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COMPARISON OF FUMIGANT GASES USED FOR RABBIT CONTROL IN GREAT BRITAIN

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ABSTRACT: The two most commonly used fumigant formulations, one generating hydrogen cyanide (HCN) and the other phosphine (PH_3), were compared in paired field trials using the spoon-gassing technique. The two formulations were equally effective in reducing rabbit numbers seen in spotlight counts. The PH_3 generating formulation was more convenient and slightly cheaper to use. Safety and humaneness aspects of the two formulations are discussed and alternative formulations (generating HCN and PH_3) are considered. The potential usefulness (for rabbit control) of some other fumigant gases is briefly reviewed.

INTRODUCTION

The European rabbit (Oryctolagus cuniculus) is the major vertebrate pest of British agriculture, currently causing damage estimated to cost tens of millions of pounds each year (Rees et al. 1985). Rabbits were a serious pest during the first half of this century, but the arrival of myxomatosis in 1953 led within two years to a 99% reduction in rabbit numbers (Lloyd 1970). Although rabbit numbers gradually built up again, economic rabbit damage to agriculture was negligible until the mid-1970s. Since then, rabbit numbers have increased more quickly, and it is estimated that nationally the rabbit population is now about 20% of the pre-myxomatosis population (Lloyd 1981). In some areas,.however, rabbit densities are well above the national average and crop loss is again serious.

As rabbit numbers have increased, the need for effective control has also increased, but the methods of rabbit control available in Britain have changed little for many years. A number of traditional methods are still used, some regularly and others only rarely. Ferrets (Mustela furo), are widely used to drive rabbits from their warrens, to be caught in nets placed over warren entrances, or to be shot as they emerge. Other traditional methods are snaring, netting, trapping and shooting, with shooting being probably the most frequently used of these. Trapping is restricted by law to the use of spring traps which have been approved as humane, and which must be set within warren entrances. Most of these traditional methods are very labour-intensive and available evidence suggests that, as practiced, none is effective in controlling rabbits. The use of poison-baiting for rabbit control is illegal in Britain, and the only legal method of poisoning rabbits is the use of toxic gases to fumigate warrens.

A survey of co-operative rabbit control organizations in 1982 indicated that burrow fumigation was the main method of control used (61%), with ferreting (26%) and shooting (11%) being the only other methods used to any extent (McKillop, unpubl.). This survey may not reflect the relative use of the different control techniques in Britain, since many farmers and landowners carry out rabbit control independently, and shooting and ferreting are probably used more frequently than the results of the survey would suggest. However, burrow fumigation is a widely used technique and is recommended by the Ministry of Agriculture as the most effective method available in many situations where access to warrens is possible. There are three methods of burrow fumigation used in Britain; "spoon-gassing" in which a powder or tablet that will generate a poisonous gas is introduced by means of a long-handled spoon into burrow entrances; "hand-pump gassing" in which a gas-generating powder is pumped into burrow entrances using a hand-operated pump; and "power-pump gassing" in which a motor-driven impeller or pump is used to introduce the powder. Of these, spoon-gassing is the most commonly used method.

There are two commercial products currently used for burrow fumigation in Britain. Powders containing sodium or calcium cyanide, which generate hydrogen cyanide (HCN) gas when exposed to moisture, have been used since the techniques of rabbit burrow fumigation were first developed in the late 1930s. Only one such powder, "Cymag" (I.C.I. Ltd.)*, is currently available. Since 1979 certain products containing aluminium or magnesium phosphide, which generate phosphine (PH_3), have been available and one such product, "Phostoxin Tablets" (Degesch, Frankfurt)*, has been increasingly used in rabbit control. This paper reports the results of field trials to compare the efficacy of "Cymag" and Phostoxin Tablets" using the spoon-gassing technique.

MATERIALS AND METHODS

"Cymag" is a tradename (I.C.I. Ltd.) for a powder containing 40% by weight of sodium cyanide. "Phostoxin Tablets" is the tradename (Degesch, Frankfurt) for tablets each weighing 3 g and containing 55% by weight of aluminium phosphide.

Paired trials were carried out on two different soil types (sand and chalk); one Cymag treatment and one Phostoxin treatment on the same soil type and on adjacent sites being carried out simultaneously. A total of 10 paired trials on sand and 7 on chalk were completed, but some were excluded from analysis (see below).

*Mention of commercial products does not necessarily signify official Ministry of Agriculture recommendation of their use.

Field sites in different parts of England were selected on the basis of soil type, accessibility of all burrow entrances, and night counts (using spotlight and binoculars) of at least 20 rabbits from a discrete population based on the warrens to be treated. Two trials, on sand, were omitted from the analysis of results as immigration of rabbits into the areas was shown to have occurred.

Four spotlight counts of rabbit numbers were carried out on each site within the 2-week period ending not more than 48 h before treatment, and a further four spotlight counts were made in a similar period after treatment. The effectiveness of each treatment was expressed as the reduction (%) in rabbit count numbers, calculated thus:-

$$\% \text{ reduction} = 1 - \frac{\text{(maximum number counted after treatment)}}{\text{(maximum number counted before treatment)}} \times 100$$

The positions of all burrow entrances were recorded before treatment, and each area was searched carefully with dogs, if possible, to drive rabbits into the burrows. Treatment consisted of placing either one heaped spoonful (approximately 28 g) of Cymag powder or one Phostoxin tablet into each entrance, which was then sealed with turf.

The amount of material used, the number of man-hours involved, the number of burrows treated, and the number reopened within 48 h were recorded. Paired t-tests were used to compare fumigants, and unpaired t-tests were used to compare soil types.

RESULTS

The results of the comparative field trials are summarized in Table 1, in which is shown the mean percent reduction in rabbit numbers achieved by treatment with each fumigant on each soil type. There were no significant differences between fumigants (t=0.3; df=13) or between soil types (t=1.68; df=28); Although the mean reduction after Cymag treatment on sand (54.4%) was considerably lower than after Cymag treatment on chalk (79.3%), the difference was not significant (t=2.12; df=13).

Table 1. Mean percentage reduction in rabbit count numbers after treatment of warrens with Cymag and Phostoxin in field trials on sand and chalk in England and Wales, 1981-1985.

	Soil type					
	Sand		Chalk		Total	
Fumigant	Mean (%)	SD	Mean (%)	SD	Mean (%)	SD
Cymag	54.4	25.0	79.3	17.3	64.4	25.0
Phostoxin	62.1	27.7	66.9	21.9	64.3	24.4
Total	58.0	25.8	72.6	20.1		

If the percentage of holes reopened within 48 h was used to compare effectiveness (Table 2), there were again no significant differences between fumigants, with a mean of 5.5% of holes reopened after Cymag treatment and 5.2% reopened after Phostoxin treatment. However, there were significantly more holes reopened on sand (mean 7.1%) than on chalk (mean 3.3%) (t=2.32; df=30; $p<0.05$).

Table 2. Mean percentage of holes reopened within 48h. of treatment with Cymag and Phostoxin on sand and chalk in field trials in England and Wales, 1981-1985.

	Soil Type					
	Sand		Chalk		Total	
Fumigant	Mean (%)	SD	Mean (%)	SD	Mean (%)	SD
Cymag	7.1	5.9	3.6	5.2	5.5	5.7
Phostoxin	7.1	4.9	3.0	2.6	5.2	4.4
Total	7.1	5.2	3.3	2.9		

Analysis of the man-hours required for each treatment (Table 3) showed that the mean number of holes per man-hour treated with Phostoxin (34.0) was significantly higher than with Cymag (25.6) (t=3.88; df=16; $p<0.01$). Phostoxin treatment was significantly faster than Cymag treatment, on sand (t=3.79; df=7; p<0.01), but not on chalk. The labour requirements for all (Cymag and Phostoxin) treatments on sand (31.1 holes per man-hour) and chalk (29.0 holes per man-hour) were very similar.

Table 3. Mean number of holes per man-hour treated with Cymag and Phostoxin on sand and chalk in field trials in England and Wales, 1981-1985.

	Soil Type					
	Sand		Chalk		Total	
Fumigant	Mean	SD	Mean (%)	SD	Mean (%)	SD
Cymag	25.1	5.8	26.1	13.9	25.6	10.0
Phostoxin	35.9	7.8	31.6	13.8	34.0	10.7
Total	31.1	8.7	29.0	13.6		

DISCUSSION

When choosing a control method, three factors--efficacy, humaneness and safety--must be considered. The trials reported here are part of a programme designed to evaluate and improve the fumigation techniques currently used for rabbit control in Britain and to investigate other possible methods.

No significant difference was found between the reductions in rabbit numbers achieved by treatments with Cymag and Phostoxin (Table 1), and it is concluded that the two fumigants are equally effective. It should be noted that much greater reductions in rabbit numbers would normally be expected in a control exercise, when any burrow entrances which were reopened within 1 to 2 days would be retreated. There were a number of trials in which rabbit count numbers were reduced by less than 50%, leading to the large standard deviations recorded. These "poor" treatments may have been due to failure to drive rabbits into warrens before treatment. It is well known that some rabbits live above ground at least part of the time, and consequently difficulty in driving rabbits underground is probably not uncommon. It is also possible that, despite careful searching, some warren entrances were not found and treated.

Previous reports on the effectiveness of HCN fumigation of rabbit burrows have used the number of percentage of holes reopened to compare different control methods. The results of the present trials can be analyzed in the same way, and show that Cymag treatment (mean of 5.5% reopened) and Phostoxin treatment (mean 5.2%) were not significantly different. Thompson (unpubl. 1950) reported that 4.76% of treated holes were reopened 4 days after pump-gassing, increasing to 11.3% reopened after 21 days. Phillips (1955) found that a mean of 16.3% of holes were reopened 4 days after fumigation by a combination of techniques, and a mean of 27% after 8 days. The method employed by Phillips was somewhat different to that of Thompson in that all holes were blocked about 5 weeks before fumigation and only those holes which had been reopened were treated. Phillips pointed out that this was a mistake, and it may well explain the higher percentage of reopened holes.

The use of reopened holes as a measure of efficacy of rabbit fumigants is likely to prove misleading. Phillips (1955) showed that blocking rabbit holes without gassing resulted in only a gradual reopening over a period of at least 5 weeks. Further, a comparison of the results in Tables 1 and 2 indicates that counting rabbits is a more accurate means of comparing treatments. Significantly more holes were reopened within 48 h after treatments on sand than on chalk (Table 2), although the reduction in rabbit numbers was not different (Table 1). The explanation may merely be that digging in sand is easier than in chalk. It appears, therefore, that the reopening of blocked holes is not a reliable indication of a reduction in rabbit numbers and can be affected by soil type.

Treatment with Phostoxin was significantly faster than with Cymag (Table 3), as might be expected, since Cymag treatment is somewhat less convenient. (Cymag powder is spooned from a container, the lid of which must be replaced after each spoonful; Phostoxin tablets are tipped from a tube onto the spoon.) The absence of a signficant difference between the rates of treatment on chalk may be because it is less easy on chalk than on sand to dig turf suitable for sealing warren entrances, and this means that the sealing of entrances determines the speed of treatment, whether Cymag or Phostoxin. On sand, the greater speed with which entrances can be sealed enables the greater convenience of Phostoxin to become evident.

As pointed out by Oliver and Blackshaw (1979), spoon-gassing treatments with cyanide powder produce lethal concentrations of HCN only close to entrances, and rabbits remaining in the main parts of treated warrens until HCN concentrations have decreased will be unaffected. Also, Phostoxin treatment, as normally practiced (one tablet per entrance), results in "concentrations of PH_3 which are insufficient to ensure death soon enough to prevent rabbits digging out" (Oliver and Blackshaw 1979). Evidence from the concentrations of PH_3 after Phostoxin treatment of an artificial rabbit warren (Ross, unpubl.) suggests that rabbits remaining in the main passageways of warrens treated with Phostoxin may be exposed to levels of PH_3 which may not result in a rapid death. Thus, although both fumigants are fairly effective, some rabbits may escape, and with Phostoxin some rabbits may die over a prolonged period.

Both Cymag and Phostoxin have good safety records in practice. Although very toxic gases are generated, operators are in the open air and the risks of sufficient concentrations of gas escaping from treated warrens are very small. However, since both products generate toxic gas on contact with moisture, safe practice demands that neither product is used in wet weather, because of the risk of harmful concentrations being generated. In addition, since Cymag is a loose powder, it should not be used in windy conditions because of the risk of inhalation of powder. Both HCN and PH_3 (as generated by Cymag and Phostoxin) have warning smells, although some people may not be able to smell HCN. There is an antidote to cyanide poisoning (amyl nitrite) which should be carried by operators, but the only treatment for PH_3 poisoning is moving the victim to the fresh air. It may be possible to improve efficacy, humaneness and safety by modifying gassing techniques or by using different formulations which generate HCN or PH_3. In addition, other possible fumigant gases are being considered.

There are at least two other commercial products generating HCN which may be useful in rabbit control. Degesch (Frankfurt) markets a powder called "A-dust" or "Calcyan" containing 40% calcium cyanide, and "Zyclon" (Degesch, Frankfurt), in which liquid HCN is adsorbed on cellulose. Hugon (1979) reported on the successful use of Zyclon for the control of foxes as part of the rabies control programme in France.

Apart from Phostoxin and another very similar compound ("Phostek", Anglo-Oil & Supply International), there are a number of different products generating phosphine which have been used successfully for the control of burrowing rodents in the USA. For example, Byers (1980) reported on control of the eastern woodchuck (Marmota monax) with "Mag-discs" (Degesch, Frankfurt). Treatment of active entrances resulted in a 67% reduction of active dens and 82% reduction in active holes 3 days after a single treatment. Mag-discs (each weighing 10 g) contain magnesium phosphide and greater quantities of PH_3 are generated more quickly than by Phostoxin tablets. Treatment of rabbit warrens with Mag-discs may result in higher concentrations of PH_3 in the main parts of the warrens and may therefore improve efficacy and humaneness.

The use of engine exhaust fumes as a means of introducing carbon monoxide (CO) into burrows was a common method of rabbit control in Australia. Oliver and Blackshaw (1979) concluded from studies of its toxicity and the concentrations in treated warrens that engine exhaust was an effective fumigant. About 40 years ago a pyrotechnic cartridge generating CO and a mixture of other poisonous gases was developed in the USA. Recently a cartridge producing only CO has been developed and shown to be effective in controlling coyote (Canis latrans) pups and Norway rats (Rattus norvegicus) (Savarie et al. 1980). A smaller cartridge has been used for control of ground squirrels (Spermophilus richardsonii) (Matschke and Fagerstone 1984), and, in combination with exhaust fumes, for pocket gopher control (Thomomys bottae) (Plesse 1984). The use of CO for euthanasia of mink (Mustela vison) (Lambooy et al. 1985) and other animals (Carding 1977) suggests that, if sufficient concentrations can be achieved in burrows, pure CO, but probably not exhaust fumes, should be a relatively humane fumigant. The pyrotechnic cartridge has also proved to be safe in use.

Gleeson and Maguire (1957) tested the toxicity to rabbits of gases that had been used in Australia for rabbit control. As well as HCN and CO, chloropicrin, carbon disulphide (CS_2) and sulphur dioxide (SO_2) were tested, but it was concluded that, at the concentrations tested, only HCN and chloropicrin were of high enough toxicity for consideration as effective fumigants. The results of Gleeson and Maguire and of Oliver and Blackshaw (1979) also showed that the irritant effect of chloropicrin (which makes it easy to detect at low concentrations and therefore relatively safe), and the relatively long exposure times required at the concentrations in treated warrens, indicate that rabbits are likely to suffer unpleasant symptoms for considerable periods before death.

Carbon dioxide (CO_2) was under consideration in Australia as a rabbit fumigant but was ruled out (Hayward and Lisson 1978) because of difficulties in obtaining dispersion through the warren and also because rabbits could tolerate high concentrations of CO_2. Hayward (1966) found that the levels of CO_2 in the ends of rabbit burrows reached 6 to 8%, and Bar-Ilan et al. (1984) reported that wild rabbits can tolerate atmospheres containing 14.5% CO_2 for 6 h.

CONCLUSION

Comparative field trials have shown that the two commercially available products used for fumigation of rabbit warrens in Britain are equally effective, reducing rabbit numbers by 64% after single treatments. However, there is scope for improvement of efficacy, humaneness and safety by considering other formulations which generate HCN or PH_3, or other fumigant gases. Of the fumigants which have been considered as alternatives to HCN and PH_3, CO_2, CS_2 and SO_2 are probably insufficiently toxic, and chloropicrin and engine exhaust are likely to be relatively inhumane, leaving only CO as worthy of further study.

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