	Mortality %	Reference
Acomys cahirinus	Egypt	oatmeal	0.002	2	7/10	70	Mahmoud & Redfern 1981
				4	7/10	70	
				8	6/9	67	
				10	7/10	70	
				11	7/10	85	
				14	8/10	80	
				18	17/20	85	
				20	9/10	90	
				22	8/10	80	
				23	10/10	100	
				24	8/10	80	
				25	10/10	100	
Akodon spp.	Argentina	ICI Pellet	0.005	1	27/30	80	Dubock & Kaukeinen 1978
Apodemus flavicollis	Czech.	ICI Pellet	0.001	1	14/14	100	Chmela, Dub & Rupes 1985
	Denmark	Ground Oats	0.0005	1	2/5	40	Lund 1981
				2	4/8	80	
		Ground Oats	0.005	1	20/20	100	
				2	20/20	100	
A. sylvaticus	Denmark	Ground Oats	0.0005	1	10/10	100	Lund 1981
				2	9/10	90	
		Ground Oats	0.005	1	10/10	100	
				2	10/10	100	
Arvicanthis niloticus	Sudan	ICI Pellet	0.005	1	20/20	100	Poche, Pers. Comm. 1982
	Egypt	ICI Pellet	0.005	1	10/10	100	ICI, Unpub.
			0.001	1	19/20	95	
Arvicola terrestris	W. Europe	Grain Meal	0.0025	1	5/5	100	Dubock & Kaukeinen 1978
	Finland	ICI Pellet	0.001	1	8/8	100	Myllymaki 1984
	Denmark	ICI Pellet	0.001	1	3/3	100	Lund 1983
Bandicota bengalensis	Burma	Fish Meal, Rice, Corn, Peanuts	0.001	1	13/32	41	Brooks, Htun & Naing 1980
				2	18/29	90	
				3	18/20	90	
			0.001	4	11/11	100	
			0.005	1	21/21	100	
	India	Wheat Corn, Oil, Sugar	0.005	1	13/13	100	Parshad, Ahmad & Chopra 1985
		NA	0.005	1	20/20	100	Renapurker & Kamath 1982
				3	20/20	100	
	Bangladesh	Millet	0.00003	4	0/6	0	Sultana et al. 1981
			0.00006	4	3/6	50	
			0.000125	4	7/12	58	
			0.00025	4	11/11	100	
			0.0005	4	11/11	100	
			0.0010	4	6/6	100	
			0.0020	4	7/7	100	
B. indica	Thailand	Rice	0.005	1	10/10	100	Tongtavee 1980
B. nemorivaga	Taiwan	Rice	0.0025	1	10/10	100	Shien-Tay Tseng 1981
			0.005	1	12/12	100	
			0.010	1	5/5	100	
Citellus beecheyi	US	ICI Oat Groats	0.005	1	12/12	100	Marsh, Pers. Comm.
				2	12/12	100	
				3	20/20	100	
C. richardsoni	US	ICI Pellet	0.005	1	14/14	100	ICI, Unpub.
C. variegatus	US	ICI Pellet	0.005	1	9/10	90	Maupin, Pers. Comm.
Cricetus cricetus	Hungary	ICI Pellet	0.001	1	10/12	83	Kaiotas & Kaiotas 1984
				6	12/12	100	
Clethrionomys glareolus	Czech.	ICI Pellet	0.001	1	9/9	100	Chmela, Dub & Rupes 1985
	Denmark	Ground Oats	0.0005	1	10/10	100	Lund 1981
		ICI Pellet	0.001	1	10/10	100	Lund 1983
		Ground Oats	0.005	1	10/10	100	Lund 1981

Species	Source/ strain	Form.	Conc. (%)	Days given	Mortality no.	Mortality %	Reference
				2	10/10	100	
		Wheat	0.005	1	20/20	100	Lund 1982
Funambulus pennanti	India	Wheat, Corn Sugar, Oil	0.005	1	8/8	100	Parshad, Ahmad & Chopra 1985
		Millet	0.005	1	8/12	67	Mathur & Prakash 1980
				2	7/10	70	
				4	9/10	90	
				6	12/12	100	
		Wheat, Oil, Sugar	0.005	3	5/5	100	Saxena & Sharma 1982
			0.0025	3	5/5	100	
		Millet	0.002	1	NA	50	Soni & Prakash 1983
				2	NA	60	
				4	NA	80	
				6	NA	100	
		Wheat, Oil, Sugar	0.005	7	10/10	100	Saxena & Sharma 1984
			0.0025	7	10/10	100	
			0.00125	7	10/10	100	
Gerbillus gleadowi	India	Millet	0.005	1	5/10	60	Soni & Prakash 1981
				2	9/10	90	
				3	10/10	100	
Golunda ellioti	India	Millet	0.005	1	8/10	80	Soni & Prakash 1984c
				2	10/10	100	
Holochilus brasiliensis	Argentina	ICI Pellet	0.005	1	20/21	95	Dubock & Kaukeinen 1978
Mastomys natalensis	Africa	Oatmeal	0.002	1	7/20	35	Gill & Redfern 1979
				2	18/20	90	
				3	18/20	90	
				4	20/20	100	
Meriones hurrianae	India	Millet	0.005	1	10/12	83	Soni 1981
		Millet	0.005	3	12/12	100	Mathur & Prakash 1981
			0.002	3	12/12	100	
		Wheat	0.0125	1	NA	100	Saxena & Sharma 1981
			0.005	1	NA	100	
		Liquid	0.005	1	10/12	83	Soni & Prakash 1984b, 1985
				2	12/12	100	
		ICI Wax Bait	0.005	1	10/10	100	Soni, Jain & Soni 1984
		Wheat, Oil, Sugar	0.005	7	10/10	100	Saxena & Sharma 1984
			0.0025	7	10/10	100	
			0.00125	7	10/10	100	
Meriones shawi	Morocco	Oatmeal	0.005	3	1/20	5	Gill & Redfern 1983
				4	4/10	40	
				5	4/10	40	
				6	7/10	70	
				7	9/10	90	
				8	10/10	100	
		Corn	0.005	1	27/50	54	Hoppe 1979
				3	20/20	100	
M. unguiculatus	US, Domestic	ICI Pellet	0.005	1	20/20	100	Marsh, Pers. Comm.
Mesocricetus auratus	Europe, Domestic	Meal	0.001	1	NA	100	Dubock & Kaukeinen 1978
	UK, Feral	Oatmeal	0.005	1	7/9	78	Bradfield & Gill 1984
				2	9/10	90	
				3	10/10	100	
Microtus agrestis	Finland	Apple Bait	0.005	1	11/12	92	Myllymaki 1984
		ICI Pellet	0.005	1	6/10	60	
				2	7/10	70	
		ICI Pellet	0.001	1	10/16	62	
				2	15/16	94	

Species	Source/ strain	Form.	Conc. (%)	Days given	Mortality no.	%	Reference
	Denmark	ICI Pellet	0.001	1	5.5	100	Lund 1983
		Ground Oats	0.0005	1	10/10	100	Lund 1981
				2	10/10	100	
M. arvalis	Czech.	ICI Pellet	0.001	1	18/19	95	Chmela, Dub & Rupes 1985
	E. Europe	Grain Meal	0.005	1	52/52	100	Dubock & Kaukeinen 1978
	Denmark	Ground Oats	0.005	1	10/10	100	Lund 1981
				2	10/10	10	
		ICI Pellet	0.001	1	5/5	100	Lund 1983
		Ground Oats	0.0005	1	10/10	100	Lund 1981
				2	10/10	100	
	Hungary	ICI Pellet	0.001	1	17/20	85	Kalotas & Kalotas 1984
				5	19/20	95	
M. californicus	California	ICI Oat Groats	0.005	1	14/15	93	Marsh, Pers. Comm.
		Artichoke Bait	0.01	1	10/10	100	Marsh & Tunberg 1984
				2	10/10	100	
				3	10/10	100	
				4	10/10	100	
		Artichoke Bait	0.001	1	10/10	100	Marsh & Tunberg 1984
			0.005	1	8/10	80	
		ICI Pellet	0.001	2	9/10	90	
M. pinetorum	US	ICI Pellet	0.005	1	10/10	100	ICI, Unpub.
Mus booduga	India	Millet	0.00125	1	2/6	33	Balasubramanyam, Christopher & Purushotham 1984, 1985
				2	3/6	50	
				3	4/6	67	
			0.0025	1	4/6	67	
				2	5/6	83	
				3	6/6	100	
			0.005	1	5/6	83	
				2	5/6	83	
			0.01	1	6/6	100	
				2	6/6	100	
				3	6/6	100	
			0.02	1	6/6	100	
				2	6/6	100	
				3	6/6	100	
Mus musculus	UK LAC Grey	Meal	0.005	1	30/30	100	Dubock & Kaukeinen 1978
	Denmark	Ground Oats	0.0005	1	5/10	50	Lund 1981
				2	10/10	100	
		Ground Oats	0.005	1	10/10	100	
				2	10/10	100	
	India	Wheat, Corn, Sugar, Oil	0.005	1	11/11	100	Parshad, Ahmad & Chopra 1985
	Finland	ICI Pellet	0.005	1	10/12	83	Myllymaki 1986
		Rolled Oats		1	11/12	92	
M. m. (warfarin resis.)	Denmark	Ground Oats	0.0005	1	0/10	0	Lund 1981
				2	0/10	0	
		Ground Oats	0.005	1	9/10	90	
				2	9/10	90	
				3	10/10	100	
	Canada	ICI Pellet	0.005	3	17/23	74	Siddiqi, Blaine & Taylor 1983
	UK	Oatmeal, Oil	0.002	21	10/10	100	Rowe & Bradfield 1976
			0.005	21	18/18	100	
			0.01	21	20/20	100	
M. m. bactrianus	India	Millet	0.005	1	6/10	60	Soni & Prakash 1984
				2	7/10	70	
				3	8/10	80	
				4	9/10	90	
				5	10/10	100	
			0.002	1	7/12	58	
				3	10/12	58	

Species	Source/ strain	Form.	Conc. (%)	Days given	Mortality no.	Mortality %	Reference
				5	11/12	92	
				7	12/12	100	
Mystromys albicaudatus	South Africa	ICI Pellet	0.005	1	20/20	100	Marsh, Pers. Comm.
Peromyscus maniculatus	USA	ICI Pellet	0.005	1	20/20	100	Dubock & Kaukeinen 1978
Rattus argentiventer	Malaysia	Rice, Oil	0.001	1	16/20	80	Lam Yuet Ming 1978
			0.005	1	20/20	100	
		Rice, Oil	0.005	1	10/10	100	Buckle, Rowe & Husin 1982
			0.0005	1	2/20	90	
				2	9/10	90	
			0.001	1	16/20	80	
				2	9/10	90	
			0.002	1	10/10	100	
	Thailand	Rice	0.005	1	10/10	100	Tongtavee 1980
	Bangladesh	ICI Pellet	0.005	1	9/10	90	Dubock & Kaukeinen 1978
	Indonesia	ICI Pellet	0.005	1	10/10	100	ICI, Unpub.
R. exulans	USA, Hawaii	ICI Pellet	0.005	1	5/5	100	Marsh, Pers. Comm.
				3	10/10	100	
R. linntus	Taiwan	Rice	0.005	1	3/3	100	Shien-Tay Tseng 1981
			0.010	1	3/3	100	
R. losea	China	Rice	0.010	1	5/5	100	ICI, Unpub.
	Taiwan		0.005	1	9/10	90	
		Rice	0.0025	1	10/10	100	Shien-Tay Tseng 1981
			0.0005	1	24/24	100	
			0.010	1	11/11	100	
R. meltada	India	Wheat, Corn, Sugar, Oil	0.005	1	10/10	100	Parshad, Ahmad & Chopra 1985
		ICI Wax Block	0.005	1	NA	80	Soni, Jain & Soni 1984
				2	NA	100	
		Millet	0.005	1	8/10	80	Soni 1981
		Liquid	0.005	1	18/22	82	Soni & Prakash 1985
				2	12/12	100	
R. norvegicus, wild	Hungary	Pellet	0.0075	1	5/5	100	Bajomi 1984
	Denmark	Rolled Oats	0.0005	1	5/10	50	Lund 1981
				2	8/10	80	
		Rolled Oats	0.005	1	10/10	100	Lund 1981
				2	15/16	94	Lund 1981
	UK	Oatmeal	0.002	2	60/60	100	Anon. 1978
	India	NA	0.005	1	16/20	80	Renapurkar & Kamath 1982
				3	20/20	100	
	Egypt	Oatmeal	0.002	2	9/9	100	Mahmoud & Redfern 1981
	UK	Oatmeal, Oil	0.001	2	20/20	100	Redfern, Gill & Hadler 1976
				2	29/30	97	
			0.010	1	10/10	100	
				2	20/20	100	
			0.0005	1	17/20	100	
				2	20/20	100	
	Taiwan	Rice	0.005	1	6/6	100	Shien-Tay Tseng 1981
			0.010	1	5/5	100	
	US	ICI Pellet	0.005	1	20/20	100	ICI, Unpub.
R. n., warfarin, coumatetralyl & bromadiolone resistant	Denmark	Oatmeal	0.005	6	20/20	100	Lund 1982
R. n. warfarin resist.	UK	Oatmeal	0.002	2	20/20	100	Redfern, Gill & Hadler 1986
				2	39/40	97	Anon. 1978
		Oatmeal, Oil	0.001	1	10/10	100	Redfern, Gill & Hadler 1976
				2	20/20	100	
			0.0005	1	6/10	60	
				2	9/9	100	

Species	Source/ strain	Form.	Conc. (%)	Days given	Mortality no.	Mortality %	Reference
R. rattus	Egypt	Oatmeal	0.002	2	9/10	90	Mahmoud & Redfern 1981
				3	20/20	100	
	US	ICI Pellet	0.005	1	18/20	90	Dubock & Kaukeinen 1978
						100	
		ICI Block	0.005	1	10/12	83	ICI, Unpub.
		Rolled Oats	0.005	1	10/10	100	Lund 1981
				2	10/10	100	
	India	Wheat, Oil,	0.005	7	10/10	100	Saxena & Sharma 1984
		Sugar	0.0025	7	10/10	100	
			0.00125	7	10/10	100	
		Millet	0.005	1	10/12	83	Soni 1981
		NA	0.005	1	15/20	75	Renapurkar & Kamath 1982
				3	20/20	100	
		Grain Bait	0.005	1	24/24		Jain, Saxena & Nag 1982
		Liquid	0.005	1	9/10	90	Soni & Prakash 1985
		ICI Wax Block	0.005	1	NA	100	Soni, Jain & Soni 1984
		Millet	0.002	4	12/12	100	Mathur & Prakash 1984a
			0.005	4	16/16	100	
		Wheat, corn, Oil, Sugar	0.005	1	10/10	100	Chopra & Parshad 1985
	Japan	ICI Pellet	0.005	1	9/11	82	Ikeda, Pers. Comm.
				2	12/12	100	
	UK	Oatmeal, Oil	0.002	2	29/30	97	Anon. 1978
			0.005	2	20/20	100	Redfern, Gill & Hadler 1986
R. rattus	Denmark	Rolled Oats	0.0005	1	2/10	20	Lund 1981
				2	6/10	60	
			0.005	1	10/10	100	
				2	10/10	100	
	India	Wheat, Corn, Sugar, Oil	0.005	1	10/10	100	Chopra & Parshad 1985
		ICI Wax Block	0.005	1	24/20	100	Jain, Soni & Jain 1982
		Wheat, Corn, Sugar, Oil		1	19/19	100	Parshad, Ahmad & Chapra 1985
		Wheat	0.001	1	6/6	100	Rai, Lal & Srivastava 1984
				2	6/6	100	
				3	6/6	100	
				4	6/6	100	
				5	6/6	100	
	US	ICI Pellet	0.005	2	8/10	80	Ecke, Dennis & Godfrey 1979
R. r., warfarin resist.	UK	Oatmeal, Oil	0.005	2	5/5	100	Redfern, Gill & Hadler 1976
			0.002	2	4/5	80	
R. r., warfarin & pival resistant	US	ICI Pellet	0.005	3	7/7	100	Ecke & Lewallen 1979
R. r. frugivorus	Cyprus	Barley, Wheat, Corn, Oil	0.005	1	10/10	100	Hoppe & Krambias 1984
R. r. mindanensis	Philippines	Grain Meal	0.005	3	8/10	80	Savarie, Pers. Comm.
		Rice	0.002	3	20/20	100	Hoque 1983b
R. tiomanicus	Philippines	Grain Meal	0.005	1	17/17	100	Anon. 1976
Sigmodon hispidus	US	Meal Bait	0.005	1	5/5	100	Dubock & Kaukeinen 1978
		ICI Pellet	0.005	1	8/10	80	ICI Unpub.
	UK	Oatmeal	0.002	1	17/30	57	Gill & Redfern 1980
				2	24/30	80	
				3	20/20	100	
Spermophilus (See Citellus)							
Suncus murinus	Burma	Lab Diet	0.005	4	4/4	100	Brooks et al. 1979
Tatera indica	India	Millet	0.002	3	12/12	100	Mathur & Prakash 1984a,b
			0.005	3	12/12	100	
		Millet	0.005	1	9/10	90	Soni 1981

Species	Source/ strain	Form.	Conc. (%)	Days given	Mortality no.	%	Reference
		Wheat, Corn, Sugar, Oil	0.005	1	10/10	100	Parshad, Ahmad & Chopra 1985
		Liquid Bait	0.005	1	8/10	80	Soni & Prakash 1984b, 1985
				2	11/12	92	
				3	20/20	100	
		Wax Block	0.005	1	NA	100	Soni, Jain & Soni 1984
Thomomys bottae	US	ICI Oat Groats	0.005	1	2/2	100	Marsh, Pers. Comm.
T. mazama	US	ICI Milo Bait	0.005	3	19/23	83	Matschke, Pers. Comm.

NA - Information not available.

APPENDIX 6. Restricted feeding study results. No-choice 6-hr and 12-hr tests - ICI 0.005% brodifacoum formulations (ICI unpub., unless noted).

Species	Hr. feed[a]	Formulation type	Mortality	Av. dose (mg/kg)	Av. DOD[b]
Articanthis niloticus	6	pellet	12/12	1.2	6
	6	block	12/12	1.8	6
Geomys bursarius	12	milo	21/24	0.5	8[c]
Mus musculus (wild)	6	block	5/9	3.9	8
	12	block	11/12	8.0	6
Rattus argentiventer	6	block	10/12	2.1	4
	6	pellet	12/12	1.9	7
Rattus norvegicus (wild)	6	pellet	23/24	2.4	7
Rattus rattus	6	block	10/12	2.3	8
	6	pellet	8/8	1.7	6
Sigmodon hispidus	6	block	10/12	1.8	9

[a] unfasted animals, offered bait beginning 1800 hrs, normal 12/12 light cycle, 22 C 2 C, 50% 5% R.H.

[b] DOD = Day of Death

[c] R. Case, pers. comm., May, 1979

APPENDIX 7. ICI brodifacoum formulations-acceptance and mortality (3-day single-cage choice tests vs EPA meal, unless noted; 1 S.D. in paren., ICI unpub. unless noted).

Species	VOLID 10 ppm pellet Acc.	Mort.	TALON/KLERAT 50 ppm pellet Acc.	Mort.	TALON/KLERAT 50 ppm block Acc.	Mort.
Arvicanthis niloticus	49.0(20.6)[b]	19/20	62.6(10.3)[c]	12/12		
Citellus richardsoni			31.1(7.7)[c]	20/20[d]		
Citellus tridecemlineatus					20.5(18.6)	11/12
Citellus variegatus			39.0(28.7)[c]	9/10[e]		
Cynomys ludovicianus			60.8(14.7)[c]	10/10[e]		
Meriones unguiculatus					51.0(19.9)[cb]	10/10
Microtus pennsylvanicus					31.5(20.3)[cb]	10/10

Species	VOLID 10 ppm pellet Acc.	Mort.	TALON/KLERAT 50 ppm pellet Acc.	Mort.	TALON/KLERAT 50 ppm block Acc.	Mort.
Microtus pinetorum	53.1(32.3)[b] 72.8(10.3)[b]	10/10 10/10	75.7(10.0)[b]	10/10		
Mus musculus (wild)	39.6(27.3)	5/10	57.5(35.8) 34.2(17.0) 36.2(28.1) 37.5(21.0) 57.4(27.0)	19/20 9/10 19/20 19/20 20/20	33.6(32.5) 24.5(10.8) 41.4(24.0)	19/20 10/10 10/10
Peromyscus maniculatus	40.6(19.6)[a]	18/20			36.8(16.3)[b] 40.2(21.4)	10/10 10/12
Rattus exulans			55.0(14.2)	10/10[f]		
Rattus norvegicus (wild)	72.8(17.0)	10/10	59.7(26.3) 53.2(34.0)	10/10 19/20	48.9(24.0) 54.3(grp) 48.9(41.0) 59.4(35.6)	20/20 19/20 7/10 19/20
Rattus rattus			58.0(24.0)	18/20	54.2(39.0)[b]	8/10
Sigmodon hispidus			54.2(39.0)[c] 53.8(14.3)[c] 54.3(14.9)[b]	8/10 9/10 10/10	88.4(7.7)[b]	10/10

a - EPA meal consists of 65% ground whole corn, 25% ground rolled oats, 5% sugar and 5% corn oil
b - versus Microtus challenge diet (50% ground rolled oats, 50% ground rodent chow)
c - 4-day choice test
d - G. Pallister and S. Baril, pers. comm., Dec., 1980
e - G. Maupin, pers. comm., Dec., 1979
f - R. Marsh, pers. comm., Jan., 1978

APPENDIX 8. Non-U.S. commensal field efficacy trial results.

Reference	Subject
URBAN - PUBLIC HEALTH RELATED	
Brooks, et al. 1979, Richards 1986a	plague importance and brodifacoum efficacy for Bandicota and Rattus spp. from Burma
Gill and Redfern 1979	plague importance and brodifacoum efficacy for Mastomys from Africa
Karaseva, et al. 1984	control of rodent leptospirosis focus with brodifacoum in USSR
URBAN - GENERAL	
Brooks, et al. 1979, Htun, et al. 1984, Dubock 1984a, Brooks et al. 1980	trials against commensal Bandicota and Rattus species in Rangoon, Burma, giving effective control
Kadhim, Muhsen & Mustafa 1984	Baghdad, Iraq, Norway rat trials, 25 g per bait station
Muhr 1984	successful urban PCO experiences in Switzerland, esp. against Mus
Richards 1986a	urban trials in Sao Paulo, Brazil; Zhuo Xian, China; and Hlegu, Burma
VILLAGE AND FARM STRUCTURES	
Anon. 1985	reports successful control on S. African poultry farms

Reference	Subject
Bajomi 1984	75 ppm baiting on dairy and sheep farms in Hungary showed effective control
Bruggers & Valvano 1981, Rahman & Brooks 1982	village housing cluster trials in Bangladesh, giving 97% control
Chmela & Rupes 1983	farm structure baiting for rats and mice in Czechoslovakia gave good results with TALON pellet; has baiting density advice
R. Poche, pers. comm., Apr. 1982	complete rat control in Sudan poultry houses with 2 rounds of 10-15-g 50-ppm baits in burrows or near signs
Richards 1986a,b	village trial in Vietnam with baiting of structures and adjacent areas gave 95% reduction in activity
Wolf 1980	commensal trials among 5 farm sites, e.g., poultry houses, near Yaffo, Israel, giving 85-100% control.
CROP STORES	
Anon. 1980 rept. to ICI	50 ppm-pellets gave good control in 3 rat-and mouse-infested grain stores in USSR
Conway 1984	trials in Bangladesh godown against *Bandicota bengalensis* with population reduction, but immigration or inadequate baiting problems
Dubock 1978	useful general review of rodent problems in crop stores and uses of brodifacoum
Hoppe 1979	superior control of *Meriones* pest of stored crops in Morocco
Khryanina 1981	5-ppm wheat bait with 20-30 g placements for rats and 4-6 g for mice in USSR storehouses showed overall 96% reduction in activity
Lanting, Andres & Randon 1981	successful house mouse control in 26-day trial in Philippines with high density of bait points
R. Poche, pers. comm., Apr., 1982	2 baitings at 2-wk intervals in Sudan flour mill gave 93% reduced activity

APPENDIX 9. Agricultural pest rodent field efficacy trials (non-U.S.).

References	Subject
RICE	
Anon. 1979a	deepwater rice rodent control in Bangladesh gave 90% reduction using bait boxes
R. Brown, pers. comm., Dec., 1985	5-g wax block trials in Philippines at 1.2-1.7 kg/ha in rice gave 42% yield gain. Thailand rice application 5-g wax blocks at 0.77 kg/ha during dry season in 2 baitings at 2-wk intervals in 480-ha plot. Damage significantly reduced
Dubock 1980, Tongtavee 1980, 1984	Thailand rice trials with *R. arventiventer* and *Bandicota indica* using 10-g rice sachets or 5-g wax blocks gave 74-86% reduced tiller damage at rates of 1.25-1.65 kg/ha in 3 baiting rounds 1 mo. apart
Hoque & Olivida 1986	Philippine comparisons of sustained vs pulsed baiting in rice

References	Subject
Indrarto 1984	50-ppm KLERAT reduced rice losses Indonesia from 27% pre-trt. during 1979-80 to 16% during 1980-81 on 248,255 ha, saving 110,230 metric tons worth about US $1 million
Khan, Ahmed & Choudry 1984	trials in Pakistan rice showed 2% rodent activity in treated vs. 37% in control of Bandicota bengalensis, Millardia meltada and Mus spp.
Ku 1984	Mus formosanus, Rattus losea and R. norvegicus in Taiwan rice controlled in island-wide campaign in 1978-82 using over 1 million tons 50-ppm wax bait yearly with good results
Lam Yuet-Ming 1980, Buckle & Rowe 1981, Buckle, Rowe & Husin 1982	5 or 15-g wax blocks were applied in Malaysian rice fields under various application regimes, giving 80-87% reductions
Taylor 1983, Tantawy Omar 1984	country-wide control campaign in Egypt against rodent pests
Tongtavee 1986	characteristics of KLERAT wax blocks and their use in Thailand
Williams & Vega 1984, Williams & Pereira 1984	Venezuela rice trials with Sigmodon or Holochilus in non- and irrigated rice
WHEAT	
Bruggers & Valvano 1982	3-4 g of 50-ppm bait cakes were applied per burrow in Bangladesh wheat fields, with rat damage after trtmt. at 2.6% vs 7.6% in untreated
Bruggers & Valvano 1983	Bangladesh demo trials in 1 sq. km. with 50-ppm bait cakes against B. indica in wheat fields and nearby structures, 4 baitings over 3 mo gave 86-90% reduced tracks or active burrows
Dubock 1980	trials in Pakistan wheat resulted in 87% reduced damage
Khan, Ahmed & Choudry 1984	85% fewer B. bengalensis, M. meltada and Mus were trapped after baiting over 3-4 days at each of 3 monthly applications; damage reduced 88% and yield up 7-fold
Parshad, Ahmad & Chopra 1985	50-ppm bait in 2 baitings of 3 days each gave activity redn. 3 census methods of 61-93% in Pakistan
Poche, et al. 1980, Bruggers 1980	after 12% losses to Bangladesh wheat crop to rodents for 1978-79, trials against B. bengalensis with weekly 50-ppm baiting gave 40% reduced tracks and trappings
SUGAR CANE	
Hampson 1984	thorough general review of rodent problems and evaluations in Mexico, Nicaragua and elsewhere
Hitchcock, Kerkwyck & Hetherington 1983	Australian trials of 50-ppm baits against R. sordidus at 1.68 kg/ha suggested possible 1080 replacement
Humbert 1983	cane trials in Mexico reduced rodents such that none could be trapped post-treatment
Wang 1978, 1981, 1982	Taiwan studies with cane species; field needs with 50-ppm bait in 10-15 g placements estimated at 1-2 kg/ha for good control
FRUIT TREES	
G. Anderson, pers. comm., Feb., 1979	Thomomys talpoides in Canadian orchard work with 50-ppm bran bait applied with hand probe gave 89% mound-building activity reduction

References	Subject
Bouchard 1978, 1979	Canadian orchard trials with 9 kg/ha 50-ppm bait gave 73% vole reduction
V. Kneifl, pers. comm., Dec., 1984	VOLID trials in Czech orchards gave 80% reduced activity of M. arvalis after broadcast at 5,10 or 20 kg/ha
Khryanina 1981	baiting vole burrows in Soviet Union gave 97% control
Myllymaki 1984	applications for Finnish orchards
Siddiqi, Blaine & Taylor 1983b, Siddiqi 1982	50-ppm pellets efficacious in Canadian orchard trials when used in bait stations
K. Taylor, pers. comm., Jan., 1981	Arvicanthis attacking oranges in Egypt were completely controlled with 50-ppm wax blocks applied at the base of each tree
OTHER TREE CROPS	
Han & Bose 1980	in Malaysian cocoa under coconuts, R. tiomanicus and R. argentiventer reduced after baiting
Hoque 1983a	Philippine coconut-pineapple intercrop trials compared crown with tree base baiting in 50 or 200-g sachets; both gave effective control but pineapples better protected with ground baiting
Khoo Chin Kok 1979, 1980, 1984, Khoo Chin Kok & Dubock 1981	Yearly av. 5% losses Malaysian oil palm cut by applications 13-g wax blocks of 30 ppm placed at base trees under different schedules, giving 72-97% activity reduction from totals of 2.0-7.5 kg/ha applied
Lund & lodal 1986	Danish trials near young forest plantings with 50-ppm wax block against M. agrestis and A. sylvaticus showed good bait take and significant population reductions
Mitchell & Valvano 1984	severe coconut damage R. rattus in Maldives, Indian Ocean prompted preliminary bait comparisons; Talon pellet take higher than for other toxic baits tested
GRASSLAND AND RANGELAND	
Anon. 1980 rept. to ICI	Soviet field trials with Rhombomys opimus gave 96% control
Chmela, Dub & Rupes 1985	Czech VOLID trials against M. arvalis in grassland at 10 kg/ha gave 92% reduced activity
Mathur & Prakash 1984a,b,c	desert scrub grassland in India treated for 10 days using bait stations; census results averaged 90.5% reduction Meriones activity
O'Connor 1979, Williams 1984	range and crop damage New Zealand from rabbits, hares and possums described; trials of 50-ppm bait at 1.6 kg/ha gave good rabbit control, with 3.2 kg/ha recommended for higher rabbit densities (to 33 rabbits/ha)
Vanurova 1980	field voles in Czech alfalfa successfully controlled even though this crop rich in vitamin K and other anticoagulants had failed
OTHER CROPS AND DAMAGE AREAS	
Anon., 1980 rept. to ICI	in USSR crop trials against common voles, burrow baiting with 50-ppm pellets gave 97% control
Hoque 1981, 1983b	Philippine research found 50-ppm bait effective in pineapples for protection against R. r. mindanensis and R. exulans, and returned a 1:5 cost benefit ratio
Soni, Rana & Jain 1985	crop trials in Indian desert gave 94% reduction in rodent activity after baiting

References	Subject
K. Taylor, pers. comm., Oct., 1983	trials in barley against M. socialis in Iraq with 4-17 kg/ha 50-ppm pellets applied; census bait take and active burrow counts revealed 71-92% reduction in activity
Tantawy Omar 1984	efforts in Egypt in wheat, beans, maize, cotton and other crops

APPENDIX 10A. USA registration trials - TALON pellets (1977-79) ICI development field trials (bait station or burrow stuffing).

Site & state	Bait cons. (g)	No. of points	Trtmt. days	%RDN census bait	%RDN tracks	Species
Storage barn, NY	860	35	11	90	70	NR
Corn crib, WV	1434	19	32	100	NA	NR
Seed warehse., GA	860	25	8	79	83	NR
Pig farm, MS	1451	19	18	95	92	NR
Feed store, OK	575	27	12	98	99	NR
Feed room, NM	206	19	5	78	65	R/M
Feed mill, TX	893	22	13	86	65	R/M
Grain Elev., CA	1051	5	13	100	100	RR
Poultry hse., LA	9031	64	11	64	95	R/M
Storage bldg., TX	109	10	11	98	100	HM
Storage bldg., GA	198	19	6	96	98	HM
Barn, MS	1451	19	26	95	92	R/M
Poultry hse., IL	238	18	7	96	99	HM
Dog kennel, FL	3240	16	11	83	98	RR
Poultry hse., IL	1745	18	10	92	84	NR
Poultry hse., MI	1698	60	8	96	79	R/M
Seed plant, MN	296	33	10	82	80	HM
Storage bldg., MO	13	10	7	81	85	HM

Site & state	Bait cons. (g)	No. of points	Trtmt. days	%RDN census bait	%RDN tracks	Species
Seed plant, IL	536	30	13	99	100	HM
Feed barn, NY	435	10	25	70.8	79	HM
Hog farm, FL	3006	28	11	70	53	RR
Seed storage, FL	409	8	15	100	100	RR
Horse barn, OR	3509	21	17	99	NA	NR
Farm bldg., OR	1319	33	16	95	NA	NR
Turkey farm CA	8052	10	11	99	100	NR
Hog farm, OH	3089	42	10	58	80	R/M

NR = Norway rat, RR - roof rat, HM or M = house mouse

APPENDIX 10B. USA registration field trials - Talon weatherbloks ICI development field trials (1979-81).

Site & state	Bait cons. (g)	No. of points	Trtmt. days	%RDN census bait	%RDN tracks	Species
Turkey farm, NC	3630	100	16	83	98	NR
Grain elev., OR	908	6	10	100	100	NR
Poultry hse., GA	24062	50	10	92	88	NR
City sewers, OH	4767	10	48	90	NA	NR
Duck farm, CA	31780	400	14	99	81	NR
Hog farm, LA	13393	200	6	88	NA	NR
Bus. office, CO	681	22	20	86	95	HM
Horse barn, OK	681	20	6	100	97	HM
Cotton shed, CA	3745	25	5	98	97	RR

NR = Norway rat, RR = roof rat, HM = house mouse

APPENDIX 11. U.S. agricultural pest rodent field efficacy trials - 50-ppm brodifacoum.

Reference	Subject
ORCHARDS	
Byers 1977	50-ppm apple bait and pellets applied by hand in Virginia at 10 lb/A gave excellent vole control
Byers 1978a,b,c	handbait trtmt. of 50-ppm pellets at 5.6 kg/ha gave 99% vole control
Byers 1979a	broadcast trtmt. of 50-ppm pellets at 13.4 kg/ha gave 88-100% control; handbait at 5.4 kg/ha gave 100% meadow vole reduction
Byers 1979b	pine voles showed 93% control after 12 kg/ha pellets broadcast; and 99% control using 1 50-g sachet per tree
ICI, unpub., Aug., 1979	C. beecheyi in Calif. walnut orchard treated 460 burrows with TALON pellets; activity reduced by 88% from trtmt.
ICI, unpub., July, 1979	Thomomys bottae in Calif. almond orchard received 30-g bait in tunnels with hand probe; showed 74% reduced activity
ICI, unpub., July, 1979	C. beecheyi in Calif. almond orchard were completely controlled following 15 days of trtmt. with TALON pellets in bait stations
Kaukeinen 1977	reviews preliminary studies as orchard rodenticide
Kaukeinen 1978	reviews lab data and 3 handbait and 3 broadcast trials from Virginia or Indiana
Kaukeinen 1979	gives results of 19 field trials with 50-ppm pellets against 4 Microtus spp. in apple and pear orchard trials throughout the U.S.
Richmond and Miller 1980	a 10-lb/A broadcast treatment of 50-ppm pellets gave good control
Young 1979	50-ppm pellets were applied by air at diff. rates, ground broadcast at 10 lb/A, and handbaited at 10 lb/A in runs or stations
Young 1980	describes air and ground broadcast and hand-placement trials at 8-14 lb/A, with 72-81% average activity reduction
Young 1981	50-g sachets or loose bait were applied 1 per tree; more of loose bait was taken than sachets. Vole reductions after 6 mo noted
RANGELAND/TURF	
ICI, unpub., July, 1979	C. columbianus trials in Washington mt. meadow used TALON pellets maintained in 10 bait boxes within 10 A plots. Activity was reduced 82-95% following treatment
ICI, unpub., May, 1979	Thomomys spp. were controlled in a Washington meadow with TALON applied at 1-1.4 lb/A in a burrow-building machine on 30-ft centers; mound-building was reduced 89-93%
ICI, unpub., Aug., 1979	Thomomys bottae in Washington was controlled with TALON equally well as strychnine when both were applied with hand probe baiter at same rate
ICI, unpub., July, 1979	C. beecheyi damage at a Calif. golf course was reduced with TALON after baiting 317 burrows with 30-50 g; 90% activity reduced
ICI, unpub., Oct., 1979	C. beecheyi in Calif. turf near industrial area controll-ed 100% after 35-40 g applied to 104 burrows

Reference	Subject
ICI, unpub., Nov., 1979	C. beecheyi activity reduced 90-97% at Calif. airport using 25 bait stations each with 500-g TALON pellets over 5 days
ICI, unpub., July, 1979	T. bottae showed 87% reduced mound-building activity at a Calif. golf course following 50-ppm milo bait applied by hand at 8 g per active tunnel
ICI, unpub., June, 1979	gopher activity at a Calif. football field was reduced by 94% at 21 days after trtmt. when 30 g of TALON placed in each tunnel system
G. Matschke, pers. comm., July, 1982	Geomys bursarius in Minnesota pastureland was studied with telemetry and closed-hole technique before and after trtmt. on 10-ha plots with 50-ppm milo bait using burrow builder; 81-88% reduction was noted
R. Marsh, pers. comm., Nov., 1982	Calif. rangeland trials against C. beecheyi fisheri used 6 lb/A aerial applic. of 100 ppm oat groats or 12 lb/A hand bait of 50-ppm oat groats. Control equalled or surpassed 1080
OTHER CROP SITUATIONS	
ICI, unpub., Mar., 1980	C. fereticaudus colonies on desert perimeters of soybean and cotton fields showed 70-89% reduced activity following 200-400 g TALON placement in bait stations or broadcast trials in Arizona

APPENDIX 12. USA Volid rodenticide orchard field trials (10 ppm brodifacoum pellet, pine or meadow voles, Microtus spp.).

Rate kg/ha	Application	Crop	State	Redn. activity (%)	Year	Reference
19	broadcast	apples	VA	98	1979	Byers 1980, 1982a
23	broadcast	apples	VA	89-98	1980	Byers & Merson 1981
11	hand bait	cherries	OR	100	1981	ICI unpub., Nov., 1981
11	hand bait	apples	WA	80	1981	ICI unpub., Nov., 1981
18	broadcast	apples	WA	100	1981	ICI unpub., Nov., 1981
6	hand bait	apples	NY	67-100	1981	Steblein & Miller, pers. comm., Jan., 1982
14	broadcast	apples	NY	99	1982	Steblein, Miller & Richmond 1983
11	hand bait	apples	NY	89	1981	Pagano & McAninch 1983
15	broadcast	apples	VA	91	1982	Merson & Byers 1983
11	broadcast	apples	VA	100	1984	R. Byers, pers. comm., Feb., 1985
3	handbait	apples	VA	89	1984	R. Byers, pers. comm., Feb., 1985