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THE STATUS AND USE OF GOPHACIDE

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INTRODUCTION

Toxicants have been widely used for several decades to reduce numbers of problem animals. The utility of these substances, however, has been limited by hazards to other animals and man, inadequate effectiveness against the target species, and restrictions on use. The ecological complexity of most habitats in which animal control is undertaken requires utilization of new poisons that are less hazardous, more effective, and more specific. Gophacide[1], Bayer 38819, 0_, 0-bis(p-chlorophenyl) acetimidoylphosphoramidothioate, is generally favorable in these respects.

Tests with Gophacide were initiated at the Denver Wildlife Research Center in late 1961; and more recently, this chemical has also been tested at several field stations under different conditions. The initial and major emphasis has been to determine its usefulness in pocket gopher control. Techniques of use have been described (Ward et al., 1967).

PHYSICAL AND CHEMICAL CHARACTERISTICS

Technical Gophacide is a white crystalline powder which is soluble in chlorinated hydrocarbons, acetone, or warmed corn oil, and melts at 104-106 F. It is an organophosphate, and like related compounds, inhibits the cholinesterase activity of the blood. We don't know yet what the animal metabolites or oxidates of Gophacide are or the activity of such materials. The anticholinesterases, in general, are not accumulated for long periods in fatty tissues, and the hazard to wildlife is considered to be less from chronic than from acute poisoning (Casida, 1964).

SYMPTOMS OF POISONING

Visual evidence of Gophacide poisoning is usually not apparent in animals until 8-12 hours after ingestion or intubation, but the time and intensity of reaction varies with the quantity of toxicants the species, sex, and age of the animal, and its prior history of exposure to chemicals. Gophacide-caused depression of blood cholinesterase activity can be detected in blood samples by colorimetric and electrometric methods (Glick, 1938; Michel, 1949; Augustinsson, 1957).

Common symptoms include dermal twitching, body trembling, copious salivation and lacrimation, diarrhea, loss of appetite, loss of body weight, poor muscular coordination, and labored breathing. Carnivores frequently try to regurgitate. Death is ascribed to respiratory and/or cardio-vascular paralysis (World Health Organization, 1962).

ANTIDOTES

The slow action of Gophacide allows time for administration of an antidote. The preferred ones are atropine sulfate and protopam chloride (2-PAM or pralidoxine chloride), which may be used singly or together. Either may be given intramuscularly or intravenously, and protopam chloride may also be given orally. Both of these compounds are readily available.[2]

REGISTRATION

Federal registration of DRC-714, under the trade name of Gophacide, was recently obtained for control of pocket gophers. Under this registration 0.1 and 0.2 percent prepared bait will be. available to county, state, or other personnel experienced in rodent control. A 2.0 percent bait concentrate is also being considered for registration, now under a USDA temporary, experimental permit; this concentrate can be used to prepare 0.02 to 0.5 percent grain bait for control of house mice and rats.

[1] Also known as DRC-714. The use of trade names in this paper does not imply endorsement of commercial products by the Federal Government.

[2] Atropine sulfate may be obtained from Wittney and Company, Denver *h,* Colorado, and protopam chloride from Campbell Pharmaceuticals, Inc., New York, New York.

ASSESSMENT AS A RODENTICIDE

Four sequential steps are used in testing Gophacide on rodents. These are (1) determine acute oral toxicity by intubation; (2) test bait acceptance by individually-caged rodents in the laboratory; (3) ascertain the degree of control achievable in the field; and (4) determine hazards to other animals by intubation, baiting, and feeding rodents that died in laboratory tests to carnivores. In testing this chemical on any species, the result of each step is the determinant for completing or discontinuing further testing.

Acute Oral Toxicity

The desired dosage (mg of toxicant per kg of animal body weight) is given to rodents by intubation; i.e., it is placed directly into the stomach by way of the mouth and esophagus with a blunt needle attached to a suitable syringe. When enough rodents of a species are available, they are intubated at four or five dosage levels in groups of three or more per level. Deaths per total animals treated at each dosage level are recorded as a mortality fraction from which the ALD_{50} (approximate lethal dose for 50 percent mortality) for the animals is estimated. The results of some of these tests are presented in Table 1.

Table 1. Acute oral toxicity of Gophacide to various rodents and lagomorphs.

Species	Area Collected	Total No. of Animals Treated	ALD_{50} (mg/kg)
Pocket Gophers (*Thomomys*, *Geomys*, *Cratogeomys*)			
Southern (*J. bottae* sp.)	Arizona	9	2-5
Northern (*T. talpoides* sp.)	Colorado	19	1-2
Plains (*G. bursarius*)		9	5-10
Mexican (*C. castanops*)	New Mexico	7	2-5
Ground Squirrels (Citellus)			
Richardson's (*C. Richardsonii*)	Colorado	8	10-15
13-1ined (*C. tridecemiineatus*)		4	25-50
Rock (*C. variegatus*)		13	10-25
Squirrel-like Rodents			
Yellow-bellied Marmot (Marmota flaviventris)	Idaho	6	50-100
Black-tailed Prairie Dog (*Cynomys ludovicianus*)	Colorado	5	50-75
Townsend's Chipmunk (*Eutamias townsendii*)	California	20	40-50
Other Rodents			
Ord's Kangaroo Rat (*Dipodomys ordi i*)	Colorado	14	5-10
Meadow Mouse (*Microtus sp.*)	New Mexico	15	1-5
Pine Vole (*Pitymys pinetorium*)	Ohio	6	8-12

Table 1. Continued.

Species	Area Collected	total No. of Animals Treated	ALD_{50} (mg/kg)
Other Rodents (Con't.)			
Black Rat (Rattus rattus)	Louisiana	23	20-30
Muskrat (Ondatra zibethica)		5	20-30
Lagomorphs			
Black-tailed Jackrabbit (Lepus californicus)	Idaho	28	5-7
Nuttall's Cottontai1 (Sylvilagus nuttallii)		13	10-15

These results indicate that the pocket gophers (Thomomys, Geomys, and Cratogeomys spp.) kangaroo rats (Dipodomys ordii), meadow mice (Microtus sp.), pine voles (Pitymys pinetorium), and lagomorphs (Lepus and Sylvilagus spp.) tested are susceptible to Gophacide. In general, ground squirrels are quite resistant, but the degree of resistance varies considerably (data on other squirrel species will be given elsewhere); only the Richardson's (Citellus richardsonii) is sufficiently sensitive to be controlled by use of this chemical. Close relatives of ground squirrels, the prairie dog (Cynomys ludoyicianus), chipmunk (Eutamias townsendii), and marmot (Marmota flaviventris), were markedly resistant.

Bait Acceptance

This step in testing is usually limited to species relatively susceptible to Gophacide via intubation. Preparation of baits has varied at times with the type of grain and the species of animal being tested, but, in general, grain is mixed with 3 percent of acetone by weight in which is dissolved the desired weight of Gophacide. Mixing is continued until most of the acetone has evaporated. One percent by weight of corn oil is then added, for adhering the toxicant to the kernels of grain.

Dow Latex 512R, Rhoplex AC-33, Lecithin oil, and Plyac were also tested as adhesives for Gophacide. Rhoplex AC-33 (a 1:9 dilution with water) was tried with 0.1 percent Gophacide; it reduced acceptance on the first day and decreased mortality in pocket gophers when compared with the acetone-corn oil formulation. All these adhesives were tried with peromyscus (Peromyscus spp.). The Dow Latex 512R formulation yielded the best acceptance-mortality ratio; Rhoplex AC-33 the least favorable, and Lecithin oil and Plyac were intermediate. Laboratory acceptance tests on pine voles showed propylene glycol formulations to be equal to baits prepared with acetone and corn oil. At a 1.5 percent level, propylene glycol was used as both solvent and adhesive for the Gophacide.

To test bait acceptance, individually-caged rodents were offered more bait than they would consume each day for 3 consecutive days or until they died. Laboratory chow and free water were always available as alternative foods during the tests. Some results of these tests are shown in Table 2.

Bait acceptance by pocket gophers was generally excellent and mortality was high. Various grains were tried in baits with the different gopher species, and the grain most readily eaten was used in subsequent tests. Thus, crushed barley was used for Camas gophers (T_. bulbivorus) — reported on elsewhere, whole milo for plains gophers (G. bursarius), and whole oat groats for all others. Bait was readily eaten by meadow mice, peromyscus, house mice (Mus musculus), Ord's kangaroo rats, and black-tailed jackrabbits (Lepus californicus).

Acceptance of oat groat-Gophacide bait by pine voles varied greatly with length of time the test animals were held in captivity; the longer held, the poorer the acceptance. A concentration of 0.2 percent gave best results. A higher and quicker mortality was attained by offering diced carrots dusted with 0.1 and 0.2 percent Gophacide and activated charcoal.

Table 2. Results of some Gophacide-grain bait acceptance tests* on various animal species.

Species	Gophacide Conc. (%)	Av. Grams Bait Eaten	No. Deaths/ Tot. Animals
Pocket Gophers (*Thomomys*, *Geomys*, *Cratogeomys*)			
Northern			
(*T. talpoides*)	0.1	2.7	103/105
(1:9 Rhoplex)	0.1	2.8	66/75
Plains			
(*G. bursarius*)	0.1	2.1	18/25
	0.2	1.1	10/10
Mexican			
(*C. castanops*)	0.2	1.9	6/7
Other Mammals			
Richardson's Ground Squirrel			
(*C. richardsonii*)	0.2	4.6	8/10
Meadow Mice			
(*Microtus* sp.)	0.01	2.8	4/5
	0.05	1.1	10/10
	0.1	1.0	10/10
	0.2	0.6	15/15
Peromyscus			
(*Peromyscus* sp.)	0.1	0.7	4/5
	0.2	0.4	13/15
Ord's Kangaroo Rats			
(*Dipodomys ordii*)	0.1	1.6	5/5
House Mice			
(*Mus musculus*)	0.1	0.5	17/20
Black Rats			
(*Rattus rattus*)	0.1-0.5	3.5	4/26
Pine Voles**			
(*Pitymys pinetorium*)	0.2	0.3	14/15
(1.5% propylene glycol)	0.1-0.2	0.5	10/10
Black-tailed Jackrabbits			
(*Lepus californicus*)	0.1	17.5	24/31
	0.2	12.0	8/8
Birds			
Canada Geese			
(*Branta canadensis*)	0.1	20.7	0/2
Mallard Ducks			
(*Anas platyrhynchos*)	0.1	8.3	0/2

*This is the acetone-corn oil formulation except as indicated.
**For those voles held in laboratory for only a short time.

Bait acceptance by black rats (Rattus rattus) in Louisiana and by Canada geese (Branta *canadensis*) and mallard ducks (*Anas platyrhynchos*) in Colorado was poor.

Bait shyness toward Gophacide-grain baits has not been noted. Sick pocket gophers will normally continue to eat the bait until death. Prairie dogs tested at Denver continued to eat it each day for as long as 2-3 weeks, while exhibiting pronounced symptoms of Gophacide poisoning. Other species such as meadow mice have consumed several successive sublethal increments of Gophacide bait without showing aversion to it.

Field Tests

Pocket gophers.—Where possible, burrow builders (described by Ward and Hansen, 1960, and Kepner et al., 1961) were used in all field tests. A good gopher population, high soil moisture content, and minimal vegetation and trash were major considerations in operating the burrow builder. Soil moisture content is critical, but topography and obstructions in the plow zone can also limit use of this machine.

Burrows were made lengthwise (if convenient) in each field 20-30 feet apart until the test area was covered. A burrow was then made around the entire perimeter of the field close to the edges (Figure 4, Sargeant and Peterson, 1963). On flood-irrigated fields, a burrow was made in each border. The depth of the burrow was adjusted to correspond with that of natural burrows on the area being treated. This reduces the time required for gophers to discover the bait distributed in the artificial burrow, and enhances control. Well-formed burrows, in which bait is readily found by pocket gophers, are essential for effective control.

Control success was evaluated by the open-hole technique (Miller and Howard, 1951). This consists of (1) flagging occupied burrow systems, as indicated by fresh mounds at the time of treatment; (2) opening flagged burrows 3-5 days following treatment, by which time gophers will usually have consumed a lethal amount of bait; (3) counting the number of plugged and unplugged holes 24 hours after opening, by which time live gophers will usually have plugged a hole into the burrow; and (4) using 20-30 burrow systems on a nearby untreated area as an activity check. The degree of control is expressed as the percentage of burrows remaining open, adjusted to the activity check; e.g., if 100 burrows are flagged, opened, and remain open after treatment, and the activity check shows that only 90 percent of opened burrows on a nearby untreated area are plugged, the degree of control is computed as 90 percent instead of 100. The use of a check cancels out the effects of extraneous variables, so that the percentage of burrow systems that remain unplugged after treatment with a poison bait tends to be a reliable index of the degree of control achieved. The computed control still tends to be conservative because of plural occupancy of some burrow systems, which may be pronounced during the breeding and early post-lactation periods.

Table 3 shows that good control of gophers was generally achieved with the burrow builder when the above procedures were followed. It also shows that a drastic reduction in control occurs when conditions are not favorable — in this case, low soil moisture content. Results in California were similar to those reported here.

Table 3. Results of burrow-builder field tests with Gophacide-coated oat groats and milo for pocket gopher control.

% Conc.	Application Rate (lbs/acre)	No. of Tests	% Control Average	% Control Range
Colorado				
0.1	2.0	2	84.0	83-85
0.1	1.5	2	97.7	95-100
0.1	2.5	2	79.0*	73-85
0.2	1.5	4	98.1	97-100
Arizona				
0.1	2.0	2	82.4	81-84
0.2	2.0	3	94.7	94-96

*Poor result due to dry soil and poor burrows.

A hand-operated bait dispenser can be satisfactorily used (Hansen, 1956) on areas that are rocky, steep, or cannot otherwise be treated with the burrow builder. Successful use of this method depends on the ability to locate gopher tunnels by probing, insertion of bait into the tunnel, and covering of the hole made by the probe. The bait dispenser method is, however, somewhat arduous. For good results, the soil should be firm (not hard) and quite moist, and the operator should be conscientious and acquainted with the technique.

In four tests with the Hansen bait dispenser (Hansen, 1956), an average control of 90 percent was achieved in Colorado under fairly good conditions. Five such tests in California gave comparable results under similar conditions.

Field tests have so far been relatively unsuccessful on the Mexican pocket gopher (*Cratogeomys castanops*), even with hand baiting methods, because of poor bait acceptance in the field and unfavorable field conditions. This gopher usually inhabits heavy clay-loams and commonly occurs deep in banks of irrigation canals where it is difficult to operate burrow builders or hand bait dispensers. The average control in three bait-dispenser tests in Colorado and two in New Mexico was 61 percent.

Kangaroo rats.—Holes that were being used were plugged with soil and checked the following day for unplugging. Bait was then placed in or near holes of occupied systems and rechecked 24 hours later. In nearly all cases, bait had been eaten or cached during the first night. A week after baiting, the burrow systems were again plugged and checked for activity. The animals in burrows that had not been unplugged were assumed to be dead. In 11 tests in eastern Colorado, average control was 95 percent.

Pine voles.--Cubed carrot, cubed apple, and whole oat groats were treated with 0.2 percent Gophacide and used in Ohio fruit orchards to control pine voles. Bait was applied by hand, by the Elston mouse burrow builder, and by the U. S. Fish and Wildlife Service trail builder; the trail builder makes an open-topped runway. Bait rates varied with the method of application and the kind of bait used. Both sides of tree rows were treated just within the canopy drip-line. Conditions were generally unfavorable for treatment and results of baiting by hand and machine varied from 31 to 100 percent control. Nonetheless, results were encouraging. One hand-bait test with apple cubes gave 100 percent control, and one test with the trail builder gave a control of 87 percent, using oat groats.

Black-tailed jackrabbits.–A control of over 90 percent was achieved in one test in Idaho by using 0.05 percent Gophacide on chopped carrots. Further testing was discontinued due to the secondary hazard of Gophacide-contaminated carcasses to eagles.

Effects of storage & exposure on bait.--Bait treated with 0.1 percent Gophacide was stored for 3.5 years and then offered to northern pocket gophers. Bait acceptance was equal to that for fresh bait, but toxicity was reduced. Feeding tests showed that freezing Gophacide bait for 91 days did not adversely affect its toxicity or acceptability. Bait exposed for 14 days and 30 days in gopher burrows in Colorado were less acceptable and less toxic, but bait exposed for only 7 days was equal to unexposed bait.

Insecticidal properties of Gophacide.–Confused flour beetles (Tribolium confusum) were placed in boxes of oat groats treated with Gophacide at 0.5, 0.3, 0.1, and 0.05 percent concentrations and in untreated oat groats. These boxes were then sealed for 3.5 years except for several supplemental introductions of beetles into the boxes containing treated grain. Observed differences in the degree of grain damage by beetles shows that Gophacide has marked insecticidal properties.

Hazards to Non-target Animals

Primary.–Gophacide was administered to several species of birds (Table 4) by dropping gelatin capsules containing this chemical into the stomach through a suitable glass tube. Geese, ducks, magpies, and owls were highly susceptible, but sparrow hawks and leghorn chickens were markedly resistant.

Table 4. Acute oral toxicity of Gophacide to some species of birds.

Species	Total No. of Birds Treated	ALD_{50} (mg/kg)
American Magpie (Pica pica)	4	below 2.5
Sparrow Hawk (Falco sparverius)	8	100-200
Leghorn Chicken (Gallus domesticus sp.)	6	over 1700
Canada Goose (Branta canadensis)	5	8-10
Mallard Duck (Anas platyrhynchos)	12	14-18
Great Horned Owl (Bubo virginianus)	3	15-20

Dog food containing Gophacide was fed to two red foxes (Vulpes fulva) and several coyotes (Canis latrans) in Colorado; the LD_{50} is probably between 15 and 20 mg/kg for coyotes and over 20 for the foxes. Gophacide in cat food was given to one spotted skunk (Spilogale putorius), two opossums (Didelphus virqiniana), and six raccoons (Procyon lotor) in California. There were no deaths below 37 mg/kg. One raccoon in Idaho survived a dose of 45 mg/kg.

Rainbow trout (Salmo gairdneri) fingerlings were subjected to several different concentrations of Gophacide In trials at Denver. All were killed within 24 hours at a concentration of 0.75 ppm in the water. The ALC_{50} (approximate lethal concentration for 50 percent mortality) was 0.58 ppm for an exposure period of 24 hours.

Personnel mixing and handling the baits have taken the usual precaution of avoiding dermal and respiratory contact with the chemical. No individuals have experienced any ill effects.

Secondary.--Secondary hazards were checked by feeding carcasses of rodents and birds that had died of Gophacide poisoning to carnivores. The animals were given as many carcasses daily as they would consume. Water was always provided, but no other food was usually given. The results of these and other tests (Table 5) show that Gophacide poses little hazard to common mammalian carnivores.

Table 5. Tests of the secondary hazard of Gophacide to various common carnivores.

Species	Animal Number	Bait Consumed	Days Offered	Results*
Coyote				
(*Canis latrans*)	1	13 ducks and geese	13	NR
	2	91 pocket gophers	7	NR
	3	59 pocket gophers	10	NR
Sparrow Hawk				
(*Falco sparverius*)	4	36 meadow mice	36	NR
Ferruginous Hawk				
(*Buteo regalis*)	5	62 meadow mice	15	NR
Swainson's Hawk				
(*Buteo swainsoni*)	6	3 pocket gophers	20	R
Golden Eagle				
(*Aquila chrysaetos*)	7	10 pocket gophers	3	R
	8	1 jackrabbit	1	R
	9	3 jackrabbits	8	R
	10	6 jackrabbits	24	R
	11	3 jackrabbits	14	R
Bald Eagle				
(*Haliocetus leucocephalus*)	12	1 jackrabbit	1	R
Great Horned Owl				
(*Bubo virginianus*)	13	46 meadow mice	22	R**

*NR: No reaction noted; R: Reaction, symptoms of Gophacide poisoning.
**No physical symptoms were apparent, but a chemical test of blood indicated a marked inhibition of cholinesterase activity.

Some of the raptors, however, are easily poisoned by consuming Gophacide-contaminated carcasses. Symptoms of Gophacide poisoning were verified in eagles by colorimetric and electrometric chemical tests; an appearance of physical stress was always accompanied by a fall in the cholinesterase level of the blood. The cholinesterase levels of the blood sera of five eagles tested in Idaho were 0.22, 0.21, 0.22, 0.24, and 0.15 before eating the Gophacide-contaminated offerings and 0.09, 0.06, 0.12, 0.08, and 0.02, respectively, after eating them.

Very few pocket gophers have been found on the surface of the ground after baiting for field tests. This, plus the fact that all bait is placed underground, reduces the hazard of Gophacide to non-target species to a low level in well-supervised gopher control programs.

Field tests on the kangaroo rat have also shown that few rats die above ground. Bait placed near the holes of these rats is nearly always removed from the surface the first night. This greatly reduces hazards to other species, especially when the bait is distributed in the evening.

CONCLUSIONS

Numerous tests with Gophacide since 1961 have demonstrated its utility in controlling pocket gophers (except the Mexican pocket gopher) in the United States. Gophacide is superior to common rodenticides for gopher control; it is less hazardous to other animals than some rodenticides and is better accepted than others. Gophacide is safe for the operator to use if handled with care -- the slow action and availability of good antidotes provide some measure of safety.

This chemical shows promise for use in the control of meadow mice, house mice, kangaroo rats, and pine voles. It also may prove useful for control of other species such as the Richardson's ground squirrel.

Black-tailed jackrabbits are highly susceptible to Gophacide, but rabbits killed with this toxicant present a secondary hazard to eagles and large hawks that live in the vicinity. This prohibits the use of Gophacide for jackrabbit control, unless a solution to this problem is found.

The effects of Gophacide on animals may vary greatly from one species or subspecies to another. This variation can be extremely useful and advantageous in the selective, judicious reduction of a nuisance animal in a complex eco-system.

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