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RESPONSES OF DAIRY COWS TO BADGER URINE AND FAECES ON PASTURE WITH REFERENCE TO BOVINE TUBERCULOSIS TRANSMISSION

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SUMMARY

Grazing cattle were observed when they encountered badger urine or faeces which, in all but the first study, came only from badgers which were not infected with bovine tuberculosis. The faeces were very strongly avoided and there was generally a strong avoidance of ingestion of badger urine. There was no evidence that cattle were attracted to badger latrines in an area where some infected badgers were present and cows actively avoided faeces up to 28 days old which was placed on grass turves or on pasture. 99.3% of cows took no bites from small grass plots contaminated with faeces and 88.7% of cows took no bites from urine-treated plots. There was generally avoidance of pasture treated with badger urine up to 14 days old. However, two cows out of 240 were willing to graze close to faeces and seven out of 240 were willing to graze near urine. Contaminated herbage was eaten most when attractive herbage became scarce. Wet weather did not reduce the strength of avoidance of urine. Some cows responded to badger urine, and to a lesser extent to faeces, by more sniffing, particularly when herbage was scarce. The odour of faeces, and sometimes that of urine, often resulted in the ejection of mouth contents. As a consequence of their avoidance of badger faeces and urine, the vast majority of cows are unlikely to contract tuberculosis from infected badgers by ingestion. Most cows totally avoid badger products so they are unlikely to be infected via inhalation. However, the small minority of unselective cows must be more at risk and this finding warrants further investigation.

INTRODUCTION

Bovine tuberculosis exists in some badger populations and transmission from badgers to cattle is possible (Little *et al.*, 1982). It is clear from a previous study by

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the authors (Benham & Broom, 1989) that direct transmission from live badgers to cattle at pasture is unlikely. However, badgers spend a large proportion of their above ground time in pastures (Kruuk, 1978). As a consequence of this and the fact that an infected badger can produce extremely high numbers of *Mycobacterium bovis*, 300 000 organisms per ml of urine excreted when the kidneys are infected (MAFF, 1979), it is perhaps surprising that the number of cattle that become infected is as low as it is. However, even calves confined with excreting tuberculous cattle sometimes do not become infected (Neill, personal communication).

The objective of this study was to investigate the likelihood that cattle would come into close enough contact with badger faeces or urine to allow infection if the badger had been excreting *M. bovis*. First, cattle in an area with a high badger population were observed. Since it was not desirable to use infected badgers in experimental presentations, these were done by investigating the responses of cattle to the faeces and urine of normal badgers, both in fields and in controlled exposure to housed cattle. Both investigatory behaviour and ingestion were relevant since it has been shown that large numbers of marker bacteria reach the lungs after being eructated from the gut (Waldo & Hoernicke, 1961). Responses to both fresh and older badger urine and faeces were studied (see also Benham, 1985), as were the effects of herbage availability on cattle behaviour.

MATERIALS AND METHODS

In study 1, the responses of three cattle herds to badger latrines in their pastures in an area of Gloucestershire were recorded. It was known that a small proportion of the badgers in this population were infected with bovine tuberculosis. Since it was thought that cattle would be more likely to investigate in their pasture shortly after turn-out the observations were confined to the first 3 days after turn-out. Badger latrines, all but one of which were located on badger paths, were identified, measured and marked with stones or sticks of the kinds found in the fields. They varied in size from 2 m square to 75.9 m square. Control areas of similar sizes were marked out in the same way as the latrines, their sites being chosen so that they could be seen at the same time as the latrines. The herds, latrines and control areas observed were as follows: herd A, 40 Ayrshire cows, one latrine and seven control areas; herd B, 23 Ayrshire cattle, three latrines and four control areas; herd C, 45 Friesian heifers, four latrines and nine control areas. Observations, all during daylight, were made as follows: herd A, 22.5 h from a tree; herd B, 23.7 h from ground overlooking all sites; and herd C, 32 h from a scaffolding platform. The recording technique is described below for study 3.

The responses of housed cattle to badger urine or faeces on grass turves were investigatged in study 2. The adult Friesian dairy cows were kept in a cubicle house at the AFRC Institute of Grassland and Animal Production (IGAP), Arborfield, Berkshire and were able to feed at will by operating their individual Callan Broadbent feeders. Grass turves with good growth of grass on them were placed on square 0.3 m^2 metal trays and held in place by metal rods which divided the turf into four equal areas. Urine and faeces were collected from captive badgers.

Fresh urine (25 ml) was applied in a stream to one-quarter of a turf which was either presented to a cow immediately or stored under cover for 1–14 days before presentation. Faeces (50 g) were placed in the centre of one-quarter of a turf while fresh or after weathering for 1–28 days before application.

Cows were studied in early winter or early spring. All were tested when they had chosen to visit their feeding place. Clean turves were presented to each cow until she was familiar with the experimental procedure and would graze the turf readily. Two turves with a particular treatment were presented to each cow but if the responses were not consistent between the two a further two turves were presented. If two consecutive urine- or faeces-treated turves were rejected by a cow she was presented with a clean turf. The major part of the study was carried out on 18 cows which were given two, three or four of the types of treated turves. After turf presentation, the behaviour recorded was: bite, sniff or lick in area 1, 2, 3 or 4, and spit out.

The responses of cows at pasture, to badger urine and faeces placed on the pasture, were investigated in study 3. Two herds of dairy cows at IGAP, Arborfield, Berkshire rotationally grazed on a 3-day or 1-day system were watched between May and July. Four days before the cows entered a new strip of pasture, 1 m square plots were marked out by killing grass at the corners with paraquat. Plot positions were identified using string between pegs at the edge of the strip. Grass measurements were taken before grazing, half way through grazing and after grazing and behaviour was recorded from an observation tower during grazing. Upon each plot 100 ml of badger urine, or 100 g of badger faeces, or nothing was distributed.

When a cow approached a plot its behaviour was recorded. If the direction of movement was altered so as to travel around the plot, avoidance was recorded. If the cow investigated the plot, but did not graze, it was recorded as rejecting the plot. When the head was within a plot, behaviour was recorded continuously using the following categories: grazing—head within 30 cm of ground and harvesting bites; selecting—head within 30 cm of ground and moving but no bites; investigating/sniffing—head low and stationary with nose directed towards ground; licking—tongue extended towards soil or herbage; spitting out—mouth contents ejected; mouth movements—jaw movements more rapid than normal chewing and sometimes accompanied by dribbling.

In experiment 1 of study 3 there were seven 3-day trials, before which 24 plots in three rows of eight across the strip comprised: 10 controls, 10 urine-treated and 4 faeces-treated. Five of the urine plots were replenished after 1.5 days in order to detect any alteration in responsiveness towards urine as it ages. The height of ten grass plants per plot was recorded. A 60-cow herd then entered the strip and was observed for two half days (09:00–15:00 or 16:00–21:00) per trial, one when the cows entered the strip and one just before leaving. Data concerning some plots could not be collected since long grass obscured the marker spots. In experiment 2, three trials were carried out on strips occupied for 24 h. Twelve plots in three rows were used in each trial and all could be seen clearly since the grass was shorter than in experiment 1 and the observation tower was 5 m instead of 3.8 m tall. A total of 14 urine (100 ml), 14 control and 8 faeces (100 g) plots were used, these numbers being determined by availability of badger material. The lengths of 20 grass plants in each plot were measured. After this a herd of 150 cows started

Table I
Time spent by cattle at pasture on activities in badger latrine areas or in control areas

Herd	*Total latrine or control area*	*Grazing*	*Time spent walking or selecting*	*Sniffing*	*Total*
A	Latrine 44 m^2	698	151	119	1098
A	Control 44 m^2	1458	164	12	1829
B	Latrine 42.5 m^2	155	108	270	769
B	Control 42.5 m^2	554	68	5	958
C	Latrine 136.4 m^2	1306	468	231	2107
C	Control 136.4 m^2	1945	410	7	2676
All	Latrine 222.9 m^2	2159	727	620	3974
All	Control 222.9 m^2	3957	642	24	5463
Wilcoxon test on matched areas: latrine v control		$P<0.01$	$P=0.05$	$P<0.01$	$P=0.05$

grazing and their behaviour was recorded between 09:00 and dusk throughout the 24 h that they were in the strip. The larger number of cows and smaller strip resulted in more encounters with the marked plots in this second experiment.

RESULTS

Study 1

The stones used to mark the badger latrines were of the same kind as other stones in various places in the pasture but they still elicted investigatory responses, especially from the group of 2.5-year-old heifers. All time spent on behaviour directed to the markers was excluded from the results. Observations on the general behaviour and movements of the cattle around the grazing areas produced no evidence to suggest that cattle were attracted to latrines from a distance in order to investigate them. Responses to latrines were only seen when the animals were on top of them or at least very close. As can be seen from Table I, the total time spent and the time spent grazing was less in latrine areas than in control areas. Sniffing and walking or selecting occurred more in latrine areas. The distribution of time spent in the different latrine areas was not random because the young cattle in herd B spent more time in the latrine which was near the field exit gate whereas older cattle spent more time in the middle of the field and were thus recorded in the latrine in that area more frequently.

Study 2

The numbers of bites taken from clean turves was greater (mean 99.1) than from urine-treated (mean 57.2) or faeces-treated turves (mean 41.0). If the contaminated quarters of turves are considered, the mean number of bites from clean turves was 24.8 per quarter but from urine-treated quarters it was 0.37 and from faeces-treated turves it was 0.35 per quarter. The number of bites from non-contaminated quarters was 18.9 for urine-treated turves and 12.9 for faeces-treated turves.

Figure 1 shows the responses to turf quarters treated with weathered faeces. Bites directed to a treated quarter would be 25% of the total for that turf by chance so the quarters were clearly avoided and 77% of cows took no bites at all from them. Figure 2 shows that 91% of cows tested with fresh badger urine took less than 5% of bites from the area containing the urine. However, two cows took 10–15% of bites from the urine area and one cow appeared to be totally unselective towards urine contamination. It was clear that there was tremendous variability in the degree of selectivity that was exhibited by individual cows towards contamination. The general appearance of a contaminated turf after presentation was that the contaminated area was totally untouched but everything else was eaten (Fig. 3). This was a moderately selective response. Greater selectivity was displayed by individuals that left a zone of clean grass immediately surrounding the contaminated area or took only a few bites from the opposite side of the turf from the contaminated area. Extremely selective individuals totally refused contaminated

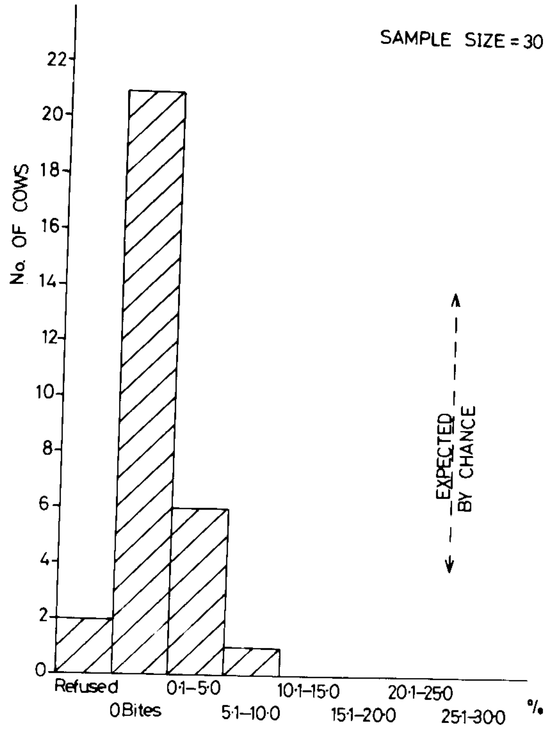

Fig. 1. The median percentage of bites which cows took from the contaminated area on turves with badger faeces.

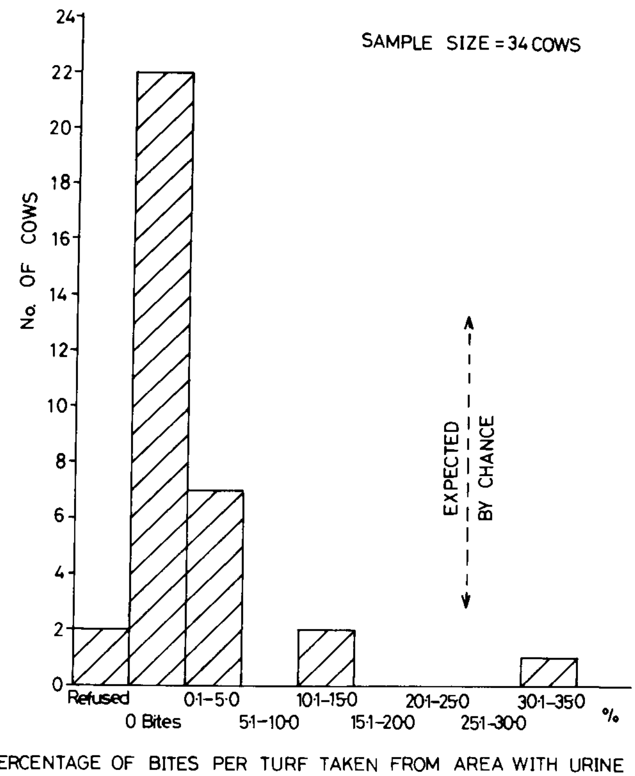

Fig. 2. The median percentage of bites which cows took from the contaminated area on turves with fresh badger urine.

turves. Those animals that were slightly unselective occasionally took bites from the edge of contaminated areas. The unselective cow avidly ate the contaminated grass.

The general response to grass contaminated with stored (1–4 days) urine was avoidance since 65% of animals took less than 5% of bites from the contaminated area. However, more bites were taken from stored urine contaminated areas than from fresh areas (sign test, x=2, N=19, P<0.002). There were four animals that took 15–25% of bites from the stored urine contaminated areas. These were animals that were in the slightly unselective category with fresh urine and had become more unselective with the stored urine. For 6–10-day stored urine the general response was still avoidance although two of the 17 animals were close to being totally unselective. Similarly with 11–14-day-old urine the general response was avoidance, but two of the small sample of seven cows became distinctly less selective. Slightly unselective cows ate clean herbage first and took bites from contaminated quarters only after the clean herbage had been eaten. The unselective cow spent very little time sniffing urine-treated turves, this being significantly less than other animals when considering the contaminated area (P=0.04) or the whole turf (P=0.016). In general, any reduction in selectivity was associated with lower fre-

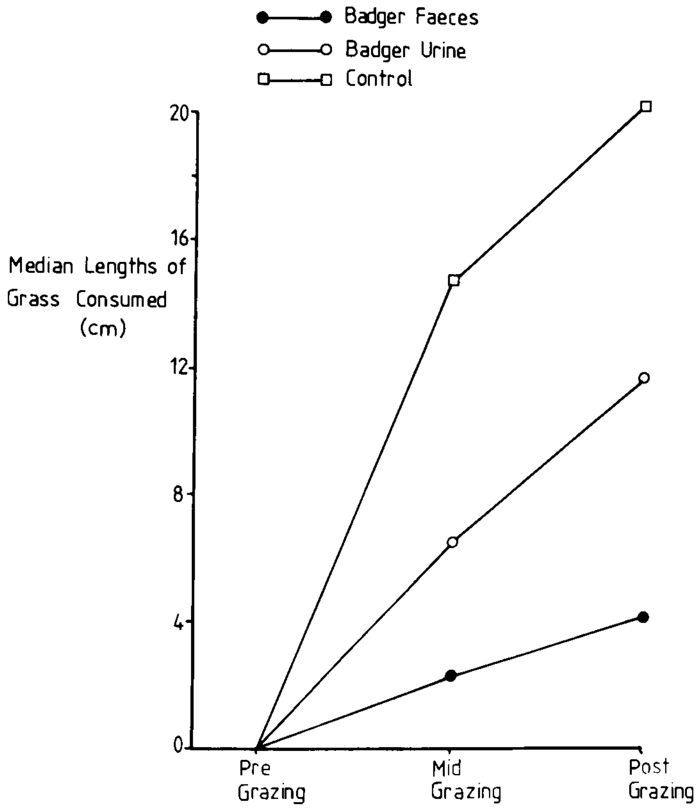

Fig. 4. The median lengths of grass consumed within control, badger faeces and badger urine plots during the first and second halves of progressive defoliation. In the first half and over the whole grazing the differences between control and urine, control and faeces and urine and faeces were all significant ($P<0.02$, Wilcoxon matched pairs test). During the second half the control was not significantly different from urine or faeces plot.

than from the control plots (Fig. 4). Much grass was eaten from the control plots during the first half of the 3-day period but less than half as much from the urine-treated plot and little from the faeces-treated plot. There was less difference in the second half, by which time much grass had been removed from the control plots.

Behaviour observations, during the last five trials when identification of individual cows was sufficiently accurate, were made when 371 encounters with experimental plots and 125 encounters with control plots occurred. Grazing was recorded during 69.6% of encounters with control plots but occurred much less often during encounters with urine-treated plots (26.8%; $P<0.001$) or faeces-treated plots (30.16%; $P<0.001$). One cow (No. 3384) was responsible for 44.9% of all grazing on urine-treated plots and 26.3% of all grazing on faeces-treated plots. When cows did graze from the plots, the duration of grazing was much shorter on the experimental than on the control plots (Fig. 5). The only grazing durations which were as long as those on the control plots were those of cow 3384 on urine-treated (24 s) and faeces-treated (20 s) and of cow 3268 on urine-treated (16 s).

quencies of sniffing. When individuals were presented with turves they sniffed clean turves for a median of 1.1 s, urine areas for 7.0 s and faeces areas, from a greater distance, for 3.9 s per quarter turf. If contaminated areas were sniffed this was sometimes followed by rapid withdrawal, mouth movements and dribbling or active spitting out of mouth contents. Cows that had eaten from clean areas of contaminated turves quite frequently responded to sniffing a contaminated area by ejection of the mouth contents. This behavioural sequence was performed more often in response to badger faeces than to urine ($P<0.001$). Table II shows that there was considerably more spitting out if eating from urine- or faeces-treated turves than if eating a clean turf.

Study 3

In experiment 1, less grass was eaten from the urine- and faeces-treated plots

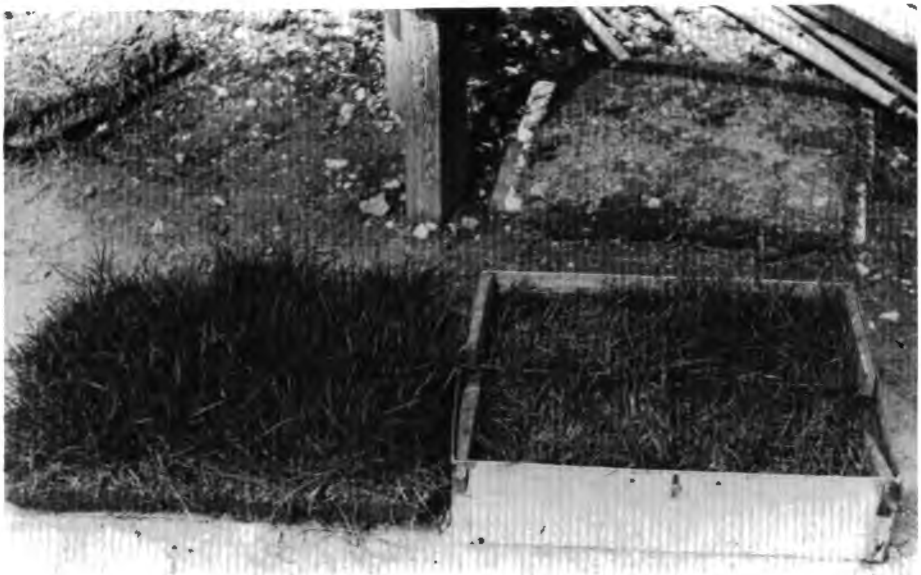

Fig. 3. The turf on the left is before presentation to a cow whilst that on the right is typical of those treated in one quarter with badger urine and then offered to a cow.

Table II

The number of times cows spat out mouth contents eaten from clean turves and those with badger faeces and urine

Treatment	*No. turves given*	*No. spit outs*	*No. spit outs per 100 bites*	*No. spit outs that followed a bite in a different area*
Clean turves	59	1	0.02	0
Turves+urine	201	80	0.54	14 (17.5%)
Turves+faeces	39	29	1.46	16 (55.17%)

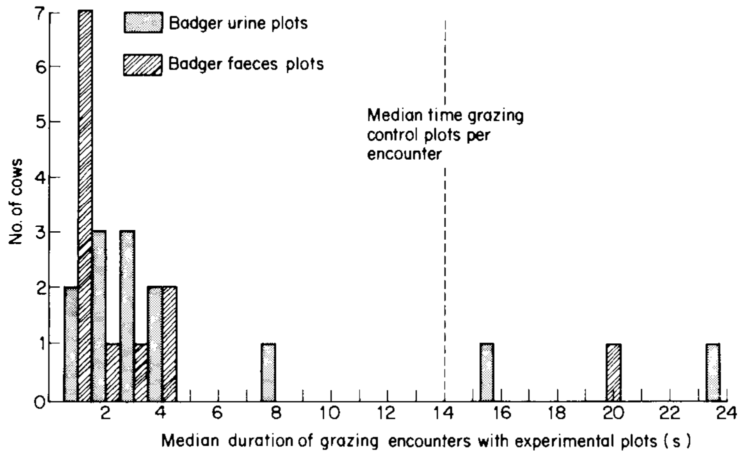

Fig. 5. The numbers of cows showing different durations of grazing on badger urine and faeces plots.

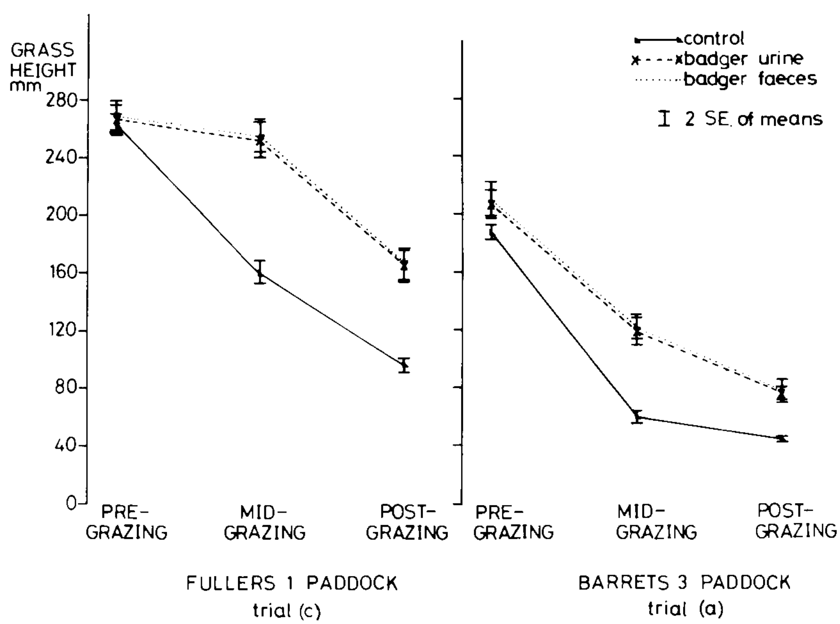

Fig. 6. The mean grass heights on control, badger faeces and badger urine plots before, during and after 24-h strip grazing.

However, whilst cow 3384 grazed on 91.7% of her encounters with urine-treated plots and on 62.5% of her encounters with faeces-treated plots, cow 3268 grazed on only 37.5% of her encounters with urine-treated plots. Cow 3384 was observed spitting out mouth contents on two occasions when grazing urine-treated plots. She had a history of being an unusual feeder and had been removed from a production experiment because she would not eat maize silage. With the exception of the unselective cow 3384, grazing from contaminated plots occurred mainly in hot, dry weather when the extent of presence of volatiles would have declined. Where urine was replenished during the 3-day period, grazing occurred less often than in unreplenished plots and sniffing occurred much more often.

In experiment 2 also, less grass was consumed from urine- and faeces-treated plots. The data for the two trials in which it was possible to make grass height measurements at the beginning, middle and end of the 24-h grazing period are shown in Fig. 6. Less herbage was available in the trial in Barretts 3 Paddock so relatively larger amounts were consumed from the contaminated plots by mid-grazing. When the cows entered the paddock they started grazing the tops of the grass shoots. If they encountered a contaminated plot they usually raised their heads and walked on a few paces before grazing again. As a consequence, most grazing in the first part of the 24 h occurred at some distance from the experimental plots. The behaviour data are presented in Figs 7 and 8 for four equal consecutive time segments, I–IV, during which the progressive defoliation over 24 h occurred. The frequency of grazing the control plots decreased whilst that in the contaminated plots increased, as the amount of available herbage declined

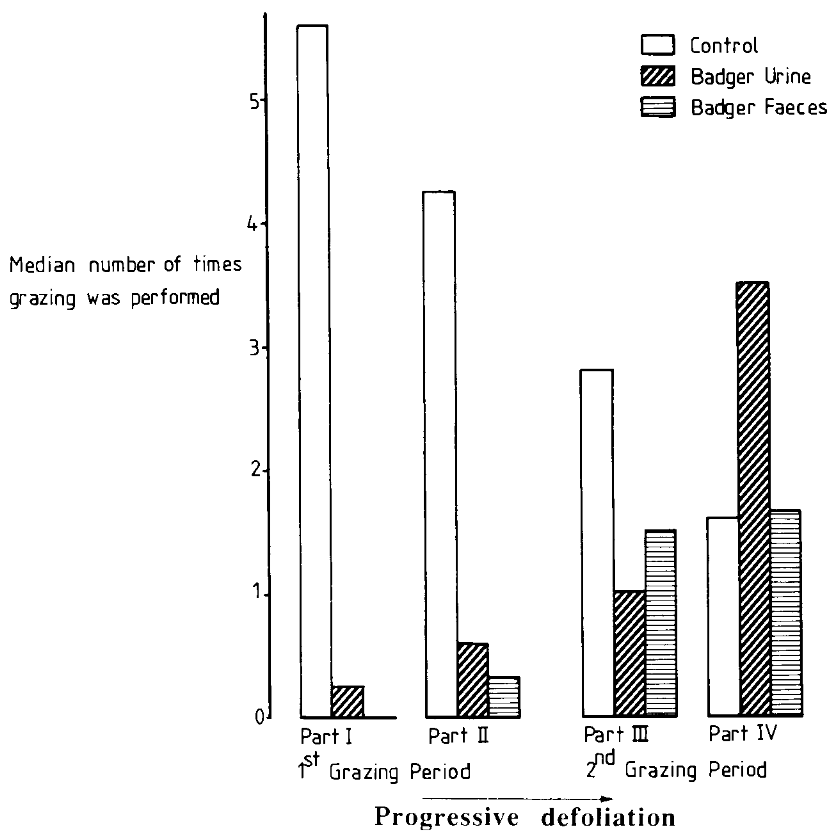

Fig. 7. The median number of times cows grazed control, badger faeces and badger urine plots during 24-h strip grazing.

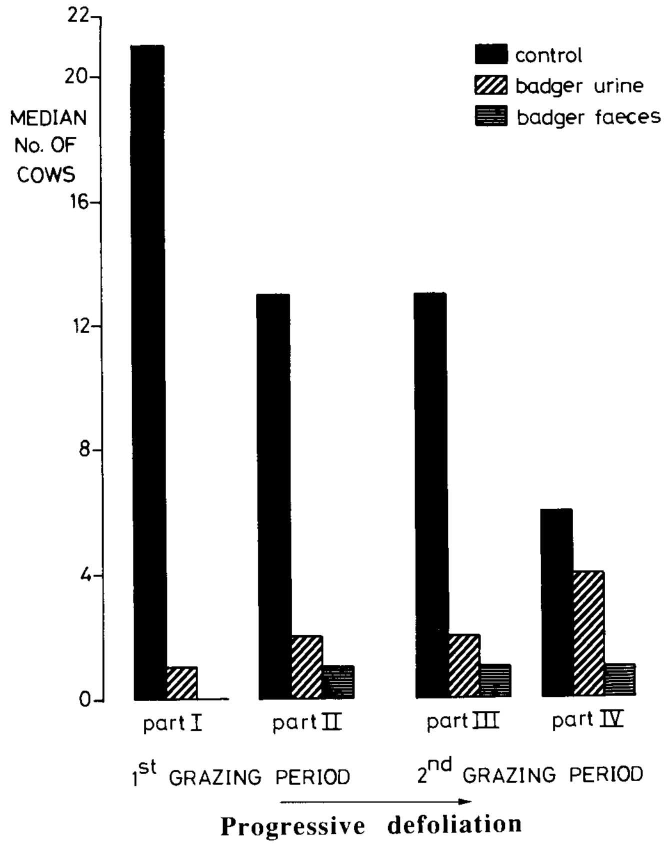

Fig. 8. The median number of cows that grazed control, badger faeces and badger urine plots during progressive defoliation in a 24-h strip grazing trial.

(Fig. 7). However, when the number of cows grazing the plots was assessed (Fig. 8) it was clear that most cows did not graze the contaminated plots despite the low availability of other herbage by the end of the trial. Of 150 cows in the herd, only one individual, No. 3028, ever grazed in the faeces-treated plots. She did so on 38 occasions with a total duration of 15.1 min and also grazed the urine-treated plots more than did any other cow, 32 occasions totalling 12 min. Cow 3889 grazed urine-treated plots 17 times and cow 3815 six times; two cows did so twice and 11 cows once. Three of these cows spat out their mouth contents immediately after grazing. It is of interest that the unselective cow, 3028, was observed on several occasions to eat the grass around fence posts which was contaminated with dung from birds sitting on the posts. No other cow would eat grass at these sites. This cow often spent time at a considerable distance from the rest of the herd and grazed at a time when no other cows were grazing. She was the 6th oldest cow in the herd and had previously been removed from a production experiment because she would not eat the concentrate food offered to her.

During one trial much rain fell so it was possible to test the hypothesis that rain might dilute and wash away the badger urine and hence reduce the level of response shown towards it by cows. However, the avoidance of urine contamination was as great, if not greater than during the other trials.

The duration of sniffing per 24 h was 3.4 s m^{-2} for control plots, 83.4 s m^{-2} for urine-treated plots and 38.7 s m^{-2} for faeces-treated plots. Obvious withdrawal responses and mouth contents ejection were seen during respectively 5.6% and 1.8% of encounters with urine-treated plots and 19.2% and 12.2% of encounters with faeces-treated plots. All spit outs in response to badger faeces occurred when no grazing had occurred in the contaminated plots and 64% of spit outs in response to urine followed no grazing in the plot.

DISCUSSION

The major result of this study is that almost all cows strongly avoid close contact with badger faeces or urine on pasture and only a very few individuals are unselective in grazing.

Study 1 assessed the behavioural responses of cattle to badger latrines immediately after cattle turn-out. Some badgers infected with tuberculosis were present in this area but their contributions to the latrines were not known. Attempts were made to answer two main questions. First, what is the chance that cattle will come into contact with badger latrines at this time when investigatory behaviour is likely to be at a premium? Second, what are the immediate responses to the latrines in situations of potential contact? It had been suggested that grazing behaviour may be less selective immediately after turn-out. In answer to the first question, there was no indication that cattle were drawn towards latrines from a distance in order to investigate them. It was shown that the likelihood of potential cattle contact with latrines immediately after turn-out was dependent on a number of factors, two of which were the position of the latrine within the field and the age of the cattle. However, the immediate responses to the latrines in situations of potential contact could be more clearly defined. The general response was that more sniffing was elicited and less grazing was performed than in non-latrine areas. However, it was clear to the observer that there was great individual variability in responsiveness. Many individuals very obviously detected the presence of the badger material and strongly avoided it. A small number of cattle, having monitored the presence of the material, performed much sniffing behaviour. A very small number grazed with little apparent concern through the latrine area apparently either not perceiving or not caring.

A disadvantage of study 1 was that the extent and distribution of urine and scent deposits were not known. Also the quantity of faeces present was generally low in relation to the size of the latrine area. Since it is more likely that badger urine, rather than badger faeces, is involved in tuberculosis transmission, the results of study 1 are not as relevant to the transmission question as are studies 2 and 3. However, it was useful to gain an understanding of behaviour in the 'natural situation' and reassuring to find that the general types of responses were similar to those identified in the experimental studies.

In general, the results were consistent in showing that, apart from two unselective feeders, cattle avoided badger faeces and urine. The greatest discrepancy occurred in experiment 1 of study 3 in which a larger proportion of animals appeared to be occasionally or partially unselective feeders on urine plots. This can be explained since in this experiment the method of applying the badger material resulted in relatively large areas of clean grass being present in the contaminated plots. Two other contributory factors may have been that the grass was very long and the weather was dry and hot. When grass is long, cattle will graze the tops of the leaves over areas contaminated with cattle slurry (Broom *et al.*, 1975; Pain & Broom, 1978) and in hot, dry conditions traces of urine will disappear rapidly. The result that cattle would spit out clean mouth contents after sniffing contaminated pasture demonstrated that olfactory discrimination can over-ride taste sensation whilst cattle are feeding.

This work supports previous theories (MAFF, 1976) that badger faeces is likely to be of minor importance in the transmission of *M. bovis* to cattle. The rationale behind this claim is as follows: (1) faecal material is deposited in widely distributed discrete areas, generally in dung pits, and so a large proportion of it is relatively inaccessible to cattle; (2) infected faeces contains a relatively small number of *M. bovis* organisms; (3) the weathering of faeces and any trampling of faeces by cattle will make available only small numbers of organisms at one time; (4) cattle very strongly avoid ingestion of badger faeces; (5) although more sniffing is directed towards badger faeces than clean grass, urine is sniffed much more.

The results demonstrate that there are two ways in which transmission from badger urine could occur: by eating contaminated grass and by inhaling organisms whilst investigating. It is surprising that such a small percentage of cows do contract TB in areas where very high levels of *M. bovis* must be present in the environment. The fact that a very small number of cattle will eat badger urine on grass allows one possible explanation for the relatively low cattle infection rate. The theory that cattle with unselective feeding habits become infected could be tested relatively easily. Another possibility is that cattle become infected whilst sniffing infected badger products, particularly urine. In order for contaminated grass to be rejected it must first have been detected by olfactory investigation. Considerable individual variability in sniffing behaviour was recorded. Some individuals avoided the contaminated plots from a distance, others from just outside the area. Some animals put their noses close to the contamination and performed either much or little sniffing. It is not known whether the individuals that perform a lot of sniffing do so out of curiosity or in order to decide whether the material is palatable or for both reasons. When performing olfactory investigation cattle often initially let out a rapid snort through the nostrils. This may have the function of clearing the sensory olfactory mucosae and emptying the very large volume of air, which is probably infiltrated with methane gas, from the nasal cavity. This leaves all parts clear and free of contamination and so accurate assessment would be facilitated. After snorting there is a rapid, almost involuntary, intake of air into the nose. This may result in the air arriving in a more appropriate area for sensory discrimination than if the active part is the in-breath, which could possibly take the air in too quickly and past the sensory mechanism before odour detection. The snorting behaviour could help to form an aerosol and this could readily be drawn into the nose and thus facilitate detection of the substance. An aerosol is most likely to be formed when grazing occurs during the night or early morning when moisture in the form of heavy dew is present on the tops of grass plants. It is difficult to predict how easily *M. bovis* could be combined into an aerosol after initial drying out of the urine material had occurred. Mullenax *et al.* (1964) suggested that particles carried in moisture droplets are more susceptible to being deposited in the lungs than are dry or unattached particles. It seems likely that single nuclei infections occur in cattle (McIlroy *et al.*, 1986; Neill *et al.*, in press) but there are many occasions when infections might occur but do not. It must be said that there is at present no answer, based on scientific study, of the important question of whether an infective dose of *M. bovis* can be drawn up into the respiratory system during olfactory investigation. It is of interest that nostril lesions can occur in cattle (Neill *et al.*, 1988).

The results from experiments 1 and 2 of study 3 demonstrated that most grazing of urine contaminated herbage occurs when cattle are forced to be less selective due to limited supplies of attractive food. Similar patterns in grazing behaviour have been shown by cattle in response to herbage contaminated with cattle faeces (Broom *et al.*, 1975; Arnold & Dudzinski, 1978). When herbage is scarce selective individuals will still avoid from a distance but moderately unselective animals may perform more olfactory investigation and unselective animals will graze contaminated grass. Thus, in these conditions there will be a greater risk that some animals will take in *M. bovis* by inhalation or ingestion. Kruuk *et al.* (1979) reported that badgers prefer to search for earthworms in areas of short grass but this was not found to occur in the study situations reported in this paper.

Study 2 demonstrated that rejection of ingestion of badger urine waned to some extent as the urine aged from 1 to 14 days. There were also indications of this from experiment 1, study 3. The grass measurements did not show a significant difference, but the ten measurements per m^2 plot may have been inadequate to detect what is probably a relatively small difference. There was no indication of reduced rejection of badger urine under wet conditions. However, it appeared that more grazing of older badger urine was performed under very hot, dry conditions. It is likely, as mentioned above, that the volatile, odoriferous substances will be quickly lost under these conditions. It is also likely that most *M. bovis* on grass leaves will be killed within a short time, perhaps even within a few hours. Information is available on the longevity of *M. bovis* in faeces (Mitscherlich & Marth, 1987) but this does not include the mortality rate of the organism on grass leaves within the first few days after urination. Experiments such as that of Schneller (1959) do not provide the complete answer to this question. All this experiment shows is that if phenomenally high numbers of *M. bovis* are put on to a pasture, a low level of transmission will occur with cattle grazing 7 days later. This result would be relevant if it were possible to eradicate TB from badgers and cattle. However, it seems that TB is endemic in the English badger population (Cheeseman *et al.*, 1989) and eradication is now accepted as unrealistic. The major effort must be devoted to minimizing the rate of transmission. MAFF (1979) report that although in winter *M. bovis* can survive on whole plants for more than 7 days, in summer no organisms survived at 3 days. In order to predict accurately the reduction in risk of transmission under different grazing systems it is essential to obtain more information on the rate at which *M. bovis* dies on the parts of the plants that cattle contact, particularly during the first day after urination. The effect of major climate differences should also be assessed. Most cattle actively avoid badger products on herbage and thus are likely to become infected from environmental contamination on pasture. However, a very small number of unselective cows will eat contaminated herbage and their olfactory investigation can be considerable so these individuals are at risk of receiving an infective dose by direct inhalation of an aerosol produced while grazing or investigating. In addition they are at risk if ingested organisms are deposited in the lungs following eructation. For most cattle, provided that sufficient herbage is available, substantial inhalation is unlikely in close proximity to badger urine or faeces for many hours or days after deposition. If the mortality rate of *M. bovis* is high, or if the propensity for an aerosol to be produced is low, or if cattle will not sniff close to the badger material, the chance that an infective dose will be taken in by inhalation will be very low.

As a consequence of the results of this and other recent studies, it is possible to formulate recommendations for cattle management procedures which would minimize the risk of the transmission of bovine tuberculosis from badgers to cattle. A further paper detailing such recommendations is in preparation. It is also clear that detailed investigations of the grazing behaviour of cattle which do contract tuberculosis are urgently required if the recommendations on how to avoid the disease are to be comprehensive.

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