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AN INVESTIGATION OF THE RAT PEST PROBLEM IN QUEENSLAND CANEFIELDS: 6. CONTROLS AND CONCLUSIONS.

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SUMMARY.

Rat controls in Queensland canefields are reviewed.

Poisoning is discussed in detail and cage data are correlated with field results obtained by the use of marked rats. Results from simultaneous and consecutive choice tests were proved to be of little value.

An Intake-Toxicity-Factor (I.T.F.) was developed to cover all phases of cage poisoning associated with bait technology. For successful results in canefields, a rat poison must have a minimum I.T.F. of 3.5. Experimental evidence and extensive field work have shown that thallous sulphate, zinc phosphide, alcoholic extract of red squill and yellow phosphorus fulfill this requirement.

Poisoned food attractants, feeding stations and various baits are discussed. It was found that the chief factor governing successful field poisoning was rat movement. This factor cannot be controlled artificially by any known method of preparing or presenting poisoned foods. It is concluded therefore that poisoning, as a method of rat control, can only have very limited application.

The destruction of rat harbourage, drainage, barriers, the use of resistant cane varieties, deterrents, gassing, trapping and indirect control measures such as bounties and large-scale poisoning campaigns are discussed. It is concluded that economic control of rats in canefields will depend on the amount of crop protection afforded. Definite recommendations are given.

Emphasis is placed on the necessity for extensive experience for field workers dealing with cane rats, and also on the continuous collecting of reliable records and data.

A distinction is made between possible economic controls for normal times and those during a plague.

INTRODUCTION.

From a survey of the available literature on control of rats in the field it appears that, fundamentally, all countries have followed well-known lines. "Virus" and poison baits, track poisons, poisoned food at feeding stations or at pre-baited feeding stations, exclusion and/or protection in many forms, spraying, fumigation, gassing, trapping, tanglefoot preparations and methods based on ecological observations—e.g., destruction of harbourage or cover and drainage—have all been used either singly or in various combinations.

"The first point is . . . . that it is universally accepted as essential to successful control that the individual who desires to control any rodent must study his particular species continually and in detail, and especially must he check on results and worth of each effort at control. It would seem that this dictum as a whole is universal more in theory than in practice, for in accounts of many rat problems a knowledge of the animals concerned and checks of recommended controls are rather vague. Two other important considerations when formulating a control are the economics and agriculture of the crop with which the investigator is concerned" (McDougall, 1936). Therefore, a detailed review of methods used in the many field rodent control problems would not serve a very useful purpose. Storer and Mann (1946) have recently provided a bibliography on the subject.

Elton (1939) reviewed some aspects of rodent control as follows: "The economic problem of rodent damage to crops and trees is as old as the history of agriculture and forestry. Surveying the enormous control campaigns that go on in most agricultural countries of the world, one is conscious that the problem still remains unsolved, or is only solved with great trouble and expense. Indeed, sometimes it is a case of 'win your lawsuit and lose your money' . . . . practical problems of rodent outbreaks often appear to be simple in the form of their challenge, and most of the methods of attacking them have been of an empirical order, applied without any particularly deep knowledge either of the original problem or of the results of application . . . . . For this situation there are at least two reasons, apart from the generally quite valid one that practice cannot during an emergency wait for the matured results of long research. One is that the science of population dynamics is very young whereas the problem of rodent outbreaks is very ancient. The other is what one may call the political aspect of rodent control. The sequence of events during outbreaks has always been curiously the same since the time when the Philistines delivered up the Ark of the Lord in order to be freed from a frightful outbreak of field mice and of bubonic plague, up to the vigorous control campaigns of the present day. There was the unexpected and catastrophic increase of rodents, the damage, the outcry, the prayers for help, the action by authorities, and the eventual subsidence of the outbreak, almost always attributed to the action that had been taken. The only difference is that whereas the Philistines appealed to their priests and the Greeks to their god Apollo, the modern farmer prays to the Government, which applies a more material organisation to the problem.

The rodents always disappear eventually. Their disappearance coincides with control measures. Therefore the control measures have been responsible for the disappearance of the rodents. This line of reasoning has always seemed natural to authorities, and in most cases it is not unaccompanied by political convenience. One of the first contributions of population research has been to throw some doubt on the validity of this reasoning, which leads us to a consideration of natural fluctuations among rodent populations.'' The present author terms this type of work a token* control or a token campaign, i.e., doing something merely because something is expected or demanded and not because it has any actual or real effect on the pests themselves or on the economic lessening of crop losses. It is logical to include in this category mechanically applied controls associated with normal times and which are not subject to thorough checking.

The main concern with token controls and campaigns in this investigation is their due recognition as such; otherwise conclusions would be on an unsound basis.

REVIEW OF RAT CONTROL METHODS IN QUEENSLAND CANEFIELDS.

As stated earlier (McDougall, 1944a) ''few records of a detailed nature concerning rats in Queensland canefields were published prior to 1935.'' This certainly applies to control measures. Illingworth (1918) stated: ''Rats are by far the worst pest at Mossman. Soluble strychnine proved a failure, for the rats would not eat the bait. White arsenic has been used there with success; and 'Rat-nip,' a trade preparation containing phosphorus, also gave good results. These poisons were applied to pieces of bread and other kinds of food.''

Jarvis (1925) reported of the Herbert River district: ''An offensive campaign against rats has been started by the Colonial Sugar Refining Company under the superintendence of their officer, ... , the plan of procedure being to distribute poison-baits, manufactured by the Company, to 'controllers' in the various rat infested districts. These are supplied with a list of growers to receive the poison; and in the Macknade area a man acting under the controller's direction goes from farm to farm systematically laying the baits. Although supplied free of cost many growers will not take the trouble to do the work themselves unless their cane happens to be severely attacked. Many different poisons are being tried, but phosphorus bait is thought to have given best results so far. To prepare a good bait of this description, dissolve 2 oz. of phosphorus in 50 oz. of boiling water; stir in slowly 40 oz. of flour, and when this mixture is almost cold add, while still tepid, 40 oz. of molten tallow and 20 oz. of sugar. Definite evidence with regard to the effect of these poisons is not always forthcoming, dead rats being seldom found; but I believe good work is being done, although we cannot expect to see any decided results within a few months after application.'' Continuing, that author (*loc. cit.*) lists the current ideas

* The use of this term here is quite distinct from ''token pre-baiting'' as used by Chitty (1942).

on rat control as follows—"Briefly, these should consist in such common-place methods as (1) leaving wide headlands and keeping them clean; (2) poisoning the rats, especially on infested blocks when nearly cut out, and during November and December when rats are forced to congregate on smaller areas of uncut cane; (3) cleaning up breeding haunts, when possible, in the immediate vicinity of plantations."

In 1933 Gard recommended control measures agreeing in principle with those listed by Jarvis above, but with certain reservations: poisoning, trapping and destruction of natural food and cover should be combined as far as possible, and be in constant operation.

Cilento (1936) gave an excellent description of a two-year anti-rat campaign in the Herbert River district following the 1933-34 rat plague. Destruction of cover and bait poisoning were considered the chief essentials and according to Cilento: "An officer of the Shire Council at this stage reported officially to his council as follows—'A large proportion of the rats now being caught by me and forwarded to the Townsville Laboratory are of the young variety, and although I have been within the Shire since the plague scare of ten or twelve years ago poisoning and trapping rats, I have not at any time so much difficulty in trapping as at present.'" This reference to population composition is what could be expected for a natural population crash rather than the result of the campaign described. Also the timing of this job, the general technique, methods of checking and the concurrent natural abatement of the plague in other districts label it as the best available example of the "classic" form of token campaign undertaken in Queensland canefields.

Authentic accounts have been collected of the use of feeding stations, both straight and pre-baited,* in the Mackay district towards the end of the last and the beginning of this century. Also at this time, and as with feeding stations on occasions later, cut pieces of bamboo were used as containers for several types of bait, including phosphorus-bread. Strychnine and other poisons were sprinkled or smeared on pieces of split sugar cane as a form of rat bait.

On several occasions, mostly during plagues, a "tailing" or bounty system has been used to stimulate trapping.

Appendix 1 is a copy of a mill circular issued in a northern mill area during 1925. The barium biscuit concerned was made up as follows:—20·5 lb. barium carbonate, 42·5 lb. flour, 8·0 lb. pollard, 12·0 lb. tallow and 1·2 lb. salt. In other mill areas, a cereal-derivative-tallow-strychnine bait was also popular. For some years this type of circular, based on the best available literature on rat control, was used. To a great extent bait formulae, methods of manufacture and application followed closely those used in the sugar fields of the Hawaiian Islands (e.g., Pemberton, 1925; Barnum, 1930). In some instances mill officers specializing in general agriculture were responsible for helping the farmers to combat rats, and finance for the ventures was secured by voluntary levies.

* Pre-baiting has been sometimes called "free-feeding" and the principle has been used also for trapping; i.e., the traps, though baited, are not set over the first few nights.

In 1930, the idea of specialist officers was expanded; in most mill areas over the past decade, supervisors, directed by Pests Boards created and financed by compulsory levies on both growers and millers according to "*The Sugar Experiment Stations Acts,* 1900 *to* 1941," have been responsible, amongst other duties, for initiating and supervising rat controls. All Boards submit annual reports to the Minister for Agriculture and Stock and these usually appear in the Press. Extracts and quotations from some of the reports, as given in Appendix 2, present a fair picture of methods of rat control in canefields over recent years. During this period health officers have provided data, in the Annual Reports of the Health and Medical Services of the State of Queensland, on rat control in canefields. These are the results of inspections and collection of figures; the most comprehensive in any year along these lines is by Kennedy (1946), and is repeated here as Table 1.

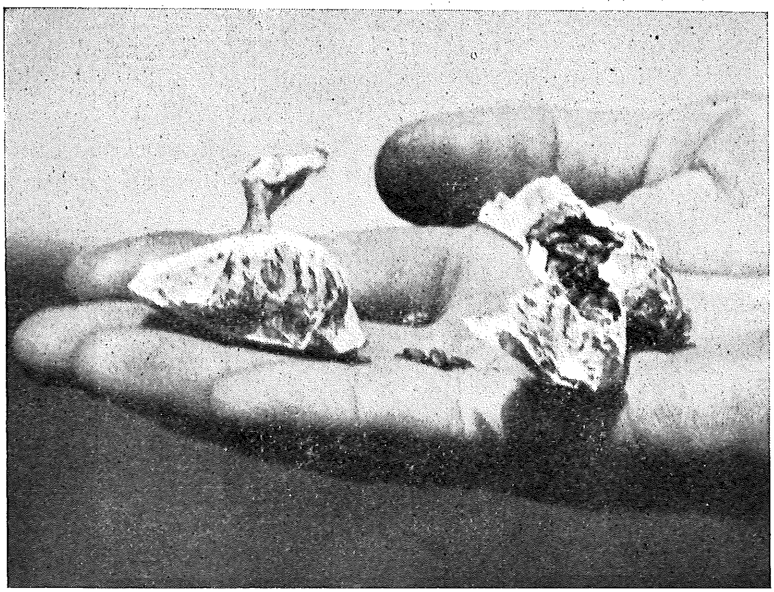
Table 1.

NUMBER AND TYPES OF BAITS USED IN EACH NORTHERN MILL AREA DURING 1945 (AFTER KENNEDY).

Mill Area.	Thallium Sulphate (Wheat).	Zinc Phosphide (Wheat).	Phosphorus (Bread).	Strychnine (Wheat).	Other.
Goondi	..	467,870	..	..	..
Mourilyan	..	..	10,080,000	..	15,000
Johnstone	..	Trial supply only	150,000	264,000	..
Tully	546,800	..	..	..	..
Babinda	..	..	1,562,240	..	..
Mulgrave	56,000	..	2,140,000	..	..
Hambledon	..	1,061,888	..	..	..
Victoria	..	1,240,000	..	..	..
Macknade	..	1,595,648	..	..	..
Mossman	..	862,000	..	..	..
Totals	602,800	5,227,406	13,932,240	264,000	15,000

In 1931, thallous sulphate was first used in Queensland canefields by the South Johnstone Pests Board. The use of this poison spread rapidly to other areas. For some years, including the 1933-34 plague, most areas (Tully with 1 : 290 was one exception noted) were using this poison at a strength by chemical analysis of 1 : 1000–1 : 1200. In 1938, a strength of 1 : 300 was recommended (McDougall, 1938) to the industry and used until 1944, when because of war-time shortage of the poison the last of the stocks was made up at 1 : 400. This author (*loc. cit.*) also pointed out that, for most present purposes in canefields, phosphorus-bread was as efficient as the more expensive thallium food bait and some Boards have used this poison extensively and exclusively. In 1945, zinc phosphide was introduced (see Appendices 2 and 3).

(*a*)



(*b*)

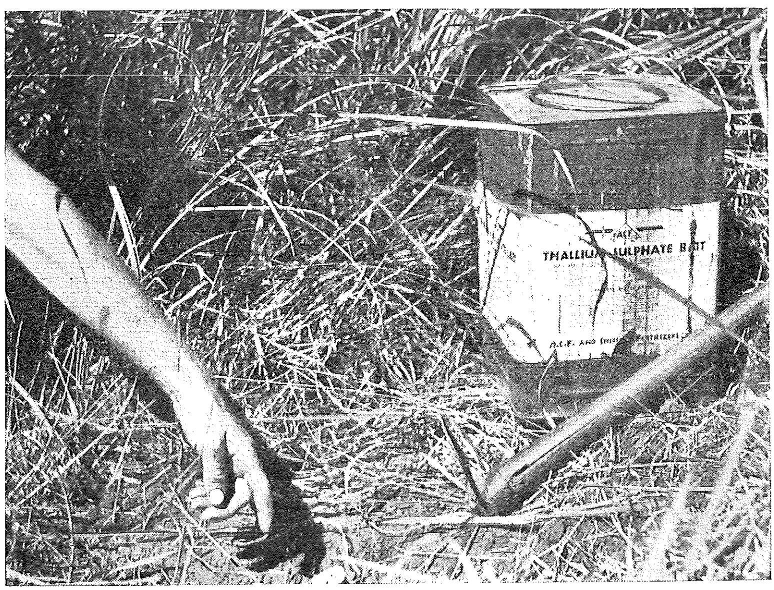


Plate 1.
Baiting of rats: *a*, packeted and waterproofed food baits; *b*, a prepared rat bait site.

Gard (1935) described a "Poisil" or handy wet weather bait, but this was not used extensively. The packeted food bait which has been used for some years is illustrated in Plate 1, *a* and *b*. After placing the wheat in the paper packet and screwing the top, the bait is dipped in paraffin wax for waterproofing. Following the success of linseed oil as a trap bait in 1934 (Gard, 1935), many of the baits are lightly sprayed or otherwise treated with this oil.

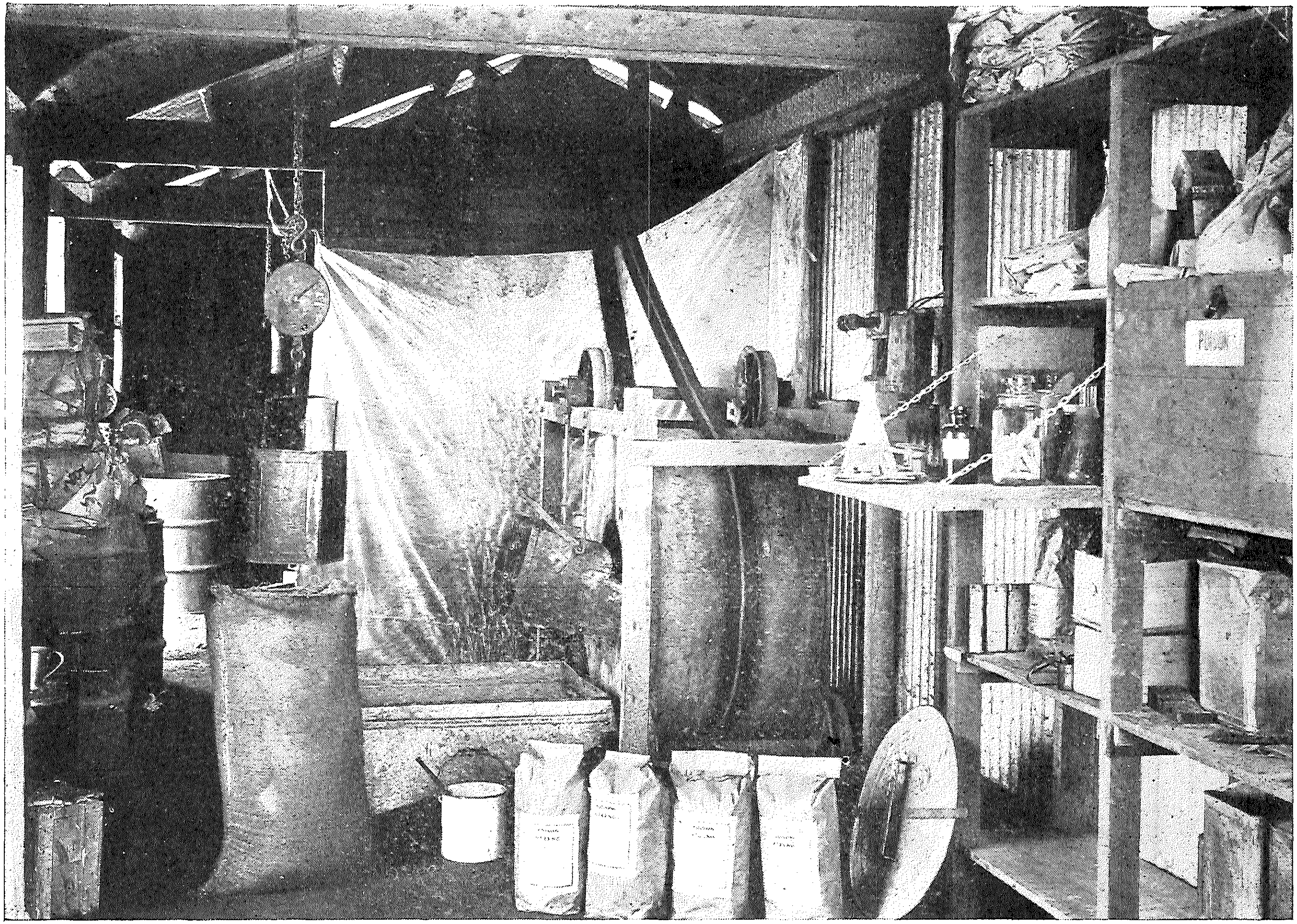


Plate 2.

Rat bait manufacture: facilities and equipment used by the South Johnstone Cane Pest and Disease Control Board. Note power mixer for the preparation of food baits and labelled bags of baits ready for distribution to farms.

Bait manufacture may be carried out under Board supervision, as shown in Plate 2. Costs are usually carefully watched by the Boards: see Fox (1937) for the manufacture of phosphorus-bread at a cost of 9·3 pence per 1,000 baits and Appendix 2 for the cost of thallium baits. Firms also provide food baits as specified, and some Boards purchase prepared phosphorus paste.

In some instances the $\frac{1}{8}$-oz. packeted thallous sulphate-whole wheat bait has been used at the rate of 600 per acre per application, and the phosphorus-bread bait as high as 3,000. Methods and rates of application differ in various mill areas and also according to estimated infestation. Baits may be scattered or put out on poison sites (Plate 1, *b*), and though spacing of baits was recognized at an early date (note Appendix 1), working methods have been empirical. When bait sites are used spacing is seldom less than 15 yards.

Headland baiting is still prevalent. This aspect is concerned with a very old concept of rat control in canefields and is discussed at length on pp. 111-2.

The author divides rat controls into two classes, direct and indirect. The former are concerned with methods undertaken in, or in close proximity to, particular fields; the latter, such as bounties and blanket or general poisoning campaigns, are aimed at pest populations as a whole over large areas.

Following is a brief summary of past efforts at control in Queensland canefields:—

1. Poisoning and clearing harbourage have been considered as essentials.

2. Methods of approach have been to a large extent indirect. Some of these methods are of long standing and have been used continuously, with varying detail, in some areas for more than 20 years.

3. The general influence of weather conditions on pest infestations has often been recognized. However, "take" and consumption of baits and degree of rat attack (often on a seasonal or yearly basis) have been the chief criteria for evaluating control measures. Occasionally line-trapping has been used. Small-scale testing of baits in the field has been by simultaneous poisoned food preference or choice tests.

4. During recent years the administrative side of rat control has been developed.

5. Storer *et al.* (1944) remarked that "rodent control operations, past and present, have involved huge expenditures—half a million dollars or more annually in California alone, in recent decades. Small sums have been spent on the study of control methods: in California this has amounted to about one per cent. of the control expenditure in recent years . . . . almost nothing has been set aside for actual study of the animals themselves." This state of affairs

is paralleled in principle in Queensland canefields, where up to the present little interest has been taken in research other than work best covered by the term bait technology. The possibility of obtaining a new poison or a new bait for general use is the usual conception of rat research along sound lines. This possibly is the best commentary on results expected and obtained from past efforts.

METHODS OF INVESTIGATION.

Population work (McDougall, 1946d) has been used as the basis of methods for studying controls, in particular the use of tagged rats and multiple grids. The approach is also the same, i.e., through work on small areas to the larger aspects. The inclusion of additional information on populations in this paper and the supplying of further evidence concerning earlier conclusions have been governed by convenience of presentation.

Detailed studies have been mostly concerned with *Rattus conatus* Thomas.

POISONING.

Though vast sums are spent throughout the world on poisoning as a major means of rat control there are usually grave doubts about the efficacy of the method. The author has attempted to collect evidence which will allow conclusions on what has been done, possible improvements to and reasonable expectations of poisoning as a method in lessening rat damage in Queensland canefields.

Early cage data used as the necessary adjunct to the field work reported in this paper have been given by the author (McDougall, 1944c). Later work along the same lines has not affected the main theme of this text, and is presented as Appendix 3.

Most of the field work has been done with thallous sulphate and yellow phosphorus.

Studies on Small Areas.

Initially this type of work covers settled populations and is also the first step in correlating laboratory and field data. Whole wheat was used where possible as the standard poison carrier; exceptions were with yellow phosphorus (prepared food or bread), zinc phosphide (cracked grain or prepared food), "109" and barium carbonate (prepared food). The primary method of presentation was by feeding stations.

Tables 2, 3, 4, 5, 6, 9 and 10 are examples of multiple or twin grids for poison studies; though such trials have been used under other circumstances, the author preferred if possible to place them in a population which had been under observation for some time. The reason is that a twin-grid system for any important treatment was always at least triplicated, and even a single

Table 2.

SERIES OF 10-YARD INTERVAL GRIDS, 10 YARDS APART; GRIDS A–D 4 x 5, GRID E 4 x 8.

Date. (1938.)	GRIDS.				
	A.	B.	C.	D.	E.
May 6–9	A.P.* = 24	..	..	..	..
May 10–12 ..	..	A.P. = 26	..	..	..
May 13–14 ..	..	..	A.P. = 12	A.P. = 18	..
May 12–18 ..	Wheat feeding station grid. Intakes : 13th 107g. ; 14th 140g. ; 18th (for 3 nights) 808g.		..	..	..
May 18–20 ..	..	..	Wheat feeding station grid. Intakes : 19th 37g. ; 20th rain spoilt wheat		A.P. = 46
June 22–30 ..	..	37 *R. conatus* tagged ; population movement particularly from 25th onwards when more young appeared	..	..	..
June 21–July 1 ..	..	..	Wheat feeding station grid. Intakes ; 22nd 325g. ; 24th (two nights) 901g. ; 25th 398g. ; 29th 582g. ; 1st 469g.		..
July 6–9	..	Feeding station grid. Intakes : 7th 184g. ; 8th 286g. ; 9th 967g.	A.P. = 31	..	..

July 27–29 ..	A.P. = 58	..	..	..	..
Aug. 1–9	..	..	Wheat feeding station grid. Intakes: 2nd 452g.; 3rd 685g.; 4th 610g.; 5th 629g.; 8th (3 nights) 1990g.; 9th 791g.	Feeding station grid with *thallous sulphate wheat* 1 : 1000. Intakes: 2nd 309g.; 3rd 282g.; 4th 243g.; 5th 174g.; 8th (3 nights) 414g.; 9th 13g.	..
Aug. 2–19	T.O.†: 16, 15, 14, 14, 5, 5, 1, 1, Nil, 3, 2, Nil, 2. Total 78 (77 *R. conatus* and 1 *M. littoralis*)	..	..	..	..
Aug. 10–19 ..	..	T.O.: 11, 11, 6, 3, 2, Nil, Nil. Total 33 (all *R. conatus*)	T.O.: 12, 15, 8, 3, 1, Nil, 1. Total 39 (34 *R. conatus* and 5 *M. littoralis*)	T.O.: 15, 7, 1, Nil, 3, 1, 2, Nil, Nil. Total 29 (28 *R. conatus* and 1 *M. littoralis*), 7 *R. conatus* exhibiting extreme alopecia	..
Aug. 19–26 ..	..	..	..	..	T.O.: 15, 10, 7, 4, 1, Nil, Nil. Total 37 (all *R. conatus*)

* A.P. = Apparent population. † T.O. = Trap-out.

Table 3.

SERIES OF 4 x 5, 10-YARD INTERVAL GRIDS, 10 YARDS APART.

Date. (1938.)	Grids.				
	A.	B.	C.	D.	E.
May 21–26 ..	A.P. = 11	A.P. = 12	A.P. = 10	..	..
May 27–June 2 ..	..	..	..	A.P. = 14	A.P. = 12
May 31–June 9 ..	Wheat feeding station grid. Intakes: 127, 154, 254, 322, 317, 401, 476, 580, 639g.	Wheat feeding station grid. Intakes: 241, 107, 281, 358, 447, 496, 449, 536, 550g.	..	..	..
June 9–13	Put out poison bait grid on 9th using $\frac{1}{4}$oz. 1 : 500 thallous sulphate packeted wheat, 3 to a place. On 10th: take 95%, consumption 23·6%. Repeated grid on 13th; take 98%, consumption 50%	Put out poison bait grid using standard phosphorus bread at 6 to a place. Take 50%	A.P. = 14 (A settled population)	..	..
June 15–July 1 ..	..	T.O. 4 (including two May tags), Nil, Nil, Nil, 1 (a May tag).. Nil until 1st July. Total 5 (all *R. conatus*)	..	..	..

June 15–18 ..	T.O. : 2 original May tags, Nil, Nil, Nil, 6, including 2 May tags. Total 8 (all *R. conatus*)	..	T.O. : 8, 4, 2, Nil. Total 14 (13 *R. conatus* and 1 *M. littoralis*)	T.O. : 9, 4, Nil, 2. Total 15 (all *R. conatus*)	T.O. : 5, 4, 3, Nil. Total 12 (all *R. conatus*)
June 24–29 ..	..	..	..	..	Wheat feeding station grid. Intakes : 85, 55, (2 nights) 77, 107g.
July 1–2	..	..	..	..	T.O. : 3 *R. conatus* and 1 *M. littoralis*
Aug. 17–20 ..	T.O. : 18 *R. conatus*	T.O. : 23 *R. conatus*	T.O. : 20 *R. conatus*	T.O. : 20 *R. conatus*	T.O.: 19 *R. conatus* and 2 *M. littoralis*

Table 4.

SERIES OF STANDARD GRIDS, 10 YARDS APART.

Date. (1938.)	Grids. A.	B.	C.	D.	E.	F. Slight rise in ground.	G.	Remarks.
Aug. 11–17	A.P. = 22	..	..	..	..	..	..	
Aug. 15–22	..	Whole wheat, F.S. grid. Intakes: 111, 159, 379, 41, 459g. (two nights)	Thallous sulphate treated wheat, 1 : 500. F.S. grid. Intakes: 112, 49, 3, Nil, 164g. (2 nights)	..	..	..	..	
Aug. 18–23	..	..	..	..	..	..	A.P. = 20	
Aug. 19–22	..	..	..	Phosphorus - bread at 6 a place on 19th. Take on 22nd 6·7%	..	..	..	Very little inter-grid movement
Aug. 23–27	..	Thallous sulphate treated wheat, 1 : 500. F.S. grid. Intakes: 148, 3, 28, 141g.	T.O.: 4, 11, 2, Nil, Nil. Total 13 (all *R. conatus*; 1 died in cage)	T.O.: 8, 3, 1, Nil. Total 12 (all *R. conatus*; 8 died in cages)	..	..	T.O.: 9, 3, 2, 1. Total 15 (all *R. conatus*)	
Aug. 30–Sept. 3	T.O.: 9, 5, 1, Nil. Total 15 (all *R. conatus*, 9 Aug. tags)	T.O.: 5, 4, 2, Nil. Total 11 (all *R. conatus*)	T.O.: 1 *R. conatus*	T.O.: Nil ..	T.O.: 9, 3, 1, 1. Total 14 (13 *R. conatus* and 1 *M. littoralis*)	T.O.: 5, 1, Nil, Nil. Total 6 (all *R. conatus*)	T.O.: Nil ..	

grid entails considerable labour. With a known population there is less chance of an upset in the purpose for which the grids are intended, and 97 satisfactory systems using the two major poisons only were observed.

For a number of years much of the trapping-out following test grid treatments with the slow-acting poisons, phosphorus and thallous sulphate, was done with live traps, and the catches were caged for observation. Latterly, this procedure was confined to phosphorus when the time interval between initial poisoning and trapping-out was greater than three days. From the results of many trials the cage death rate following thallium field treatment seldom exceeded 8 per cent., but for phosphorus this figure was as high as 94.8 per cent. in fairly large residual catches. Furthermore, there are sometimes rats which at the time of the trials cannot be poisoned (McDougall, 1946c).

Settled Populations.

Working with 1: 1000 thallous sulphate-wheat* the maximum kill obtained was 25·6 per cent. In Table 2, Grids C and D, the data presented for August must be considered indefinite for the technical reason that tag-trapping was not concurrent with the poisoning; however, the occurrence of alopecia in the large residual population is typical of attempts to poison with thallous sulphate in low concentrations. At 1: 500 the kill in the field is increased to a range from 40 per cent. to 84 per cent. (mean 73·5 per cent.) and 1: 300 is the lowest strength at which thallous sulphate on whole wheat, or in prepared food, will give the best possible field kills of *R. conatus*.

After working with thallous sulphate, twin or multiple grids with other poisons for which cage data were available (McDougall, 1944c) were set out. It was soon discovered that, as with low-strength thallous sulphate-wheat, the kills recorded in cages were not attainable in the field. Data from 43 preliminary twin grids using various poisons (see Table 7) were examined and eventually the Intake-Toxicity-Factor (I.T.F.) mentioned by inference in Part 3 of this series (McDougall, 1944c) and discussed more specifically at the first post-war Cane Pest and Disease Control Boards' Conference (McDougall, 1946b)—was developed during 1938. Over this period the I.T.F. was the fundamental basis of all recommendations by the author to the sugar industry on rat poisons; also every opportunity was taken to recheck this factor thoroughly for all poisons at the most efficient poison strengths, and for thallous sulphate, phosphorus and zinc phosphide over ranges including these strengths.

I.T.F. covers the two factors usually considered of the utmost importance in poisoning, viz., intake and toxicity. An I.T.F. of not less than 3·5 is required to obtain regularly the best possible kill in a settled *R. conatus* population. If all the active rats at the time of the field trial were capable of being poisoned, then the kill would be 100 per cent. If an I.T.F. of 3·5 is unattainable, then the poisons concerned are practically valueless in Queensland canefields. Only

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* The standard method of preparing thallous sulphate-wheat for field work was the simple one given in a previous paper (McDougall, 1944c, p. 28).

Table

TWO PARALLEL SERIES OF SIX GRIDS; FROM LEFT TO RIGHT A–F AND

Date (1938).	GRIDS. A.	B. (Slight rise in ground).	C.	D.	E.	F.
Sept. 15–17	A.P. = 36	A.P. = 16	..	..	..	..
Sept. 19–23	..	..	A.P. = 32 (All tagged)	A.P. = 30 (All tagged)	..	..
Sept. 21–24	T.O. on area covering both grids and 30-yard margins to north and south: 66, 19, 6, Nil. Total 93 (91 *R. conatus*, 32 tags, and 2 *M. littoralis*). Catch on actual grid areas, 25, 4, 2, Nil. Total 31 *R. conatus* (inc. 16 tags out of 40 releases) and 2 *M. littoralis*		..	..	..	..
Sept. 27–30	..	..	..	..	29 *R. conatus* tagged (inc. 5 tags from other grids). Rats moving	..
Sept. 27–Oct. 4	..	..	..	Whole wheat. F.S. grid. Intakes: 152, 211, 239, 1314g. (four nights)	..	Thallous sulphate treated wheat 1 : 1,000. F.S. grid. Intakes: 49, 120, 30, 122g (4 nights)
Oct. 4–11 ..	..	..	..	Thallous sulphate treated wheat, 1 : 1000. F.S. grid. Intakes: 282, 18, 0, 57g. (three nights)	Whole wheat F.S. grid. Intakes: 68, 133, 133, 750g. (3 nights)	..
Oct. 5–7 ..	..	..	..	..	..	"Dead" trapping 8, 3, 5. Total 16 *R. conatus*, inc. 3 tags from other grids
Oct. 11–15..	..	..	"Dead" trapping 9, 7, 5. Total 21 *R. conatus*, inc. 10 Sept. tags	"Dead" trapping 7, 6, 3. Total 16 *R. conatus*, inc. Sept. tags	Thallous sulphate treated wheat, 1 : 500. F.S. grid. Intakes: 127, 11g., Nil	..
Oct. 13–18..	..	..	..	..	..	..
Oct. 19–22..	..	"Dead" trapping 4, 5, 3. Total 12 *R. conatus*, inc. 2 tags from other grids	..	..	"Dead" trapping 5, 3, 3. Total 11 *R. conatus*, inc. 4 tags from other grids	..

5.

G–M with G adjacent to C. Five Yards between Grids.

GRIDS.						Remarks.
G.	H.	J.	K.	L.	M.	
A.P. = 30	..	..	..	..	..	
..	..	..	A.P. = 28	..	..	
..	..	..	..	..	..	
..	..	..	..	..	..	
..	..	..	..	..	..	
..	..	..	..	..	..	Rats commenced to move September 29. Eight September tags and one October tag from these series taken elsewhere during late October.
16 *R. conatus* tagged, inc. 4 Sept. tags. Rats moving	..	..	..	..	..	..
Thallous sulphate treated wheat, 1 : 500, F.S. grid. Intakes: 42, 18g, Nil	..	"Dead" trapping 11, 1, 4. Total 15 *R. conatus* (inc. 2 tags) plus 1 *Thetomys g. ultra*	"Dead" trapping 10, 1, 4. Total 15 *R. conatus*, inc. 5 Sept. tags	..	..	
"Dead" trapping 5, 4, 1. Total 10 *R conatus*, inc. 4 tags	Thallous sulphate packeted wheat baits, ¼ oz., 1 : 500 at 3 a place. On 13th, take 14·3%; consumption 10·8%. On 18th take 43·5%, consumption 14·2%	..	Thallous sulphate packeted wheat baits, ⅛ oz., 1 : 100 at 3 a place. On 13th, take 13·3%, consumption 12%. On 18th, take 38·3%, consumption 29·2%	Strychnine packeted wheat, ¼ oz., 1 : 160, at 3 a place. On 13th, take 25%, consumption 10·8%. On 18th, take 89·5%, consumption 45·8%	Thallous sulphate packeted wheat, ¼ oz., 1 : 1,000, at 3 a place. On 13th, take 25·8%	
..	"Dead" trapping 5, 4, 4. Total 13 *R. conatus*, inc. 3 tags from other grids	"Dead" trapping 4, 4, 5. Total 13 *R. conatus*, inc. 5 tags from other grids	..	"Dead" trapping 8, 3, 2. Total 13 *R. conatus*, inc. 6 tags	..	

Table 6.

Section A.

An apparently isolated 3-acre field of Saccaline sorghum was divided into three equal parts, and in the centre of each a standard grid was placed. A cordon of break-back traps was set wherever cover was available 20 yards out and around the three acres; no rats were taken.

Date. (1938.)	Part I.	Part II.	Part III.	Remarks.
June 15–17 . .	17 *R. conatus* " dead " trapped on grid area	23 *R. conatus* tagged on grid area (9 others killed by dogs)	10 *R. conatus* tagged on grid area	Early and continued movement of rats throughout the three acres
June 24	Phosphorus-bread at six a place throughout	1 : 500 thallous sulphate $\frac{1}{4}$-oz. packeted wheat at 3 a place throughout		
June 25	Take 16·4 %	Take 15·0 %, consumption 10·0 %	Continued to tag rats on grid area	
June 27	All excess baits picked up			
June 28–30 . .	T.O. : 14 *R. conatus*	T.O. : 23 *R. conatus*	T.O. : 7 *R. conatus*	

Table 6—continued.

SECTION B.

Four standard grids (A, B, C and D) were placed within two of the three acres. The other acre had been harvested and a standard grid E was placed in the centre of the regrowth.

Date. (1938).	Grids. A.	B.	C.	D.	E.	Remarks.
Nov. 9–23	Whole wheat, F.S. grid. Intakes: 2,490+* (2 nights), 5,660+* (4 nights), stations closed for 7 nights, 2,839g.	Whole wheat, F.S. grid. Intakes: 1,783+* (2 nights), 4,276+* (4 nights), stations closed for 5 nights, 2,755, 2,819, 3,837g.	..	..	..	
Nov. 22-Dec. 9	..	..	Whole wheat, F.S. grid. Intakes: 735, 1,826, stations closed for 4 nights, 2,015, 1,227, 6,362 (4 nights), 1,220, 1,318, 2,103, 1,101, 1,386g.	Whole wheat, F.S. grid. Intakes: 2,653, 2,413, stations closed for 4 nights, 513, 117, 6,544 (4 nights), 1,715, 1,473, 2,750, 1,318, 1,101g.	T.O.: 19, 8, Nil, Nil, Nil, Nil, Nil, Nil, Nil, Nil, Nil, Nil, 5, Nil, Nil. Total 32 *R. conatus*	Movement only slight except for a disturbance on night of December 6. Heavy movement had been recorded in this field during October
Nov. 24-Dec. 9	T.O.: 12, 12, 9, 3, Nil, Nil, Nil, Nil, Nil, Nil, Nil, Nil, 5, 3, 2. Total 46 *R. conatus*	T.O.: 10, 8, 5, 2, 2, Nil, Nil, Nil, Nil, Nil, Nil, Nil, 2, 2, 3. Total 34 *R. conatus*	..	..	T.O.: 19, 8, Nil, Nil, Nil, Nil, Nil, Nil, Nil, Nil, Nil, Nil, 5, Nil, Nil. Total 32 *R. conatus*	
Dec. 7–9 ..	..	..	16 *R. conatus* removed ..	22 *R. conatus* removed ..	..	
Dec. 14–15	T.O.: 4, Nil. Total 4 *R. conatus*	T.O.: 12, 1. Total 13 *R. conatus*	..	..	..	
Dec. 15–16	Whole wheat, F.S. grid. Intake 164g.	Whole wheat, F.S. grid. Intake 320g.	..	..	..	
Dec. 16–23	..	..	A.P. = 32	A.P. = 30	..	Only slight movement
Dec. 17–22	T.O.: 3, Nil, Nil, Nil. Total 3 *R. conatus*	T.O.: 3, Nil, Nil, Nil. Total 3 *R. conatus*	..	..	..	
Dec. 17–22	Heavy movement during January; on February 17–28 A.P.'s on grids ranged from 8 to 17					

* No excess wheat available, *i.e.*, amounts presented were eaten.

Table 7.

Poison.	Most Efficient Poison Strengths.	Mean Standard Intake of Bait (g./g.)	L.D. 50 (mg./kg.).	Intake–Toxicity Factor (I.T.F.).*
As_2O_3	1 : 20	·004 ± ·005	100 ± 10	1·90
$BaCO_3$	1 in 5	·009 ± ·00025	700† ± 75	2·57
$BaCl_2$	1 in 20	Poor and irregular	600 ± 50	At best slightly above 1·0
Yellow phosphorus ..	1 in 395	·004 ± ·0003	<1	>10
Powdered red squill (Sample A)‡	1 in 10	·035 ± ·0032	350 ± 50	<2
Alcoholic extract of red squill‡	1 : 10	·0065 ± ·0015	100 ± 20	5·9
Strychnine alkaloid	1 : 200	·018 ± ·002	No practical figure	Varying around 1·0
Thallous sulphate ..	1 : 300§	·037 ± ·003	30 ± 3	4·11
Alpha - naphthyl - thiourea	1 : 100 — 1 : 25	·012 ± ·008 > ·003 ± ·0005	109·1	$<1·09$
Zinc phosphide ..	1 : 50	·008 ± ·0004	38·4	4·02

* $\text{I.T.F.} = \frac{\text{Mean Standard Intake of bait (g./g.)} \times 10^6}{\text{Poison Strength} \times \text{L.D. 50 (mg./kg.)}}$: for poison strength where expressed in form 1 in x, x is the required figure ; if as 1 : x, x + 1 should be used. This concerns only high poison strengths

† Class (*a*) rats only (McDougall 1944c, p. 13).
‡ As specified (McDougall, 1944c).
§ See Table 8.

four of these in Table 7—viz., phosphorus, alchoholic extract of red squill, thallous sulphate, and zinc phosphide—can be efficient rat poisons. The author has been unable to correlate ratio of available I.T.F. to required I.T.F. (3·5) with percentage kills in the field by such poisons as As_2O_3, strychnine, &c. Firstly, the kills are very variable but seldom exceed 70 per cent.; secondly, the status of poisoning as a rat control (see p. 108) is such that, if in a settled population a poison does not give the best possible kill, then it has little real value.

Phosphorus is used commercially as a snap bait (McDougall, 1944c) with a recommended I.T.F. of > 10. Twin grids were set out, using this poison as a paste in prepared food, and also thallous sulphate on whole wheat and in prepared food, all at high I.T.F.—note Table 8 for thallous sulphate. Obviously these high I.T.F.'s have little additional effect on settled populations, since the best possible kill cannot be improved, but they are useful in studying intakes and secondary feeding with thallium (McDougall, 1944c).

Large I.T.F.'s can be attained with phosphorus and thallous sulphate, which are both slow-acting poisons. The author considers that the reverse reasoning—i.e., the slow action being responsible for the high I.T.F.'s—need not be sound. There are no detailed data available on I.T.F.'s well above those for economic use for alcoholic extract of red squill and zinc phosphide, and both of these in lethal doses near their L.D. 50 result in fairly quick death. The I.T.F. is a practical attempt at the physiological approach to poisoning, but it has not been dissected into components, such as taste or other immediate responses by the rat to the intakes of different poisons.

Table 8.

I.T.F.'s FOR THALLOUS SULPHATE AT VARYING POISON STRENGTHS.

Poison Strength.	Mean Standard Intake* g./g.	I.T.F.
1 : 3,000	·068 ± ·0045	·76
1 : 1,000	·067 ± ·0055	2·23
1 : 500	·038 ± ·003	2·53
1 : 300	·037 ± ·003	4·11
1 : 250	·029 ± ·0017	3·81
1 : 100	·028 ± ·002	9·33
1 : 50	·027 ± ·002	17·60
1 : 25	·025 ± ·002	32·05

* From McDougall (1944c, Table 21).

In recent topical literature it has been stated that one of the new rat poisons, "109," is more effective against *R. norvegicus* than against *R. rattus*. The latter, a climbing rat, is notoriously difficult to poison, and no evidence based on marked populations and different poison presentations has been given to support the above contention. With cane rats the variations in effective poisoning of different species are often due to behaviour and habit, but it is evident that the requisite I.T.F. for all poisons used by the author is constant, as far as the poison itself is concerned, against all murine species encountered during this investigation.

It is now possible to discuss various foods and adjuncts as poison carriers, the depression of intakes due to poison strengths, and the value of preference or choice tests based on acceptance as against twin-grid data, i.e., experimental results from direct population work.

With the aid of feeding stations and the careful checking of abnormal intakes (i.e., comparatively excessive feeding by animals other than rats), some of the results of two- and three-food cage preference tests, both simultaneous and consecutive (McDougall, 1944c), were repeated in the field. In cages consecutive tests are incidental to mean standard intake work; in the field the sequences, using chiefly whole wheat, crushed wheat, prepared food, maize, barley, hulled oats, rolled oats, peanut meal and bran, were varied in the 19

Table 9.

TWIN STANDARD GRIDS, 10 YARDS APART.

Date. 1939.	Grid A.	Grid B.	Remarks.
May 15–17	A.P. = 31. (19 tags)	..	
May 25–27	..	A.P. = 22	
June 20–22	A.P. = 26. (12 tags)	..	
June 27–July 5	Whole-wheat on an F.S. grid. Intakes : 475, 325, 402, 448, 2,605g. (4 nights)	..	A settled population.
July 5–8	Rolled oats on an F.S. grid. Intakes : 661, 716, 753g.	A.P. = 24	
July 11–15	T.O.: 16, 10, 3, 2 ; total 31 *R. conatus* (inc. 15 tags) plus 2 *M. littoralis* and 2 bandicoots	T.O.: 11 (traps disturbed by a pig), 7, 5, 1 ; total 24 *R. conatus* (inc. 5 May tags) plus 2 *M. littoralis* and 2 bandicoots	

Table 10.

THREE STANDARD GRIDS, 10 YARDS APART.

Date. 1938.	Grid A.	Grid C. (Check).	Grid B.
July 25–27	..	A.P. = 10 Rats steady	..
July 25–Aug. 2	Whole wheat, F.S. grid. Intakes : 32, 90, 140, 162, 698, 140, 90g.	Tagging continued. Influx of rate on night of 29th and then a sudden emigration	Thallous sulphate treated wheat, 1 : 1000, F.S. grid. Intakes : 90, 42 59, 35, 305, 100, 70g.
Aug. 3–6	T.O.: 5, Nil, Nil ; total 5 *R. conatus*	T.O.: 3, Nil, Nil ; total 3 *R. conatus*	T.O.: 2, Nil, Nil ; total 2 *R conatus*

multiple grids set out for this purpose. Table 9 is an example of a consecutive test with whole wheat the first, and rolled oats the second treatment. It was found that even for experimental purposes finely divided grain derivatives were difficult to handle in the field.

In simultaneous tests the order of preference was: (1) rolled oats, hulled oats and prepared food; (2) barley and wheat; (3) maize; and, much less attractive, (4) peanut meal and bran. The most significant difference, and much greater than in cages, was between (3) and (4), i.e. between favoured and secondary foods.

In consecutive tests intakes of oats were 3·7 to 33·4 per cent. (mean 15·2 per cent.) greater than those of whole wheat irrespective of order of presentation. Intakes of the secondary foods were negligible and much poorer than in cages.

Using the various favoured foods with poisons over a range of I.T.F. on twin grids the intakes did not control the kill, and the order of preference was of little consequence when the I.T.F. was low; when it was 3.5 or greater all poisoned food was equally effective.

Linseed oil was used on grain in a comprehensive series of twin grids incorporating both types of choice tests. In simultaneous tests with whole grain treated and untreated—e.g., wheat versus wheat plus linseed oil—there were no significant differences in intakes; and with other whole grains the addition of the oil did not alter the order of preference. In consecutive tests the field intake of food was not increased by the addition of linseed oil.

Other materials tried with the various foods were maize oil, coconut oil, oil of rhodium, coumarin, oil of aniseed, diacetyl, fish paste, several animal fats and oils, fruit essences, saccharin and sucrose. These also proved inffective as appetizers (McDougall, 1938) or attractants in settled populations. This was checked further by increasing the intervals of multiple grids and using wheat and thallous sulphate-wheat (1:300) sprayed with linseed oil and some of the other materials. Their use had no significant effect on either intakes or kills.

Both twin grids and choice tests were used in studying the effect of colouring food, and of colouring either or both the poisoned food and the bait wrapper. The spectral range was used and bait wrappers or packets were made of coloured cellophane and various grades of paper including brown wrapping and glacine. Baits dipped in paraffin wax, with or without linseed oil spraying, were also included in these tests. Attempts to treat paper with candle grease, and candle grease plus various oils, were not successful in laboratory trials. None of these bait technology aids had any appreciable influence on choice or on poisoning efficiency when a satisfactory I.T.F. was used, or increased the efficiency when I.T.F. was lower than 3·5.

Field tests with wetted grain and grain derivatives confirmed cage data as given previously (McDougall, 1946c).

Wheat and thallous sulphate-wheat baits stored over a number of years were tested respectively against new wheat and newly prepared baits on twin grids. There were no significant differences in either intakes or kills, and the use of a material such as linseed oil for the possible rejuvenation of old grain baits is therefore unnecessary.

Over a large series of twin grids with varying strengths of thallous sulphate-wheat, depressions of intakes were: 1 : 1000, approximately 10 per cent.; 1 : 500–1 : 300, approximately 50 per cent.; and $> 1:300$, very variable. Where it has been possible to keep feeding stations in settled populations under observation for some time peculiar happenings have been observed. Using a strength of 1 : 1000 gradual decreases in nightly intakes, e.g., from 490 g. to nil, were recorded over nine nights but the rat population had not decreased, original tags were still present and alopecia was evident. This is quite distinct from a sudden drop in intake when in two such instances the cause was traced to emigration of marked bandicoots. With a strength of 1: 500 there was often a progressive decrease until the fourth or fifth night, when an increase occurred followed by a sharper decrease; and rats were still present.

Working with poison strengths giving an I.T.F. of 3·5 (see Table 8), the decrease in intake is rapid: e.g., 350 g., 75 g., nil; and 493 g., 30, 7 g. Firstly, it is concluded that secondary feeding as defined earlier (McDougall, 1944c) is, for practical purposes, only a cage concept and is one of the results arising from artificial interference with the movements of the rats. The second conclusion, however, is more important, viz., that the greatest percentage of effective poisoning in a settled population is due to intake on the first night. This is also indicated by data from food feeding stations. It has been confirmed by work with poison feeding stations and baits using effective I.T.F., and by live-trapping and caging the catches from a series of twin grids on the first and succeeding nights after poisoning with 1 : 300 thallous sulphate-wheat; then a similar procedure commencing on the second and third nights for other twin grid series. Poison feeding stations and/or baits of the four efficient rat poisons at the required I.T.F. showed in twin grids that 83.7 per cent. of effective poisoning was due to intake on the first night. It follows that pre-baiting (either token or excess) of feeding stations does not contribute to successful poisoning in settled *R. conatus* populations.

In normal years there is no difference in effect between feeding stations and proven baits. The former entail more field labour than does baiting, which has always been recommended as more economical for attempts to deal with the sporadic infestations occurring in Queensland canefields. Feeding stations have the advantage of giving the operator an indication of the actual amount of poisoned food necessary to clean out the settled populations. Rats and other animals have the habit of picking up baits and dropping them elsewhere without otherwise interfering with them. Using twin grids with known A.P.'s and population compositions, and varying the number of baits per place from one to eight, it has been found that, unless there is excessive interference by other animals, at least three to four baits per active rat present are necessary to give the best possible kill. This remains true whether the $\frac{1}{4}$-oz. or $\frac{1}{8}$-oz. 1 : 300 thallous sulphate-wheat bait is used—the latter contains approximately L.D.50 x 4 for an average *R. conatus*—or the usual $\frac{1}{2}$-inch cube or only half this cube of phosphorus-bread. No experiments have been undertaken varying the multiple of L.D.50 in a bait below 4, as they were considered of little importance. The I.T.F. should not be altered and there is, for mechanical reasons, a limit to the smallness of the bait.

In many rodent problems frequent or periodic change of bait is recommended. When using a good thallium bait in settled *R. conatus* populations only interference by other animals has warranted a change of bait. On a number of occasions 1 : 300 thallous sulphate-wheat, both as baits* and at feeding stations,

* As an example:—Continued A.P. on check grid, 30; takes on treatment grid—1st night 148 (160 $\frac{1}{8}$-oz. baits set out), 2nd night 340 (360), 3rd night 287 (360); fourth to sixth nights rats including some original tags still present, A.P. 25; seventh and eighth nights poisoned with phosphorus-bread; ninth and tenth nights trapped out with live traps and five *R. conatus* taken—four of these died in cages within five days.

had disappeared in excessive quantities, while the rat population remained undisturbed. A change to the highly toxic phosphorus-bread killed both the rats and the other animals which had been taking the thallium baits.

During 1936-38 the hamburger bait as described by Spencer (1936) and Garlough (1938) was tried and found valueless against *R. conatus* and other cane rats.

During the springs of 1936 and 1939 poisoned water stations with 10-yard intervals were set out on the treatment grids of twin grid series. Poisons used were thallous acetate, the soluble strychnines, and alcoholic extract of red squill. Kills did not exceed 5 per cent.

Moving Populations.

During the winters of 1936 and 1939 the author trapped rats in many northern Queensland cane areas where baiting is practised extensively. For the obvious reason that the presence of baits probably indicated rat habitat, and particularly in those areas where baits had been set out on prepared sites in canefields just prior to trapping, traps were set out amongst the baits. Baiting rates encountered, including older baits, were as high as 2,000 $\frac{1}{4}$-oz. thallium baits per acre; catches were often fairly large, and in 1939 up to 30 *R. conatus* were taken over six nights on one standard grid. During 1936 the phenomenon of taking rats in numbers amongst fresh baits was not understood. When catches were mostly *R. rattus* and/or *M. littoralis* the bait failure was related to the difficulties of poisoning climbing rats, as stated in the literature. At this time also 1 : 1000 thallous sulphate-wheat was in general use, but in 1939 there was a change to a strength of 1 : 300. Though up to the present the tagging or marking of rats for study has been negligible in northern areas, it is now known by the recorded slowness of the trap-out in relation to the number of rats taken that moving populations had been encountered.

On many occasions in the Mackay district after trapping-out or poisoning on treatment grids and then setting out either fresh thallium or phosphorus baits, rats have moved in during the night without touching the baits. This is found to be common behaviour in moving populations, and rats marked off the grids the day before or from check grids have been captured on the poison grids under observation. Sometimes a proportion of these immigrants remain on poison grids but still do not take the baits to any extent. That some leave the grids without being poisoned is demonstrated by capture elsewhere.

Population studies (McDougall, 1946d) have shown that rats move off both trap and feeding station grids and this also happens with poison grids. Again observation on marked rats supplies the proof, as it was not possible to set out twin grids for the specific study of moving populations. Data on the relationship between rat movement and poisoning, which the author considers the key to an understanding of poisoning as a rat control, were collected during periods of general movements; on the other hand, twin grids for I.T.F. or other settled population work were not attempted during recent years except in autumn and spring.

When small sections of grids, such as 100 square yards, are completely enclosed by field cages it is not difficult to poison all rats (whether *R. conatus, R. rattus, R. culmorum*, or *Melomys* species) inside these cages with 1:1000 thallous sulphate-wheat. This has been done repeatedly while at the same time the remaining areas of the girds have failed to respond to 1:300 thallous sulphate-wheat or phosphorus-bread, when populations are moving. This is the first step from cages to field and again demonstrates the effect on poisoning efficiency of interference with natural rat movement.

Studies on Larger Areas.

Work on large areas consisted chiefly of detailed observations on marked rats associated with numbers of standard grids. With settled concentrated populations definite results can be obtained from a simple expansion of single grid data, but roving and scattered populations are of most concern in large-scale work.

For enclosed areas greater than the 100-square-yard field cage the author was dependent on apparently isolated fields cordoned by traps (see Table 6) and on discrete ecological units. The latter consisted of fairly large areas containing suitable rat habitats and populations and completely surrounded by unlikely rat country. Sometimes this isolation was broken by the rats but the cordon or guard traps recorded the fact.

From 1937 to 1944, 68 isolated fields yielded data on the effects of rat movements on poisoning over large areas. The isolation of 17 of these was broken, five by invasion during observations. The largest ecological unit used for any detailed work was 143 acres; detail decreased with increase of area and at 6-7 acres there was a sharp change-over in the type of work possible with a two-man trapping outfit. In fields under six acres contiguous grid systems could be operated, while in larger areas sample twin grid series were placed according to the type of habitat.

Working with units of one acre, isolated fields of three acres were found to be the largest areas to show the influence of enclosure on poisoning efficiency; at this limit the effect varied from 5 to 15 per cent., which can be regarded as negligible.

Large areas were always considered as a collection of small grids, irrespective of whether or not all potential grids were actually worked. Therefore with baiting in a moving population rats on some grids can be considered as moving off without touching the baits, and through or on to other baited grids without being poisoned. During the years when *R. conatus* was being studied, movement in isolated fields was seldom continuous over long periods, and its intermittent nature was usually well marked. However, in one field of $2\frac{1}{2}$ acres 450 active rats were known to be present and during one movement over three nights poisoning was carried out with 1:300 thallous sulphate-wheat; take and consumption appeared to be good but further tag-trapping showed that the kill during the movement was only 33 per cent. after making due allowance for the presence of the tag-trapping check grid.

Data on bait technology aids as previously mentioned, and set out for experiments in settled populations, were also collected for moving populations. None of these aids at any time had any effect whatsoever in increasing poison efficiency or in interfering with rat movements. Perhaps the biggest disappointment was the failure of the high I.T.F.'s or higher poison strengths of thallous sulphate to yield better kills than the 1:300 strength. This was also true for alcoholic extract of red squill and zinc phosphate; and it was found repeatedly that the highly toxic yellow phosphorus-bread snap bait did not give kills better than those given by good food baits in moving populations.

With *R. norvegicus* in Hawaiian canefields an attractant or lure such as linseed oil has proved of value in rat control by poisoning (Doty, 1945). Lubitz *et al.* (1941) investigated numerous claims for rat lures and, after preference tests in cages, reported that "it would seem from the results of this investigation that the value of some lures lies chiefly in the psychological appeal that their odors have to the customer rather than any supposed worth as pest attractants." In Queensland canefields data based on work with marked populations show very clearly that linseed oil and the other materials mentioned earlier are valueless as poison bait or poisoned food attractants. The successful use of linseed oil and corn oil as trap bait attractants has no doubt played an important part in the supposition that these oils would be a help in poisoning.

The trap-rat and food-rat relationships have been variously described and for the mathematical approach both have been referred to as collisions during search. In very dense *R. conatus* populations traps set, but either non-baited or baited with leather only, in grids with only 2-yard intervals do not catch many rats. The presence of food or of a so-called attractant as a bait is necessary for worth-while trapping. Rats will leave previously searched areas containing traps and food, but data from series of grids across highways of travel show that moving populations can be more often trapped than poisoned. Using alternate live trap and coloured food grids, examining the stomach contents of catches at stipulated times, and noting the colour of the pellets in and near the traps, it was found that rats had passed through food grids without touching the coloured food. During 1939, counts and observations were made on the condition of the leather-linseed oil baits in filled live and dead traps and also in sprung dead traps. Although in a population recorded as moving there are often some settled rats, these counts confirmed the general observation that in moving populations the sharp edges of new baits remain sharp, while in the more settled populations there is a rounding-off by rat chewing. It is concluded that a rat may investigate a baited trap and be caught, but while moving about it often inspects food with no resultant intake. On canefield evidence, therefore, there is in effect a clear distinction between trap-rat and food-rat relationships; search for food is a common factor in both, with inquisitiveness a fairly constant component even during rat movement.

As in settled populations, intakes during rat movement from poisoned feeding stations and take and consumption of food baits provided good negative evidence on kill, but the positive evidence was erratic and quite unsatisfactory.

Continuity of movement was always carefully checked when evaluating changes of baits in moving populations. These were found of little consequence provided there was no settling down just prior to a baiting.

The intermittent rat movements usually encountered and recorded on series of grids in partially tagged populations have helped to demonstrate a fundamental and important difference between the bait and feeding-station methods of presenting poisons to *R. conatus.* As previously stated, these rats will settle in a baited grid without taking the baits; for a good kill new baits are required. On the other hand, poisoned feeding stations will keep a grid or field clear of settled populations; after settling in, rats will feed from stations charged before the immigration. During 1938, four small fields, two baited and two with feeding stations at 10-yard intervals, were kept under observation by means of tag-trapping grids during the general winter movement and also in the spring. Though the feeding station fields were kept free of settled *R. conatus* populations there was still damage to cane by this species. This type of work was not sufficiently extensive and the rat movements and population densities encountered were not suitable for yielding data on the full economic possibilities of this use of feeding stations. Certainly in the fields concerned the work with feeding stations as a control measure was definitely uneconomic.

Scattered Populations.

Areas up to one-half square mile were searched by an experienced field worker. Signs of the presence of rats were noted, and on occasions some of the rats were marked. A second field worker then independently searched the area and poisoned either at prepared bait places or feeding stations, or by broadcasting. The first worker then checked on the poisoning. The allotting of tasks to each man was varied for the different trials. In areas of good harbourage with fairly even distribution of very low population densities the kills were poorest, but where some of the colonies present were easily seen a kill of the order of 10 per cent. of the marked rats was sometimes attained. When tagging rats from these colonies feedings areas could be clearly defined. The placing of baits along the pads between these areas and the used burrow openings, or in parts of the areas, did not consistently result in successful poisoning. Apparently the rat leaves the burrow intending to go to the feeding areas and takes little notice of baits encountered elsewhere. Of course, traps in place of baits yield better results.

The author found poisoning studies in scattered populations as unsatisfactory as population work under similar conditions (McDougall, 1946d). The basic difficulties are the large areas involved, the small number of rats actually contacted, and the large amount of work necessary to obtain even a minimum of data.

Discussion.

A full discussion on the poisoning of rats cannot be attempted at this stage, but some comment, based chiefly on data already presented, is desirable.

In any investigation of rat poisoning cage work is the usual starting point. Unfortunately, this has also been taken as the end-point for much of the rat work in Queensland cane areas, particularly in connexion with bait testing. On the few occasions when this testing has been taken further, percentage kill in cages and take or consumption of baits (feeding stations have not been used commercially during recent years) have been the criteria of efficiency. Using the effects of poisoning on partially marked populations as a working basis it has been found that cage work with poisons does serve a useful purpose, but only to the extent of providing data on I.T.F.

The factors governing successful poisoning in canefields are suitably prepared poisoned foods, methods of presenting these foods, amounts offered and rat movement. The preparation of many poisoned foods for rats is according to formulae and recipes, which often result in the so-called "fancy" baits, and depend for checking, if ever checked, on preference or choice tests. With these methods there is no doubt of statistically valid differences in bait value due to different ingredients; but when these various baits are tested in canefields* the differences are quite worthless.

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* During August and September, 1943, the author on behalf of the Australian Wheat Board and through the courtesy of the Commonwealth Council for Scientific and Industrial Research repeated some of the introductory cage work as for *R. conatus*, using *Mus musculus* L. from bagged-wheat stacks and other sources in the Warracknabeal district of Victoria. As well as poison work with food and water, rolled oats (wetted and unwetted), bran, pollard, wheat, cheese, scorched cheese, sunflower seeds, barley, fish, green lucerne, peanuts and split peas were tried in simultaneous and consecutive choice tests. Working with these small animals in lots of ten the normal intake of wheat per mouse per 24 hours was 213 g./kg., or approximately 3⅓ g. for an adult.

Possible attractants such as linseed oil, maize oil, oil of rhodium, diacetyl, fish paste and several animal fats were tested on wheat. In simultaneous choice tests with untreated wheat there was a significant preference for larded wheat, but attempts to use this preference for poisoning in wheat stocks resulted in complete failure.

The mouse populations encountered were sluggish, 9 of some 900 adult females dissected were pregnant, only small percentages of young and very old animals were present, and there was no discernible difference between behaviour and composition in wheat stacks and elsewhere. Obviously these populations were concentrations and were in no way connected with an upsurge. Mice populations did exist in the fields and to the author these concentrations helped to confirm a canefield observation, viz., that scattered populations are difficult to study or to estimate but they nevertheless do exist and are often only brought to general notice and appreciation through concentrations.

It is also of interest that numbers of mice, in stacks only, had swollen hind feet, which is popularly referred to as a disease. That this is correlated with a particular food habitat and is found only in the older rats suggests a trouble caused by an unbalanced diet rather than by a disease. The disorder has not been observed in cane rats either in cages or in the field.

A common method of evaluating a rat bait or poisoned food is to use it in rat-infested places and state the fraction or percentage of "successes." In canefields, success with poisoning depends to a great extent on rat movement, which, as far as is known, cannot be influenced by any variations in the preparation or presentation of poisoned food. The type and amounts of food offered, as will be pointed out later, depend on the economic background of the particular poisoning projects.

After considerable cage and field work with rat poisons it is concluded that the presumed vast possibilities which bait technology, based on choice tests, opens up are more apparent than real so far as actual economic results are concerned. It is comparatively simple to obtain the essential I.T.F. from cage work and the poisoned food may then be taken to the field with the assurance that field work may be commenced with the optimum poison-strength. However, it is a fairly common occurrence to use a weak strength in commercial control work and increase the poison percentage later—note Appendices 2 and 3 and Doty (1945) for accounts of the use of thallous sulphate and zinc phosphide in Queensland and Hawaiian canefields. The simplicity of poisoning as a rat control ends with cage work, and the ending is so abrupt that poisoning as a method of control actually has very limited uses. It is popular, but much of its popularity is due to demonstrations in cages, and population fluctuations; it fails when most wanted, i.e., when rats move.

On a number of occasions Pest Boards had concluded from observations and poor field results that thallium and zinc phosphide baits used from stocks must have deteriorated during storage. The author has bio-assayed some of these baits and also others specially stored under known conditions, and no decreases in toxicities or palatabilities were discernible, irrespective of the original poison strengths.

The extensive rat plagues of 1918, 1922, and 1933-34 in Queensland canefields destroyed the popularity of yellow phosphorus as a rat poison; thallous sulphate in general use has still to survive a plague.

A new rat poison, unless it is used merely for the sake of change as is so often required for token work, should not be hailed as the possible secret of rat control, but rather its particular properties, if any, should be considered as a possible help only, and with due regard to the requirements of the problem in hand. This point is discussed further on p. 121.

DISTURBING RAT HABITATS AS ADJUNCTS TO CONTROL.

The destruction of harbourage or ground cover and the provision of drainage are the two common recommendations along this line as aids in rat control in Queensland cane districts.

Harbourage.

The importance attached to the destruction of harbourage in cane areas is no doubt due to the emphasis in literature on harbourage in the distribution of *R. norvegicus* and *R. rattus* populations in city, suburban, and farm problems; to the low incidence of rat damage in canefields in seasons when harbourage is most easily destroyed; and to the fact that *R. conatus* is often associated with creeks and low places supporting ground cover.

The relationship between harbourage and rat populations, based on observations on marked rats, has been dealt with elsewhere (McDougall 1944b, 1946d); the main point is that harbourage can be extensive without the presence of large numbers of rats. It is often forgotten that the cane itself, which may cover many thousands of acres in the one district, is rat harbourage. During springs of 1936 and 1937 large areas of hill country in the Habana area were burnt off. After comparisons of populations in succeeding years in these areas with those in similar country not burnt off, it was concluded that this treatment has no effect on rat populations or their distribution.*

During normal years much country not planted to cane, but rat-infested during upsurges, is automatically kept clear of harbourage by grazing. This provokes the idea that grazing helps in rat control, but little thought is given to the grazing population which would be wanted for a comparatively brief time to keep this country in normal order under the weather conditions of a rat population upsurge. Gard (1935), without a critical consideration of the relationship of rat harbourage and pest populations and considering economic and practical aspects only, remarked: "Fencing and stocking creek areas is a very valuable practical means of reducing cover; however, in a climate like that of North Queensland it will be readily understood that grasses and other vegetation thrive rapidly, and except where farm implements can be used, large outlays of money would be involved in keeping them down." Doty (1945) stated: ". . . . viewing the rat-harbourage problem as a whole in the wetter districts of Hawaii, it is economically impossible to make any real progress towards clearing the large areas of wasteland beyond the immediate confines of the canefields."

Perhaps cane infestations by *Melomys cervinipes,* a rain-forest rat, illustrate more simply than work with *R. conatus* the role of harbourage destruction in lessening damage to cane. Many fields of cane adjacent to scrub and known to have been attacked by *M. cervinipes* in bad rat years have been watched and sometimes trapped during the past 10 years. Rat populations in these fields have been negligible but the cane-rainforest relationship has not changed. As yet no one has suggested the felling of rain-forest adjacent to cane as a

* During 1936-40, five completely closed wire-netting field cages, containing 5, 14, 11, 23 and 7 *R. conatus* respectively and altogether 11 *M. littoralis* (the five females were not breeding), were either purposely placed in cane and other harbourage prior to burning off or were accidentally burnt out. After being through the fires all *R. conatus* were found alive and well; even though one cage was not checked until two weeks after the burn. Two *M. littoralis* were killed. This type of experiment is rather forced for the small khaki rat, since the caging prevents normal movement and under natural conditions ground rat burrows may not always be so conveniently available as bolt-holes.

control of *M. cervinipes,* yet it would be more permanent* than the destruction of harbourage of other native species and would remove completely the habitat of the species concerned.

Farm hygiene, of which harbourage destruction is a part, is usually considered an important factor in the control of some rat species. The author has concluded, after extensive field studies, that this method of control has little true or practical value when dealing with canefield species.

Drainage.

Rats in large numbers are found even on steep hillside country during plagues. Over the following declines and in normal times *R. conatus* is, to the extent of the population available, certainly associated with wet areas. A number of these wet spots—in some instances with improvements such as cross drains above seepage areas, the gradual ploughing-in of hollows and surface drainage, including bedding—have been kept under observation for many years. Sometimes during population disturbances rats appeared for a short time in these places irrespective of drainage improvements.

Since 1931 the author has worked on the wireworm pest of cane, which also has years of peak infestations; following ecological studies, drainage was the chief recommended control (McDougall, 1934). The working of this control has been observed for many years, and where drainage is economically necessary for cane growing then some control of wireworms follows in normal seasons (McDougall, 1947). But in years of heavy infestations—i.e., following heavy and extended summer season rains—the value of drainage as a help in controlling the pests is considerably reduced. Furthermore, topographical alterations are not the only consideration in attempts to improve these low spots, as they are associated with definite soil properties. Even after being in beds with blind-end drains (see Clarkson, 1936) for over 10 years they remain wetter for longer periods than the surroundings, are more difficult to work into good tilth, and when drying-out commences lose moisture more quickly. In the Mackay district wireworms are a much more serious pest of cane than rats and require a much shorter period of wet weather at a critical time to become troublesome.

* When a ground cover such as rain-forest is removed the replacement question arises. This point has been closely observed over many years in connection with rat harbourage at Abergowrie (Herbert River district) and in the Habana area, Mackay. Actually the new ground covers have been of little consequence; the soil type and conditions have been found the important factors. Economically this fact has been of considerable importance in the central cane districts. Until recent years Badila, a variety very susceptible to attacks both by rats and by white grubs, was grown extensively on creek flats which originally were mostly covered by rain-forest. Fortunately the soil type is not basically suited to *R. conatus* or the provision of habitat for other native rat species. Large tonnages and areas of Badila have been grown on these flats, without being attacked by rats, in years when heavy rat populations existed in many parts of Queensland sugar districts, including other localities within the central cane districts and sometimes close to these Badila flats.

It is concluded that drainage, which as a help in rat control usually comes to the fore during plagues, is a type of ecological control which is only superficially sound. The weather conditions under which it might be of value make it both impracticable and uneconomic.

EXCLUSION AND PROTECTION

Barriers.

While tag-trapping, both clean and dirty* headlands up to 20 yards wide and two or three plough furrows filled with rain water were included as barriers in grid areas. The inclusion of the headlands depended on the extent of rat habitat on either side. Such barriers did not interfere with the journeyings of marked rats on the move, or in many instances with those of settled populations (note, for example, McDougall, 1947, Fig. 4).

When rats are present in large numbers—i.e., usually under wet conditions—it is not easy or economical to keep headlands constantly and reasonably clean, even if such work was of some value in lessening rat damage to the cane. Under efficient farming, headlands form only a minor portion of farm areas, and keeping them clean is part of farm hygiene, which has already been discussed.

In some cane areas considerable headland baiting is practised. A close study of the history and vicissitudes of rat baiting in Queensland canefields, as presented by the meagre literature and credible reports and accounts by those familiar with the subject over many years, sheds some light on the reasons for this type of work. Well-grown cane is not a crop in which work such as rat baiting can be undertaken with any freedom of movement, and this close or confined work has been avoided whenever possible (see Doty (1945) for Hawaiian opinions and the older methods of direct poisoning in that country). No doubt this is one of the reasons for the introduction and development of pre-baited feeding stations for cane-rat work and has also given rise to the concept that rats may create a feeding front.

Roebuck *et al.* (1944) found that the wood-mouse, *Apodemus sylvaticus* L., in its attacks on winter-grown cereals in England created a well-defined feeding front which was pushed forward as the attacks proceeded. Population studies (McDougall, 1946d) have demonstrated, however, that this phenomenon is not a characteristic of *R. conatus* behaviour. The only instances where headlands could be considered as feeding fronts occurred when they coincided with the edges of rat habitats containing settled populations, either nearly all in cane or mostly in nearby grasses, &c.

In some of the northern districts during 1939, trap-out grids in cane bordering on heavily poisoned headlands cutting across rat habitat or adjacent to rain-forest showed by the nightly catches that rat movement occurred across

* Headlands on which grass and other possible rat harbourages are allowed to exist are referred to as "dirty." Under normal weather conditions these may interfere with farm routine and also constitute an unnecessary fire hazard.

the headlands. In the Mackay district, when working with marked rats, the movements were quite definite across baited headlands and through feeding stations either on dirty headlands or in cane near clean headlands. It is concluded that poisoned headlands are not efficient barriers against cane rats.

Materials for use as structural barriers, mostly as field cages for experimental work, were given careful consideration. It was found that for *Rattus rattus* and *Melomys* spp. fully roofed half-inch-mesh galvanized netting cages were necessary. Fences of 3-feet wire netting suitably erected held only the older *R. conatus* and *R. culmorum.* When working with all ages of these ground rats the hessian fence previously described (McDougall, 1946d) was satisfactory over a short period.

Use of Resistant Varieties.

In cane districts it is common practice to refer to canes as rat-resistant or rat-susceptible. However, this does not simplify the task of defining and placing in order of importance the factors influencing varietal resistance to rats. A large number of cage tests was carried out using different varieties, but the value of the data obtained was negligible. Buzacott (1940) studied in detail a somewhat similar type of problem with the beetle borer (*Rhabdoscelus obscura* Boisd., syn. *Rhabdocnemis obscura* Boisd.); but with rats it is not practicable to set out formal field trials since there are many interwoven factors involved with which it is difficult to deal quantitatively. With varieties in strip plots, for example, an attack on one variety only raises the question as to whether some of the other canes would have been attacked if the variety damaged had not been present (note also McDougall, 1944a, p. 5). Frequently in randomized Latin-square variety trials, one or two plots only of a particular variety have been attacked by *M. littoralis.* Such an attack even to the extent of 58·7 per cent. rat-damaged stalks with an average of two bites per stalk did not, with careful harvesting, interfere with the normal statistical analysis of yields.

Bell (1938) briefly discussed varietal factors influencing rat attack on cane in Queensland, and later (Bell, 1939) published, as of interest, a stalk count of a rat-infested, randomized variety trial in the Innisfail district (Table 11). The species of rats concerned in the attack were not given, but results suggest *M. littoralis* as chiefly responsible.

Table II.

DATA FROM A RANDOMIZED VARIETY TRIAL IN THE INNISFAIL DISTRICT.

Variety.	Total Stalks Examined.	Per Cent. Stalks Damaged.	Comparative Hardness.	Remarks.
Q. 2 ..	2,407	0·33	18–20	Thin, free trasher
Q. 10 ..	2,110	11·85	4	Badly lodged, sweet cane
Q. 13 ..	1,711	0·29	12	Fairly free trasher, sweet cane

The present author, though dependent on extensive field observations for information on factors associated with varietal resistance to rats, has had the advantage of reliable data on relevant rat populations.

It was found that there is definitely no direct relationship between sweetness of cane and rat attack. Other factors considered were thickness of barrel, rind hardness, brittleness, trashing habits and growth characteristics such as sprawling, lodging and evenness of growth.

From 1937 to 1941 the hand penetrometer as figured by Buzacott (1940) was used extensively for comparing the hardness of the different varieties and also of the internodes of each variety. It soon became apparent that different growing conditions affected this factor, as well as many of the others. For example, Q.45 is a medium- to hard-rinded cane, but in wet spots, as inhabited by *R. conatus,* the lower two or three internodes, i.e., those most subject to the preliminary attack of this ground rat, were very soft. However, though this variety may taper under certain growing conditions, these lower internodes are usually stout. This means that the variety remains upright and is seldom lodged by rats for further attack. The natural lodging or sprawling of cane is also associated to some extent with growing conditions. These habits are normal for some canes, while for others they denote rank growth often accompanied by varying reductions in rind hardness. Further, some varieties, depending on soil type and seasonal conditions, tend to produce thin stalks in ratoons, and still others as both plant and ratoons yield uneven stools containing both thick and thin stalks.

The bite of a rat should be considered from the mechanical point of view. The effective force of the bite into a cane is limited by stalk thickness, rind hardness and the position for attack. Thick upright canes with hard rinds do not offer scope for the full power of the jaws of rats feeding from the ground. If Q.45, or a hard-rind cane such as Q.29, is artificially lodged in appreciable ground rat populations, attacks on the lodged stalks eventuate. Hardness itself does not deter rats if the food is in a favourable position for attack. In the spring of 1939, seven acres of Q.29 and P.O.J.2878 were planted against rain-forest on two farms in the Mackay district. Both varieties were allowed to stand over and in 1941 yields approximating to 60 tons per acre were obtained. Rats were present as scattered populations in these fields but did not attack the cane. Adjacent to one field, Queensland nut trees (*Macadamia ternifolia* F. v. M.) were growing, and on the ground the hard shells of these nuts chewed by rain-forest rats, after the manner illustrated by Doty (1945), were plentiful. Thin canes, irrespective of hardness, are rat-susceptible. This was very evident in the central cane districts when rats were last present in numbers, and thin canes such as Co.290, P.O.J. 213, Uba, D.1135, N.G.66, Rose Bamboo, White Bamboo, and fodder canes were often attacked by the pests.

The trashing habit of a variety does not affect the feeding habits of ground or rain-forest rats, but is an important consideration for *M. littoralis* (see McDougall, 1944b, p. 44).

So far only the actual biting of cane by rats has been discussed, and as the number of rat bites per stalk, which indicates rat attack only, cannot be positively correlated with economic damage, some other factor must be of importance. This is found to be brittleness. During 1938, six acres of M.1900 Seedling, one of the softest commercial varieties, were rat infested (360 *R. conatus* per acre, plus *M. littoralis*—estimated in September) with 55·4 per cent. rat-eaten stalks, averaging four rat bites per stalk. The crop was not well stooled and the stalks were exceptionally thick. The rat bites did not weaken the stalks sufficiently to cause much snapping and economic losses were negligible. Many of the thin canes are not brittle and though attacked by rats do not give the reduced yields of similarly damaged moderately thick, soft and easily snapping varieties, such as N.G.15 and S.J.2.

Favourable characteristics to look for in a cane to be grown in country infested with ground rats are non-brittleness, upright growth, thickness of barrel and hard rind. Free trashing is desirable if *M. littoralis* is likely to be present.

The practical aspects of the use of varieties in combating rats—i.e., the lifting of the project from the small experimental and observational scale to commercial practice—can now be considered.

The variety Trojan has been grown extensively in the Herbert River district since 1944, and, as well as increasing the sugar yield per acre, has been credited with helping to lessen rat attack on cane in that district (Appendix 2, Macknade Mill, 1944 and 1946). Over the past five years the Mackay seedling, Q.28, has spread rapidly in the central districts and has been grown as a standover; it has yielded nearly half a million tons of cane in one year. It is at present the staple variety in one area which has not experienced heavy rat-infestations since 1928, and it is also grown extensively in the Habana area, but from trapping results it is known that rats have not been prevalent in these districts for some years, and no damage by rats has been noticed. Despite the absence of damage, the thin, brittle Q.28 must be classed as a rat-susceptible variety. Varietal changes in recent decades in many Queensland cane districts have been comparatively rapid (Hughes, 1946, 1947). Though the author considers that, by keeping a check on rat populations, it is possible to give a warning of an impending rat plague, it would not be in time to affect appreciably the varietal percentages, even of plant cane, which would be subjected to the plague attack. Therefore, the use of varieties in combating rat attack over extensive areas is to a great extent fortuitous; it will depend on whether the best commercial canes being grown when plagues occur have any appreciable degree of rat resistance.

The recommendation on varieties in Appendix 4—written in 1938 for extension purposes, and not delving too deeply into factors concerned with varietal resistance to rats—is for the individual farmer, who should know from past experience the extent of the rat hazard on his farm as a whole and also in particular fields.

MISCELLANEOUS.

Deterrents.

The results with preliminary cage tests with deterrents (McDougall, 1944c, and Appendix 3) did not warrant extensive field work. Sulphurized linseed oil was brushed on to stalks of soft varieties used as "supplies," and creosote was used as a spray. Both were found valueless. In these exploratory attempts to study possible methods of application, the experience with knapsack sprays again demonstrated the difficulties of close work in a well-grown cane crop.

Gassing.

During 1937 and 1938, several attempts with Cyanogas A and carbon bisulphide were made to gas concentrated and scattered *R. conatus* populations in burrows in both cane and other ground cover. All burrow openings of 12 small isolated colonies or single burrows were dug in after pouring or spooning in the fumigants. Searching for the openings was time-consuming work. When the soil type was heavy and blind-end tunnels were short and not extensive, some positive results* were obtained. In the lighter soils gassing yielded poor results†.

This type of work was not tried over extensive areas. The use of twin grids would be limited, since dealing with the burrows on a treatment grid need not constitute an attack on the population system associated with that grid. Furthermore, the finding of the burrow openings in canefields and elsewhere is a difficult job and only high percentage kills in the preliminary trials would have warranted an expansion of the work. It was concluded also that gassing, as distinct from true fumigation where poison concentration and times of exposure are under some control, as a method of rodent control is basically unsuited to the problem under investigation.

Trapping.

In the past, but not during recent years, trapping has on many occasions (sometimes on a large scale) been given thorough trials in Queensland canefields. It is obviously uneconomic under most circumstances, and has also proved a failure during plagues (Gard, 1935, and McDougall, 1944b, p. 21).

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* Examples: (*a*) June, 1937. Two pints CS_2 poured down main opening and five openings closed. Seven dead *R. conatus* dug out. (*b*) Treatment similar to (*a*). Mother and 11 young taken in a blind-end tunnel which was being constructed towards the soil surface about 20 ft. from main opening, at the time of digging out. (*c*) 3 oz. Cyanogas spooned into each of three openings which were then sealed. Two live rats dug out later.

† In 1943 the opening up of mice-infested bagged-wheat stacks at Batchica (Warracknabeal district, Victoria) was observed a few days after gassing with Cyanogas. The author helped in the gassing with pumps and long hoses from the sides of the stacks. The kill was insignificant and of no economic importance; in one instance healthy young were noticed in a nest surrounded by the grey residue of the Cyanogas.

NOTES ON OTHER SPECIES.

Naumov, according to Elton (1942), has observed: "When several species of rodents live together, it does not follow that their populations are mixed at random together; there is a tendency for them to separate into different types of microhabitat—a situation of considerable interest epidemiologically, and . . . . practically, since control measures during minimum years must be economically applied to each species according to its habits." This certainly applies to conditions in Queensland canefields. Fields infested with *M. littoralis* have been treated with baits of proven efficacy at rates approximating to 3,000 baits per acre but with little diminution of attack on cane. "It is doubtful if poisoning as has been carried out in the past is even more than ten per cent. efficient against *M. littoralis* when in appreciable numbers" (McDougall, 1946b).

Until such times as more is known about this species little can be suggested for lessening attacks by it, other than the use of resistant varieties in situations where it would be economically sound. Population studies, especially on movement, are particularly desirable; but the author considers that a full study will be required eventually.

In Appendix 4, it is recommended that where poison baits are not satisfactory further authoritative advice should be sought. This concerns *M. littoralis* to the extent that, if this rat is chiefly responsible for the continuing attacks, a good cheap bait has failed, and economic loss is probable, then arrangements for the earliest possible harvesting of the affected cane should be made.

DISCUSSION.

After many years of experience, during which many field men have attempted to deal with rats in Queensland canefields, it is to be expected that several possible working hypotheses would have been evolved. The following, as stated by Garlough (1938), after his studies of rat movements, is also popular in Queensland cane districts: "In view of this rather wide range where cover is available, it is quite evident that to make much progress towards control it is necessary to prevent rapid re-infestation. Spot work is slow and expensive, because the same areas have to be treated so often." Another popular idea is that the mere killing of rats (or mice) is good work well done, and that continued artificial efforts at reducing the population as a whole are worth while. This outlook is illustrated in Plate 4, where a large number of dead mice from a bagged-wheat stack have been piled up in the foreground. The economic objective in killing these mice, most of which authorities agree would have died within a few weeks, was to save a stack; unfortunately the stack, riddled and broken down by mice, is to be seen in the background. These two ideas, with the laudable aim of prevention of damage, are the basis of the blanket poisoning or poisoning campaigns and other indirect controls undertaken in canefields.

Several authors, including Fracker (1937), have pointed out the difficulties of large-scale control projects having a general public interest and the differences between these and the "type of control measures which the private

Plate 3.
Setting out experimental grids in rat-infested grass harbourage during May, 1938.

Plate 4.
Mice killed in a wheat stack during a plague in Victoria. (Illustration from Winterbottom, 1922.)

grower or land owner can apply himself and which are purely voluntary" (Fracker, *loc. cit.*). It is generally agreed that large-scale efforts are not merely a simple multiplication of a small-scale control. Another difference between direct and indirect controls of rats in canefields is that the results of the former can be much more easily checked than those of the wider scope. It follows that it is unsound to recommend highly organized large-scale rat controls based on, say, cage work, unless results can be checked in the field.

Population studies have demonstrated that the estimate of damage and/or rat populations on a yearly basis, as used by Doty (1945) in connexion with pre-baited feeding stations in Hawaii, is not applicable to the rat problem of Queensland canefields. Figures for the numbers of baits distributed, such as in Table 1, are merely records of materials used and give no indication of their ultimate economic worth. It is considered that the best evaluation of indirect controls must be based on records by as many workers as possible at different observation posts over many years, and under varying conditions. These records should include actual cane and other monetary losses (as distinct from rat attacks only), areas infested, control methods and their timing, weather conditions, other relevant matters such as cane varieties, etc., *and* data on rat populations, including breeding and composition and, if practicable, some estimates of densities of settled populations. This course was suggested to the industry in 1946 (McDougall, 1946c, see Appendix 5), but for a number of reasons due emphasis was at the time not placed on rat population data. Up to the present, this work has been carried out in the Mackay district only, and results have been extended to the northern mill areas mostly by inference based on weather records, present knowledge of the habits and behaviour of the pests and reported rat attacks on cane.

The slope of the population decline on two Mackay farms as figured in an earlier part of this series (McDougall, 1946d, Fig. 9) is steep; that for an area or district is very much steeper. Those who have experienced a rat plague are usually impressed* by the vast difference in areas infested (which are related to rat numbers) during a plague and during the year following. There is no doubt that the natural rate of decline is extremely rapid and there appears to be little room for acceleration of the rate by artificial means. Nor is there any evidence that such an acceleration would be of economic value. In normal times, scattered populations have to be dealt with and it is known that, in spite of large-scale baiting, rats appear as the result of disturbances and according to expectations based on the weather. The upsurge period is a transition stage from scattered to concentrated populations, and has not been studied during these investigations. However, the same problems associated with poisoning at other times would have to be considered; for instance, large areas would still have to be worked on small grid intervals and rats would still move on to and away from the baits. In addition, all field operations would have to be carried

* During 1935, the author unsuccessfully attempted to collect *accurate* data on areas rat-infested in the Herbert River district during the plague of 1933-34.

out under wet conditions. Though many attempts have been made it has yet to be demonstrated that poisoning in any form will lessen or prevent a plague. The author has concluded that, on present knowledge, collective poisoning campaigns and attacks on rat populations as a whole are not of primary importance in lessening rat damage in Queensland canefields. In some districts these attempts at control have been carried on for so many years that they have become traditional. Superficially they appear to be effective, for after all there are many more years when rats are not prevalent and baiting seems to do some good, than there are years when rats are present in numbers and poisoning fails. The sudden deletion of poison campaigns from field programmes in these districts would be difficult.

A time commonly recommended for wholesale baiting is early summer after the harvesting, when cover is scarce. It is a period of movement under very harsh conditions, a fact which causes the natural deaths of many rats; further, scattered populations have to be dealt with and there is a long time period between possible kills and the redistribution of populations for attacks on cane during the following winter. It should be noted also that there is least movement amongst rats, and therefore greater chances of reasonable kills on the areas treated thoroughly, in autumn and spring than at other times. Furthermore, at these other times, when rats may for various reasons be concentrated on smaller areas, they still move in these areas and hence decrease the efficacy of baiting.

Recommendations in Appendix 4 for the best use of a poison in normal years against *R. conatus* in canefields are based on the following premises:

(1) Poisoning is essentially a direct control, i.e., one of protecting specific fields by immediate attention to these fields and close surroundings.

(2) The first signs of rat attack usually are seen before excessive rat movement occurs and are therefore a convenient and useful help to the field operative.

(3) As the value of poisoning as a control is limited, use of the cheapest proven bait is desirable.

(4) Poisoning is close and detailed work and requires considerable experience and effort.

The emphasis on experience with poisoning work points to another reason why keeping check on rat populations in mill areas and districts is desirable. It would help in "the training of at least one person in each mill area in rat control work; this cannot be done unless the persons concerned gain their experience by actually working with the pests in the field. The maximum benefit to be gained from the use of a rat control method, such as poisoning, will be obtained only when those doing the work have an understanding of the pests. Generalized recommendations and rule-of-thumb methods alone will not yield dividends'' (McDougall, 1946b). At the present time in most districts rat traps for use in guiding control work are either not used or do not exist. Often the first indication of rat attack on cane is obtained when the cane is burnt prior to harvesting. Experience should also indicate when to persist with poisoning and when to ''cut losses.''

In any serious attempt at poisoning, labour costs are a large item of expenditure, and therefore with this direct control the farmer himself must make the decision and the greatest effort. The following is an example of some work done. In 1943 a farm of 143 acres of cane in the Mackay district was rat infested; a total of 21 acres showed concentrated populations of an average density in June of 25 active *R. conatus* per acre. *M. littoralis* was not present and the farm was a well-defined ecological unit. In early June the whole farm was inspected thoroughly by experienced men; where signs of rats existed phosphorus-bread baits were placed on a 10-yard interval grid. This procedure was repeated in late August when the rats had settled down again. Total cost was £20 for labour and approximately £1 for bait. In August, kill plus natural deaths was estimated at 80 per cent. of the June population. Appreciable loss of cane weight and sugar content was not expected when the job was first considered; the purpose was to lessen nuisance value during difficult wartime harvesting operations. The author was doubtful if without poisoning it would have been necessary to pay one shilling per ton extra harvesting costs on 420 tons of rat-damaged cane, but the farmer was of the opinion that the money was well spent.

The Mackay Cane Pest and Disease Control Board has been able to work on a policy in agreement with Appendix 4, and provides farmers, on application, with phosphorus paste in tins free of charge. The farmer may discuss his problem with a trained extension worker, but makes his own decision as to whether he will use the poison. For many years the average cost of rat poison for the whole district has been under £1 per year, and most of the poison has been used for ''quietening'' house rats around stables and farm dwellings. It is appreciated that the present organization of some districts may require the ready-to-use but expensive grain baits.

Special efforts may be required during a plague. Any extensive use of feeding stations during normal times is obviously uneconomic, but during a plague this type of presentation, which is better suited than baiting for dealing with the I/F factor and populations settling down, may have to be considered. Until such work is actually studied under plague conditions data on both the technical and economic aspects will not be available. The necessity for the experimental approach, with the project kept quite separate from any commercial controls which may be attempted, cannot be too strongly stressed. Rat plagues come and go in Queensland canefields as elsewhere, but in the hurry and bustle of ''doing something'' the plague passes without leaving any worthwhile data on which improved future efforts can be based.

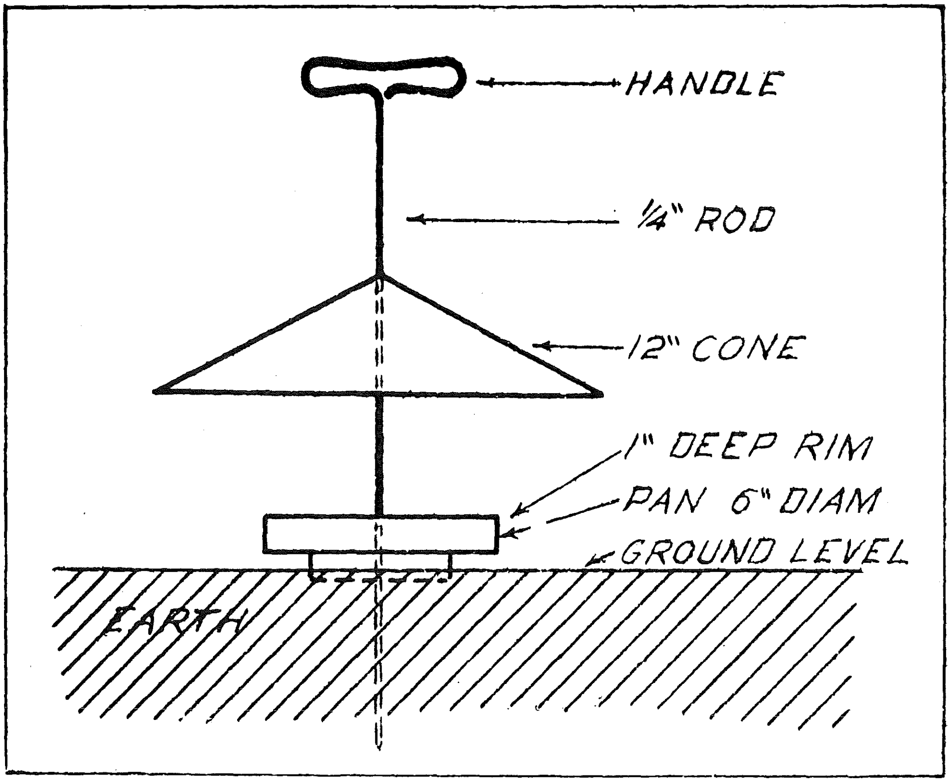

Figure 1.
A type of feeding station. (After Beeley, 1939.)

The following are a few of the problems which present themselves during plague periods. A suitable type of feeding station will have to be developed. That used by the author for experimental purposes meant approximately 68 lb. of equipment per acre, excluding poisoned food; the feeding station as illustrated in Fig. 1 was found too expensive, and unsuitable for canefields, where the stations must be of simple but stout construction. The proportion of ultimate damage to cane caused by the moving population before settling down has yet to be determined; furthermore, *M. littoralis* in many instances would have to be dealt with also. There is no thoroughly tested poison available which is suitable for use at feeding stations under plague conditions. No method is known of using yellow phosphorus other than as a snap bait; zinc phosphide is not suitable under wet conditions, and the expensive thallous sulphate allows excessive intakes of poisoned food*. The poison wanted for use during a plague is a reasonably cheap one with a high L.D.50, which may be used with whole grain, but with a

* In the Mackay district during the small upsurge in the spring of 1938, and also in 1939, intakes of 1 : 300 thallous sulphate treated wheat by rats and other animals present were as high as 25 lb. per night per standard grid. The feeding stations normally used were too small for the amount of grain required and the I/F was often greater than 1.

possible I.T.F. at high poison-strengths not greatly exceeding 3·5. Of the older rat poisons, these requirements warrant a detailed study of the alcoholic extract of red squill or fortified red squill. Though a scattered literature on this poison is in existence, squill has not been used or studied to any extent as a field poison in this country.

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REFERENCES.

BARNUM, C. G. 1930. Rat control in Hawaii. Hawaii. Plant. Rec. XXXIV. (4): 421-43.

BELL, A. F. 1938. Report of the Division of Entomology and Pathology. Ann. Rpt. Bur. Sugar Expt. Stas. Qld. 1937-38.

———. 1939. Report of the Division of Entomology and Pathology. Ann. Rpt. Bur. Sugar Expt. Stas. Qld. 1938-39.

BEELEY, F. 1939. Rat control. Rubber Res. Inst. Malaya Circ. 7, rev.

BUZACOTT, J. H. 1940. The relationship between hardness of sugar cane and varietal resistance to the beetle borer (*Rhabdocnemis obscura* Boisd.). Bur. Sugar Expt. Stas. Qld. Tech. Comm. 8 of 1940.

CHITTY, D. 1942. A relative census method for brown rats (*Rattus norvegicus*). Nature 150: 59.

CILENTO, R. W. 1936. The control of Weil's disease in the canegrowing areas. Appendix to Ann. Rpt. Dir.-Gen. Health Med. Serv. Qld. 1935-36: 56-9.

CLARKSON, F. E. M. 1936. Surface drainage in the Mackay district. Proc. Qld. Soc. Sugar Cane Tech. 1936: 51-6.

DIEKE, S. H., and RICHTER, C. P. 1946. Comparative assays of rodenticides on wild Norway rats, 1. Toxicity. Public Health Rpts. (U.S.A.) 61 (19): 672-9.

DOTY, R. E. 1945. Rat control on Hawaiian sugar plantations. Hawaii. Plant. Rec. XLIX. (2): 71-239.

DRAIZE, J. H., WOODARD, G., FITZHUGH, O. G., NELSON, A. A., BLACKWELL SMITH, R., Jr., and CALVERY, H. O. 1944. Summary of toxicological studies of the insecticide DDT. Chem. and Eng. News Sept. 1944: 1503-4.

ELTON, C. 1939. The natural control of rodent populations. Proc. 6th Pacific Sci. Congr. Vol. 5.

———. 1942. Voles, Mice and Lemmings: Problems in Population Dynamics. Oxford: Clarendon Press.

FOX, E. H. 1937. Some notes on rat control in the Mourilyan area. Proc. Qld. Soc. Sugar Cane Tech. 1937: 37-9.

FRACKER, S. B. 1937. Technique of large-scale operations in pest control. Proc. Entom. Soc. Wash. 39 (3): 41-58.

GARD, K. R. 1935. The rat pest in cane areas. Proc. Inter. Soc. Sugar Cane Tech. 5th Congr. 1935: 594-603.

GARLOUGH, F. E. 1938. Rodents in relation to sugar cane growing. Proc. Inter. Soc. Sugar Cane Tech. 6th Congr. 1938: 98-106.

HUGHES, C. G. 1946. The varietal revolution in south Queensland. Proc. Qld. Soc. Sugar Cane Tech. 1946: 66-8.

———. 1947. The varietal revolution in the Ingham district. Proc. Qld. Soc. Sugar Cane Tech. 1947: 103-6.

ILLINGWORTH, J. F. 1918. Monthly notes on grubs and other cane pests. Bur. Sugar Expt. Stas. Qld. Entom. Bull 8, p. 9.

JARVIS, E. 1925. Notes on Queensland cane insects and their control. Bur. Sugar Expt. Stas. Qld. Entom. Bull. 18, p. 11.

KENNEDY, J. 1946. In Ann. Rpt. Dir.-Gen. Health Med. Serv. Qld. 1945-46: 57.

LUBITZ, J. H., FELLERS, C. R., and LEVINE, A. S. 1941. Rat lures. Soap and Sanit. Chem. Feb. 1941.

McDOUGALL, W. A. 1934. The wireworm pest and its control in central Queensland sugar cane fields. Qld. Agric. J. XLII. (6): 690-726.

————————. 1936. Progress report on rat investigations. Proc. Cane Pest and Disease Control Boards Conference (Qld.) June, 1946 (Unpublished).

————————. 1938. Improved baits and poisons for rats. Proc. Cane Pest and Disease Control Boards Conference (Qld.) May, 1938 (Unpublished). Part published in Qld. Agric. J. L. (5): 625-7.

————————. 1944a. An investigation of the rat pest problem in Queensland canefields: 1. Economic aspects. Qld. J. Agric. Sci. 1 (2): 32-47.

————————. 1944b. An investigation of the rat pest problem in Queensland canefields: 2. Species and general habits. Qld. J. Agric. Sci. 1 (2): 48-78.

————————. 1944c. An investigation of the rat pest problem in Queensland canefields: 3. Laboratory experiments on food intake and toxicity. Qld. J. Agric. Sci. 1 (3): 1-32.

————————. 1946a. An investigation of the rat pest problem in Queensland canefields: 4. Breeding and life histories. Qld. J. Agric. Sci. 3 (1): 1-43.

————————. 1946b. Notes on the rat problem. Proc. Cane Pest and Disease Control Boards Conference (Qld.) Aug., 1946 (Unpublished).

————————. 1946c. Records. Proc. Cane Pest and Disease Control Boards Conference (Qld.) Aug., 1946. (Unpublished.)

————————. 1946d. An investigation of the rat pest problem in Queensland canefields: 5. Populations. Qld. J. Agric. Sci. 3 (4): 157-237.

————————. 1947. Investigations in the control of wireworms (*Lacon variabilis* Cand.) in canefields with "Gammexane." Qld. J. Agric. Sci. 4 (4): 140-50.

PEMBERTON, C. E. 1925. The field rat in Hawaii, and its control. Expt. Sta. Hawaii Sugar Plant. Ass. Entom. Ser. Bull. 17.

ROEBUCK, A., BAKER, F. T., and WHITE, J. H. 1944. The grazing of winter cereals by the wood-mouse (*Apodemus sylvaticus*). J. Ani. Ecol. 13 (2): 105-9.

SLADE, R. 1947. The new British insecticide. The gamma isomer of benzene hexachloride. Chem. Trade J. 116 (3017): 279-81.

SPENCER, H. J. 1936. Quarterly narrative report, Jan. 1-March 31. AAA. Rat abatement project—Hawaiian Is. Control Methods Research Lab. co-op. with Hawaiian Agricultural Experiment Station. (Unpublished.)

STAMMERS, F. M. G., and SAREL WHITFIELD, F. G. 1947. The toxicity of DDT to man and animals. Bull. Entom. Res. 38: 1-73.

STORER, T. I., and MANN, P. M. 1946. Bibliography of rodent control. Nat. Res. Counc. Insect Control Comm. Rpt. 182.

WILSON, G. 1946a. Alpha-naphthyl-thiourea ("ANTU") as a rat poison. Proc. Cane Pest and Disease Control Boards (Qld.) Conference Aug., 1946. (Unpublished.)

—————. 1946b. "1080" (sodium fluoracetate) as a rat poison. Proc. Cane Pest and Disease Control Boards (Qld.) Conference Aug., 1946. (Unpublished.)

WINTERBOTTOM, D. C. 1922. Weevil in Wheat and Storage of Grain in Bags: A Record of Australian Experiences during the War Period (1915-1919). Adelaide: Government Printer.

APPENDIX 1.

POISON.

"Barium Biscuit No. 2."

How to Poison Field Rats.

1. Handle biscuits as little as possible.

2. Rub about six drops of Aniseed Oil over the hands before touching the bait, so as to smother the human odour. Failing the Aniseed, spread biscuits with a spoon.

3. Scatter bait at the rate of six of the $\frac{1}{2}''$ by $\frac{1}{2}''$ by $\frac{1}{4}''$ biscuits every five yards, wherever rats are likely to be found, such as along dirty headlands, round swamps, gullies, drains, etc.

If rats are damaging standing cane, spread the bait through the block as follows:—

Walk (or ride) round the block scattering the bait about the headland and into the cane near the edge of the block at the rate of three biscuits every ten yards. Then go up every twentieth row scattering on each side at the rate of six biscuits every ten yards.

Note.—It takes only one-third of one of the $\frac{1}{2}''$ by $\frac{1}{2}''$ by $\frac{1}{4}''$ biscuits to kill a rat.

It takes about three biscuits to kill a fowl.

It takes about eight biscuits to kill a man.

It takes about fifteen biscuits to kill a dog.

From this it is seen that even if stock pick up a few stray biscuits while feeding, they probably will not be affected. However, farmers, are advised not to lay baits on land where stock will be feeding, nor too close to the homestead or stables.

4. Arrange with your neighbours to lay baits on adjoining land at the same time as yourself, to get the best results.

APPENDIX 2.

Extracts and quotations concerning rat controls from the available formal Annual Reports of Cane Pests Boards in Northern Queensland.

Mossman.

1944.

"The rat poison position improves."

"Experimental results proved that this poison (zinc phosphide) is nearly as good as thallium."

1945.

"Zinc phosphide: some adverse reports, but on the whole is considered a good substitute for thallium."

Hambledon.

1942.

More rats than usual reported.

1943.

Rats again troublesome in 1943.

"As in previous years, farmers have been advised to carry out frequent and systematic poison campaigns, to trap regularly, and to destroy all natural cover on their farms."

Mulgrave.

1942.

"An abnormal increase in spite of systematic poisoning . . . ." £569 15s. 6d. spent on rat baits.

1943.

652,000 thallium sulphate-wheat baits and 341 lb. of prepared phosphorus paste were used.

1944.

£158 7s. 9d. was spent on poisons.

"Heavy damage was the rule from this pest in the wetter sections of the area."

"Owing to wet conditions and lack of man-power farm sanitation in infested areas was neglected, thus conditions were most suitable for this type of pest."

South Johnstone.

1940.

530,000 thallium sulphate-wheat baits costing 12s. 6d. per thousand were used.

1942.

345,000 rat baits, costing £215 14s. 5d., were distributed.

"Rat damage was slight in the early half of the year but suddenly became serious from June onwards."

1944.

"Rat damage was serious."

957,500 whole wheat baits (one-quarter with strychnine, three-quarters with thallium sulphate), costing £577 19s. 1d. were used; also flour-corn-fat as a bait base.

"Ordinarily it is not usual for an authentic loss of a hundred tons of cane from one farm to occur in this area, but it is considered that this year several farmers lost over a hundred tons (each)."

1945.

720,000 strychnine baits at a cost of £529 16s. 3d. were distributed.

Macknade.

1935.

"In my report to you last year I stated that a reduction in the rat infestation could be expected in 1935 and judging by the lower percentage of rat eaten stalks delivered to the Mill, this did occur.

"The main factor contributing to the reduced infestation was dry weather conditions, particularly during the normally wet months December, January and February. However, I consider that we can justly claim that the general effort made by the farmers in the matter of trapping and cleaning up in 1934 and the effective poison drives conducted by your Board at the conclusion of the crushing season also played a material part. It was unfortunate that we were not in a position to follow up these drives, for despite a reduced infestation an aggregate of well over 10,000 tons of cane was lost, and it is logical to assume that this could have been reduced."

"Our programme for this year begins with three poison drives with thallium baits during the first six months and is at present operating. Our plans have been worked out on the assumption that there are no migrations of rats in large numbers over long distances and that those now in and around cane fields are the ones which will mainly cause the damage to crops. In my opinion, however, the possibility of large migrations is a subject calling for immediate investigation."

1936.

Six general poisoning campaigns carried out. Consumption was as follows:—

December-January 37%; May 52%; June–July 53%; August–September 41%.

"Throughout the work it was strongly indicated that the main urge actuating movement of field rats is the seeking of adequate protection and cover."

1937.

"Four general poison campaigns were conducted throughout the year using waterproof thallium sulphate baits . . . . ." "Last year ⅛-oz. packages were adopted in lieu of ¼-oz. packages previously used, and we consider that these have tended towards a more economic distribution of the poisoned grain." "Approximately three million baits were distributed in 1937."

"Natural control of rats was facilitated by dry weather conditions up till December, 1936, but appreciable rains at that time promoted growth of grassy harbour, and in January such harbour was more extensive and suitable to rats than during the similar period of 1936."

"A series of trapping tests throughout the district were conducted in February, 1937, with the surprising result that from 1,300 sets the catch only amounted to five per cent. A small population was therefore indicated. However, subsequent experience leads us to the conclusion that these trappings did not truly indicate the order of young generation rats."

"I would like to compliment the growers on their work with poisons during 1937, and to state that a higher standard was attained than during the previous year, particularly with regard to poisoning in the actual cane. However, there was a definite tendency to neglect poor ratoon crops in favour of better grown cane, and many were inclined to argue that the baiting of the variety P.O.J. 2878 was unnecessary, as it is generally less affected than most other canes grown. The fallacy of these practices is readily apparent, for breeding grounds are thus created for the re-infestation of crops that have been thoroughly treated. We are endeavouring to eliminate these practices, and appeal to the growers for their full co-operation in this regard."

1938.

"Conditions favourable to breeding and rapid multiplication of the rat population began at the end of November, 1937. At this time good rains occurred which stimulated the growth of grasses and harbourage. These conditions prevailed until the beginning of March, 1938. During March and April the weather was abnormally dry, and this provided a natural check. However, this was again offset by a period of regular rainfall during winter and early spring which rendered the clearing away of grasses and harbourage extremely difficult."

"Four general poisoning campaigns were carried out for the protection of the 1938 crop, and these were augmented by extra sectional and individual poisonings where necessary. The campaigns took place during the following periods:—December–January, February, April and June. The one in April was on a smaller scale than the other three and was directed mainly to the places where the heaviest bait consumption had occurred during the February campaign. From our systematic checking of the poisoning throughout the year, we estimated that the consumption of poisoned grain amounted to 38 per cent. during the December–January campaign, 37 per cent. during the February and April ones combined, and 48 per cent. during the campaign in June."

"The approximate number of ⅛-oz. baits laid in the poisoning for the 1938 crop was 2,282,000, whilst for the campaign at present in progress some 449,000 baits were issued."

1939.

2,330,000 thallium sulphate whole-wheat baits used. This is approximately the same amount of bait used as in 1938 but the poison strength was increased to 1:300. Cost of baits was £1,688.

1940.

"Weather conditions were generally unfavourable and the degree of natural control was high."

1,670,000 ⅛-oz. thallium sulphate-wheat baits used.

1941.

2,300,000 $\frac{1}{8}$-oz. thallium sulphate baits were distributed. Consumption was: first quarter 9.3 per cent., second quarter 14.5 per cent., third quarter 20.0 per cent., and fourth quarter 24.7 per cent.

1943.

Rat damage was more serious than for some years.

''Natural conditions in conclusion of 1942 and beginning of 1943 favoured rat populations.''

Bulk of baits used was thallium sulphate whole-wheat at a strength of 1:400. Total number of baits was 1,211,000.

1944.

''It cannot be claimed that general control measures were responsible for this reduction (comparing damage for 1944 with similar figures for 1942 and 1943) because much less poisoning was accomplished than usual due to the exhaustion of thallium baits and our inability to obtain suitable substitute baits until a few weeks ago.'' ''Perhaps the main factors were the dry spring and summer of 1943 and a light wet season.''

The new variety Trojan provided 50 per cent. of the crop and yielded 6.3 per cent. rat damaged stalks; other varieties yielded 13.2 per cent. rat damaged stalks.

General distributions were made in February and September; 541,000 thallium and wheat baits and 237,310 arsenic and wheat baits were used.

1945.

Two general campaigns undertaken during January, May and June.

''The satisfactory control achieved in 1945 speaks well for the efficiency of the new zinc phosphide poison baits.''

1946.

''The extremely light rat damage created a further record for cane destroyed and the estimated loss, 479 tons, was much less than the record low figure established in 1945.''

''Control measures carried out in 1946 contributed much to the foregoing results, but it is well to bear in mind that the severe drought was an important factor.''

''The resistance of Trojan to rat attacks also contributed in no small measure and the large representation of this variety in the crops is a valuable adjunct to control.''

''The position is very satisfactory at present, but there should be no tendency to relax because rat control calls for continuous effort and change in weather conditions may quickly swing the balance in favour of heavy rat infestations.''

''Three general poison issues were made during the year, in January, again in April and May, and in August. Additional poisoning was carried out on various farms, when necessity arose, to check localised infestations. Altogether approximately 1,571,070 zinc phosphide baits were used.''

''Zinc phosphide was again satisfactory. In several instances where growers sought assurance as to its killing powers, demonstrations with caged field rats were made. This poison, however, soon deteriorates when the poison packets are opened and the baits are moistened. For this reason your Board is anxious to change to a better wet weather poison as soon as possible.''

Victoria.

The general ideas behind controls are similar to those given in the Macknade area; difference between these areas is in detail only.

1941.

£1,004 9s. 8d. spent on rat poisons.

1942.

Thallium sulphate-wheat (1:300) used at a total cost for baits of £305 13s. Two general campaigns undertaken.

1943.

Poison baits cost £910 13s. 2d.

Two general campaigns undertaken, one during the wet and the other at mid-season.

"Thereafter, on account of weather conditions and the shortage of thallium poison baits, it was decided to hold all remaining stocks of poison for a wet season campaign in 1944. From August until the end of the year conditions were abnormally dry and this exercised an unusually good natural control."

1944.

Compared with 1943 there was a marked decrease in rat damage.

"This is attributed to weather conditions and extra man-power being available for destruction of harbourage rather than the direct result of poisoning, as much less poisoning was accomplished due to exhaustion of thallium stocks, and the difficulty of obtaining a satisfactory substitute."

Two general campaigns undertaken; one during the wet season and the other at the close of crushing. One ton of thallium-wheat baits and one ton of zinc phosphide-wheat used in the first, and one ton of zinc phosphide-wheat in the second campaign.

Invicta.

North of Townsville.

1939.

"Rats were not troublesome, and baits were supplied to those who applied for them."

1944.

"Only twenty-five applications were received for rat baits."

"Thallium sulphate is getting low, only 260 lb. [of baits] left, and based on past consumption these should last until next winter."

APPENDIX 3.

Since 1944, methods of dealing with poisons and bait bases in cages have not altered to any extent. Data from more recent work with poisons have been examined by probits; also some of the earlier results have been re-examined by this method. There are no material differences between results calculated by this method and those obtained by the older and more direct method where a number of 25-rat series was used and $L.D.50 \pm \frac{L.D.50}{10}$ indicated range. As previously pointed out care has been taken in selecting test animals (note Appendix Table 1).

Appendix Table 1.

Item.	Poison.	L.D. 50 (mg./kg.) by direct methods.	By Probits.			Remarks.
			L.D. 50 mg./kg.	Range (P = ·95)	Range%.	
A	Thallous sulphate	30 ± 3	32·2	25·9–40·0	80–124	Only one standard 25 - rat series examined by probits
B	Alpha - naphthyl - thiourea	100 ± 10	109·1	96·1–123·9	88–114	Only one standard 25 - rat series examined by probits
C	Alpha - naphthyl - thiourea	. .	43·1	11·1–167·5	26–388	Rats other than virile adults also used and included in analysis
D	Zinc phosphide . .	38 ± 4	38·4	35·5–41·4	93–108	. .

Appendix Table 2.

SHOWING SOME CAGE TEST RESULTS WITH ALPHA-NAPHTHYL-THIOUREA IN PREPARED FOOD.*

Rat No.	Poison Strength.	Poisoned Food.		Poison.		Date Food Offered.	Date of Death.	Weight (g.) and Sex of Rat (*R. conatus*).*	Remarks.
		Intake g.	Standard Intake g./g.	Intake mg.	Standard Intake mg./kg.				
26/44	1 : 500	3·86	·050	7·70	100·06	25–10–44	26–10–44	77F.	..
27/44	1 : 500	3·14	·050	6·27	101·09	25–10–44	..	62M.	..
28/44	1 : 500	·02	..	..	..	30–10–44	..	68M.	..
†R5/44	1 : 300	1·94	·013	6·44	43·55	18–10–44	..	148M.	..
R6/44	1 : 300	2·27	·023	7·54	75·42	18–10–44	..	100M.	..
7/44	1 : 300	3·73	·045	12·39	149·30	18–10–44	19–10–44	83M.	..
8/44	1 : 300	2·17	·022	7·21	72·09	18–10–44	..	100M.	..
R9/44A‡	1 : 300	1·46	·011	4·85	37·03	19–10–44	21–10–44	131M.	..
R10/44A	1 : 300	1·62	·016	5·38	52·25	19–10–44	21–10–44	103M.	..
R11/44A	1 : 300	·71	·009	2·36	29·86	19–10–44	..	79F.	..
24/44	1 : 300	5·07	·045	16·84	150·40	25–10–44	27–10–44	112F.	Sluggish on 26th
R25/44	1 : 300	·61	·006	2·03	18·76	25–10–44	..	108F.	Gave birth to pups on night of 25th
29/44	1 : 300	·66	·007	2·19	23·58	30–10–44	..	93F.	..
1/44	1 : 100	1·24	·012	12·28	114·74	18–10–44	19–10–44	107M.	..
2/44	1 : 100	·55	·005	5·45	46·15	18–10–44	..	118M.	
3/44	1 : 100	·89	·006	8·81	64·80	18–10–44	..	136M.	..
4/44	1 : 100	·54	·005	5·35	49·06	18–10–44	..	109F.	Sluggish on 19th
13/44	1 : 100	3·61	·030	35·74	300·40	19–10–44	21–10–44	119F.	Sick with watery eyes on 20th
14/44	1 : 100	·22	·002	2·18	21·57	19–10–44	..	101F.	..
15/44	1 : 100	1·07	·012	10·59	123·20	19–10–44	20–10–44	86F.	..
R9/44	Prepared food only	10·61	·081	Check		18–10–44	..	131M.	Normal
R10/44		7·21	·070			18–10–44	..	103M.	
R/11/44		4·43	·056			18–10–44	..	*R. culmorum* 79F.	
R/12/44		6·87	·068			18–10–44	..	101M.	

22/44	1 : 100	1·95	·022	19·31	221·90	25–10–44	26–10–44	87F.	. .
23/44	1 : 100	2·03	·030	20·1	295·6	25–10–44	27–10–44	68F.	Very sick on 26th
30/44	1 : 100	1·09	·015	10·79	145·80	30–10–44	. .	74F.	. .
33/44	1 : 100	·13	·0015	1·29	15·15	30–10–44	. .	85F.	. .
R6/44B	1 : 100	·22	·002	2·18	21·78	30–10–44	. .	100F.	Weighed 81g. on 30th
34/44	1 : 100	1·44	·010	14·26	101·10	30–10–44	. .	141M.	. .
R25/44B	1 : 100	2·95	·027	29·21	270·50	30–10–44	. .	108F.	Weighed 91g. on 30th. Sick on 31st
35/44	1 : 100	1·23	·018	12·18	179·10	3–11–44	. .	68F.	. .
36/44	1 : 100	·95	·010	9·41	101·10	3–11–44	. .	93F.	. .
37/44	1 : 100	·83	·008	8·22	76·81	3–11–44	. .	107F.	. .
20/44	1 : 75	1·36	·016	17·89	205·70	25–10–44	26–10–44	87F.	. .
21/44	1 : 75	1·76	·026	23·16	340·60	25–10–44	27–10–44	68F.	Very sick on 26th
R25/44A	1 : 75	·78	·007	10·26	95·4	27–10–44	. .	108F.	Weighed 94g. on 27th
R3/44A	1 : 75	·26	·002	3·42	25·16	27–10–44	. .	136M.	Weighed 113g. on 27th
R5/44B	1 : 75	·16	·001	2·10	14·22	30–10–44	. .	148M.	Weighed 118g. on 30th
38/44	1 : 75	1·30	·013	17·11	167·70	3–11–44	. .	102F.	. .
39/44	1 : 75	·71	·006	9·34	78·52	3–11–44	. .	119M.	. .
40/44	1 : 75	1·00	·007	13·16	86·00	3–11–44	. .	153M.	. .
41/44	1 : 75	·77	·008	10·13	99·33	3–11–44	. .	102F.	. .
18/44	1 : 50	1·31	·018	25·70	356·80	25–10–44	26–10–44	72F.	. .
19/44	1 : 50	1·14	·015	22·35	290·20	25–10–44	27–10–44	77M.	Very sick on 26th
R5/44A	1 : 50	·15	·001	2·94	19·87	27–10–44	. .	148M.	Weighed 126g. on 27th
R6/44A	1 : 50	·16	·002	3·14	31·37	27–10–44	. .	100F.	Weighed 78g. on 27th
31/44	1 : 50	·22	·003	4·31	66·36	30–10–44	. .	65M.	. .
32/44	1 : 50	·25	·003	4·90	62·84	30–10–44	. .	78F.	. .
16/44			Some	nibbling	. .	22–10–44	23–10–44	149M.	Died about noon
R12/44A	Fresh		Some	nibbling		22–10–44	. .	101M.	
17/44	bread		. .	. .	. .	22–10–44	. .	62F.	
42/44	rolled		Some	nibbling		3–11–44	5–11–44	50F.	Both sick on 4th
43/44	in the		Some	nibbling		3–11–44	5–11–44	51M.	
44/44	poison		Some	nibbling		3–11–44	. .	107M.	
45/44						3–11–44	. .	100F.	

* Unless stated otherwise. † R—before the rat number denotes the specimen will be or is being returned for test.
‡ A, B.—after the rat number denotes first or second return test.

Bait Bases.

The mean standard intakes (in g./g.) of Saccaline and Wheatland sorghums are respectively ·060 ± ·002 and ·065 ± ·0033. The necessary difference for significance at the 5 per cent. level between favoured foods, of which these two grains are an addition to those listed earlier (McDougall, 1944c), is .012.

There are no significant differences between intakes of Saccaline and Wheatland sorghums and whole wheat in two-food preference cage tests.

Wetting of Bait Bases.

The addition of industrial methyl or ethyl alcohols or methylated spirits does not decrease intake after drying of cracked grain or cereal derivatives as does water. Therefore these fluids are suitable, when and if required, for the introduction of poisons into bait bases.

Poisons.

Alpha-naphthyl-thiourea: This poison is a white powder, is also known as "ANTU" or "109," and for all practical purposes is insoluble in water, alcohol and linseed oil. It has been given some publicity as a new rat poison during the past few years and is on the Queensland market as a paste.

Dieke and Richter (1946), using wild *R. norvegicus* as test animals, list "ANTU," with an L.D.50 of 6·9 ± ·05, as more toxic than thallous sulphate, L.D.50 15·8 ± ·09; method of administration is by stomach tube. Several Government departmental reports (Australian) on rat work with this poison have been made available to the author; these are unsatisfactory in methods used, in kills obtained, and in the small number of nondescript rats subjected to tests. Wilson (1946a) details results and methods used with *R. conatus* and *R. rattus* as test species; his conclusion is that "ANTU" is not sufficiently toxic to be an efficient rat poison.

Appendix Table 3.

ALPHA-NAPHTHYL-THIOUREA WITH PREPARED FOOD AS A BASE.

Poison Strength.	Mean Standard Intake g./g.	I.T.F.
1 : 500	·049 ± ·005	·90
1 : 300	·020 ± ·002	·61
1 : 100	·012 ± ·0018	1·09
1 : 75	·008 ± ·001	·96
1 : 50	·005 ± ·001	·90
1 : 25	·003 ± ·0005	1·06

The material used by the author was, by chemical analysis, 93 per cent. pure (total nitrogen 12.9 per cent. and M.P. 191°C.). Examples of individual tests are given in Appendix Table 2, and fundamental data in Appendix Table 1, Item B, and Appendix Table 3. Field tests with twin grids in settled *R. conatus* populations and using the poison on bread and in prepared food (highest poison-strength 1 : 5) at feeding stations confirm the conclusions from cage work, viz., that alpha-naphthyl-thiourea is of little value as a rat poison in Queensland canefields.

Zinc Phosphide: The well-known mouse and rat poison (also insecticide), zinc phosphide, has been used to some extent (note Table 1 of text) during the past two years in Queensland canefields. This followed the need for a suitable substitute for thallous sulphate in food baits and also probably the recent use of this poison in Hawaiian canefields. Doty (1945) has consolidated much of the available information on bait manufacture associated with this poison; the chief points are that the killing agent is phosphine, liberated by the action of gastric juices on the zinc phosphide, and it is desirable to use this chemical in dry baits. Both in Hawaiian (Doty, *loc. cit.*) and Queensland canefields zinc phosphide has been used at a strength of 1 in 200, i.e. 0.5 per cent. In the former country crushed or broken grain has been the bait base whereas in Queensland whole wheat, as with thallium, has carried zinc phosphide also.

Appendix Table 4 gives examples of individual cage tests with zinc phosphide. The two samples of this poison used were of commercial quality purchased in 1936 and 1944; no difference in toxicity to and intake by rats was discernible. Appendix Table 1, Item D, and Appendix Table 5 provide fundamental data from which, with other information, it is concluded—

1. With a grain derivative as the food base a strength approximating to 1 in 50 is required for a satisfactory I.T.F. At this poison strength the reduction in intake of prepared food is about 88 per cent.

2. This poison is essentially for use when intimately mixed with the food. With whole grain the necessary I.T.F. was not attained though poison strengths as high as 1 in 50 were tried.

Percentage kills in suitable twin grid field trials, using whole wheat baits at strengths of 2, 1 and 0.5 per cent., and the poison in prepared food at strengths of 2, 1.25 and 0.66 per cent. at feeding stations, confirm the conclusions from cage data.

The whole-wheat-zinc phosphide baits as packed in tins for use in Queensland canefields were stored for 12 months but no deterioration was discernible by bio-assay.

Miscellaneous.

No claims have been made for DDT and "Gammexane" (the gamma isomer of benzene hexachloride) as efficient rat poisons. Draize *et al.* (1944) give 200 (±) mg./kg. as an L.D.50 for DDT and Slade (1945) found the beta isomer of hexachlorocyclohexane with an L.D.50 of 190 mg./kg. the most toxic to rats.*

Appendix Table 6 is an example of routine tests with DDT (90 per cent. para para isomer). This chemical was also used at a poison strength of 1 in 10. DDT and "Gammexane" (10 per cent. dust, 1.3 per cent. gamma isomer) were found valueless both as poisons and as deterrents when working with cane rats.

During 1945, the author received a small sample of sodium fluoroacetate ("1080") for testing. Unfortunately this was in a cardboard container and on arrival at Mackay encountered hot, humid conditions. The highly deliquescent material ran out on the bench and was lost. Further samples have been kept in sealed containers but for some time it has not been possible to obtain sufficient rats for thorough testing. The author considers from past experience, and on general principles, that it is more profitable to leave new poisons alone until such times as conditions are suitable for testing.

While trapping rats during the drought of 1946 with the intention of breeding sufficient numbers for immediate requirements, one interesting observation was made. After as long as two months in captivity the nine suitable specimens taken did not respond sufficiently to cage conditions to breed during spring-early summer (see McDougall, 1946a). These rats did not commence breeding until March, 1947, when three litters totalling 12 pups were produced.

* Stammers and Sarel Whitfield (1947) provide a later bibliography on the effects of DDT on rats and mice; no claims for this material as a practical rodenticide are made.

Appendix Table 4.

EXAMPLES OF CAGE TEST RESULTS WITH ZINC PHOSPHIDE.

Rat No.	Poison Strength and Bait Base.	Poisoned Food.		Poison.		Date Food Offered.	Date of Death.	Weight (g.) and Sex of Rat (*R. conatus*).	Remarks.
		Intake g.	Standard Intake g./g.	Intake mg.	Standard Intake mg./kg.				
	Prepared	Food.							
459	1 : 50	1·23	·014	24·6	273·3	10–11–37	11–11–37*	90F.	Weight 86g. on 11th
460	1 : 50	1·78	·013	35·6	252·5	10–11–37	11–11–37*	141M.	Weight 132g. on 11th
461	1 : 50	2·17	·020	43·3	394·5	11–11–37	12–11–37*	110F.	Weight 99g. on 12th
462	1 : 50	·89	·009	17·8	185·4	11–11–37	12–11–37*	96M.	. .
463	1 : 50	·54	·005	10·8	96·4	11–11–37	12–11–37*	112M.	. .
464	1 : 50	1·10	·009	22·0	189·7	11–11–37	12–11–37*	116F.	Dissection showed pregnancy (7)
465	1 : 50	·04	·0004	·8	7·9	11–11–37	12–11–37*	101F.	. .
466	1 : 50	1·03	·010	20·6	196·2	11–11–37	12–11–37*	105F.	Dissection showed R3L2
261/44	1 : 100	·95	·006	9·4	62·70	8–11–44	9–11–44	150M.	. .
262/44	1 : 100	1·68	·018	16·63	182·8	8–11–44	9–11–44	91M.	. .
263/44	1 : 100	·07	·001	·69	7·07	8–11–44	. .	98F.	. .
358/44	1 : 200	1·10	·013	5·47	66·73	8–11–44	. .	82F.	. .
359/44	1 : 200	2·93	·020	14·57	97·18	8–11–44	. .	150M.	Sick only
240/44	1 : 200	1·25	·013	6·21	62·82	8–11–44	9–11–44	99F.	. .
147/44	1 : 300	·64	·006	2·126	20·44	7–11–44	. .	104M.	. .
148/44	1 : 300	1·44	·016	4·78	53·16	7–11–44	8–11–44	90F.	. .
149/44	1 : 300	1·04	·009	3·455	28·79	7–11–44	8–11–44	120M.	. .
150/44	1 : 300	·59	·006	1·960	20·63	7–11–44	8–11–44	95F.	. .
151/44	1 : 500	·68	·007	1·36	14·29	7–11–44	. .	95F.	. .
152/44	1 : 500	1·10	·010	2·20	19·43	7–11–44	9–11–44	113F.	. .
153/44	1 : 500	1·26	·013	2·51	26·47	7–11–44	. .	95F.	. .
154/44	1 : 500	1·37	·025	2·73	49·72	7–11–44	8–11–44	55F.	Too young for standard test
155/44	1 : 700	Nil	. .	. .	. .	8–11–44	. .	77M.	Too young for standard test
156/44	1 : 700	1·69	·024	2·41	34·44	8–11–44	9–11–44	70M.	Too young for standard test
157/44	1 : 700	1·55	·021	2·21	29·48	8–11–44	9–11–44	75F.	Too young for standard test

	Whole	Wheat.							
101/45	1 : 200	·08	..	..	..	12–12–45	..	137M.	..
102/45	1 : 200	·83	·005	4·13	22·94	12–12–45	14–12–45	180M.	Too old for standard test
103/45	1 : 200	·43	·004	2·14	20·37	12–12–45	..	105F.	..
104/45	1 : 200	·46	·004	2·29	21·80	12–12–45	..	105M.	..
105/45	1 : 200	·52	·005	2·59	26·40	12–12–45	..	98F.	..
106/45	1 : 200	·58	·009	2·89	42·43	12–12–45	13–12–45	68F.	Too young for standard test
107/45	1 : 200	·90	·009	4·48	46·63	13–12–45	..	96F.	..
108/45	1 : 200	·31	·003	1·54	12·44	13–12–45	..	124M.	..
109/45	1 : 200	·93	·010	4·63	48·19	13–12–45	12–12–45	96F.	
110/45	1 : 200	·29	·002	1·44	9·07	13–12–45	..	159M.	Too old for standard test
111/45	1 : 200	·30	·004	1·49	17·98	13–12–45	14–12–45	83M.	Too young for standard test
	Crushed	Wheat.†							
203/45	1 : 200	·80	·009	3·98	44·22	18–12–45	19–12–45	90F.	..
204/45	1 : 200	·64	·006	3·18	29·48	18–12–45	19–12–45	108M.	..
205/45	1 : 200	·50	·006	2·49	28·59	18–12–45	20–12–45	87F.	..
	Crushed	Wheat.‡							
287/45	1 : 200	·10	·001	0·50	4·90	21–12–45	..	102F.	..
289/45	1 : 200	·75	·008	3·73	40·13	21–12–45	22–12–45	93F.	..
290/45	1 : 200	·62	·009	3·08	42·85	21–12–45	22–12–45	72M.	Too young for standard test
291/45	1 : 200	·47	·004	2·34	19·98	21–12–45	..	117M.	..
292/45	1 : 200	Nil	..	..	..	21–12–45	..	112M.	..
293/45	1 : 200	Nil	..	..	..	21–12–45	..	120F.	..

* Dead within twelve hours. † Wheat crushed after impregnation with zinc phosphide.
‡ Wheat crushed after impregnation with zinc phosphide and left standing a week before presentation.

Dieke and Richter (1946) give .022 ± .01 mg./kg. as the L.D.50 of "1080". Wilson (1946b), using mostly *R. rattus* found the L.D.50 of this poison to be "slightly greater than 1.". That author (*loc. cit.*) concluded "'1080' is a deadly and readily accepted rat poison which should prove a valuable addition to the list of poisons at the disposal of the sugar industry. Its extremely high toxicity would make it inadvisable to place it before the public except in the form of recognisable prepared baits."

Samples of 1 : 300 thallous sulphate packeted whole-wheat baits were stored in airtight tins during 1938. When tested in the field during 1945, these had not lost any efficiency.

Appendix Table 5.

Zinc Phosphide.

Poison Strength.	Mean Standard Intake g./g.	I.T.F.	Remarks.
1 : 700	·025 ± ·001	·94	With prepared food as base
1 : 500	·017 ± ·002	·84	
1 : 300	·016 ± ·001	1·40	
1 : 200	·013 ± ·001	1·71	
1 : 100	·010 ± ·0005	2·65	
1 : 50	·008 ± ·0004	4·02	
1 : 200	·006 ± ·0003	·79	With whole wheat as base
1 : 200	·008 ± ·0002	1·05	Wheat crushed after impregnation with zinc phosphide

APPENDIX 4.

Rat Control in Central Queensland Canefields.

During the harvesting seasons of some years rat damage to cane may concern farmers in certain areas. To lessen this damage the following procedure is recommended:—

1. Plant harder-rinded varieties in rat-infested country and on places on farms (such as near well-grassed creeks or scrub) where past experience has shown that rats may be expected to attack cane.
2. Poison with phosphorus paste on bread. Cut the bread into thin slices, spread the poison as thinly as possible, cover lightly with flour, and cut the bread into pieces about half an inch square.

Baits should be put out during the day of making.

Place the baits (about four a time) on the ground on small areas (which have been cleared with a hoe or boot) every 10 yards along every seventh row of damaged cane. They may also be placed in patches of damaged cane and in harbourage near rat-eaten cane. Baiting should commence immediately the presence of rats is noticed in the fields. Further baits should be put out whenever and where fresh rat bites are seen.

Appendix Table 6.

EXAMPLES OF CAGE TEST RESULTS WITH DDT IN PREPARED FOOD.

Rat Number.	Poison Strength.	Poisoned Food.		Poison.		Date Food Offered.	Date of Death.	Weight (g.) and Sex of *R. conatus*.
		Intake g.	Standard Intake g./g.	Intake mg.	Standard Intake mg./kg.			
4/45	1 : 50	7·41	·075	145·3	1,483·0	25–6–45	..	98F.
18/45	1 : 50	2·70	·025	53·0	490·3	25–6–45	..	108F.
29/45	1 : 50	3·31	·042	64·9	821·5	25–6–45	..	79F.
27/45	1 : 50	3·20	·026	26·4	521·7	25–6–45	..	121F.
17/45	1 : 50	3·93	·034	33·9	664·2	26–6–45	..	116F.
15/45	1 : 50	1·74	·018	18·0	351·7	25–6–45	..	97F.
16/45	1 : 50	3·45	·030	29·5	571·8	25–6–45	..	117F.

Do not handle baits more than is necessary and thoroughly wash the hands immediately afterwards. It is important that the poison should be very thinly spread on the bread. If the poison becomes too thick for easy spreading the tin should be stood in hot water for about 30 minutes. When not in use the tin of poison should be kept airtight.

It might be pointed out that—

1. The phosphorus-bread bait is the most deadly rat poison known. A very small portion of a fresh bait is quite sufficient to kill any rat and the effectiveness of these baits should never be judged by the number of baits taken in the field.

2. On occasions poison baits will not satisfactorily control rats in cane. Under such circumstances damage is likely to be widespread and will not be overcome by farmers themselves trying a change of bait. Further authoritative advice should be sought.

The provision of poison is a matter which is best carried out by the local Pests Board or other growers' organization.

APPENDIX 5.

[Extracts from paper on "Records" read at the Aug., 1946, Conference of the Cane Pest and Disease Control Boards.]

"Availability and easy access to records of pest infestations, damage or economic losses caused by them, efforts and cost of attempts to lessen the losses, and other relevant items of interest are necessary for advances in both research and the handling of economic pest problems. Lack of such information in definite and concrete form about many pests is generally recognized and deplored, but in many instances little has been done to rectify the position. The writer considers that some of our cane pests are in this category; however, with our present organization within the Industry, considerable improvement could be made with only a small additional expenditure of effort and money (if any). No doubt many valuable records and observations did exist at some time or other, but now they must be included in 'vanished data' which eventually must cover the unrecorded experience of different individuals and figures collected by them . . ."

"Until recent years (1935 onwards), there were very few available records concerning rats in canefields and even now statistical data are meagre and unsatisfactory. Occasionally an observation of passing interest is to be found amongst older writings dealing mostly with other pests. These often hint at a fact born of poor recording, viz., that in many instances ideas presented unconsciously as new are actually basically unimproved old ones regarnished or clothed in a new set of words. As examples, a well-known phosphorus trade preparation has been given considerable attention along stereotyped lines in one sugar-growing country during the past few years. Dr. Illingworth mentions in five lines amongst a report on 'Cane Grub Investigations, August, 1918' that this preparation gave good results at Mossman, Q. The idea of pre-baited feeding stations and other types of feeding stations now so much in vogue in many countries for the presentation of poisoned food to rats and mice, was used in the Habana area, Mackay district, towards the end of last century."

"Attempts to improve, but not merely repeat, old methods may be sound, but if some details of earlier work were available much effort could be saved. Some years ago, the writer conversed with a farmer experienced in trapping rats. His ideas were not otherwise recorded, but by chance it was possible to incorporate them in a trapping scheme which for experimental purposes was convenient and successful. This same farmer was an adept at trapping *Melomys*. Now, when more detailed work on this species is scheduled, a preliminary basis for the mechanical work of trapping is available for a quick check-up."

"The point the writer wishes to stress is: many records of observations and experiments are not suitable for the usual type of annual report or for formal scientific articles, and under present circumstances they are more or less lost. The Minutes and Proceedings of this Conference, concerned only with cane pests, could serve as an ideal vehicle for the primary recording of pest data under three sections—

1. Accounts of experiments of interest at the moment, and the disseminating of ideas on the latest measures of combating cane pests.
2. Reports on unusual happenings connected with pests of cane or their control.
3. Annual statistical data.

Section 3 is considered of the utmost importance.

"Expectations from items in section 1 may not be realized, and those covered by section 2 may ultimately be of little value. But if good statistical data on the economics of controls and problems are collected continuously and conscientiously, this Conference would be able to debate and evaluate along sound lines. Obviously, the outlook should not be one of destructive criticism of existing controls and their applications, but rather the guiding of future work along the more profitable channels . . ."