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SPECIFICATIONS FOR WIRE MESH FENCES TO EXCLUDE THE EUROPEAN WILD RABBIT FROM CROPS

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ABSTRACT: The sizes of hexagonal and rectangular meshes needed to exclude all age classes of rabbits (Oryctolagus cuniculus) were 31 mm and 50 x 25 mm, respectively. In an enclosure, fences 0.75 m high excluded >90% of adult rabbits, a similar percentage to that obtained using the commonly accepted height of 0.9 m. In a subsequent field experiment using fences with a mesh size of 31 mm and heights of 0.9 m and 0.75 m, the numbers of rabbits seen on protected fields were reduced by about 80% for each height and therefore the 0.75-m-high fence was more cost-effective.

INTRODUCTION

The European wild rabbit (Oryctolagus cuniculus) is the most serious vertebrate pest in Britain, causing crop losses valued at millions of pounds annually. One method of protecting crops from rabbit grazing is to erect mesh fences, particularly where burrows are inaccessible and therefore methods of rabbit control such as gassing, the recommended method in Britain, cannot be used. Wire mesh fences have been used for many years to protect crops from rabbits (Harting 1912, McKnight 1969). However, there appear to have been no rigorous studies of the design of these fences based on cost-effectiveness, resulting, for example, in different specifications being recommended within Britain (Thompson and Worden 1956, Pepper and Tee 1972).

Enclosure trials were conducted to determine the size of mesh and the most cost-effective fence height required to exclude rabbits. The mesh size and height selected were then compared in field trials with 0.9-m high fencing, the height recommended at the time by both the Ministry of Agriculture, Fisheries and Food (MAFF) and the Forestry Commission (FC). These trials were conducted between July 1977 and April 1984 in the south and east of England.

METHODS

Mesh-size Enclosure Experiment

The effectiveness of hexagonal meshes of 31 mm and 36 mm, of a square mesh of 50 x 50 mm, and of rectangular meshes of 75 x 25 mm and 50 x 25mm were examined once for each of three age/weight classes of rabbits in trials each of 2 weeks' duration. Further trials were conducted on the rectangular meshes which were found to exclude rabbits. In these trials, the effectiveness of the mesh was re-examined after it had been distorted into a rounded shape which rabbits might get through more easily. The aim was to simulate the effects of machinery damage to the mesh caused, for example, by accidents during sowing or harvesting. In each trial, three wild rabbits, either all juveniles (<800g), immatures (800-900g), or adults (>900g), fitted with colour-coded ear tags to allow individual identification, were placed in a 4 x 3 x 3-m enclosure. The enclosure contained water and a wooden hutch to provide shelter at one end and a bowl of pelleted food at the other. Mesh sizes and age/weight classes were allocated randomly to each of the three enclosures used.

A fence was erected across the width of each enclosure from ground to roof level to separate the rabbits in the hutch from the food bowl at the beginning of the second week of each trial. A 0.5-m-wide strip of smooth wet sand was placed along the fence on the bowl side. The sand was examined daily for rabbit tracks and smoothed and wetted when necessary. A hide was erected next to each enclosure and observations were made daily during the second week between 0600-0900 hours and 1800-2200 hours. A bowl of food was also provided on the hutch side of the enclosure between 0900-1800 hours when any rabbits had not crossed the fence within the previous 24 hours.

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Minimum Height Enclosure Experiment

The effectiveness of fence heights of 0.9 m, 0.75 m, 0.675 m, 0.6 m, and 0.45 m was examined in trials which lasted 4 weeks each, with three replicates for each height. In each trial, five adult wild rabbits, fitted with colour-coded ear-tags to allow individual identification, were placed in a 50 x 40-m grass enclosure which contained three wooden hutches at one end to provide shelter and five bait points of chopped carrot to represent an attractive food source at the opposite end. Throughout the experiment the grazing available exceeded that required by the rabbits. The aim was to produce a situation similar to that on farmland where rabbits live in woodland containing grazing but move to feed on preferred crops in adjacent fields.

On 4 consecutive days each week, 400 g of carrot were laid at each bait point and additionally in three rabbit-proof cages to enable calculation of weight changes in the carrots resulting from changes in moisture content. Each morning the carrot which had not been eaten during the previous night was removed and weighed. For the rest of each week about 1500 g of bait were laid at each of the bait points to maintain the attraction of the bait points for the rabbits. Bait laid on the fourth day of the first week was treated with the dye rhodamine B and the following day rabbits were examined for the presence of the dye around the mouth; bait laid on the penultimate day of the fourth week was treated with "Microtaggants"® (Minnesota Mining and Manufacturing, Inc., St. Paul, Minn.), and the following day rabbits were examined post mortem for the presence of Microtaggants in the stomach and caecum (Cowan et al. 1984)..

At the beginning of the third week of each trial, fences with a 50 x 25-mm rectangular mesh were erected to separate the hutches from the bait piles by dividing the enclosure in half. Any rabbits found on the bait side of the fence during the daily visits to change the carrots were identified and returned to the hutches.

Minimum Height Field Experiment

The effectiveness of the 0.9-m and 0.75-m fence heights, both with a wire mesh size of 31 mm, were each examined at seven sites, each site having at least 20 rabbits emerging from woodland to feed on an adjacent field crop. The crop selected was restricted to winter barley to eliminate the effects of possible crop preferences by rabbits. Adult rabbits were counted by pairs of observers walking a predetermined route along the boundary between the field and the wood 2 to 4 hours after dusk, one observer using binoculars to count rabbits illuminated by the light of a 110-watt spotlight carried by the other. Three or four counts were conducted a weekly intervals before and again immediately after fence erection. Thereafter, counts were conducted at fortnightly intervals until crop height made counting impracticable.

Fences were erected along field boundaries adjacent to the woodland and extended a further 50 m at each end; usually only 1 but sometimes 2 sides of the field were fenced. Fences were inspected at weekly intervals and any damage was repaired, and points at which rabbits had dug under the fences were noted and blocked with earth.

After harvest, the farmers on whose land the field trials using 0.75-m-high fencing had been conducted were asked whether, in their opinion, crop yields on the protected fields were greater than expected. They were asked to estimate any increase considered to be entirely due to the exclusion of rabbits.

Statistical Analyses

Paired t-tests were used to determine if there were reductions after fence erection for each height used in the amount of bait consumed in the enclosure experiment and in the numbers of rabbits counted in the field experiment. Unpaired t-tests were used to compare reductions among the different heights in each experiment. In the unpaired tests, adjusted t statistics and degrees of freedom were calculated to allow for unequal variances in bait consumption data, and square root transformations were used where necessary to normalize counts data (Snedecor and Cochran 1980). Retransformed means and retransformed 95% confidence limits are presented in the results for clarity.

RESULTS

Mesh-size Enclosure Experiment

The 31-mm hexagonal and 50 x 25-mm and 75 x 25-mm rectangular meshes excluded all rabbits; juvenile and immature rabbits passed through all other sizes used. However, after distorting the rectangular meshes, only the 50 x 25 mm continued to exclude all rabbits; juveniles and immatures passed through the other. Sufficient information was not always obtained by observations from the hides and from rabbit tracks in the sand to say how many of the three rabbits in a class had passed through the mesh. Therefore effectiveness was categorized as complete or incomplete (Table 1).

Table 1. The age/weight classes of rabbits excluded (*) by the different sizes of mesh (mm) used in fences in enclosure trials.

Mesh type		Age/weight class		
		Juvenile (< 800 g)	Immature (800-900 g)	Adult (> 900 g)
31	hexagonal	*	*	*
36	hexagonal			*
50 x 25	rectangular	*	*	*
50 x 25	distorted	*	*	*
75 x 25	rectangular	*	*	*
75 x 25	distorted			*
50 x 50	square			*+

+Only rabbits < 1200 g were excluded.

Minimum Height Enclosure Experiment

All rabbits were eating carrots by the end of the first week, as demonstrated by the dye marker, and the amount of bait consumed per rabbit increased during this week but remained relatively constant during the second week (Fig. 1). This follows the pattern noted by Cowan (in press) and indicates a period of familiarization before optimum consumption is achieved. Results from the first week, therefore, were omitted from further analysis.

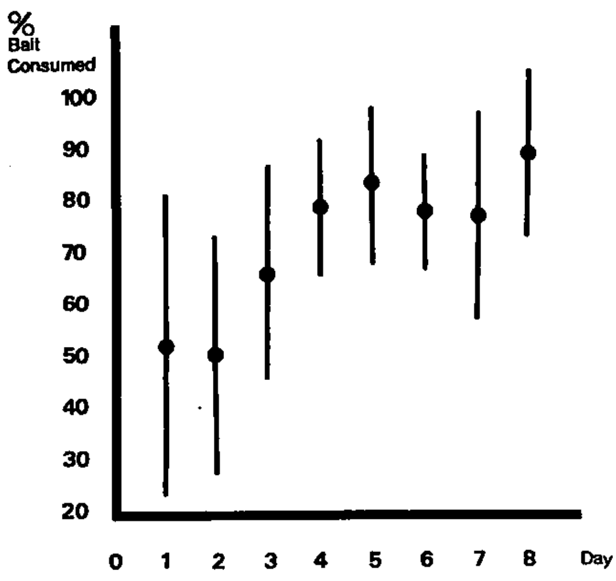

Figure 1. Daily bait consumption (% of maximum weight eaten/day/rabbit/trial) prior to fence erection for all trials in the enclosure experiment to determine the minimum height of fences required to exclude rabbits.

In the first week after fences were erected, the three highest excluded all rabbits and, although the two lowest fences did not exclude them all, the weight of bait consumed daily per rabbit nevertheless decreased ($P < 0.001$) compared with that consumed prior to fence erection (Table 2). In the second week, only the 0.75-m fence excluded all rabbits. The 0.9-m, 0.675-m, and 0.6-m fences were crossed by 2 out of 14, 1 out of 13, and 8 out of 14 surviving rabbits, respectively, and the average weight of bait consumed daily per rabbit was still less than that prior to fence erection ($P < 0.001$, $P < 0.001$, and $P < 0.05$, respectively). However, the extent of this decrease was similar in the 0.9-m and 0.675-m trials and was greater than in the 0.6-m trial ($P < 0.1$). The 0.45-m fence was crossed by all 14 rabbits which survived and the weight of bait consumed was similar to that prior to fence erection ($P > 0.05$). Over the 2 weeks, therefore, there was little difference among the effectiveness of the three highest fences.

Table 2. The amount of bait consumed (g) per rabbit in the week before and 2 weeks after fence erection, and the numbers of rabbits with Microtaggants in the stomach or caecum on the last day of the trials conducted in the enclosure using fences of different heights.

	Bait consumed						
	Before		After				
	Week 2		Week 3		Week 4		Numbers of rabbits with Microtaggants[c]
Height (m)	Mean	SD	Mean	SD	Mean	SD	
0.450	294	98	122[a]	39	310	90	14
0.600	319	37	50[a]	87	175[b]	179	8
0.675	290	55	0	0	34[a]	59	1
0.750	201	53	0	0	0	0	0
0.900	240	62	0	0	7[a]	12	1[d]

[a]Means after erection differ from means before erection at 0.001 level.

[b]Means after erection differ from means before erection at 0.05 level.

[c]The maximum number of rabbits which could have eaten Microtaggants at any height was 14 except at 0.675 m where it was 13, due to deaths during the trials.

[d]One other rabbit crossed the 0.9 m fence but did not eat Microtaggants because it crossed on a day when none was used.

Minimum Height Field Experiment

There were no differences among the sites used in 0.9-m and 0.75-m fence field trials in the lengths of fencing erected (Table 3, $P > 0.05$), in the density of rabbits seen on protected fields prior to fence erection (Table 3, $P > 0.05$), or in the numbers of rabbits counted prior to fence erection (Table 4, $P > 0.05$).

Table 3. Lengths (m) of fencing erected and density of rabbits seen in fields (Number/ha) before erection of fences 0.75m and 0.9m high at sites in the south of England.

Height (m)	Number of sites	Fence length		Rabbit density	
		mean	SD	mean	95% CL
0.750	7	784	198	3.3	1.3-6.3
0.900	7	681	155	4.9	2.9-7.4

Table 4. Numbers of rabbits counted on fields [a]before and after erection of fences 0.75 m and 0.9 m high and the % reductions in numbers obtained at sites in the south and east of England

	Rabbits counted							
	Before		After[b]			After[c]		
Height (m)	Mean	95% CL	Mean	95%CL	% Redn..	Mean	95%CL	%Redn.
0.750	34.2	26-43	7.2	4-12	77	5.9	3.9	81
0.900	42.5	24-66	10.4	5-18	75	7.0	5.9	81

[a]Means of the maximum numbers counted at each site.

[b]Numbers counted in the first 4 counts after erection.

[c]Numbers counted in the last 4 counts after erection.

The 0.9-m and the 0.75-m fence each reduced ($P < 0.001$) the numbers of rabbits seen on the protected fields throughout the experiment by about 80% (Table 4). Yield increases were reported for all the fields protected by the 0.75 m but only in three of these cases did farmers consider that the increase was caused solely by the exclusion of rabbits. The mean increase over expected yields at these three sites was 21% (range 20%-23%) or 1.3 T/ha which was equivalent to an increase of approximately £1,700 ($2,400.00) per field at 1985 British prices.

The costs of materials and labour to erect a fence 0.75 m high and 750 m long, the mean length used in this experiment, were £1,800 ($2,500), after deduction of 15% government grant. This was 6% less than the cost of an equivalent fence 0.9 m high (Table 5).

Table 5. Costs (£ & $) of materials and labour for fences 750 m long.

Height (m)	Materials[a] £	($)	Labour[b] £	($)	Cost/m[c] £	($)
0.750	585	(820)	1,535	(2,150)	2.40	(3.35)
0.900	660	(925)	1,590	(2,225)	2.55	(3.55)

[a]Includes the costs of netting, 2 high-tensile-steel straining-wires, 16 straining posts, and 35 stakes.

[b]Based on quotations from 8 fence contractors.

[c]Includes deduction of 15% for grant paid by government on these costs.

DISCUSSION

The 0.75-m fence was selected for field evaluation rather than the 0.675-m fence because in practice it is impossible to erect a long fence to an exact height. Fences lower than 0.675 m would allow an unacceptable number of rabbits to cross.

Fences were erected at field sites along the woodland edges of rabbit harbourage, the way in which they are most often used by farmers. Currently, a reduction of 80% in rabbit numbers is considered adequate with this method of erection, and trials using different methods of erection are planned to determine the proportions which go over, under, or round the ends.

In the past, the high cost of fencing as a method of crop protection has meant that farmers have been reluctant to use it. These experiments have produced soundly based specifications which have reduced costs. This reduction, although small, is in addition to the savings that can be achieved by using fencing lapped 0.15 m on the surface (FC recommended 1972) instead of fencing buried 0.15 m vertically and 0.15 m horizontally (MAFF recommended 1956), and supporting fences with high-tensile steel-straining wire instead of mild-steel-straining wire (McKillop and Wilson in prep.). Taken together these modifications have resulted in the cost-per-metre to erect a wire netting fence being reduced by 36% compared with the cost of MAFF's 1956 recommendation. Based on the farmers' rough estimates of increases in crop yields, these purchase costs would be recouped within 2 years.

The costs of excluding rabbits by fencing are being further reduced by the development of successful electrified fences. Portable electrified netting fences* have been found to be as effective (80% reduction in numbers) as wire mesh fences but were up to 80% cheaper than the 1956 MAFF specification for a wire-mesh fence (McKillop and Wilson in prep.). An experiment is also in progress to examine the effectiveness of a permanent electrified wire fence which is recommended for rabbit management by Gallagher Ltd. of New Zealand. The costs of this kind of fence are about the same as the portable electrified netting fences.

These developments in fencing are occurring at a time when conservation interests and humaneness are having to be taken into account increasingly in pest management programmes. Therefore, improvements in the cost-effectiveness of nonlethal methods such as fencing are timely as such methods may need to be used more frequently in the future.

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*Manufactured by Bramley and Wellesley and by Livestock Fencing Ltd., both of Gloucester, England.

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