RAT REDUCTION WITH INDIGENOUS METHODS

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INTRODUCTION

Mujumdar (1968) has recorded that there are 566,000 villages in India as compared to 2699 towns, and that there is 322,460,000 acres of cultivable land and probably 500 million domestic rats in India.

The food production target in 1968 in India was to be 110 million tons. National rodent committee 1967 mentioned of a loss of one million ton of food grains by rats alone. Deoras (1968) has mentioned that 3 common rats in Bombay were consuming 26 gm. of food grains per day, that is, about one ounce, while the quantum of cereal rations available per man in some parts of India is 6 oz. per day. If rat reduction was done, this 16% denial of human food could be saved, and 7.7% import of food grains improved (Deoras 1968).

It was further observed that the small rat Laggada booduga climbed up a paddy plant and ate every grain, while the field rat B. bengalensis took a few grains, may cut a plant and remove it to burrows. The presence of the bigger rat drove the smaller ones away. The smaller rats did more damage than bigger ones, and if indiscriminate baiting was done, the bigger ones that did less damage were wiped out, leaving the smaller ones to do more damage. The knowledge of the frequency of rat population and the habits seemed necessary to do a large-scale rat eradication programme.

Rat eradication programmes if not continued every year bring about an increase of about 40% in the rat population. Considering the meagre staff employed by the Agriculture Department in various States, it was very necessary that this continuity has got to be maintained by someone else apart from government employees, and these would be the Agriculturists themselves. The farmer has apart from Agriculture operations, to look to other pests also, as such, unless specially interested or disturbed, he normally does not devote sufficient time and money, from his small per capita income.

Rat control measures are well-known. The improper use of zinc phosphide and other poisons have killed poultry and even domestic animals. Rats died in the open (or crevices) of poison baits, leave a foul smell also. The farmer therefore needs to be assured of safety and less of a nuisance and be convinced that if efforts are properly applied he stands to gain thereby.

Government of Maharashtra was interested in rodent control and had sanctioned Rs. 3,21,000 to purchase rat poisons vide CPS 3066A of 2.3.1967. A meeting was held in the chambers of the Deputy Secretary, Agriculture Department, Government of Maharashtra, where Dr. V.G. Joshi, Additional Director, Agriculture, Dr. P.J. Deoras, Assistant Director, Haffkine Institute, and Mr. Talgiri, Director, Plant Protection were present. It was decided in this meeting to make the best use of this amount to go in for pilot scheme to get the maximum results from the amounts sanctioned and cultivate motivation of the farmers. The pilot scheme was to be done initially in 4 villages of Panvel Block and Dr. P.J. Deoras was to initiate, formulate and execute the scheme. Later on the entire Block was to be taken and then the District.

With a view to start this motivation in the farmers, studies were initiated in 1967 in four villages of Panvel Block, 45 miles from Bombay. Here the frequency of different rats was first studied. The damage aspect of rat to grain, houses, clothing, material and health was brought to the notice of villagers and baiting inside the houses was avoided. The eradication was started with the denial of rats access to houses, use of rat repellent like 50% BHC and 1% Malathion around houses, educating the public of rat damage and the actual control work for 4 monsoon months only.

The last point was taken into account, because it was observed that since the rainfall was up to 3136 mm in 4 months the fields were flooded and the rats migrated towards higher ground or residential areas where there would be a concentration of all rats. The rats were removed by trapping from houses, poison baits were applied in bait boxes outside, and the rat burrows fumigated with sulphur dioxide. The trapped bigger rats were skinned and

the hide sold to tanneries for 30 paisa which became an incentive to farmers. This gave encouragement and a number of local volunteers came forward to complete the project. The work was stopped as the rains ceased and the crop was ripe in the field.

The pilot scheme undertaken at Kalundre, Kolke, Kon and Palaspe (population 6310, houses 2932) for 4 months was responsible for collecting 2063 rats of which only 95 were by baiting. It showed that the predominant rat there was R. rattus (2055) and the female rats were in an overwhelming majority. The damage to clothing was Rs. 621/- apart from food grains and cattle fodder. The amount of bait used in traps was 67 kg of which rats consumed 15.56 kg. In the case of baits, it was 60.145 kg and used was 12.20 kg. The use of BHC 50% suspension @ 1.% and Malathion at one percent prevented re-entry of rats for six days.

The entire Panvel Block was therefore taken for eradication in 1968 on the same basis as the Pilot Scheme in four villages. Later on, next year it was to be taken into adjacent blocks. The work was to be started just before monsoon and stopped as the rains ceased and the paddy crop by that time was ripe for harvesting. No amount of baiting would succeed when the crop is full of fresh grains.

The work given here records the result of eradication up to 134 villages, by which time the monsoon had ceased.

MATERIAL AND METHODS

Panvel, Headquarters of Panvel Block lies 45 miles from Bombay. The Block has mountainous terrain in the East and South, sea and creeks in the West, and cultivable area separated by mountain ranges from Bombay in the North. The maximum temperature in the area is 30.7°C and the minimum 22.8°C. There are 104 days of rains in the year and the total downpour in that period comes to 3136 mm. The Block belongs to Kolaba District in Maharashtra State and comprises of 198 villages of which 177 have habitable houses numbering 16,785. The population as per 1960 census was 115,378 of which 97,248 was in smaller villages. Nearly 64.57% of the population are cultivators. Total area of the Block is 215.3 sq. miles, consisting of 143,400 acres; of this, 59100 acres is under crops. Paddy cultivation in 40,100 acres only, brings out rice at the rate of 1701 pounds per acre to the tune of 3,41,05050 kg., bringing to the farmers about Rs. 30,000,000 in rice produce alone. Vegetables, flowers, and fruits, as well as poultry, bring in additional income.

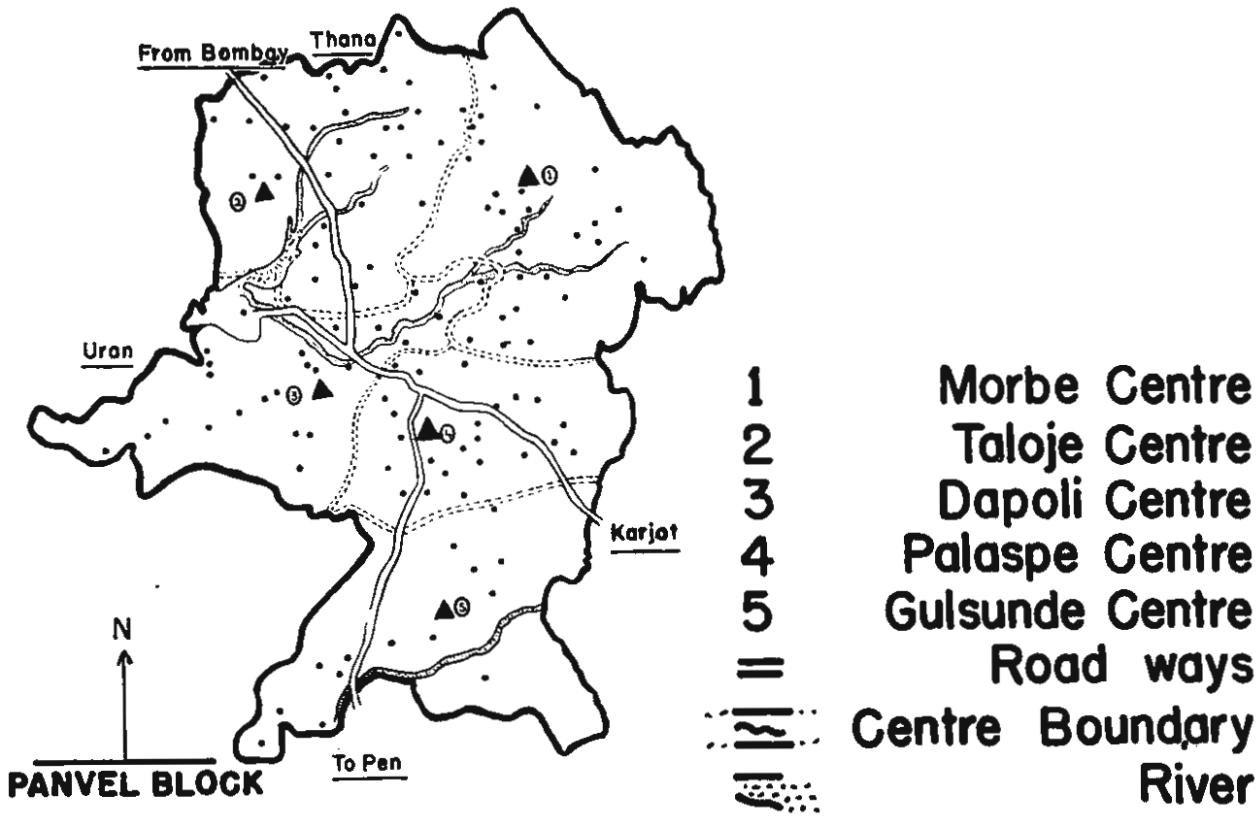
Five centres were selected for operation to various villages in groups. These were Morbe (creek filled area), Taloje, Dapoli, Palaspe and Gulsunde. Three Laboratory Assistants, four Laboratory Attendants, one Sanitary Inspector and three paid labour workers were working equally at the centres. The work was regulated by one Senior Scientific Officer, two Junior Scientific Officers of the Entomology Department of Haffkine Institute, Assistant Block Development Officer and Gram Sevaks of the area. The entire supervision, guidance, planning, execution and recording was done by the Assistant Director, Department of Entomology, Haffkine Institute.

Total number of rat traps (designed by Dr. Deoras) used were 652 and the bait boxes were 600. These were supplied by Haffkine Institute, Directorate of Public Health and the Zilla Parishad. Wheat flour used for bait was 3 quintal, and wheat grains for poison baits were one quintal. Other material used was zinc phosphide 20, Malathion 5, Benzene hexachloride 50 kg, Alluminium phosphide tablets 5000, and sulphur powder, 5 pounds.

Mode of Operation

a) Initial survey was done to see the damage done to wooden doors, windows, clothing, food grains and fodder. Rat pellets were collected to see initial infestation and they were repeated after repairing the doors, windows or spraying BHC 50% suspension at 10% of Malathion 1% around bamboo huts. This was to see and show to farmers the reduction in the infestation (reduction or status quo of pellet numbers). This was done at the end of June before the monsoon started.

b) Taking the above centres as headquarters, trapping was done in villages for four days and the party shifted to next village for trapping in houses. The records were sent to Bombay. The collected rats were deflead, sexed and were either skinned, (this was sold to Madras Tanneries) if it was a big rat, or the meat taken out to feed dogs and cats. In In case of small rats they were used to make compost after killing them by drowning. The bait in the trap was wheat flour with a dash of sweet oil.



The above map of Panvel designates the centres by numbered triangles with the villages indicated by round marks.

c) Once trapping was done, the next team started laying bait boxes outside the houses. One day of prebaiting was done with whole wheat, charcoal and a dash of oil. Zinc phosphide at 1% was mixed in whole wheat grains after a dash of oil has been applied to them. Two grammes of this bait on a piece of paper was put in each bait box. These were laid at night and removed before dawn, along with any dead rats seen in the locality. This operation was done for two days in each house and the party shifted to next village after recording the results.

d) The third team moved in to count the rat burrow openings, blow in BHC 5% in them, put in broken glass bricks and close the same after blowing in burning sulphur fumes. At some places Alluminium phosphide tablets or HCN gas was used.

e) The last operation consisted of using zinc phosphide in small paper cups that had been dipped in melted paraffin to stand the moisture of rains. These pieces were stuck to field border edges and a spray of 1% Malathion applied to inner borders of standing paddy crop. By this time the paddy had borne the grains and was getting ready to be harvested.

f) To see the effect of operations, two villages Jasai and Ris were kept as control as compared to two villages of Dapoli and Pargaon from the experimental area. The control villages were away from Panvel Block.

Observations

Table No. 1 gives the statistics of the number of villages available in India, cultivable land and the number of probable rat numbers available. This is to show the immensity of the problem.

Table No. 2 indicates the details at a glance for the Panvel Block. Since four villages were done in 1967, the remaining entire lot was taken in 1968 to be followed by ever increasing circle to take up the entire District.

Table 1. Indian conditions for rat control.

Total cultivable area	322,460,000	Acres
Total forest lands	126,099,000	Acres
Total fallow lands	54,490,000	Acres
Total pasture lands	97,720,000	Acres
Total unused lands	116,201,000	Acres
Total number of villages	566,000	
Total number of towns	2,699	
Probable rat population	24,000,000,000	
Food production	104	Million Tons
Rat damage	6	Million Tons

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Table 2. Particulars of area for rat control.

Panvel Block area	215.3	Sq. Miles
Rural area in the block	210.6	Sq. Miles
Population as per 1960 census	115,378	
Rural population	97,248	
Total houses	16,785	
Total area in acres	143,400	Acres
Total area under crop	59,100	Acres
Area under paddy cultivation	40,100	Acres
Produce per acre	1701	Lbs.
Cost of produce approximately	68,040,000	Rs.
Days of rainfall 104, total 3136 m.m.		
Maximum temp. 30.7°C		
Minimum temp. 22.8°C		

Table No. 3 shows at a glance the various damages seen in the houses and the number of burrows in and around.

Table 3. Damage to various articles and burrow.

Centre	Villages covered	Damage to										
		Clothing		Food		Doors	Window	Burrow	Other Material		No. of Houses	
		No.	Rs.	Kg.	Rs.	No.	No.	No.	No.	Rs.	Brick	Mud
Taloje	36	89	356	506	503	37	-	187	-	-	726	1267
Morbe	8	31	285	42	42	-	-	7	-	-	200	545
Palaspe	34	36	113	61	61	14	16	390	29	48	571	1712
Dapoli	20	228	512	93	93	2	-	58	-	-	955	1998
Gulsunde	82	9	7:25	20	16	7	3	211	-	-	481	1291
Total	126	393	1273:25	722	715	60	19	853	29	48	2933	6913

From this table, it will be seen that the loss of clothing is high-lighted. The villagers do not normally have a number of sets of clothing and whatever single set they have is a grave loss to them when damaged by the rat. This apparent loss and its protection by rat removal impresses the villager. Morbe area was surrounded by water, since it is a creek area. The houses here are predominantly of bamboo matting and thatch. Hence no records of door and window damage was seen. Due to being submerged in water, baiting outside the houses could not be done here by the time the rains subsided and the time limit of finish the work was over. Once the crop in the field is ripe and grains have set in, no

amount of baiting or trapping will collect rats, and therefore all the operations in these experiments have been directed to reduce the number to the maximum before the migration to the field starts. Baiting in the field when the crop is full of grains is a failure, because the rat would prefer the fresh crop to the stale bait, that is why the operations were designed to terminate with the onset of the harvesting season. Six of the total number of houses at 9866 only 2933 were of brick and mortar, the remaining 6913 were just bamboo matting and thatch which definitely required a rat repellent to prevent rats from coming in at least for some time.

Table No. 4 shows the total number of rats trapped in 134 villages till the monsoon was over. From this table, it should be noted that there are more female rats trapped than males at all places. This means a loss in further breeding potential. Maximum rats trapped are at Taloje i.e. 7518 rats in 36 villages or 208 rats per village. It also shows that every 6th trap collected a rat. The rats were predominantly Rattus rattus. This was in confirmation of previous pilot scheme studies. This and baiting experiments have shown that, whether in the houses or outside and near fields this is the rat that predominates. It normally should be found in houses, but since it is collected in the fields also, there is an indication that it migrates to fields and comes back to its original habitat especially in the rains, when the fields are full of water. Thus attempts are made to reduce the number of this rat at its maximum concentration and at a very vulnerable time i.e. in monsoons, this would in the long run reduce the damage in the coming months also. This table also shows that B. bengalensis, Golunda ellioti and other field rats have also been trapped into houses indicating a migration towards the residential areas probably during the monsoon months.

Table 4. Rat trapping for seven days in various villages of the centre.

Centre	No. of villages covered	Population	Area Houses Acres	Area Farm Acres	No. Traps Set	No. Traps with Rat	Rats trapped Male	Rats trapped Female	Total Rats caught
Taloje	36	15517	15676	11116	11200	3030	3339	4179	7518
Morbe	8	3529	4802	1597	1483	231	196	311	507
Palaspe	34	17231	12268	7421	6403	967	923	1187	2110
Dapoli	28	19166	15187	8125	4957	595	880	1094	1974
									233
Gulsunde	28	10278	15132	4051	7070	900	702	1148	1859
Total	134	65721	63066	32310	31113	5723	6040	7919	14191

Rattus rattus - 12894; B. bengalensis - 168; B. gigentia - 89; L. booduga - 5; G. ellioti - 2; M. musculus - 7; Suncus coeruleus - 794; Unidentified - 233.

Total number of rats collected by trapping was 14191 in 9846 houses, and this is approximately two rats per house. Taloje is a biggish village with a sprawling market of fish and grain and the place showed maximum damage as well as collection.

Table 5 shows the baiting record, giving figures of dead rats in villages up to the time rains ceased. Morbe remained inaccessible due to creek waters and this moisture prevented baiting till the last date. A total of 2203 rats have been collected dead. At all the centres the female rat was collected more in numbers. This was outside the houses. This means that during this period, this breeding potential was reduced. Secondly, the predominant rat species in the dead were Rattus rattus, the house rat. B. gigentia the bigger field rat which does so much damage has been killed more in numbers than by trapping. Total number of bait stations kept were 20332 and the bait consumed was 5752. That means nearly every fourth bait was taken. The number of rats collected dead is just about less than half i.e. 2203 of the bait consumed. Taloje centre collected more dead rats than any other ones. Total wheat used for bait making was 213170 gm. out of which 57875 gm. was

Table 5, Rat baiting by zinc phosphide @ 1% for two days.

Centre	No. of villages	No. of Bait Box Set	No. of Bait Station Bait-Eaten	Bait consumed in Grms.	Total Rats Killed		
					Male	Female	Total
Taloje	20	10575	3878	39135	365	816	1386
Morbe	Houses surrounded by rain.						
Palaspe	23	2697	550	5500	139	225	364
Dapoli	25	4372	921	9210	81	120	201
Gulsunde	24	2688	403	4030	128	124	252
Total	101	20332	5752	57875	913	1285	2203

R. rattus - 1708; B. bengalensis - 165; B. gigentia - 248; L. booduga - 1; S. coeruleus - 81.

consumed. This means that nearly one fourth of the wheat grains as bait were taken up by the rats. Total area outside the houses was 32010 acres and in this 2203 rats were killed. Total area of houses was 63066 and in this 14191 rats were trapped. This means in baiting, 1/14 parts and in trapping 1/4th part is the ratio of the kill.

Table No. 7 shows that the total area under cultivation was 10270 and the total area covered was 2487, i.e., one fifth of this was covered for burrows. Total burrows treated were 13539. It may be clarified that only one opening was treated. This was the fresh one; the remaining were closed. The actual holes would then be on an average five times the number of treated holes. This was with 10% BHC dust or sulphur or cynogas or tablets of Alluminium phosphide, after glass pieces have been put in and the openings closed. Cynogas and sulphur fumes were used in 2 and 3 villages. Zinc phosphide capsules coated with wax were put on field borders for stray rats to be killed and Malathion at 1% was sprayed at the junction of field border and standing crop to prevent the rats from entering the fields. Alluminium phosphide tablets were used at two centres and sulphur at one centre.

Table 6 gives an account of initial rat density in the control as well as villages in the centres under experimentation. It will be seen from this table that in the case of Dapoli and Pargaon the rat density has decreased after four months of experimentation while in the case of control it has increased or remained stationary.

Table 6. Rat reduction evaluated.

Villages	Rat Density Before Expt.			Rat Density After Expt.		
	Date	Days	Rats Trapped	Date	Days	Rats Trapped
			Experimental			
Dapoli	10-6-68	2	44	10-10-68	2	5
Pargaon	10-6-68	2	157	10-10-68	2	32
			Control			
Jasai	16-6-68	2	69	10-10-68	2	51
Ris	16-6-68	2	20	10-10-68	1	26

Table 7. Post baiting operations in burrows and field borders.

Centre	No. of villages covered	Total area in acres		No. Burrow openings treated	B.H.C. 10% in kg.	Allumi-nium phos-phide tablets No.	Gases		Zinc Phos-phide capsules kg.	Malathion 1%
		Under cultivation	Covered				Sulphur	HCN		
Taloje	13	4204	470	2382	20				36	
	3	1105	800	2950		2250				1
Gulsunde	13	2672	90	720	3.40				6.80	
	3	623	45	830		1800				1
Dapoli	4	1009	745	4596	47.77		1		47	
	2	657	337	2061				3		1
Total	38	10270	2487	13539	70.17	4050	1	3	89.80	3

DISCUSSION

Rats do a lot of damage. W.H.O. World Health Magazine, of April 1967 at page 3, puts the loss of stored cereals at 33 million tons a year and 20% of the loss to planted crops due to rats all over the world. The same journal at page 16 mentions that "The saving in grain resulting from anti-rat measures alone was reckoned to be sufficient to provide food for 900,000 people." This was an observation of the condition of rat problems in the town of Bombay alone.

India was importing nearly 9.4 million tons of grain from the U.S.A. in 1966 and 3 rats were damaging nearly one ounce per day. Rat control was therefore imperative. The funds available for such a purpose were limited and whatever was available had to be used to get the best results.

Rat control measures are well-known. They consist of rat prevention and rat destruction. Rat prevention is a very wide term and it includes motivation also.

There was no point in doing rat eradication here and there. It had to be started from a focal point and the area enlarged to cover the state.

At the outset, let us call this programme as rat-reduction and not control. Rat-reduction is necessary for Agriculture as well as Public Health problems. Normally, these two aspects are kept separately. It is said that a rat in a house is a public health problem and that in the field an agriculture problem. From the work done at Panvel, it is noticed that the house rat migrated both ways, and both the aspects have to be taken together. Rat-reduction could be done all the year round but when the crop is in grain-stage the rats will not come to baits. It is therefore desirable to do this before the crop ripens. In the paddy growing area, the fields are full of water during monsoons and the rats have to migrate. This migration creates a concentration near residential areas, where they get shelter and food. It is therefore desirable to attack a concentration and do the maximum reduction. The rainy season in India is correlated with the rat breeding season. Rat-reduction operations at this time reduce the further breeding potential. Six of the total rats reduced i.e. 16394, there are 9199 females. If these females had bred, and on an average 5 young ones were born, the place would have had 45995 rats by the time the crop was ripe and damage started. Trapping was found desirable as the farmers saw with their own eyes the large number of rats collected and transported. Secondly, it made them available for skinning and the skin sold for tanning at 30 paisa per skin. Trapped rat meat was given to pet dogs and cats and this saved some food for human consumption. In baiting, the dead rats die in crevices and the foul smell was unbearable to the farmers.

Skin of Bandicota gigentia. It has been tanned to be used as kid leather. The tail grains are good for wrist watch straps. Length 12 inches. Locality of collection Panvel, near Bombay in Maharashtra, India. This development was made to give farmers a motivation, so that he gets some money if rats are killed and the skin fetches some renumeration.

Zinc phosphide in three cases during these experiments killed 3 poultry animals when one bait box was toppled. The rat died of this poison were once eaten by a cat and it died. The skin of a rat died of poison does not come out intact, nor is the meat fit for animal consumption. Lastly, it was noticed at one place that one trap collected a maximum of 16 rats at one time. This will never be possible by a single bait. Being safe the farmers preferred traps to a poisonous bait.

Zinc phosphide was used only in bait boxes to prevent its intake by domestic animals. It also gave a psychological effect. Bait box and bait station for safety was desirable. Insecticide dusted bait boxes reduced fleas that would move after rat death.

The filling of burrow holes with glass pieces was done as this was possible for any farmer. He cannot always have access to Alluminium phosphide or H.C.N. A cheap sulphur gas generator was designed and this the farmers could rig out themselves.

Once the operations were coming to a close, and as the crop was getting grains, some stray rats tried to migrate back to fields. The paraffin coated zinc phosphide capsules did kill a few of them. The spraying of 1% Malathion in the field borders touching the plants had the effect of repelling the rats for 7 days. They went towards the field, but returned to eat the zinc phosphide capsules.

The work was stopped with the termination of monsoon even though only 134 villages were covered by trapping and 101 by baiting and only 17 by burrow closing. This deadline gave an idea as to how much could be done and the results obtained. However, the villagers requested to complete some more villages and Table No. 8 shows the total reduced up to December, 1968.

Dr. Shrivastava (1958) has used chemicals and chemosterilants in the millet fields of Kalyanpur Block at Kanpur. Dr. Pingale (1953) had used good storage facilities and again chemicals. But both these schemes were done with the help of government staff, and there was no motivation of the farmers. Secondly, these chemicals cannot be applied without expert guidance. In the case of traps the illiterate farmer can set it himself. Lastly, the present method is to be done for only four months in a year.

Table 8. Details regarding population, houses and rats destroyed in different centres in Panvel Block up to December, 1968.

Sr,No.	Centre	No. of villages covered	Houses	Population	Total rats trapped	Total rats baited	Total rats destroyed
1	Taloje	41	3914	24015	8609	1609	10218
2	Morbe	32	1716	10022	1942	352	2294
3	Palaspe	37	3711	18313	2456	400	2856
4	Dapoli	32	3638	21259	2453	219	2672
5	Gulsunde	29	1665	10110	1865	355	2220
		171	14644	83709	17325	2935	20260

The cost of the operation could be estimated from the following available expenses.

CONCLUSION

I.	1.	Traps purchased by Zilla Parishad 300 in number @ Rs. 12/- per trap. Remaining were on loan.	3,600
	2.	Cost of bait boxes @ Rs. 1/- per box (600 in number)	600
II.	1.	Wheat for baits 500 kg.	250
	2.	Oil as attractant 20 pints.	75
	3.	Zinc phosphide 20 lb. @ Rs. 7/- per lb.	140
	4.	Benzene hexachloride 10% dust 50 kg. @ Rs. 5/- per kg.	250
	5.	Malathion 5 lbs. donated by Pest Control Pvt. Ltd.	--
	6.	Alluminium phosphide tablets 5000 donated by Excel Industries	--
	7.	Sulphur powder 1 kg donated by Haffkine Institute, Bombay	--
	8.	HCN powder donated by Directorate of Public Health	--
	9.	Old newspapers and broken glass in bags.	20
	10.	Petrol charges for conveyance	1,000
			5,915
III.	1.	Daily wages labour for the period.	6,664
	2.	Salaries of staff from Haffkine Institute, Directorate of Public Health, Directorate of Agriculture and Zilla Parishad is borne along with the traveling allowance and daily allowance by the respective Units.	--
		Grand Total	12,600
		Since the rat trap is a permanent investment for at least 5 years, it should not be taken into account here. The cost then would be: (Negative side)	9,000

Positive side

a) Total rats killed — 20,260
b) Damage to crops and material is to be taken into account that is saved.
c) Total skins collected and sold were 50, and the meat given to dogs and cats was 20 kg.

SUMMARY

Rat reduction measures were done in 171 villages of Panvel Block in Kolaba District of Maharashtra State. It started with rat preventive measures to doors and windows and the spraying of BHC and Malathion around bamboo matting huts. With the onset of rains trapping was done by "Deoras traps" inside houses and poison baiting by zinc phosphide on the outside. Rat burrows were closed by broken glass after the pumping in of BHC 10% dust, or sulphur fumes, or HCN or Alluminium phosphide tablets. Lastly as the rains subsided zinc phosphide capsules dipped in melted wax were put on field borders and Malathion 1% sprayed in the field near crops. Total rats reduced were 20260, of which 17325 were by trapping and 2935 by baiting. In the collection, R. rattus species predominated and female rats were more in numbers than the males in all species of rats reduced. The cost of operations minus the salary and allowances of permanent staff came to Rs. 9,000/-.

Public Health and Agriculture aspects were joined together and the rat reduction was done only for four months in the year when the monsoon was on, the paddy fields were full of water and the rats migrated to residential areas for shelter. Public motivation was done by showing the damage and utilizing the rat skin and meat.

ACKNOWLEDGEMENTS

I am extremely thankful to Mr. L.N. Bongirwar, Dr. A.V. Shaikh, Secretary, Agriculture Department, Government of Maharashtra, Dr. Vaidya, Dr. Joshi, Directors of Agriculture, Dr. Bhave, Director of Public Health, Dr. Dutta, Director, Haffkine Institute and Mr. Thacker, Executive Officer, Zilla Parishad. Mr. Vad, Mr. Renapurkar, Mr. Chaturvedi, Mr. Tare and Mr. Masurekar, Officers of my department helped me to execute the work in most difficult circumstances. Mr. Kadam, Mr. Shinde, Mr. Jadhav, Mr. Subnis and Mr. Ghag shouldered the burden at the spot. The staff of Zilla Parishad, Kolaba (Mr. Samant and Mr. Gadgil), Directorate of Public Health and Agriculture rendered me help in the execution of the project. To them all, I am very grateful. My association with the Haffkine Institute helped me to get all facilities and I owe a debt of gratitude to this Scientific Institution. I am very much thankful to the Principal, Patkar College, Bombay, for the continuance of these studies and to Mr. R. M. Joshi who has ungrudgingly shouldered all the present clerical burden.

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TOLERANCE SHOWN BY *Rattus rattus* TO AN ANTICOAGULANT RODENTICIDE

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ABSTRACT: Apart from using 0.005% concentration, the recommended field dose of 0.025% of the anticoagulant is used along with an alternate food for individual rats for a varying number of days. Those that had survived were taken as tolerant, provided they showed an mg/kg intake beyond the tolerance limit, survived a six days of feeding, exhibited bait-shyness and did not exhibit hemorrhage after death.

In determining the criteria for tolerance to an anticoagulant by a rat, one should take into account four composite factors. These are, six days of even 0.025% feeding, bait-shyness when alternate food is given, higher mg/kg intake than the tolerance level and a loss of intensive hemorrhage after death.

INTRODUCTION

Hayes and Gaines (1950) in their experiments with the rodenticide "Warfarin" concluded that it provided a completely new practical approach to rodent control in as much as, it did not cause bait-shyness, was self prebaiting and could be used as a residual rodenticide. Since then Warfarin has been the mainstay of inter epidemic anti-rat measures in plague control operations. However, later work of Boyle (1960), Cuthbert (1963) and Lund (1964) showed that the Norway rat, *Rattus norvegicus* had indicated resistance to this rodenticide.

Drummond (1966) anticipated that it will be more than just a few years before Warfarin will be virtually ineffective against most mouse populations.

In India Deoras (1965) showed that Warfarin was not as effective as zinc phosphide, during his field trials in the Vidarbha region of Maharashtra, when *Rattus rattus* from two places in Vidarbha, i.e. Nagpur and Chanda were tested in the Laboratory with field doses of Warfarin; they showed tolerance (Deoras 1966).

The most common rats in the town of Bombay are *R. rattus*; *Bandicota bengalensis* and *Rattus norvegicus*. Preliminary experiments carried out showed that the Bombay *R. rattus* and *R. norvegicus* were tolerant whereas and that *B. bengalensis* was very susceptible (Deoras 1967). The tolerance shown by the house rat posed a setback to the wide-spread use of Warfarin and this needed detailed studies for confirmation. Therefore, *R. rattus* were fetched in numbers from the town of Bombay and some other region of Maharashtra and were subjected to detailed trials to see their status to Warfarin tolerance. This paper gives an account of the studies done on the Bombay house rat *R. rattus* to confirm their susceptibility or otherwise to a locally manufactured anticoagulant.

MATERIALS AND METHODS

Rattus rattus were collected from different wards of Bombay and later from Sholapur, Osmanabad, Murud, Ambejogai, Pali, Gevrai, Daulatabad, and Pachod in wonder traps. They were made free of ectoparasites by brushing and held in the laboratory for 30 days. During this period, they were given water in bottles and weighed amount of food in hoppers. The food at this time consisted of crushed grains of wheat and Jowar (Andropogon sorgham). The rats were weighed at the beginning of the experiment. After acclimatization for 30 days, the rats were given the anticoagulant mixed in the above food, in predetermined doses. The anticoagulant tested was a locally manufactured Warfarin, developed and patented by the National Chemical Laboratory, Poona, marketed by UNICHEM and formulated by Pest Control (Pvt.) Ltd. The formula of this compound is as follows 3(alpha-phenyl-acctyl beta ethyl) 4 hydroxycoumarin.

The concentration used for experimentation were 0.005, 0.01, 0.25, 0.05, 0.1 and 0.5 per cent for Bombay rats and only 0.025 for rats from other places. The duration of feeding with Warfarin in the initial stages was up to 10 days. After trials it was reduced to 6 days, then the rats were kept on normal food for the remaining period even up to 20 days in a number of cases. To see further critical levels, these feedings with the anticoagulants were reduced to 2, 3, 4 days. In the third set of experiments, Warfarin was given along with the normal food as would be available in nature to estimate the daily intake and bait refusal if any. Each rat was dissected after death to see any internal hemorrhage due to the anticoagulant.

Table I - Showing the consumption of dry mixed cereal food by three common rats and the pellets given.

Kind of Rat	Month	Average weight of rats in grm.	Average weight of food consumed by the rats in 24 hours in grm.	Average amount of water consumed by the rats in 24 hours in cc.	Average No. of pellets given by the rats in 24 hours.	Average weight of each pellet in grm.
Rr.	January	103	9.3	24.	36	0.0196
	February	103	10.1	23.7	39	0.0197
	March	103	8.1	25.	39.6	0.019
Rn.	January	122	14.5	25.2	41	0.054
	February	122	12.9	25.1	40.3	0.054
	March	122	12.2	34.9	31.2	0.05
Bb.	January	232	14.2	26	49	0.037
	February	232	15.1	25.2	43	0.041
	March	232	12.7	34.9	43.2	0.04

Rr. Rattus rattus, Linn; Rn. Rattus norvegicus, Berkenhout; Bb. Bandicota bengalensis, Grey and Hardwicke.

Table II - Summary of trial of Warfarin in various concentrations for ten days with 10 R. rattus each, from Bombay.

Name of the product	Concentration used Percentage	Average weight of rats	Average bait food consumed till death in gms.	Mg/Kg active ingredient consumed till death.	Mean day of death	Percentage mortality
Warfarin	0.0025	105.3	31.9	7.6	5.8	70
	0.005	101.	34.9	15.	6.	70
	0.01	105.8	34.3	32.4	7.7	90
	0.025	104.4	29.9	71.	5.9	100
	0.05	108.6	29.7	135.	5.2	100
	0.1	95.	20.	209.	6.	40
	0.5	104.	21.25	100.	4.75	80
Control	0.025	469.2		12.97	5.8	100

Table III - Experimentation of Individual R. rattus with 0.025% Warfarin given for varying No. of days.

Sr. No.	Sex	Weight of Rats At start	Weight of Rats At death	Difference Wt. in gms. up to death	Lethal dose mg/kg till death	Day of death	Days of survival on control food	Warfarin consumed by surviving rats on mg/kg basis	Wt. of surviving rats in gms.
				TWO DAYS OF WARFARIN FEEDING.					
1.	M	152	-			S	12	26.31	162
2.	M	164	118	-46	12.19	7			
3.	M	164				S	12	22.52	170
4.	F	87				S	12	36.78	80
5.	F	82	70	-12	30.48	5			
6.	M	160				S	24	31.25	164
7.	M	134	119	-15	44.7	7			
8.	F	103				S	24	77.6	139
9.	F	114	102	-12	63.6	4			
10.	F	102	112	+10	31.8	3			
				THREE DAYS OF WARFARIN FEEDING.					
1.	M	127	113	-14	37.4	4			
2.	M	114				S	23	143.6	160
3.	M	172				S	23	149.5	179
4.	F	109	107	-2	68.8	5			
5.	F	87	90	+3	86.2	3			
				FOUR DAYS OF WARFARIN FEEDING.					
1.	M	142				S	10	8.8	152
2.	M	115				S	10	80.0	120
3.	M	104	70	-34	67.3	4			
4.	F	100	95	-5	95.0	3			
5.	F	82	75	-7	115.8	4			
				SIX DAYS OF WARFARIN FEEDING.					
1.	M	123	118	-5	18.2	2			
2.	M	127	140	+13	49.2	4			
3.	F	108	118	+10	94.4	5			
4.	F	119	127	+8	168.1	7			
5.	F	108	105	-3	46.29	3			
6.	M	152				S	8	70.39	142
7.	M	137	95	-42	74.4	8			
8.	M	89	72	-17	75.2	5			
9.	F	127	115	-12	23.62	4			
10.	F	109	95	-14	36.69	4			
				EIGHT DAYS OF WARFARIN FEEDING.					
1.	M	82	100	+18	173.1	5			
2.	M	92	90	-2	51.6	4			
3.	M	169				S	18	118.34	165
4.	F	105	103	-2	109.52	5			
5.	F	144	120	-24	22.5	3			

S. Surviving; M. Male, F. Female.

The rats used in the experiments were R. rattus rufuscens and Bandicota bengalensis, Grey and Hardwicke. The latter were used as controls for comparison.

OBSERVATION

Table No. I gives the normal intake of food and water by R. rattus, during the year under experimentation for comparison with the data of intake in anticoagulant experiments.

Table No. II gives the intake and mortality of R. rattus with varying concentrations of the anticoagulant, starting from 0.0025% to 0.5%. It is noted here that there is 100% mortality in 10 days for 0.025 and 0.05% concentration only. In higher concentrations the intake of the bait material is reduced. There are survivors even if the mg/kg concentration is higher. The mean day of death for the 0.025 and 0.05% is 5.9 and 5.2 respectively. B. bengalensis taken as control had died off within 10 days with 0.05% and 0.025% concentration.

These two concentrations i.e. 0.025 and 0.05% that have left no survivors were taken for observing the minimum days of intake of poison to start mortality. Table III, therefore, shows the mortality in R. rattus when fed for 2, 3, 4, 6 and 8 days. In each case after feeding on the anticoagulant for the requisite number of days, they were switched on to the normal food. B. bengalensis were kept as control (Table IV) and the mortality timings in them indicate that even with 2 days of feeding there is mortality, while in R. rattus there are survivors at 8 days also.

Table IV - Experimentation on individual Bandicota bengalensis with 0.025% Warfarin given for varying No. of days.

Sr. No.	Sex	Weight of rats in gms. At start	Weight of rats in gms. At death	Difference wt. in gms. up to death	Lethal dose mg/kg till death	Day of death	Average day of death
				TWO DAYS OF WARFARIN FEEDING.			
1.	M	430	390	-40	21.39	5th	
2.	M	425	402	-23	14.58	6th	
3.	F	437	382	-55	11.44	7th	5.8
4.	F	542	515	-27	7.38	4th	
5.	F	515	480	+65	11.06	7th	
				FOUR DAYS OF WARFARIN FEEDING.			
6.	M	384	372	-12	36.9	5th	
7.	M	552	448	+6	40.72	6th	
8.	F	442	407	-35	14.705	5th	5.4
9.	F	480	428	-52	22.29	5th	
10.	F	482	443	-39	11.92	6th	
				SIX DAYS OF WARFARIN FEEDING.			
11.	M	392	400	+8	60.48	5th	
12.	M	292	300	+8	46.89	4th	
13.	F	435	357	-73	5.10	6th	5.6
14.	F	469	453	-16	21.9	5th	
15.	F	487	400	-87	7.19	8th	
				EIGHT DAYS OF WARFARIN FEEDING.			
16.	M	564	528	-36	32.26	6th	
17.	M	427	443	+16	48.00	6th	
18.	F	327	312	-15	45.87	5th	5.6
19.	F	409	490	+81	48.89	7th	
20.	F	452	438	-14	22.12	4th	

M = Male; F = Female.

Table V - Warfarin trials with Rattus rattus. (Both Warfarin & Control food offered) Warfarin Concentration 0.025%

Sr. No.	Sex	Wt. in gms. Starting	At death or after 20 days	Diff. in wt.		Quantity of Warfarin as food consumed each day up to 20th day along with control food in gms. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total consumption gms.	Day of death or surviving.	Mg/kg of Warfarin for 20 days or death
1.	M	91	108	+17	R	2	3	3	3	2	-	-	-	3	-	-	-	1	1	-	-	3	-	3	2	26	S	71.40
					C	8	7	6	6	9	2	8	7	-	11	14	-	-	4	5	6	5	4	6	5	133		
2.	M	110	116	+6	R	2	2	2	1	2	-	1	-	1	-	-	5									16	12	36.3
					C	5	6	8	13	10	3	9	11	7	-	-	-									72		
3.	M	85	86	+1	R	3	2	1	2	4	-	-	-	3	-	1	1	3	-							20	14	58.8
					C	5	2	-	13	3	12	-	-	3	4	1	2	5	10							60		
4.	M	128	125	-3	R	4	2	2	4	3	-	-	-	-	-	4	-	-	3	1	-	-	-	-	1	24	S	46.9
					C	8	8	12	3	8	15	5	14	6	6	5	7	8	3	4	2	2	2	4	4	126		
5.	M	141	151	+10	R	6	2	7	4	3	2	1	2	2	1	5	1	3	-	1	1	1	1	-	5	52	S	92.4
					C	3	3	6	5	3	4	9	6	8	-	1	5	6	7	4	5	5	2	-	-	82		
6.	F	78	77	-1	R	3	2	3	2	3	-	-	2	-	1	6	9	5	4	-	-	-				40	17	12.8
					C	4	3	6	4	6	6	4	2	8	6	1	0	17	9	-	-	-				76		
7.	F	112	86	-26	R	2	4	2	9	4	-	-	-	-	-	4	8	3	-							36	14	80.6
					C	-	2	4	2	4	8	7	8	8	6	1	0	3	1							54		
8.	F	84	85	+1	R	2	2	5	3	2	-															14	6	41.6
					C	2	4	7	9	4	3															29		
9.	F	76	65	-11	R	2	2	2	3	1	1	-	-	8	-											19	10	62.4
					C	3	2	4	5	4	5	3	8	1	-											35		
10.	F	99	72	-27	R	3	4	2	3	-	-	-	-	1	1	-	1									15	12	37.8
					C	3	3	4	1	2	3	3	3	4	3	3	1									33		

M = Male rats; F = Female rats; R = Warfarin bait; C = Control bait food only; S = Survivors

Table VI - Warfarin trials with Rattus rattus. (Both Warfarin & Control food offered) Warfarin Concentration 0.05%

Sr. No.	Sex	Wt. in gms. Starting	At death or after 20 days.	Diff. in wt.		Quantity of Warfarin as food consumed each day up to 20th day along with control food in gms. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total consumption gms.	Day of death or surviving.	Mg/kg of Warfarin consumed for 20 days or death.
1.	M	133	120	-13	R	2	2	2	3		1	-	-	-	1	-	1	2	1	2	2	4	1	-	-	24	18	90.2
					C	10	4	4	9	13	5	4	6	5	7	4	2	7	9	4	2	2	1			98		
2.	M	69	73	+4	R	3	2	3	3	2	-	-	-	-	-	-	-	2	-	2	1	-	-	-	-	18	S	130.4
					C	3	5	8	7	5	2	1	7	7	7	6	5	10	4	8	2	2	6	7	7	109		
3.	M	126	138	+12	R	3	2	3	-	-	1	12	-	-	-	1	-	-								22	13	87.2
					C	6	8	4	17	3	15	2	14	11	5	3	-	-								85		
4.	M	113	130	+12	R	3	3	3	4	-	-	-	-	2	-	2	-	-	-	1	-	-	-	-	-	19	S	84.7
					C	7	5	8	10	11	9	5	7	7	5	4	8	6	8	6	9	4	5	5	7	137		
5.	M	106	104	-2	R	-	4	5	5	2	-	-														16	7	75.4
					C	6	5	10	17	-	-	-																
6.	F	62	56	-6	R	3	4	1	2	-																10	5	80.6
					C	7	4	4	2	3																20		
7.	F	112	122	+10	R	6	2	2	3	1	-	2	-	-												16	9	71.4
					C	7	4	10	9	6	4	7	6	-												53		
8.	F	126	113	-13	R	3	2	2	-	2	9	1	-	-	-	-	-									19	12	75.3
					C	6	6	6	14	8	8	6	7	4	7	1	-									73		
9.	F	83	90	+7	R	3	1	4	4	1	-															13	6	78.2
					C	8	6	10	9	7	-															40		
10.	F	80	79	-1	R	5	3	2	4	2	-	-	-	-	-	-	-	-	-	-	3	2	-	1	-	22	S	137.5
					C	4	1	8	10	6	3	1	4	6	3	7	6	5	7	8	2	2	6	4	5	98		

M = Male rats; F = Female rats; R = Warfarin bait; C = Control bait food only; S = Survivors

Rats were then observed with 0.025% and 0.05% anticoagulant and an alternate food at the same time. This is the condition as will be available in nature. Tables V and VI give in detail the performance of 0.025% and 0.05% concentrations. Individual rats were observed for 20 days with 0.025% and 0.05 poison along with food. Table V and VI shows that rats on an average take the food in more quantity when the choice is available. Those that have survived in Table V, have taken the anticoagulant continuously for 20 days except a break of 2 days. Secondly the mean day of death has gone from 5.9 and 5.2 to 12 and 11, respectively, for 0.025 and 0.05% concentrations.

There were three survivors after 20 days, while in B. bengalensis (Table IV) all had died by the 6th day.

Having seen the performance in R. rattus from Bombay, rats from 8 places in Marathwada were given a 0.025% dose. Table No. VII, therefore, shows the performance by 0.025% of the anticoagulant. There are survivors from Murud, Gevrai, Daulatabad and Pachod even after 20 days.

Out of this lot, Sholapur, Osmanabad and Ambejogai rats that had shown mortality were given normal food along with the 0.025% and 0.05% concentrations there were survivors from the 1st two places even after 20 days, when alternate food is given.

The survivors in R. rattus in Table III have gained weight in 3 cases and lost only 4 to 10 gm. in the other two cases; but in spite of loss in weight the rat has survived. The big rat in Table IV has lost weight from 28-42 gm. and died.

In Table V is shown the individual gain and loss in weight. The first surviving rat in Table V has gained 17 gm. It took the anticoagulant for 5 days, then stopped it for 3 days and so on. The survivors have taken 71.40, 46.9 and 92.4 mg/kg of the anticoagulant which is far more than the one taken by the control at IV.

In the case of B. bengalensis, one always saw a bleeding through nose, mouth and anus. The viscera showed extensive hemorrhage. In the case of R. rattus, there was no case seen of bleeding through nose, mouth or anus. The internal organs were just pale and there was no indication of bleeding inside the R. rattus.

The minimum lethal dose per mg/kg to kill the control (Table IV) rat is 7.19 and the maximum is 60.48. In the case of R. rattus the minimum for the susceptible rat is 12.19 and the maximum is 173.1. The surviving rats have taken 149.6 mg/kg which is far more than the 60.48 mg/kg of the controls (Table IV).

DISCUSSION

Rattus rattus, refuscens, is the common house rat in Bombay. Recent work at Haffkine Institute had indicated that in Vidarbha and Marathwada regions of Maharashtra this was the most predominant rat in the fields also (Deoras 1966). The common raticides in use in India were barium carbonate, strychnine and zinc phosphide. Firstly, nearly all of them develop bait-shyness, require prebaiting and the last two unless used carefully are dangerous to poultry and cattle. In view of these, the development of a new type of raticide in India was a handy addition to rat control operations in plague preventive measures.

In field trials with zinc phosphide and anticoagulant (Warfarin), Deoras (1965) showed that Warfarin was not giving as good a kill as the first poison. The predominant rats were fetched from Chanda and Nagpur and were tested along with similar rats from Bombay. The doses tried were 0.005% which had shown resistance in R. norvegicus by Lund (1964). It was shown by Deoras (1966) that the Chanda rats took a much longer time and further, even with the field dose of 0.025% the rat continued to live under field conditions. But B. bengalensis, which is a much bigger rat than R. rattus, died within 6 days even with the smaller dose of 0.005% of the poison (Deoras 1967).

Hayes and Gaines (1950) have used specific concentrations based on the weight of the individual rat and giving it the calculated weight of poison as a definite intake. This we think is too artificial. We have given specific concentrations over or below 0.025%, the recommended field dose and let the rat eat it as a choice. The mg/kg intake is worked out as we know the weight of each rat. Bentley and Rowe (1956) have established that both Pival and Warfarin at 0.025% are equally toxic and equally acceptable to R. rattus. A W.H.O. notification (1966) mentions the mortality as a criteria for recognizing resistance

to Warfarin in R. norvegicus by the use of 0.005% concentration for this rat, fed for 6 days, while the dose of Warfarin tolerated by the survivors was between 10.9 to 34.6 mg/kg. Lund (1964) used R. norvegicus along with R. rattus and declared resistance in R. norvegicus for 0.005% concentration of Warfarin of 6 days of feeding.

Drummond (1966) mentions that most resistant rats are able to survive not only much longer feeding periods than the five days required to kill nearly all susceptibles, but also higher concentrations of Warfarin.

R. norvegicus available in Bombay is a much heavier rat than R. rattus. As there were no such figures of concentration tolerance available for R. rattus, this concentration of 0.005% and higher were undertaken initially to test the tolerance in a simple way. These lower concentrations have been tested up to 10 days and continued up to 20 days for a rat which is lighter in weight than R. norvegicus. If the percentage concentrations of 0.005, 0.01, 0.025, 0.05, 0.1 and 0.5 of the "Warfarin" compound used and mentioned at Table II are taken and these compared with their mean days of death in a graph, it will be noticed that the curve rises from .005% to 0.01% and then it falls as the concentrations are increased. This probably means that if a dose beyond 0.01% is given, the rat may die slightly quicker, simply because the anticoagulant concentration is high, though intake is low. There are survivals of 20%, 30% and 10% even at these higher concentrations, the least being for 0.01%. It will also be seen that the mean day of death for 0.005, 0.025 and 0.05 percentages for Bombay rats come between 5.2 and 5.9 days (Table II). In fact this day in 0.005% is only 6 while at 10 times the concentration i.e. 0.05% it is 5.2. It consumed more bait with lower concentration.

Table No. I shows the food intake of the three kinds of rats in 24 hours. This is to show the comparison of ingestion of food by the rats in the raticide trials. This table as compared to the amount ingested seen in Table V indicates that the rat took 10 gm. on the 1st day, and second day but gradually it fell off by the 6th day. In all rats the anti-coagulant consumption was either left or reduced, but the control food was taken all along. In all cases the rats had consumed more of control food. It selected normal food, showing bait-shyness, as would be seen in nature. After 10 days, the food intake had gone down in all cases. The surviving rats tolerated up 92.4 mg/kg. The rats have alternate food in nature. They, therefore, would take it for a few days then stop it and then take and there would be no dead rats. This table again is an indication of bait-shyness as a form of tolerance.

The concentration between 0.01 and 0.05% leaves no survivors and beyond this they start varying. The midpoint between these two is 0.025% and this is taken as base for testing tolerance. This is also the figure taken for field trials. R. rattus showing tolerance for this figure may then be deemed to show resistance. Statistical analysis of these results, particularly the day of death, have shown significance and indicated tolerance in R. rattus.

Table III very significantly shows that of 10 R. rattus (after taking only 2 days of poison bait), only 5 have died on 3-4 and 7th day. They were not given Warfarin on 3rd, 4th, 5th and 6th day. There was no continuity of feeding with the poison beyond 2 days. The lethal dose taken by dead rats was from 12-19 to 30-48 of mg/kg. In the case of those that survived, the consumption of Warfarin equivalent to this lethal dose was between 22.52 to 77.6 mg/kg, as compared to even 23-62 of the one that died. In the case of 8 days the survivors have taken 118.34 mg/kg. The huge quantity of 173.1 mg/kg taken by one of the dead rats in this series shows the increasing tendency to tolerate a bigger dose. This is not the case with B. bengalensis. Even those that ate for 2 days have died within 7 days with an mg/kg level from 7.38 to 21.39. Even for a longer period of feeding for 8 days, the rats have died within 7 days and nothing remained on the 8th day. The mg/kg was between 22.12 and 48.89 which is much lower than what is tolerated by R. rattus.

This individual rat experiment at Table III demonstrates that once taken, the Warfarin will act, even if it is taken for just two days, provided the rat does not show tolerance. The mg/kg lethal dose can indicate for the minimum but maximum will again show a kind of tolerance.

Bentley (1967) has mentioned "for practical purposes to earn the label 'resistant' we require rats to survive a standard feeding period of 6 days on 0.005% Warfarin in the laboratory." In Table III, 16% and 20% of rats have survived this period for a much higher dose.

Table VII and VIII shows the performance of R. rattus from a number of towns in the Marathwada region of Maharashtra. The places are at least 300 miles from Bombay and never was Warfarin used there. In these trials, except for Sholapur, all the other places show variation in mortality for 0.025% concentrations. There is survival in rats beyond 10 days. Individual experiments for Bombay rats shown at Table III indicate that, if any rat was to die, it does this by the 10th day at the maximum and, if it has not died, it will survive. Experiments with alternate food were done for 3 towns, where rats had died in 10 days, and this gave a clear picture where the rats have survived. It thus seems that apart from Bombay, R. rattus from Sholapur, Osmanabad, Murud, Ambejogai, etc., are also indicating some tolerance.

All the rats were dissected after death. In the case of B. bengalensis there was always an extensive hemorrhage not only through nose but all over the viscera. In the case of R. rattus those that died by feeding on the bait for 6 days or more showed hardly any hemorrhage, but those that had actually died by feeding for less than 6 days, showed no hemorrhage at all. In all such cases the liver, heart, lungs, and the subcutaneous tissue showed only a pallor, faint pink color, unlike the deep crimson shown by these tissues in B. bengalensis after death, or in the case of R. rattus killed in normal circumstances. Does this then indicate a tolerance reaction of a poison which must show an internal hemorrhage as a characteristic?

The digestive tract of R. rattus, R. norvegicus, and B. bengalensis was dissected out. The digestive system of these 3 rats was compared to each other. It was noted that the tracts were 34.5", 38.5" and 75" long respectively, but the point of interest in them was that the length of caecum in the first was 2.5" in the second 1.5" and in the third 3.2". Anticoagulant Warfarin is said to act by inhibiting the formation of prothrombin and by causing capillary damage (Hayes and Gaines 1955). W.H.O. Chronical 1966 has indicated the role of Vitamin K in this process and the bacteria that go to form this vitamin in the animal. The role of caecum in such animal is not well established but work in future may show the growth of this organism in certain restricted regions; and caecum may be one of them. Lund (1964), however, has used sulpha drugs to destroy the so-called bacteria, that may be producing Vitamin K, and even then his rats showed resistance. It therefore remains to be seen whether studies on caecum and Vitamin K may throw more light on this phenomenon of tolerance. However, Bentley (1969) has investigated and found that the addition of sulphaquinoxaline or sulphaguanidine to suppress the Vitamin K producing bacteria or the addition of melhyltestosterone was of no avail. He has tried Racumin at 0.05% concentration and mentions that this gave good results in the Warfarin resistant rats. Unfortunately, we have found that the Bombay R. rattus left 40%, 40% and 20% survivors in 0.05%, 0.1% and 1% concentrations of Racumin. This further shows the resistance for allied anticoagulants.

Warfarin has not yet been used on a large scale in India. This phenomenon seen in Bombay R. rattus and indicated in similar species in Marathwada region of Maharashtra are probably suggestive of a natural tolerance by some of these rats in a community. Given a natural population, there will be a variation in susceptibility to a given stimulus. In the B. bengalensis, the population is uniformly susceptible. In R. rattus studied above, there are tolerant individuals who show bait-shyness or refusal, tolerating heavy doses of the anticoagulant without dying and not exhibiting internal hemorrhage. These composite criteria be therefore taken together to test tolerance in rats.

Bentley (1969) has stated that "in fact there is now little doubt that resistance largely or wholely depends on some kind of competition between Warfarin and Vitamin K, possibly for a gene controlled, repressor concerned with the production of blood clotting proteins." Further studies on R. rattus may confirm while the present studies point out a clear tolerance.

SUMMARY

Anticoagulant rat poison "Warfarin" manufactured by the National Chemical Laboratories and currently available in the market was used in the field where on a comparative basis with zinc phosphide it did not give an adequate kill in rats. The majority of these rats were R. rattus. Such rats from Bombay were given 0.005, 0.01, 0.025, 0.05, 0.1 and 0.5% of the anticoagulant in the laboratory for 6 to 10 days. They were kept on 0.025% Warfarin with alternate food for 20 days and individual rats of equal number of sexes were given 0.025% for 2, 4, 6, and 8 days and then shifted to normal food. The experiments have shown that 0.005% is probably the critical dose and that R. rattus from Bombay even if they take 0.025% Warfarin for 2 days will die within 8 days if susceptible. The individual

Table VII - Anticoagulant (0.025%) trials feeding for 6 days only for Rattus rattus from Marathwada. Held over on normal food up to 20 days.

Locality	Average wt. of rat	Feeding days of Warfarin	Average Warfarin bait consumed per rat in gms. up to death	Mean lethal dose mg/kg of body wt. (dead rat)	Mortality in 6 days No out of	Survived even after 20 days	Mean day of death
Sholapur	111.5	6	47.5	113.4	4/10	-	6.7
Osmanabad	95.5	6	58.4	156.17	4/8	-	6.4
Murud	92.7	6	42.5	125.84	4/7	1(+9)	5.6
Ambejogai	92.3	6	35.2	99.93	6/6	-	5.7
Pali	122.4	6	31.6	65.8	5/5	-	5.0
Gevrai	109.0	6	44.0	84.5	2/5	1(+4)	9.25
Daulatabad	91.0	6	36.7	101.7	4/7	1(+30)	5.8
Pachod	111.6	6	32.7	82.6	2/7	1(+6)	7.6

+ Indicates death due to anticoagulant poisoning.
- Indicates death due to some other causes.
Figures in parenthesis of column 7 indicate the difference in weight when compared with the weight of rat at the start of the experiment.

Table VIII - Trials on R. rattus with Warfarin and normal food offered simultaneously for 10 days and hereafter offered normal food till 20 days.

Locality	Average wt. of rat	Average consumption per rat in gms.		Average day of death	Lethal dose mg/kg	Mortality in days			Survival after 10 days
		Warfarin (10 days)	Normal food			6	10	20	
			(Warfarin 0.025% and normal food.)						
Sholapur	95.0	28.4	50.3	5.7	62.1	1/10	4/10	5/10	50%
Osmanabad	97.1	37.4	64.5	7.66	82.15	2/8	6/8	8/8	-
Ambejogai	120.9	24.6	29.0	5.8	59.9	3/6	3/6	6/6	
			(Warfarin 0.05% and normal food.)						
Sholapur	112.0	54.4	56.9	5.3	30.1	3/9	3/9	3/9	30%
Osmanabad	100.3	57.25	46.5	7.3	29.8	3/8	5/8	8/8	-

survivors with 0.025% concentration have tolerated 22.52 to 149.5 mg/kg, while those that died have taken between 12.19 to 173.1 mg/kg Warfarin. Those that show tolerance do not die even when they have been feeding for 20 days on Warfarin. B. bengalensis which is a much bigger rat dies within 6 days leaving no survivors even with 0.005% Warfarin. R. rattus collected from Sholapur, Osmanabad, Murud, Ambejogai, Pali, Gevrai, Daulatabad and Pachod indicate a similar phenomenon in varying proportions. The rats that died in 10 days took between 10 to a maximum of 231.7 mg/kg of 0.025% Warfarin and there were survivors after 10 days at Murud, Gevrai, Daulatabad and Pachod. With alternate food there are survivors even from Sholapur and Ambejogai. As compared to B. bengalensis, R. rattus in general do not show any profuse hemorrhage after death with Warfarin, but only indicate paleness of organs like liver, heart, spleen, lungs and the viscera.

ACKNOWLEDGEMENTS

We are extremely thankful to the Director, Haffkine Institute for the facilities, to the Bombay Municipal Corporation and Directorate of Public Health for rat collection and to our colleague Mr. Tare for the assistance in the work. We are thankful to Messers UNICHEM Laboratories and to Mr. N.S. Rao of Pest Control India (Pvt.) Ltd. for making us available the rodenticide in sufficient quantities.

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