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Some laboratory observations on the toxicity and acceptability of norbormide to wild *Rattus norvegicus* and on feeding behaviour associated with sublethal dosing*

By J. H. GREAVES

Infestation Control Laboratory, Ministry of Agriculture, Fisheries and Food, Tolworth, Surbiton, Surrey

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INTRODUCTION

Norbormide [5-(α-hydroxy-α-2-pyridylbenzyl)-7-(α-2-pyridylbenzylidene)norborn-5-ene-2,3-dicarboximide] is reported to be selectively toxic to *Rattus norvegicus* and *R. rattus* (Roszkowski, Poos & Mohrbacher, 1964) and is therefore potentially a safe and effective alternative to existing rat poisons.

This paper describes an acute toxicity assay of norbormide and also a number of laboratory free-feeding tests using norbormide and, for comparison, zinc phosphide, primarily aimed at selecting concentrations of norbormide suitable for field testing. A secondary objective was to investigate experimentally the avoidance by rats of the two poisons at candidate field concentrations and of the bait-bases associated with them.

METHODS

All tests were carried out on individually caged wild rats of about 225 g. average body weight that had been caught by hand and kept in the laboratory for at least 4 weeks before use. Warfarin-resistant rats, that is, animals that had survived for 24 days after 6 days feeding at a normal level on 0·005 % warfarin in medium oatmeal (D. C. Drummond & E. J. Wilson, personal communication) and non-resistant rats of both sexes were used, but since there were no differences in response attributable either to sex or to resistance to warfarin, the results for these animals have been pooled.

The acute toxicity assay of norbormide was carried out on rats trained to accept dough pills made by mixing water with 90 % wholemeal flour plus 10 % caster sugar. The training involved ensuring that five pills, each of which contained approximately 0·6 g. of dry matter, were available to each rat eight times at hourly intervals each day for 4 days. Each animal was allowed a daily ration of pills amounting to a dry-matter intake of 10 % of its body weight, and when this was not eaten during the day it was left in the cage overnight. On the day of the test, after being starved overnight, each rat was given a single pill containing the poison. Forty-five female rats and forty males were tested by this method. The results for five other animals were rejected because they failed to eat the poisoned pill completely soon after it was offered.

For a rodenticide to be successful at a given concentration in bait in the field, where rats must eat a lethal dose voluntarily, it must be acceptable to them at that concentration. An attempt was therefore made to take account of acceptability as well as toxicity by carrying out three types of free-feeding test.

In the first type of test the rats were given plain food for 1 or 2 days, after which poison was added at various concentrations to the food for 1 day. The results were analysed in terms of concentration and mortality by the method of Litchfield & Wilcoxon (1949), to give estimates of lethal concentration (cf. lethal dosage).

In the second type of test, rats were prebaited with a highly palatable food consisting of 5 % caster sugar, 5 % corn oil, 65 % maize meal and 25 % rolled oats for 3 days followed by 4 days with 0·5 % norbormide in the same food. For brevity this particular food will be referred to as SCOMRO. It is believed, because of the high acceptability of SCOMRO, the period of prebaiting and the long exposure to poisoned food, that conditions were very favourable for obtaining high mortality in this test.

Free-feeding tests of the no-choice type first described are probably suitable for indicating the minimum concentration of a rodenticide suitable for use in the field but they are much less useful for comparing higher field concentrations because of the numbers of test subjects necessary to obtain significant differences at high mortality levels. However, when rats are offered a choice of plain and poisoned foods, mortality is invariably lower than in the no-choice situation. This procedure therefore offers a practicable method of comparing relatively high concentrations of poison while, at the same time, approaching nearer to conditions in the field, where unpoisoned alternative food is normally available. On this basis a series of free-feeding tests of a third type was carried out in which a choice of plain and poisoned foods was offered to each animal for an initial period of at least 2 days. Surviving animals were then given further choices, in which a variety of plain and poisoned foods were offered in pairs to find what effect exposure to poisoned food was having on subsequent choice behaviour. In all choice tests the positions of the two foods were interchanged daily to minimize the effects of place preference. During the periods between these tests, normally 3 or 5 days, the rats were given diet 41 B or a new non-toxic food.

Further details of procedure are given below.

RESULTS

The bioassay

The results of the acute toxicity assay (Table 1) were analysed by the method of Litchfield & Wilcoxon (1949) to give an LD 50 for norbormide of 9·0 mg./kg. (95 % limits, 10·9–7·4 mg./kg.) and an LD 95 of 17·0 mg./kg. This estimate of the LD 50 may be compared with the figure of 12 mg./kg. reported by Roszkowski *et al.* (1964) for wild *R. norvegicus* dosed with an acid solution of the compound by stomach tube.

Among twenty-two animals whose behaviour was recorded, signs of poisoning, including locomotor impairment, tail lashing, laboured breathing and occasional,

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usually terminal, convulsions were observed from 15 min. after dosing. All deaths occurred within 24 hr., the earliest being in 40 min.

No-choice tests

The results of the free-feeding tests of the first type are summarized in Table 2. The estimates of dosage must be treated with reserve since, for individual rats, the weighings involved in estimating the amounts of bait eaten overnight were subject to errors that may have produced inaccuracies of the order of 20–30 mg./kg. for a poison concentration of 2·5 % and proportionately less for lower concentrations.

Table 1. *Mortality in rats dosed with norbormide by pill*

Dosage (mg./kg.)...	2	4	8	10	11	12	13	16	20	22	24
Mortality	0/6	0/9	7/19	3/4	5/5	7/10	4/5	18/19	3/3	1/1	4/4

Table 2. *Mortality in rats fed norbormide or zinc phosphide in medium oatmeal for* 1 *day after* 1–2 *days of prebaiting*

Poison	Concentration (%)	Mortality	Mean and range of dosages that killed (mg./kg.)	Highest dosage survived (mg./kg.)
Norbormide	0·01	0/13	— —	14
	0·05	2/10	11 (4–18)	33
	0·07	1/13	28 —	58
	0·1	1/12	19 —	26
	0·25	5/13	24 (1–59)	154
	0·5	18/28	25 (0–68)	69
	0·8	6/9	87 (0–294)	41
	1·0	15/17	89 (13–763)	22
	2·0	11/11	56 (16–136)	—
Zinc phosphide	0·1	0/4	— —	45
	0·2	2/4	36 (27–45)	59
	0·4	1/4	28 —	70
	0·5	3/4	57 (35–86)	24
	0·6	2/4	63 (58–68)	99
	1·0	5/5	57 (0–111)	—
	2·5	4/4	40 (0–109)	—

The figures illustrate, however, that there is no close relationship between dosage and either concentration or mortality. In contrast, there is quite a strong association between concentration and mortality. Analysis of the results in Table 2 gives a median lethal concentration (LC50) for zinc phosphide in medium oatmeal of 0·44 % (95 % limits, 0·27–0·81 %) and for norbormide in the same bait 0·37 % (95 % limits, 0·24–0·57 %). The respective LC95's, which are perhaps of greater practical interest, are 1·3 and 3·4 %.

The second type of test involving 0·5 % norbormide in SCOMRO, in which, as stated earlier, conditions favourable for a good kill were provided, did not result (Table 3) in a marked increase in mortality over that obtained at the same concentration in less extreme conditions (Table 2). The four animals in Table 3 that survived ate negligible amounts during their 4-day exposure to the poisoned food.

Choice tests

Responses to an initial choice between similar foods

In the third type of free-feeding test each rat was offered plain and poisoned, but otherwise identical foods. After 2 nights' feeding surviving animals were assigned to one of two categories (Table 4). These were 'refusers' which had eaten very little food and 'discriminators' which had eaten relatively large amounts of unpoisoned food. The distinction between refusers and discriminators was obvious except in a few borderline cases. The mean daily consumption of unpoisoned food by the sixteen refusers in Table 4 was 11·0 g./kg. compared with a mean of 59·3 g./kg. eaten by the discriminators. Both types of survivor ate significantly less food

Table 3. *Cumulative mortality in rats fed 0·5 % norbormide in SCOMRO* for 4 days after 3 days of prebaiting*

Day	1	2	3	4
Mortality	17/24	18/24	18/24	20/24

* See text.

Table 4. *Rats classified by response made when offered a choice of poisoned food and the same food unpoisoned*

Group	Type of rat *vis à vis* the poison	Food	Poison	Poison in food (%)	Total no. of rats	Dead (days 1 and 2)	Refusers (surviving 2 days)	Dis-criminators (dying on days 3 and 4)	Dis-criminators (surviving 4 days)
1	Naïve	Medium oatmeal	Norbormide	0·5	12	3	6	2	1
2				1·0	12	4	2	2	4
3				2·0	12	4	1	1	6
4	Naïve	Medium oatmeal	Zinc phosphide	1·0	12	2	0	0	10
5				2·5	12	6	1	0	5
6				5·0	12	7	0	0	5
7	Experienced	Medium oatmeal	Norbormide	1·0	12	2	2	1	7
8	Experienced	Sausage rusk	Norbormide	1·0	16	4	4	2	6
9	Experienced	Medium oatmeal	Zinc phosphide	1·0	11	0	0	0	11

($P < 0·001$) than a control group without access to poisoned food, in which each animal ate an average of 105·9 g./kg. daily. This depression of feeding among the experimental animals was presumably one of the effects of the poisoned food of which they ate on average 3·2 g./kg. daily. The test was ended for refusers after 2 days so as to avoid deaths that could have been due to starvation, but was continued for a further 2 days with discriminators. There were therefore two categories of mortality: animals dying in the first 2 days of the test, and those that died in the second 2 days after discriminating for the first two (Table 4).

Some animals had previously experienced the same poison in either the bioassay or the no-choice tests and the results for these are separated in Table 4 from those for the rats that had had no experience of the poison. The only obvious difference

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between the results for naïve and experienced rats offered norbormide or zinc phosphide at the same concentration is that mortality was lower among the experienced animals, which would be expected on the grounds that resistance to the poisons had been selected for in these groups. However, only the results obtained with the experimentally naïve animals are considered further.

Taking first the results for norbormide in medium oatmeal, the mortality is very similar at each of the concentrations tested, suggesting that in the field they may not differ much in effectiveness. The association ($P < 0{\cdot}025$) between the ratio of surviving discriminators to refusers and concentrations of poison in the food (1/6, 4/2, and 6/1 at 0·5, 1·0 and 2·0 % respectively) suggests that the taste of norbormide caused aversion or was more easily associated with the toxic effects of the poison at increasing concentrations. A similar apparent association between the proportion of discriminators surviving the third and fourth days and the concentration of norbormide in the food (1/3, 4/6 and 6/7 at 0·5, 1·0 and 2·0 % respectively), though not statistically significant, does not conflict with the idea that discrimination of plain from poisoned food was less easy at lower than at higher concentrations. The refusers may have been animals that associated the toxic effects of the poison with the taste of the food rather than the taste of the poison. This interpretation is supported (Table 8) by the comparative rarity of refusers in choice tests where the food containing the poison was different from the unpoisoned food, thus providing additional cues calculated to make discrimination easier. Another possibility is, however, that some of the refusers were too sick to eat because of sublethal feeding on the poisoned food. This is supported by the fact that the average daily consumption (94·4 g./kg.) of a new food on days 3 and 4 by fifteen refusers was lower than that of the control group that was not exposed to poisoned food.

With zinc phosphide, the increasing mortality with concentration suggests that 5 % may be the best of the three concentrations for field use. It also indicates that with zinc phosphide, unlike norbormide, the tendency for increased concentration (through the ranges tested) to produce higher mortality is not offset by decreased palatability or increased speed of action, both of which might be expected to reduce the chances of a lethal dose being ingested. It is apparent, however, from the high proportion of discriminators among the survivors of the first 2 days of the test and from the fact that none died in the second 2 days, that zinc phosphide has a distinct taste to rats.

Second and third choice tests on survivors

All the surviving discriminators of Table 4, except for seven (from Group 9) that had been given a choice involving 1 % zinc phosphide, were given second and third choice tests, in which the poison employed was always of the same kind and at the same concentration as in the first choice. For their second test the discriminators were offered a choice for 4 days of the food given in the first test and a new food, one of which was poisoned. It was found that the rats either died in the first 24 hr. of the test or they ate, as before, mainly the unpoisoned food throughout. The chief interest in the results (Table 5) lies in the significantly higher mortality, irrespective of the poison, where this was presented in medium oatmeal ($P < 0{\cdot}001$).

Since a control group strongly preferred medium oatmeal to sausage rusk ($P < 0{\cdot}001$) it appears that many animals died through eating poisoned medium oatmeal because the alternative was less palatable. However, the data in Table 5 do not suggest that the previous experience of some of the rats in discriminating against the same poison at the same concentration in the same food, had any marked effect on their choice of behaviour in this test.

Table 5. *Mortality in discriminators in the second test in relation to the foods offered in the first and second tests*

			Second test		
Group	Poison	Food in first test	Plain food	Poisoned food	Mortality
10	Norbormide	MO*	SR	MO	8/9
11	Norbormide	SR†	SR	MO	2/3
12	Zinc phosphide	MO	SR	MO	8/13
13	Norbormide	MO	MO	SR	0/9
14	Norbormide	SR	MO	SR	1/3
15	Zinc phosphide	MO	MO	SR	1/11

* Medium oatmeal. † Sausage rusk.

Table 6. *Preferences of discriminators, offered a choice of medium oatmeal and sausage rusk, in relation to the foods encountered in the second test*

Group	Foods offered in the second test	Percentage preference of individual rats for medium oatmeal					
16	SR* v. MO† + norbormide	0·3	0·2	—	—	—	—
17	SR v. MO + zinc phosphide	97·9	34·8	2·7	0·9	0·4	—
18	MO v. SR + norbormide	100·0	100·0	100·0	100·0	100·0	92·6
		80·4	54·6	2·3	—	—	—
19	MO v. SR + zinc phosphide	100·0	100·0	100·0	100·0	100·0	100·0
		99·2	99·1	72·8	71·2	—	—
20	Controls (experimentally	99·9	99·7	99·5	98·9	98·5	93·1
	naïve)	92·9	90·5	79·6	67·2	57·6	—

* Sausage rusk. † Medium oatmeal.

In their third test twenty-six out of the twenty-eight survivors in Table 5 were given a choice for 4 days of medium oatmeal and sausage rusk (both unpoisoned) to check whether they would show a preference, as compared with a control group, for the food that was unpoisoned in the second test. The results (Table 6) show that there was little, if any, difference between the two poisons in their effect on food preferences in this test. All but one of the rats that had experienced sausage rusk as non-toxic in the second test (Groups 16 and 17) showed, in contrast to the controls, a clear preference for this food. Any corresponding trend among the rats that had experienced medium oatmeal as non-toxic (Groups 18 and 19) is less obvious owing to the strong preference for medium oatmeal among the control animals. However, the high proportion of animals in Groups 18 and 19 that ate medium oatmeal exclusively, suggests that such a trend was present.

The aberrant animal in Group 18 that ate only 2·3 % of its food as medium oatmeal had shown anomalous behaviour before. After discriminating against 1 % norbormide in sausage rusk in the first test it had gone on to eat 19·3 g. of similarly poisoned sausage rusk in the second test as against only 4·3 g. of plain medium oatmeal.

Turning now to the refusers in Table 4, all sixteen were given, in their second test, a 4-day choice of medium oatmeal and sausage rusk, both unpoisoned, to check whether in comparison with the same control group they had learned to avoid the food offered in the first test. The results are given in Table 7 and show that, as with the discriminators, there were clear shifts in preference towards the food not experienced as toxic only when this was sausage rusk. The almost complete avoidance of medium oatmeal shown by six rats in Groups 21 and 22 compared with the behaviour of the controls indicates that the refusal of these animals to feed in the first test was a learned response in which they were using the taste of medium oatmeal as a cue.

Table 7. *Preferences of refusers, offered a choice of medium oatmeal and sausage rusk, in relation to the foods encountered in the first test*

Group	Foods offered in the first test	Percentage preference of individual rats for medium oatmeal					
21	MO* *v.* MO + norbormide	99·1	96·9	88·1	71·4	70·2	47·5
		1·5	0·6	0·3	0·3	0·0	—
22	MO *v.* MO + zinc phosphide	2·4	—	—	—	—	—
23	SR† *v.* SR + norbormide	100·0	100·0	100·0	59·3	—	—
24	Controls (experimentally naïve)	99·9	99·7	99·5	98·9	98·5	93·1
		92·9	90·5	79·6	67·2	57·6	—

* Medium oatmeal. † Sausage rusk.

At this point the rat in Group 5 of Table 4 that originally refused both medium oatmeal and 2½ % zinc phosphide in medium oatmeal was given this choice again and repeated its refusal. The remaining fifteen animals, all of which had been exposed to norbormide, were given the same test as in Table 4 but with 85 % coarse oatmeal, 10 % caster sugar and 5 % mineral oil, as the bait-base. Only two rats repeated their refusal; three others died in the first 2 days and the other ten discriminated against the poisoned food. This change to discriminatory feeding may have resulted in part from the extra practice the rats had had in choice situations. However there is evidence (see later) that some animals may have formed a discrimination in the original test that went undetected because, soon after its formation, food consumption was reduced as a result of illness.

Tests in which the initial choice lay between different foods

The results of the second test with discriminators (Table 5) had indicated that, in the choice situation, the more palatable the poisoned food as compared with the unpoisoned alternative, the higher the mortality was likely to be. The effect of palatability was therefore further investigated in two groups of experimentally

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naïve animals. One group (25) was offered a choice between 0·5 % norbormide in SCOMRO and plain sausage rusk for a minimum of 4 days while the other (group 26) was given a 4-day choice between 0·5 % norbormide in sausage rusk and unpoisoned SCOMRO. Table 8 shows that mortality was significantly higher ($P < 0{\cdot}01$) where the poison was in the more palatable SCOMRO.

Among the discriminators in Group 25 of Table 8 one rat showed unusual tolerance of norbormide. The test was therefore continued with this animal for 11 consecutive days, during which it ate a total of 68·6 g. of poisoned food and 98·4 g of plain food and survived.

Meanwhile, five of the other sixteen survivors of Group 25 (two discriminators and three refusers) were given the same choice again. This time all five survived by discriminatory feeding. At the same time the remaining eleven animals of Group 25 (eight discriminators and three refusers) were offered a 4-day choice of SCOMRO and sausage rusk, both unpoisoned. The preferences of the animals in this test, and those of an experimentally naïve control group are given in Table 9.

Table 8. *Rats classified by response when offered a choice of two foods, one of which contained 0·5 % norbormide*

Group	Poisoned food	Plain food	Total number of rats	Refusers (surviving 2 days)	Discriminators (surviving 4 days)	Dead
25	SCOMRO*	SR	44	6	11	27
26	SR†	SCOMRO	16	0	14	2

* See text. † Sausage rusk.

Table 9. *Preferences of rats offered a choice of sausage rusk and SCOMRO* after exposure to a choice of sausage rusk and norbormide-poisoned SCOMRO*

Group	Percentage preference of individual rats for sausage rusk							
Experimental	98·6	98·6	98·3	98·2	98·2	93·2	89·2	59·0
	49·8	13·5	5·0	—	—	—	—	—
Control	30·7	10·1	5·5	4·7	4·7	4·6	3·2	2·2
	0·0	0·0	—	—	—	—	—	—

* See text.

There can be little reason to doubt that the marked difference between the preferences of the experimental and control animals resulted from the prior exposure of the experimental rats to norbormide-poisoned SCOMRO.

Since the three refusers all ate virtually only sausage rusk, it seems most likely that all six of the refusers in Table 8, by the time they were classified as such, had been conditioned to avoid eating SCOMRO in favour of the normally less palatable sausage rusk.

DISCUSSION

Two methods of calculating the optimum field concentration of a rodenticide from laboratory data have been discussed by Bentley (1958). The first of these is based on evidence collected by Thompson (in Chitty & Southern, 1954) that, in the field, rats eat on average at least 1 % of their body weight in the form of dry poisoned cereal bait, and that for successful control treatments it is necessary that this amount of bait should contain about eight LD 50's. Using the figure of 9 mg./kg. as the LD 50 of norbormide and 41·3 mg./kg. for zinc phosphide (Chitty & Southern, 1954), this method indicates field concentrations of 0·72 % and 3·3 % for the two poisons respectively. In the second method more weight is given to the slope of the dosage-mortality curve by allowing one LD 95 in the same quantity of bait and multiplying the percentage thus arrived at by three to allow for particularly resistant animals and for rats eating less than average amounts of bait. Adopting an LD 95 for norbormide of 17·0 mg./kg. and for zinc phosphide 73·0 mg./kg. (calculated from data given by Chitty & Southern, 1954) this procedure yields estimates of 0·51 and 2·2 % respectively.

While empirically based, both these methods rest on the assumption that differences among rodenticides in their palatability and speed of action result in negligible differences in consumption of poison bait by rats in the field. Though this may possibly be so for the poisons involved in Thompson's observations (zinc phosphide, antu, arsenic, red squill and barium carbonate) it is not necessarily true of other rodenticides. For this reason the results of the free-feeding tests are of interest. Here, the slope of the probit mortality/log concentration line calculated from the results of the no-choice tests for zinc phosphide is significantly steeper than that for norbormide (4·14 as compared with 1·63: $P < 0{\cdot}05$) and therefore, in comparison with norbormide, the likelihood of a lethal dose of zinc phosphide being eaten rises at a faster rate with increasing concentration. Further, this difference almost certainly resulted from reduced acceptance offsetting increases in the toxicity of the baits to a greater extent with norbormide than with zinc phosphide. This follows from the fact that the slopes of the probit mortality/log dosage lines based on bioassay data for norbormide and zinc phosphide (6·25 and 6·61 respectively) are steeper, yet more nearly equal. The same effect has already been commented upon in relation to the results of the choice tests—which indicate that the effectiveness of norbormide is likely to be about equal at all concentrations from 0·5 % to 2·0 % while that of zinc phosphide may be expected to increase up to a concentration greater than 2·5 %.

The marginally lower mortality obtained in the choice tests with norbormide as compared with 5·0 % zinc phosphide suggests that the latter might give the better results if both were used in the same conditions in the field. However, since the rats discriminated less consistently against norbormide than against zinc phosphide and because, in the field, the specificity of norbormide removes limitations on the mode of distribution of this poison which must still apply to zinc phosphide, it seems possible that norbormide at 0·5 % or more may give results as good as or better than 5·0 % zinc phosphide, particularly when used over periods

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of several days without prebaiting. Nevertheless, the failure of 0·5 % norbormide to give a complete kill (Table 3) in apparently favourable laboratory conditions indicates that, like zinc phosphide, it would not often give complete kills in single treatments against sizeable infestations in the field. Further, if the resistance shown by a few individuals is heritable, and if norbormide was used extensively, then a general reduction in its effectiveness would result as resistance to the poison became prevalent.

The amounts eaten in the original choice tests showed that the discriminators avoided eating a lethal dose by reacting to the taste of the poison. It was not possible however to determine whether the taste of poison caused aversion initially, or whether it did so later through being associated with symptoms of poisoning. In either event, the increased mortality in the tests in which poison was presented in the more palatable of two foods showed that aversion to the poisons could be overcome to a marked extent by using a highly palatable bait-base. The refusers, animals that apparently did not use the taste of poison as a means to identify the unpoisoned bait, survived by virtually not feeding at all. In some cases almost certainly, this was simply owing to illness. In others however it seemed to be primarily behavioural, since several animals showed marked shifts of preference away from the food experienced as toxic and towards a normally less acceptable food (Table 7). Similarly, Tables 6 and 9 show that some animals, after surviving exposure to a choice of a palatable food containing poison, and an unpoisoned though less palatable alternative, later showed a conditional shift of preference towards the less palatable food. This result is consistent with the concept of 'bait shyness' defined by Rzoska (1953) as 'a cautious attitude towards food (and poison bait) experienced previously with harmful effects'. Thus it seems likely that in the field, when attempting to eliminate survivors of norbormide treatments, it will usually be necessary, as with zinc phosphide, to use a different poison and bait-base.

The inferences drawn here as to the practical significance of the results must, however, remain tentative until they have been checked against experience in the field. In particular, it would be useful to carry out comparative field trials aimed at assessing the validity of laboratory methods of evaluating quick-acting rodenticides. This applies especially to the choice test, which at present seems to be more capable of further development than other methods, and more sensitive to the varied factors affecting a compound's rodenticidal efficiency.

SUMMARY

The median lethal dose of orally administered norbormide for wild *Rattus norvegicus* was found to be 9·0 mg./kg. of body weight and the LD 95 about 17·0 mg./kg.

In tests in which various concentrations of norbormide or zinc phosphide were added to the food of individually caged wild rats, mortality increased with concentration of poison, though more slowly with norbormide than with zinc phosphide. The mortality that occurred among rats offered a choice between unpoisoned food and the same food with added norbormide or zinc phosphide indicates that in control treatments in the field the optimum concentration of norbormide in

bait would be about 0·5 % and that this might be expected to give results comparable with those obtainable with 2·5 % or 5·0 % zinc phosphide. Other methods of estimating suitable field strengths indicate that concentrations of norbormide higher than 0·5 % may be preferable.

Some animals that survived exposure to a choice of plain food and the same food poisoned with norbormide or zinc phosphide at field concentrations avoided eating lethal amounts by reacting to the taste of the poison. Others learned to use the taste of the food, not that of the poison as a cue and later avoided eating the food when it contained no poison.

When either poison was presented to rats in the more palatable of two foods in the choice situation mortality was relatively high. Some of the surviving animals subsequently rejected the more palatable food in preference to the normally less palatable alternative.

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