Rats and the placement of rodenticide baits for their eradication on indoor livestock farms

S. Endepols[1,*] and N. Klemann[2]

1 Bayer Environmental Science, Bayer CropScience AG, Alfred Nobel Strasze 50, Building 6220, D-40789 Monheim, Germany
2 Institut für Nematologie und Wirbeltierkunde, Biologische Bundesanstalt für Land- und Forstwirtschaft, Münster, Germany
* Corresponding author (tel: +49-2173-383895, fax: +49-2173-383891, e-mail: stefan.endepols@bayercropscience.com)

Received 29 July 2004; 26 October 2004

Abstract

The frequency and distribution of specific structural farm elements in relation to the occurrence of rats was investigated on 24 German livestock farms, 18 in Lower Saxony and 6 in the Münsterland area. Using the interactive control programme BayTool® we also examined whether the allocation of baiting-points to these elements would result in complete rat eradication. Standardized rat control measures were applied with baiting-points allocated to six specific structural elements on these farms, and the feeding activity of rats was recorded for each of these elements and their position. Rat activity mainly occurred at five specific structural elements. Farms with rat infestations held a higher number of the element 'old materials' than rat-free farms. The allocation of rodenticide baiting-points to five specific structural elements is a precondition for complete rat eradication. Most rat feeding activity was observed at baiting-points allocated to 'old materials', 'stacks' (of construction materials), and 'livestock'. Rat feeding activity was predominantly located outdoors at 'old materials' and 'stacks'. The stringent allocation of baiting-points to six specific structural elements is a reliable means of rat eradication and rat monitoring on livestock farms. As most rat activity on livestock farms is expected outdoors a rodenticide must be chosen that only poses low secondary poisoning hazards.

Additional keywords: *Rattus norvegicus*, rodent control, vector control, biosecurity, coumatetralyl

Introduction

Rats, particularly the brown rat (*Rattus norvegicus*), are considered reservoirs and vectors of a number of agents that cause diseases in humans and livestock. In contrast to other small rodents, such as house mice, rats may roam as far as 1.5 km within a single night (Herden, 1992), visiting barns, feed stores, herds, refuse dumps and even areas where game is being fed. They are capable of disseminating pathogens to livestock by building an epidemiological bridge between wild animals and farm animals, and between different herds of livestock. *Leptospira icterohaemorrhagiae*, the causal agent of Weil's disease, is an example of bacteria that are transmitted via the urine of rats (Thiermann, 1981). Another spirochete, *Borrelia burgdorferi*, the causal agent of Lyme disease, is transmitted by vector ticks engorged on rats (Matuschka *et al.*, 1996). *Listeria monocytogenes*, *Campylobacter jejuni* and the Foot-and-Mouth Disease virus can be shed with their faeces for a number of months (Capel-Edwards, 1970; Epoke & Coker, 1991; Iida *et al.*, 1998). Rat control measures and documentation on their implementation are therefore required by law, and various guidelines are stipulated for rat control routines such as those contained in the German pig farming hygiene regulation (Anon., 1999).

However, rat control is often performed irregularly and with poor preparation and documentation, especially on small- and medium-sized farms. Underestimating the extent of an infestation is considered the most common reason for the failure of control operations (Meyer, 1994). A previous study investigated whether the allocation of rodenticide baiting-points to specific structural elements as opposed to only assigning the baiting-points to places where there were obvious signs of rat activity, would result in complete rat eradication (Endepols *et al.*, 2003). The study was conducted on 25 farms in Germany's Münsterland, an area with a high density of pig farming and a long history of unsatisfactory approaches to rat control on many farms. It was found that the strict allocation of bait to specific structural habitat elements on farms guarantees a high degree of control success. As a result of this study, a rodent control programme was established that is easy to conduct, effective, and able to be monitored. This new approach was incorporated into the self-explanatory computer programme BayTool®, which is available on internet (Anon., 2002).

The aim of this study was to investigate the frequency and distribution of these identified specific structural elements in relation to the occurrence of rats on livestock farms, and to examine whether the allocation of baiting points to these elements, using the interactive control programme BayTool® would result in complete rat eradication. Besides we investigated at which baiting-points feeding activity was highest and where these points were located on the farms.

Materials and methods

The studies were conducted in Lower Saxony and in the Münsterland area of Germany between 2001 and 2004. The study in Lower Saxony was performed in July 2001 during a campaign on 18 pig farms in a restricted area near Soltau after an outbreak of

Classical Swine Fever. In the Münsterland area the study was conducted on six farms with medium to heavy rat infestations.

Using the BayTool® programme, the following structural elements were mapped for each farm: stables (any room confining livestock), feed containers with permanently food available for rats (e.g. mixers, grain heaps), ground-covering shrubs, stacked material (e.g. wood and construction stocks) straw and hay, and stored old materials. One baiting-point was proposed for each of these elements. The minimum distance between two baiting-points was 5 m in accordance with the BayTool® programme. Bait was placed hidden behind bricks, pipes, beams or other construction elements to ensure that no non-target animals could gain access to the bait. In a few cases, wooden bait stations (50 x 20 x 20 cm with a hole at either end) or commercially available plastic bait boxes were used.

Lower Saxony

One day after an outbreak of Classical Swine Fever, the government veterinarian was contacted and an immediate rat control campaign was started using the computerized rat control programme BayTool®. Within two days, two persons driving a van equipped with a laptop and a printer visited all 21 pig farms in the restricted area. Farmers were asked to contact the vehicle in front of their farm, and a rat control plan was set up for each farm. The plan, comprising a map of the farm with baiting-points and a data sheet, as well as sufficient quantities of Racumin® Paste rat bait were handed out to every farmer. In Germany, Racumin® Paste (containing 0.0375% (w/w) of the anticoagulant coumatetralyl) is an officially approved rodenticide for rat eradication according to Article 18 of the Law on Infection Protection (Anon., 2000), and has been proven effective for rat control on farms (Boecker *et al.*, 1998). Each farmer received instructions on baiting and was required to commence immediately as part of the official prevention programme during an epidemic. Baiting-points were furnished with 200 g of bait, checked by the farmers after 3 or 4 days, replenished, and tended once or twice a week for up to 4 weeks. All farms were visited again by the same two persons four weeks later, data sheets were collected, and farmers were asked for their observations and assessments of the measure. In addition, the farms were inspected for old and new signs of rat activity. Spot checks were made to confirm that baiting-points had been correctly established in order to determine whether the control plan had been implemented on each farm, whether in fact there had been an initial rat infestation, and if so, whether the infestation had been eradicated. The presence and the number of structural elements on the farms was investigated and compared with those on farms without rats. The documentation provided qualitative data on rat feeding activity according to structural elements and their indoor or outdoor position.

Münsterland area

The same experienced person conducted the trials in Münsterland area, which were carried out within a programme to investigate the efficacy of coumatetralyl-based bait. To assess the magnitude of the infestations, four days before baiting started a pre-baiting census was carried out by placing rolled oats at all sites where rats were suspected. Its consumption was measured on the fourth day. Bait consumption was recorded by weighing and replenishing bait twice a week for three weeks. Rat feeding activity and the quantity of bait consumed were analysed in relation to the allocation of the baiting-points to structural elements, and the proportion of outdoor bait consumption for each element was calculated. Statistically significant differences were established with the Mann-Whitney rank sum test using the statistical programme SigmaStat (Anon., 1992).

Results

After the campaign it was confirmed that every aspect of the rat control plans in Lower Saxony had been put into practice during the treatments. We were able to collect data from 19 farms; the data from only one farm had to be discarded due to incompleteness. Although only two farmers accepted the possibility that some rats may have been on their premises prior to the campaign, the data and inspection revealed infestations on six farms. All infestations were eradicated by implementing the control programme Baytool®, which became evident from the documentation sheets, and was confirmed after the campaign.

The structural elements 'stacks' and 'straw/hay' were both identified on 83% of the farms with rat infestations, while for the rat-free farms this percentage was 75 and 67, respectively. Ground-covering shrubs were found on one infested farm only. All rat-infested farms had 'old materials' in the form of heaps of junk and debris, against only 25% of the non-infested farms. A significantly higher number of this element was found on farms with rat infestations (Table 1). Storing old materials on farms promoted the settlement of rats.

Rat feeding activity was investigated on 12 farms in Lower Saxony and the Münsterland area. Measured over both locations the activity was lowest for the structural element 'straw/hay' (Table 2), although the rate was higher for the Münsterland area than for Lower Saxony due to one farm where straw was stored very near the old materials and stacks of construction materials. More than 70% of the baiting-points at 'stacks' and 'old materials' were visited by rats. Rats were most attracted to baiting-

Table 1. Number of specific structural elements on livestock farms in Lower Saxony, with or without rat infestation. n = number of farms.

	n	Structural element				
		Livestock	Feed	Stacks	Old materials	Straw/hay
Rats present (a)	6	4.8	3.8	1.3	2.2	1.5
Rats absent (b)	12	3.7	2.6	1.1	0.6	1.2
a/b		1.3	1.5	1.2	3.7[1]	1.3

[1] Statistically significant from other ratios (Mann-Whitney rank sum test; $\alpha = 0.02$).

Table 2. Percentage baiting-points with rat feeding activity on farms in Lower Saxony (6) and Münsterland area (6), grouped according to structural element. n = number of baiting points.

Region	Structural element									
	Livestock		Feed		Stacks		Old materials		Straw/hay	
	n	%	n	%	n	%	n	%	n	%
Lower Saxony	29	27.6	23	34.8	8	62.5	13	23.1	9	11.1
Münsterland area	26	57.7	32	50.0	27	77.8	35	88.6	18	50.0
Total	55	41.8	55	43.6	35	74.3	48	70.8	27	37.0

Table 3. Percentage outdoor baiting-points with rat feeding activity on farms in Lower Saxony (6) and Münsterland area (6), grouped according to structural element. Feeding activity expressed as percentage of the total of indoor and outdoor baiting-points. n = total number of baiting-points (indoor + outdoor).

Region	Structural element									
	Livestock		Feed		Stacks		Old materials		Straw/hay	
	n	%	n	%	n	%	n	%	n	%
Lower Saxony	29	0	23	13.0	8	50.0	13	23.1	9	0
Münsterland area	26	7.7	32	18.8	27	77.8	35	54.3	18	16.7
Average		3.9		15.9		63.9		38.7		8.7

Table 4. Total bait consumption and percentage outdoor bait consumption on livestock farms in Münsterland area during 6 treatments, grouped according to structural element.

Bait consumption	Structural element				
	Livestock	Feed	Stacks	Old materials	Straw/hay
Total (kg)	14.43	8.05	17.89	18.17	6.88
Outdoor (%)	20.8*	32.6	100.0*	83.2*	55.4

* Outdoor bait consumption statistically different from indoor bait consumption (Mann-Whitney; $\alpha \leq 0.05$).

points at these habitat elements.

In Lower Saxony and the Münsterland area 16.1% and 56.5% of the baiting-points, respectively, indicated outdoor feeding activity, compared with 24.2% and 29.1% for indoor feeding activity. Habitat elements with the highest values for outdoor feeding activity were 'stacks' and 'old materials' (Table 3). Ground-covering shrubs were found on one farm only, so that this element was excluded from the analysis.

The six infestations in the Münsterland area were assessed as medium to heavy, with amounts of 500–1000 g rolled oats consumed per day in three cases, and 1835 g, 4991 g, and 6295 g per day recorded for the more serious infestations. Indoor consumption was mainly recorded for the element 'livestock' (Table 4). Bait consumption was highest, and predominantly recorded outdoors, for the elements 'stacks' and 'old materials'.

Discussion

Farm structures preferred by rats

Monitoring of rat activity and immediate rat control are necessary measures to prevent livestock from becoming infected with diseases transmitted by rats. Our results confirm that there are farm structures that support rat settlement and that these sites are preferred by rats searching for shelter. Rat-infested farms had almost four times the number of sites with abandoned old materials than farms without rats. Bait-feeding activity was predominantly recorded at stacks of construction materials and at heaps of old materials. The importance of these sites for successful rat control has been described earlier (Endepols *et al.*, 2003). Removing such structures would obviously reduce the hazard of immigrating rats, but often this benefit is still underestimated. Monitoring and early control may be most effective if remaining old materials and stacks are watched carefully, but such activities are often beyond the scope of farmers' daily routine. Stacks and old materials are separate categories in the control programme to improve the chance that the latter are not forgotten by the farmer during monitoring and control.

The scheme for the placement of bait

All rat control measures during the campaign in Lower Saxony were started without prior inspection of the sites by an expert, professional or farmer. Bait was allocated only according to a computerized scheme based on the distribution of six typical structural farm elements. By taking into account all habitat elements involved in supporting rat life on farms, this approach eliminates the subjective risk of underestimating the infestation. Although rats were suspected on only two farms, baiting at the proposed sites revealed infestations on six farms. Site inspections after the campaign confirmed that there had not been infestations prior to the campaign on the other farms, and that all rats had been eradicated. The control scheme employed is an effective alternative to current rat control advice, which recommends carefully determining infestation by searching for signs of rat activity in order to give an indication of where to place the bait (Kaukeinen, 1994). In the case of a epizootic, a computerized eradication programme would enable simultaneous and well-documented rat eradication in the hit area if personal technical advice might be hampered by quarantine measures, and if pest management professionals are not allowed to enter farms within restricted areas. The strict allocation of bait to the identified structural habitat elements on farms is a reliable method for monitoring. It is a precondition for a high degree of success of the control measure.

In the past a number of factors influencing the efficacy of an anticoagulant baiting system have been investigated. For some anticoagulant rodenticides the success of rat control on farms varies according to the product's LFP98 (lethal feeding period of the product to reach 98% mortality in rats under laboratory conditions) (Richards & Huson, 1985). However, such a relation has not been published for the multiple-dose anticoagulant rodenticide used in our study. If rats take small amounts on five successive days the toxicity of coumatetralyl is 10 times higher than with a single dose. This characteristic may fit in well with the foraging behaviour of a proportion of the rats that regularly visit baiting places but consume very small amounts (Klemann & Pelz, 2004), or even of entire packs that are reluctant to accept the bait. Other factors affecting rat control success are the amount of bait allocated to each element, the frequency with which the bait is replenished (Richards & Huson, 1985) and the presence of stored cereals (Quy *et al.*, 1992). The principle of bait dispersal was only considered when significant control was achieved after bait was placed down burrows rather than in bait boxes. The wider dispersion of bait obtained with burrow baiting was supposedly contributing to this effect (Cowan *et al.*, 1994). Sufficient bait dispersion is guaranteed if the principle is followed of bait allocation to certain structural habitat elements, as was introduced here.

The importance of outdoor baiting

A high proportion of rat feeding activity was recorded outdoors. This was true especially in the Münsterland area for treatments conducted with medium to heavy infestation, irrespective of the season. As many of the elements 'stacks' and 'old materials' were present there, particularly outdoors, we expect that the structure of these farms supported the development of such infestations. Most bait (56%) was consumed at the outdoor baiting-points, but 100% and 83% of it was consumed at 'stacks' and 'old materials', respectively. During treatment of the smaller infestations in Lower Saxony, 40% of the baiting-points with feeding activity were located outdoors. The bait placement scheme introduced here ensured that the sites with a high probability of outdoor rat activity are accounted for when applying the control measure.

The results of this investigation provide further evidence that outdoor baiting must be part of successful rat control and rat monitoring on livestock farms, and that reducing the number of outdoor baiting sites would reduce the chance of complete eradication. Even if baits were only distributed according to the density of rat signs, increasing the distance between baits will reduce the likelihood of such baits intercepting rats with a large home range or the rats entering the premises (Cowan *et al.*, 2003). An environmental risk assessment, especially of non-target risks, is therefore inevitable. Using adequate baiting techniques will greatly reduce or eliminate the immediate exposure of non-target organisms to rodenticides, though their exposure to poisoned rats cannot be ruled out. Poisoned rodents may become a danger to predators and scavengers.

A separate environmental risk assessment of secondary poisoning from indoor and outdoor baiting is hardly possible. Irrespective of their burrowing site, rats search for food indoors, such as at livestock-feed containers and bait stations, but may nevertheless become a prey outdoors. Besides the hazard posed by the poisoned rodent, the actual risk under actual conditions depends on many other factors like feeding preferences of the predators, their species, and the availability of prey. Such data are difficult to describe quantitatively. However, investigating the potential secondary poisoning hazard of rodenticides is an important tool for evaluating possible effects (Joermann, 1998). Such investigations were recently carried out with the rodenticide used in our study (Fisher *et al.*, 2003; O'Connor *et al.*, 2003). The results showed that the anticoagulant coumatetralyl poses a relatively low hazard of acute secondary poisoning to non-targets like barn owls and ferrets.

The careful selection of a proper rodenticide in combination with the evaluated scheme for the placement of bait on farms makes it possible to provide the prerequisites for effective vector control by paying attention to outdoor habitat use by rats, and for minimizing the risk for wildlife.

Acknowledgements

We wish to thank Dr K. H. Hillmann for his support of the field work in Wolterdingen; Silke Friebe, Susanne Mitschke and Volker Gutsmann for preparing the launch of BayTool® and Elke Landschoof and Heiko Heeren from Kölner Medienwerk for their creativity in designing and programming BayTool®.

References

Anonymus, 1992. SigmaStat for Windows, Version 3.0.1. SPSS Inc., Chicago, Illinois.

Anonymus, 1999. Verordnung über hygienische Anforderungen beim Halten von Schweinen (Schweinehaltungshygieneverordnung – SchHaltHygV). Bundesgesetzblatt Teil I, Seite 1252; geändert durch Verordnung vom 18. April 2000 (Bundesgesetzblatt Teil I, Seite 2038): § 3. Bundesministerium für Landwirtschaft und Forsten, Berlin.

Anonymus, 2000. Bekanntmachung der geprüften und anerkannten Mittel und Verfahren zur Bekämpfung von tierischen Schädlingen nach §10c Bundes-Seuchengesetz. *Bundesgesundheitsblatt* 43 (Suppl. 2): 62–74.

Anonymous, 2002. BayTool. Bayer Environmental Science <http://www.baytool.de> Accessed 1 September 2004.

Boecker, T., S. Endepols & R. Sonneck, 1998. Racumin® Paste: A new bait for rat control. *Pflanzenschutz-Nachrichten* Bayer 51(2): 183–196.

Capel-Edwards, M., 1970. Foot-and-mouth disease in the brown rat. *Journal of Comparative Pathology* 80: 543–548.

Cowan, D.P., D.S. Bull, I.R. Inglis, R.J. Quy & P. Smith, 1994. Enhancing rodenticide performance by understanding rodent behaviour. In: Proceedings of the Brighton Crop Protection Conference – Pests and Diseases, 21–24 November 1994, Brighton. British Crop Protection Council, Alton, pp. 1039–1046.

Cowan, D.P., R.J. Quy & M.S. Lambert, 2003. Ecological perspectives on the management of commensal rodents. In: G.R. Singleton, L.A. Hinds, C.J. Krebs & D.M. Spratt (Eds), Rats, Mice and People: Rodent Biology and Managament. Monograph No 96, Australian Centre for International Agricultural Research, Canberra, pp. 433–439.

Endepols, S., N. Klemann & K.-L. Ziebell, 2003. A scheme for the placement of rodenticide baits for rat eradication on confinement livestock farms. *Preventive Veterinary Medicine* 58: 115–123.

Fisher, P., C.T. Eason, C.E. O'Connor, C.H. Lee, G.B. Smith & S. Endepols, 2003. Coumatetralyl residues in rodents and secondary poisoning hazard to barn owls. In: G.R. Singleton, L.A. Hinds, C.J. Krebs & D.M. Spratt (Eds), Rats, Mice and People: Rodent Biology and Management. Monograph No 96, Australian Centre for International Agricultural Research, Canberra, pp. 457–460.

Epoke, J. & A.O. Coker, 1991. Intestinal colonization of rats following experimental infection with *Campylobacter jejuni*. *East African Medicine Journal* 68: 348–351.

Herden, C., 1992. On the Importance of Riparian Habitat use Patterns of Brown Rats (*Rattus norvegicus*). Wissenschaftliche Beiträge Universität Halle 1992, Vol. Semiaquatische Säugetiere, pp. 61–69.

Iida, T., M. Kanzaki, A. Nakama, Y. Kokubo, T. Maruyama & C. Kaneuchi, 1998. Detection of *Listeria monocytogenes* in humans, animals and food. *Journal of Veterinary Medicine and Science* 60: 1341–1343.

Joermann, G., 1998. A review of secondary-poisoning studies with rodenticides. Bulletin No 28, European and Mediterranean Plant Protection Organization (OEPP/EPPO), Paris, pp. 157–176.

Kaukeinen, D., 1994. Rodent control in practice: Householders, pest control operators and municipal authorities. In: A.P. Buckle & R.H. Smith (Eds), Rodent Pests and their Control. CAB International, Wallingford, pp. 249–271.

Klemann, N. & H.-J. Pelz, 2004. The feeding pattern of the Norway rat (*Rattus norvegicus*) in differently structured living areas on farms. *Applied Animal Behavioural Scienc*. (Submitted for publication)

Matuschka, F.-R., S. Endepols, D. Richter, A. Ohlenbusch, H. Eiffert & A. Spielman, 1996. Risk of urban Lyme disease enhanced by the presence of rats. *Journal of Infectious Diseases* 174: 1108–1111.

Meyer, A.N., 1994. Rodent control in practice: food stores. In: A.P. Buckle & R.H. Smith (Eds), Rodent Pests and their Control. CAB International, Wallingford, pp. 273–290.

O'Connor, C.E., C.T. Eason & S. Endepols, 2003. Evaluation of secondary poisoning hazards to ferrets and weka from the rodenticide coumatetralyl. *Wildlife Research* 30: 143–146.

Quy, R.J., D.P. Cowan, P. Haynes, I.R. Inglis & T. Swinney, 1992. The influence of stored food on the effectiveness of farm rat control. In: Proceedings of the Brighton Crop Protection Conference – Pests and Diseases, 17–20 November 1992, Brighton. British Crop Protection Council, Alton, pp. 291–300.

Richards, C.G.J. & L.W. Huson, 1985. Towards the optimal use of anticoagulant rodenticides. *Acta Zoologica Fennica* 173: 155–157.

Thiermann, A., 1981. The Norway rat as a selective chronic carrier of *Leptospira icterohaemorrhagiae*. *Journal of Wildlife Diseases* 17: 39–43.