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The use of the anticoagulant rodenticide, chlorophacinone, was largely developed in France during the last ten years. Its special properties, with respect to those of other anticoagulants currently known, have contributed largely to finding an effective and economically acceptable solution in the struggle against the two most damaging rodents in France: the common vole (Microtus arvalis P.) and the muskrat (Ondatra zibethica L.).

THE COMMON VOLE (Microtus arvalis P.)

The Problem

This rodent is very much spread all over France; it is only absent in the mediterranean region which is occupied by a species of the Pitymys family. It is found in the coastal low lands as well as in the mountain plains, in the Atlantic environmental as well as in the continental areas.

In the crops, it lives preferably in the natural or artificial prairies, but it is also found in uncultivated lands, road ditches, etc., anywhere where he can find green vegetation for its food supply, a herbaceous cover for its protection, and a soil that will allow him to dig his burrows.

In the ecological systems, it occupies a place similar to the one occupied in North America by the Microtus ochrogaster or the Microtus californicus. Nevertheless, it is not exactly comparable to one or the other of these two species due to the difference in climates (Californian, continental of great plains) to which the American rodents are adapted.

At the peak population seasons, it is not unusual to find in the Mid-west of France average densities (in extended surfaces) of 200 animals per acre.

In spite of the fact that modern cultural practices are not favorable to them, they still maintain a substantial economic importance (Bouyx, 1967).

Up to recently, the struggle against the common vole was carried out at the end of summer or fall by means of poisoned cereal grains (at 0.5 percent zinc phosphide or 0.1 percent crimidine) which were placed fey hand in the burrows. This method had the following disadvantages:

1. The campaign was made too late as it was carried out after most of the damage was done (June-July).

2. It required too much labor and was, therefore, too costly.

3. The poisoning of game birds; partridges and pheasants were often victims (Viel and Giban, 1958 and 1961).

Starting in 1959 the I.N.R.A. developed a research program with the purpose of finding:

1. A method of preventive and mechanized treatment.

2. A rodenticide that may be less dangerous to game birds than zinc phosphide (or the crimidine).

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The Biological Research

F. Spitz worked during ten years in the Atlantic coast low lands at the Vendee. There he studied the demography of the common vole and showed the mechanism that regulated the annual cycles of peak population of this rodent as well as the level fluctuations from one year to the other (Spitz, 1963, 1965b, 1967, 1970, 1974).

He also showed that, after sampling periodically the population of a region by means of a standardized trapping method, it was possible to forecast one to three months in advance (and sometimes six months) the average level of the populations of common vole and their invasion in the crop. This method, applied in a region at one time, permits to warn the farmers of any possible risk of serious damage to their crop and to advise them to treat the field before they strike.

F. Bayon (Engineer at the National Federation of Groups for the Protection of Crops, FNGPC) applied this method in the Province of Vendée starting 1966 and J. M. Gailleton (Engineer of the Service of Plant Protection, P.V.) in the Province of Deux-Sevres starting in 1967. Thanks to their compiled observations, it is possible to simplify the sampling method by trapping and increase the accuracy of their conclusions.

Laboratory Work

Before 1964, the largest number of rodenticides (antu, DDT, fluosilicates, various anticoagulants, etc.) were tested in a laboratory to attempt to replace strychnine (the only one used before 1940) and zinc phosphide (Giban, 1965b and Giban and Grolleau, 1967)

Starting in 1964, the work was centered on the anticoagulants. Eleven of them were studied: six derived from 4-hydroxycumarine, five derived from indanedione - 1.3. G. Grolleau (1971a) could show (Table 1) that after a single ingestion of poisoned wheat at 0.0075 percent of active material the rate of mortality obtained with chlorophacinone was considerably higher (69 percent) than with the other six anticoagulants tested (ten to 25 percent). When the ingestions are raised to three, the mortality is almost total with chlorophacinone (97 percent) and acceptable with coumatetralyl (85 percent), inadequate with diphacinone and coumafuryl (75 percent), very inadequate with the last three. Also, these tests show (Table 2) that the increase in the percentage of active material in the grains does not compensate for the inadequacy of the tested products (except perhaps for the coumatetralyl).

Table 1. Percent mortality after ad_ libitum feeding of 0.0075 percent anticoagulant chlorophacinone bait on the common vole (from G. Grolleau, 1971).

Anticoagulant	Mortality After One Feeding (Percent)	Mortality After Three Daily Feedings (Percent)
Coumafene	5/20 (0.25)	5/20 (0.25)
Coumafuryl	4/20 (0.20)	15/20 (0.75)
Coumatetralyl	2/20 (0.10)	17/20 (0.85)
CPPH	2/20 (0.10)	7/20 (0.35)
Pivaldione	2/20 (0.10)	9/20 (0.45)
Diphacinone	3/20 (0.20)	15/20 (0.75)
Chlorophacinone	318/459 (0.69)	279/289 (0.97)

The Field Tests

The field tests could not be started until we developed a good method to measure accurately the rate of mortality obtained under the same practical conditions (Spitz, 1965a).

At the beginning, the most varied products were tested and dropped; toxaphene or endrin sprays, carbonic gas, etc., (Giban, 1965, Giban and Dixmeras, 1967). But in 1965, experimental proof was brought that wheat grains poisoned with 0.0075 percent of chlorophacinone, applied at the entrance of the burrows, had an effectiveness of at least equal to zinc phosphide grains at 0.5 percent or crimidine granules at 0.1 percent (same references), it then became possible to think of a study with chlorophacinone.

Table 2. Effect of anticoagulant concentration in the bait upon the percent mortality (from G. Grolleau, 1971).

Anticoagulant	Number of Feedings	Mortality in Each Test Group for Each of The Bait Concentrations (Percent)			
		0.0075%	0.0250%	0.0500%	0,1000%
Coumafene	X 1	5/20 (0.25)	10/40 (0.25)	3/20 (0.15)	3/20 (0.15)
	X 3	5/20 (0.25)	11/20 (0.55)	7/20 (0.35)	9/20 (0.45)
Coumafuryl	X 1	4/20 (0.20)	2/20 (0.10)	7/20 (0.35)	
	X 3	15/20 (0.75)	12/20 (0.60)	10/20 (0.50)	
Coumatetralyl	X 1	2/20 (0.10)	8/20 (0.40)	19/20 (0.95)	
	X 3	17/20 (0.85)	12/20 (0.60)		
Pivaldione	X 1	2/20 (0.10)	2/20 (0.10)		
	X 3	9/20 (0.45)	10/20 (0.50)		

* X 1 = one feeding X 3 = three daily feedings

The tests were made from 1965 to 1970 by the INRA, the PV, and the FNGPC. Their conclusions were the following:

1. When the grains (poisoned at 0.0075 percent of CPN) are broadcast mechanically by means of a seeder with centrifugal distribution the rate of mortality is not sufficient; about 80 percent (Giban, 1970): as it seems, only the grains that fall on the tracks are eaten.

2. When the grains (poisoned at 0.0075 percent CPN) are broadcast mechanically in line, by means of a seeder, the mortality is generally higher than 80 percent and can reach 90 percent. It is advised to allow a 5.5 yards separation between lines and a dosage of 13 to 18 pounds of poisoned grain per acre (Bayon, 1971; Gailleton, 1971; Giban, 1970).

In addition, F. Bayon (1971), J. M. Gailleton (1971), and G. de la Roche Saint-André (1971) proved the following:

1. The effectiveness of a preventive campaign.

2. The practical interest to the farmer of such a campaign.

Risk to Game Bird

The grains poisoned with chlorophacinone having been broadcast in line in the field, are liable to be eaten by partridges or pheasants. Some tests were also made in order to evaluate the potential risks to game birds as a result of their ingestion of said grains. They were described by J. Giban (1965a).

G. Grolleau (1974) demonstrated the following (Table 3):

1. The ingestion of chlorophacinone grains for 15 consecutive days did not kill any grey partridge.

2. They had either to ingest repeatedly during 30 days, or the chlorophacinone dose to be doubled to achieve a partial mortality (20-30 percent).

3. The red partridge is significantly more sensitive to chlorophacinone than the grey partridge. Chlorophacinone grains cause a week mortality after five, ten, and 12 days of consumption (ten percent) and a serious one after 15 days (90 percent).

Practically we can conclude that when grains at 0.0075 percent of chlorophacinone are broadcast at less than 18 pounds per acre, the risk is practically nil for the grey partridge; it is weak for the red partridge, but it is no longer negligible if we increase the dosage to more than 0.0075 percent of active material in the grains or if we increase the amount of bait to more than 18 pounds per acre, as, in the latter case, there remains on the soil relatively important quantities of grain not consumed by the common vole.

Table 3. Toxicity tests of various anticoagulant rodenticides to the common partridge and the red legged partridge (from G. Grolleau and G. Paris, 1974.

Species	Anticoagulant	Length of Test Period (Days)	Toxicant Administered Daily (mg)	Mortality/Number Tested
Common partridge	chlorophacinone	15	2.25	0/10
		30	2.25	4/19
		15	4.50	3/10
	coumafene	30	7.50	3/9
	coumafuryl	30	7.50	2/10
	coumachlore	30	7.50	2/9
	C.P.P.H.	30	7.50	5/10
	pival	30	7.50	1/10
Red legged partridge	chlorophacinone	5	3.00	1/10
		10	3.00	1/10
		12	3.00	2/10
		15	3.00	9/10
	coumafene	15	10.00	1/10

Conclusion

At present the campaign against the common vole in France is carried out almost exclusively by means of wheat grains poisoned with 0.0075 percent chlorophacinone (that is 280 pounds of wheat grain per gallon of oil concentrate at 0.28 percent w/w - 0.25 percent w/v).

There are no more complaints on the part of the hunters due to accidental mortality of game birds.

THE MUSKRAT (Ondatra zibethica L.)

The Problem

The muskrat was introduced in France near 1928 for its breeding in captivity. But animals that escaped from their cages settled in different points in the country starting centers of infestation that have not ceased to expand. At the present time, this rodent covers about two-thirds of the French territory -- only the southern areas have been spared.

The absence of other aquatic and herbivorous species has certainly favored the spread of the muskrat, which is found now in the rivers and plain ponds as well as in the coastal swamps or the valleys between mountains and medium altitude. Only the lack of aquatic vegetation of some importance seems to limit its settlement.

It is harmful to crops such as beets or to fish ponds but generally it is due to the digging of the burrows that the muskrat causes most damages. In most European countries the struggle against this animal is compulsory and the O.E.P.P. (European and Mediterranean Organization for Plant Protection) has considered this matter to be serious enough to hold regular conferences since 1951 and set up permanent work groups.

Up until the last years, the only means of controlling the muskrat was essentially trapping. This method of control is certainly highly effective but it is actually very difficult and costly to carry out. In effect, in order to be very effective the trapping must be done in a generalized and continued manner over vast surfaces. This requires a large number of trappers both competent and active.

The Method by Means of Poisoned Bait

In a previous paper, I had the opportunity of outlining briefly the historical use of poisoned bait and reporting the reasons why the first attempts failed (Giban, 1968).

The idea did not become feasible until the appearance of the anticoagulant rodenticides. I wish to remind you simply that the first work was carried out in California (Storer, 1958; Marsh and Plesse, 1960; Marsh, 1965; Storer and Jameson, 1965) as well as in New York (Erikson, 1966).

In Belgium, the first studies were made by R. Moens starting 1966 and led to the use of chlorophacinone (Moens, 1968). The researcher's purpose was to allow a single ingestion by the muskrat of a sufficient amount of toxicant to kill them; for this a piece of carrot (or apple) was used by digging a hole in it. Zero point six to 0.7 ml of oil concentrate (at 0.28 percent w/w of chlorophacinone) was poured in the hole and same closed again by replacing the portion scooped out originally.

Although this idea of a single lethal dosage is arguable when you are dealing with an anticoagulant rodenticide (Moens, 1971), the high effectiveness of these limited tests was confirmed when field applications were carried out over thousands of acres (Moens, 1969a and b; Moens and Ghesquiere, 1969; Moens and Colin, 1969).

In France, after an initial period of scattered uninteresting tests the serious study of the use of anticoagulants for the control of the muskrat started in 1967 and 1968 (Giban, 1969; Dixmeras and Mahieu, 1971). Its purpose was to use a bait cut in slices (carrot or beet) poisoned by mixing it with a liquid toxic material.

Laboratory Tests

Table 4 shows the results obtained by G. Grolleau. Two important conclusions were obtained:

1. The mortality obtained with a single ingestion is 100 percent when chlorophacinone baits are used up to a dosage of 0.005 percent of active material (rat dosage); this did not occur with coumafene even at the higher dosage of 0.075 percent (three times the rat dosage).

2. The concentration of 0.015 percent of chlorophacinone originally authorized in France could then be lowered to 0.005 percent without any risk of reducing effectiveness.

Table 4. Toxicity of anticoagulant poisoned bait upon muskrats (from G. Grolleau and Lipha Soc., unpublished).

Anticoagulant	Concentration In the Bait (Percent)	Bait Ingested Daily (g)	Length of the Test (Days)	Mortality/Number Tested
Coumafene	0.0750	300	1	6/8
	0.0375	-	1	2/10
	-	-	3	10/10
Chlorophacinone	0.0150	300	1	9/9
		100	1	15/15
		-	2	15/15
	0.0075	300	1	10/10
		100	1	20/20
		100	2	20/20
	0.005	300	1	9/9
		100	1	20/21
		100	2	20/20
	0.003	100	1	7/10
		100	2	8/10
		100	3	10/10

Field Tests

We do not have for the muskrat a method allowing to evaluate the rate of control obtained in a manner as accurate and as simple as the one used for the meadow mouse. We are forced to use several techniques at the same time; curve of consumption of the baits, trapping of survivors, activity, etc., (Vincent and Quere, 1973).

Since 1968 various tests were carried out by the I.N.R.A., the P.V., various official and professional institutions. Only the first ones of these tests were actually published; Giban, 1969; Dixmeras and Mahieu, 1971. They were carried out on ponds, canals or rivers. But at the same time some farmer groups organized their own campaigns over sometimes very important surfaces (over 12,000 acres). In this case again, only the results of the first applications were published (Aulois and La Roche Saint-Andre, 1971).

Out of these applications we drew the following conclusions:

1. Chlorophacinone is generally preferred to coumafene. By means of a general treatment followed by a supplementary treatment eight or ten days later with chlorophacinone bait, very high control can be achieved (90 percent and over); with coumafene the regular replenishment of bait seems indispensable.

2. The carrots and the beet slices constitute a well accepted bait, even during the vegetation season.

3. The dosage of 0.005 percent of chlorophacinone in the baits proved to be equally effective as the higher dosages.

4. The method of the artificial burrow*, devised by the chief trapper Poulain, proved to be very effective and has the advantage of placing the poisoned baits out of the reach of aquatic fowl.

5. The placement of poisoned baits on floating bait stations developed considerable interest, especially in ponds with substantial aquatic vegetation.

6. If it is desired to prolong the effect of the control over a long period of time, it is necessary to carry out the campaign over a sufficiently large territory; in the lowlands, a treatment made over 2,500 acres or more ensures keeping the muskrat population over 12 to 18 months at a negligible level.

Studies are being continued at the present time as the technique has still to be improved for the areas where there are numerous and less accessible ponds. But as of today the use of baits poisoned with 0.005 percent chlorophacinone is recommended for the struggle against the muskrat (Giban, 1972).

Risk to Game Species

In 1970, after a campaign against muskrats was carried out in the north of France using chlorophacinone baits, some hares Lepus Europaeus L. were poisoned. The accident apparently had some relation with a snowfall that occurred just after the placement of the baits. It was necessary to find out under what conditions the poisoning could take place.

As it is not possible to test on hares, G. Grolleau carried out tests on rabbits hoping that the sensitivities of both species to anticoagulants are comparable. These results have been reproduced in Table 5.

The following observations have been made:

1. The rabbit is less sensitive to coumafene than to chlorophacinone.

2. The sensitivity of the rabbit to chlorophacinone varies from one species to the other.

3. If the hare is as sensitive to chlorophacinone as the most sensitive rabbit, deadly accidents could take place after a consumption of 120 to 200 grams of bait poisoned with 0.005 percent (for hares weighing 6-1/2 to 11 pounds).

* At the river or canal bank, the operator digs an eight to 12 inch deep hole with a shovel just below the water level. The bait is placed at the bottom of this hole.

Table 5. Toxicity of anticoagulant rodenticides upon the domestic rabbit (from G. Grolleau, unpublished).

Anticoagulant	Rabbit Strain	Dose (mg per kg)	Number of Ingestions	Mortality/Number Tested
Chlorophacinone	New Zealand	6	1	1/5
		6	3	4/5
		10	1	4/5
	undetermined	2	1	4/5
		5	1	5/5
		10	1	5/5
Coumafene	undetermined	20	1	0/3

G. Grolleau and G. P. Paris (1974) have also examined this question with respect to the mallard duck, Anas platyrhynchos L. Table 6 presents their experimental results. It is noted that lethal accidents are not likely to occur unless the ducks would eat 300 grams per day for seven consecutive days, a bait poisoned with chlorophacinone at 0.005 percent; or, 100 grams per day of the same bait during ten days. The risk then, although not nil, is at least very low.

Table 6. Toxicity of anticoagulant rodenticides upon the mallard duck (from G. Grolleau, 1974).

Anticoagulant	Dose (mg per kg)	Number of Ingestions	Mortality/Number Tested
Coumafene	180	1	9/10
	120	1	2/5
	60	1	0/5
	-	3	0/5
	-	7	2/10
	-	10	1/5
	-	14	4/5
Chlorophacinone	45	1	0/5
	30	1	0/5
	15	1	0/10
	-	3	0/10
	-	7	1/10
	-	10	4/5
	-	14	5/5
	5	7	0/10
	-	10	1/5
	-	14	2/5

Conclusion

The struggle against the muskrat by means of baits (carrot or beet) poisoned with chlorophacinone (recommended dosage 0.005 percent) can be used for a long-lasting control (under certain conditions). The risk to wildlife appears as negligible in general, and nil when the bait is placed in artificial burrows or on floating bait stations.

LIST OF RODENTICIDES MENTIONED

Bromophacinone: (ρ-bromophenyl-2 phenyl-2 acetyl)- 2 indanedione- 1,3.
Chlorophacinone: (ρ-chlorophenyl-2 phenyl-2 acetyl)-2 indanedione-1,3.
Coumachlore: hydroxy-4 (oxo-3 ρ-chloropheny!-1 butyl)-3 coumarine.
Coumafene: (warfarin) hydroxy-4 (oxo-3 phenyl-1 butyl)-3 coumarine.
Coumafuryl: (α-acetonyl furfuryl)-3 hydroxy-4 coumarine.
Coumatetralyl: hydroxy-4 (tetrahydro-1 ,2,3 ,4 naphtyl)-3 coumarine.
CPPH: hydroxy-4 (oxo-3 ρ-chloropheny1 - 1 propyl)-3 coumarine.
Dicoumarol: methylene 3,3-bis (hydroxy-4 coumarine).
Diphacinone: diphenylacety1-2 indanedione 1,3.
NID: naphtyl-2 indanedione 1,3.
Pivaldione: pivaloyl-2 indanedione 1,3.
Crimidine: chloro-2 dimethyl amino-4 methyl-6 pyrimidine.

LIST OF ANIMAL SPECIES MENTIONED -- LISTE DES ESPECES ANIMALES CITEES

Scientific Name	Common Name (French)	Common Name (English)
RODENTS		
Microtus arvalis	Campagnol des champs	Common (or Continental) Vole
Microtus californicus	Campagnol de Californie	California meadow mouse
Microtus ochrogaster	Campagnol de la prairie	Prairie meadow mouse
HARE		
Lepus europaeus	Lièvre commun	Brown (or European) hare
BIRDS		
Perdix perdix	Perdrix grise	Common partridge
Alectoris rufa	Perdrix rouge	Red legged partridge
Phasanius colchicus	Faisan	Pheasant
Anas platyrhyncos	Canard Col-vert	Mallard duck

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