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DEVELOPING AN ELECTRIFIED FENCE TO EXCLUDE RABBITS FROM CROPS

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ABSTRACT: The effectiveness of a new design of electric strained wire fence (CSL fence) for managing rabbits is currently being assessed in a two year trial. It is being compared with a commercially available electric netting fence (Flexinet fence) and also with farmers' normal control methods. The study is taking place on commercial farms in Cornwall, England, where the fences are being erected to protect fields of cauliflower. The amount of rabbit damage to individual plants in each field is being assessed and the numbers of rabbits feeding in these fields are being counted. Plant yields at harvest will also be used to determine effectiveness. Observations of rabbit behavior at the CSL fence are being conducted to identify potential design problems and to assess solutions to these problems. There was no difference between the effectiveness of the two fences during the first six months of the trial. Few plants were completely eaten by rabbits in the protected fields (CSL fence: $5 \pm 6\%$; Flexinet fence: 0%) but, by contrast, most were eaten at the control sites ($82 \pm 17\%$). No more than a single rabbit was ever counted at night on the CSL- (0.7 ± 0.1 rabbits) or Flexinet- (0.5 ± 0.2) protected sites but up to 20 (17.0 ± 3.0) were counted on the control sites. The few rabbits which were observed crossing the CSL fence either jumped through or over it. The CSL fence design is proving to be extremely cost-effective and in this trial it would already have recouped its costs many times over if it had been used to protect the control fields. It will be further tested next year. The research was funded by the Horticultural Development Council.

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INTRODUCTION

The European wild rabbit (*Oryctolagus cuniculus*) has once again established itself as the major vertebrate pest of crops in Britain causing damage estimated to cost farmers tens of millions of pounds every year (Rees et al. 1985). Recent surveys have shown rabbit numbers to be increasing (Trout et al. 1986) mainly due to the waning effects of myxomatosis (Ross and Tittensor 1986). Therefore, the development of more cost-effective methods of control has become increasingly important.

Wire mesh fences have been in use for many years to protect crops from grazing by rabbits (McKnight 1969). More recently, electric fences have also been developed for this purpose. In Britain, there are two types of electric fence commonly used to manage wildlife. One is electric netting fences which are sold as ready-made fences with specific designs being recommended for specific species. The other is electric strained wire fences which are sold in their component parts (wire, posts and insulators) for farmers to construct their own designs to manage one or more species simultaneously. Research has shown that electric netting fences marketed for rabbit management are as effective as conventional unelectrified wire netting, each excluding about 80% of rabbits (McKillop and Wilson 1987, McKillop et al. 1988). Purchase and erection costs of electric netting fences are, however, about 60% less than those of wire netting (McKillop and Wilson 1987, McKillop et al. 1988).

The costs of the design of electric strained wire fence most frequently recommended by fencing companies to manage rabbits are similar to those of electric netting fences. However, when this design was tested in enclosure trials, it was about 30% less effective than electric netting (McKillop et al. 1992). The Central Science Laboratory (CSL) has subsequently conducted a series of enclosure trials to develop a more effective design. These trials resulted in a fence which was 97%

effective (McKillop, unpublished). However, rabbit behavior in the unfamiliar environment of an enclosure could be different from that in the familiar environment of their own home range. We, therefore, began a two-year field trial in July 1993 and, in this paper, we report the results of the first six months of that trial in which the fence was being used to protect fields of cauliflower from grazing by rabbits. Its effectiveness was compared with a previously untested electric netting fence (Flexinet Super Rabbit Netting) and with farmers' normal control methods.

MATERIALS AND METHODS

The Fences

The CSL fence was 0.4 m high and consisted of five parallel steel wires 2 mm in diameter at heights of 5, 10, 20, 30 and 40 cm above the ground. The bottom wire was earthed and the upper four conducted current. At one site, additional wires were added during the trial at 15 and 25 cm. The Flexinet fence was 75 cm high with an 75 x 65 mm mesh. The horizontal strands were made of polythene twine and, with the exception of the bottom strand, contained three 0.2 mm stainless steel wires which conducted the current. This type of wire is known as polywire. The vertical strands were made from non-conducting twine. Each fence was powered by a Speedrite battery-operated energizer which produces an energy output of 1.5 J, into a resistance of 500 ohms, and a maximum voltage of about 6 kV.

Fences were erected along field boundaries to enclose completely the study fields. Shorting of the fence by vegetation growth was prevented by spraying the herbicide Gramoxone (paraquat) along the length of each fence to clear a strip about 0.5 m wide. CSL fences were on average about 480 m long (range: 350 to 750 m) and Flexinet about 650 m (range: 600 to 700 m). Routine monitoring of the fences was conducted by local growers.

This involved recording fence voltages and changing batteries when the voltage fell below 2 kV.

Study Sites

The study sites were on commercial farms in the Penzance region of Cornwall, one of the major vegetable producing counties of England. Only cauliflower fields were chosen to eliminate the effects of possible crop preferences by rabbits. Cauliflower seems to be particularly susceptible to grazing by rabbits which appear to be abundant in that region.

Experimental Design

Nine fields with a history of rabbit damage were randomly assigned to one of the three treatments (CSL fence, Flexinet fence and control) so that each treatment was replicated three times. However, weather conditions were so severe that only two of the control fields were planted. Fences were erected in July, prior to planting out, and will remain in place until harvest in February. At the control sites, growers conducted their normal rabbit management procedure, which was to erect their own electric fences. These fences were intended to be 40 cm high. They consisted of four polywire strands which were meant to be equally spaced. However, due to the extreme difficulty of tensioning polywire over any great distance at these sites, the wires sagged considerably and in many places were all nearly on the ground.

Fence Effectiveness

Three methods were used to determine effectiveness. First, we measured the amount of rabbit damage to three rows of five plants at each of 10 randomly selected locations within each field. The plants were inspected each month and given a score based on the amount of damage which had occurred (Table 1). From these scores, a mean index of rabbit damage was calculated for each location and hence for each field.

Table. 1. The scoring system used to estimate the amount of rabbit damage suffered by cauliflower plants.

Score	Damage
0	No damage
1	1 to 33% of the leaf surface area removed
2	34 to 66% of the leaf surface area removed
3	67 to 99% of the leaf surface area removed
4	Only the stalk remaining
5	All of the plant removed

Secondly, the number of rabbits feeding on each field was counted at night. Counts were conducted at monthly intervals from predetermined points within each field using a spotlight and binoculars. Counting ceased after September when crop height made the technique impracticable.

Lastly, effectiveness was assessed by comparing the number of plants harvested from each field with the number originally planted and by comparing the yields of each field (T/ha).

Behavioral Observations

Rabbit behavior at the CSL fence was observed from a hide which was located where a clear view could be obtained of a 40 to 50 m length of the fence adjacent to an area of harborage with a severe infestation. Observations were conducted to determine how rabbits investigated the fence, how they responded on receiving a shock and how they crossed the fence. The first observation session took place on the day of fence erection and subsequently at monthly intervals. Each session began about half an hour before dusk and lasted 1.5 hours. Hand-held Zeiss Dialyt 10x40 binoculars were used before dark and a tripod mounted image intensifier, with an infra-red attachment, after dark.

Statistical Analysis

A one-way analysis of variance was used to compare plant damage between treatments and a t-test was used to compare voltage readings of each type of fence. Comparisons at harvest are not yet possible as the crop is just about to be harvested. Means and standard errors are presented in the results.

RESULTS

Plant Damage

There was a significant difference between the amount of rabbit damage to plants in each treatment (one-way ANOVA: $F_{2,3}=43.83$, $P=0.001$). With harvesting imminent, there has been little damage to plants protected by the CSL or Flexinet fences but, by contrast, the control fields have suffered a great deal, losing about 80% of their plants in the first two months of the growing season (Figure 1). The small amount of damage that has occurred in the fields protected by the CSL fence was as a result of a few rabbits at one site learning a method of crossing the fence. In addition, damage was caused at another site when rabbits crossed after flooding at that site rendered the fence inoperative for several weeks. However, once the design was modified at the former site (at the end of August) and once flooding subsided at the latter (December), little further damage was recorded (Figure 1).

Rabbit Counts

The CSL and Flexinet fences were equally effective at excluding rabbits from the fields (Figure 2). No more than a single rabbit was ever seen within these fields (CSL: 0.7 ± 0.1 ; Flexinet: 0.5 ± 0.2) but, by contrast, up to 20 rabbits were counted in the control fields (17.0 ± 3.0).

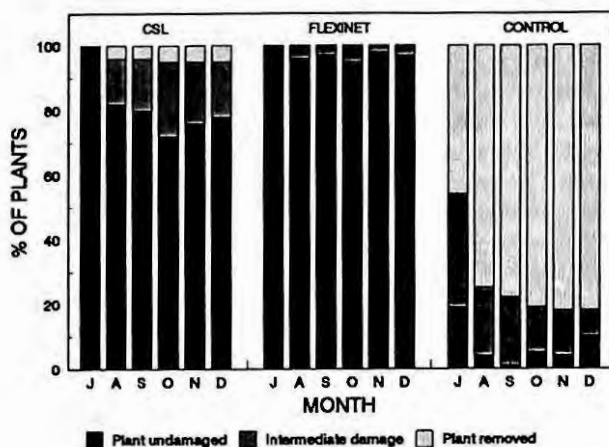


Figure 1. Rabbit damage to cauliflower plants in each of three treatments during the first six months of the study.

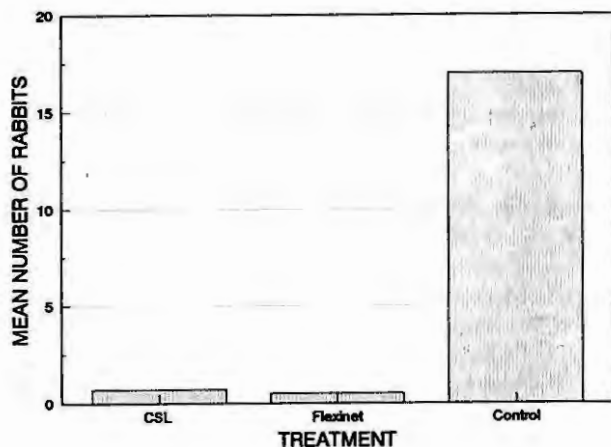


Figure 2. The mean number of rabbits observed within each of the three treatments during spotlight counts in July, August, and September.

Behavioral Observations at the CSL Fence

The majority of rabbits ($68 \pm 19\%$) touched the live wires of the fence with their noses, received a shock, and retreated into the haborage. The number observed at the fence also appeared to decrease with time; 65% fewer observations were recorded one month after fence erection (Figure 3).

Rabbits were observed crossing the fence at two of the CSL sites. At the first, two crossed by jumping between the second (10 cm) and third (20 cm) wires. At

that site, two additional wires were incorporated into the design at heights of 15 and 25 cm above the ground. No rabbits have been seen jumping between the wires of the fence since the modification although one rabbit was observed jumping over the top wire. At the second, heavy rain during October resulted in a section of the fence being under water for several weeks. This caused the fence to short out and towards the end of this period five rabbits were observed going through it (Figure 3).

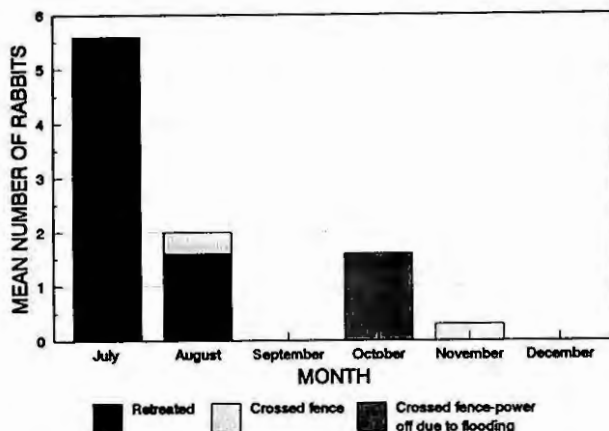


Figure 3. The mean number of rabbits observed to retreat from or to cross the CSL fence during the first six months of the study.

Fence Voltages

The mean voltage of the CSL fence was significantly higher than that of the Flexinet fence (CSL: 5.2 ± 0.3 kV; Flexinet: 4.0 ± 0.4 kV; $t=2.51$, 12 df, $p<0.05$). These figures are based on voltage readings taken immediately after fence erection and after batteries were changed.

DISCUSSION

The two electric fences tested in this field trial were equally effective at protecting cauliflower plants from rabbits. By contrast, local methods of control failed to afford adequate protection, which was not surprising given the poor design of the growers' fence.

Rabbits have been shown to display little neophobia of fences in enclosure trials but considerable amounts in field trials (McKillop and Wilson 1987). Thus erecting a fence in the field may affect rabbits' ranging behavior more than if erecting it in the unfamiliar environment of an enclosure. Consequently, neophobia could account, in part, for the effectiveness of the CSL and Flexinet fences in the field.

The initial difference between the CSL fence and the ineffective wire fence previously tested in enclosures (McKillop et al. 1992), was that the CSL fence had an earthed wire 5 cm above ground whereas the other fence had no wire at this height, its lowest being at 10 cm. This extra wire, therefore, appeared to prevent rabbits

avoiding a shock by crawling under the lowest wire, which they had done with the other design. It was added to force rabbits trying to cross at ground level to touch simultaneously a live and earthed wire thereby enhancing the shock effect and preventing crossing. This appears to have been successfully achieved.

Most rabbits initially touched the CSL fence with their noses and reacted by retreating to the harborage. This is a typical defensive reaction shown by mammals after shock from a fence (McKillop and Sibly 1988). A few rabbits were, however, seen either jumping through or over the fence and these rabbits did not first investigate it with their noses. The severity of the shock received when jumping through the fence was probably less severe than when touching it with their noses because rabbits' backs and chests are less innervated and more insulated than their noses. It is also possible that they learned that with all four paws off the ground they would not receive a shock if they touched only the live wires. Modification of the fence by adding wires at 15 and 25 cm made it more difficult to jump through and at the same time made it more likely that rabbits trying to do so would receive a shock as they hit the fence.

From the data on spotlight counts of rabbit numbers and from the crop damage data, a few rabbits obviously also learned to cross the Flexinet fence. From previous studies of rabbit behavior at this type of fence, it is likely that they too crossed by jumping through the fence (McKillop et al. 1992).

The decrease in the number of rabbits approaching the CSL fence, particularly after the first month, is typical of a conditioned avoidance response to the presence of an electric fence (McKillop et al. 1992). It is unlikely to have been as a result of a decline in the size of the local population, as numbers counted on control fields at that time did not decrease. The increase in the number of rabbits observed in October (Figure 3) only occurred as a result of power failure at the flooded site enabling some loss of conditioned avoidance to take place. The flooding did, however, highlight the limitations of electric fencing in that it would be advisable to consider using some other method of crop protection in fields susceptible to flooding in bad weather.

Cauliflower appears to be most susceptible to rabbit grazing in the first few weeks after planting when the small plant "modules" were easily damaged or completely eaten. It is therefore essential that farmers have fences in position at that time when protecting this crop. It is also likely that the plants become less susceptible to rabbit grazing as the growing season progresses and it may be possible to identify a stage of growth when the crop was no longer vulnerable. Consequently, growers could safely remove fences, rather than having to incur the expense of fence maintenance until harvest.

The higher voltage readings obtained in the CSL fence compared with the Flexinet fence are probably due to the fact that the wires of the CSL fence were less electrically resistant, because of their greater diameter, rather than because the CSL fences were not as long as the Flexinet fences. This would be easy to confirm in the field by setting up fences of equal length at the same site and electrifying the fences using the same energizer. In practice, this higher voltage means that rabbits are likely to receive a more severe shock from the CSL fence than from the Flexinet fence and this should provide a greater deterrent effect.

Using the CSL or Flexinet fences to protect the control fields would have cost the grower about £2000 while the damage so far incurred on these fields has resulted in net losses of about £15000. Therefore, the fences would have paid for themselves many times over in just one growing season.

In conclusion, the CSL fence shows considerable promise as a cost-effective method of crop protection which should be further confirmed next year at the end of the trial.

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