A Strain of *Damalinia ovis* (Sheep Body Lice) Resistant to the Gamma Isomer of Benzene Hexachloride

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SUMMARY.—A strain of *Damalinia ovis* infesting sheep in the North of England is shown to be resistant to gamma-BHC. The resistance varies and is widespread. Several breeds of sheep are involved and the problem is most acute amongst hill flocks.

Introduction

SHEEP dips used in the autumn contain gamma-BHC as the principal active ingredient so that when they are diluted with water to make up a dipping bath the concentration of gamma-BHC is 0·016 per cent. After the passage of 20 to 50 sheep, according to the size of the dipper, a replenishment is made with dip concentrate and water, but concentrate is added at a rate half as much again as the initial dilution rate. This compensates for selective stripping or depletion of the active ingredient.

In January, 1965, reports were received of lice in flocks which had been dipped only four weeks previously in 0·016 per cent. gamma-BHC; some cases were examined, and lice were confirmed on sheep immersed four times in as many months in dips some of which contained dieldrin and gamma-BHC.

To kill the sheep body louse an insecticide must be lethal to adults, eggs and immature forms, or persist at a lethal concentration in the fleece for at least two to three weeks to kill emergent lice.

Graham and Scott (1948) and Scott (1952) have shown that low concentrations of gamma-BHC will control sheep body lice. Seddon (1950) found that 0·007 per cent. gamma-BHC effectively eradicated lice. Skerman (1959) reported that 0·01 per cent. gamma-BHC would eradicate lice and protect from reinfestation for at least 16 weeks. Thomas (1958) found that 0·00125 per cent. dieldrin or aldrin would eradicate lice and protect sheep for three months. Yet, in Westmorland, higher concentrations of gamma-BHC and dieldrin were apparently failing to control the parasite.

Barr and Hamilton (1965) reported the apparent failure of dips to control lice in Westmorland, and Page, Brown and Flanagan (1965) removed lice from sheep in the same county and found a high survival rate for lice when sheep were immersed in concentrations of dieldrin up to 0·01 per cent.

Two possibilities were considered initially, (1) that farmers had failed to replenish their dipping baths at the higher than initial rate so that the last sheep dipped in a large flock were immersed in a very low concentration of gamma-BHC, or (2) that, as Allen (1955) reported, degradation of gamma-BHC had occurred due to bacterial action, and that some flocks had been immersed in dips kept far too long. However, lice were found in flocks where neither of these conditions had to take account of resistance or some other factor.

This paper deals with the failure, in field tests, of gamma-BHC to control the sheep body louse, *Damalinia ovis*, and the confirmation, by checks on wool samples from flocks spread over a wide area, that the louse was living and breeding in concentrations of gamma-BHC hitherto thought to be lethal to the parasite.

The control of the louse by means of the phosphoric ester, Carbophenothion, is described in another paper (Treeby, 1966).

Materials and Methods

Laboratory Tests

Fifteen farms were visited at which the presence of lice was confirmed. Five separate wool samples, taken over the shoulder, were clipped from lousy sheep and taken to the field laboratory. They were measured and divided into three segments—Tip, Middle and Lower—and each segment was bio-assayed for gamma-BHC. The results are shown in Table I.

The bio-assay method was similar to that described by Harrison and Johnson (1961) for dieldrin and aldrin with two modifications: (1) the larvae were floated in serum for a maximum of two minutes prior to expulsion into the tubes by means of a rubber bulb pipette which dispenses approximately 50 larvae per tube, and (2) the serum used was Difco beef blood serum dissolved in distilled water at 50° C. A bio-assay method was used for convenience as *Lucilia sericata* are bred at the field laboratory and personnel are experienced in this type of work.

From nine of the 15 farms, wool and large numbers of lice were removed for exposure to *in vitro* immersion in 160 p.p.m. gamma-BHC. The results can be seen in Table II. Many lice were studied to determine if any gross morphological change accompanied the apparent resistance. Measurement of 400 specimens showed no significant difference in length from that quoted by Lapage (1956) or from that of non-resistant lice bred at the laboratory. Sheep body lice have been bred at the field laboratory for several years and may be considered normal in the sense that their hosts are never treated. These lice are extremely sensitive to gamma-BHC and concentrations of 160 p.p.m. produce total mortality within six hours of exposure. These "normal" lice were used as controls in each test of suspected resistant lice.

Table III shows the range of lengths of male and female "resistant" lice compared with those of "nor-

TABLE I
ALL FLOCKS DIPPED IN THEORETICAL 0·016 PER CENT. GAMMA-BHC

Expt. No.	Area in which flock located	Interval between dipping and sampling	Breed	Flock size	Concentration of gamma-BHC in wool segments. Range for 5 samples in p.p.m.			Degree to which flock infested with lice
					Tip	Middle	Lower	
1	Kaber Westmorland	8 weeks	Swale	1,000	0—5	5—50	0—5	Severe
2	Sedburgh N. Yorks	,,	Rough	800	50—100	5—50	5—50	Moderate
3	Ravenstonedale Westmorland	,,	,,	170	100	100	50—100	Severe
4	Appleby Westmorland	,,	Swale	1,100	0—5	0—50	0—5	,,
5	Appleby Westmorland	,,	,,	1,200	50	30	30	Light
6	Sedburgh N. Yorks	,,	Rough	280	50—100	50—100	50—100	,,
7	Hawes N. Yorks	15 ,,	Swale	300	0	0	0	Severe
8	Gaisgill Westmorland	10 ,,	Rough	300	0—50	0—50	0	Light
9	Heggerscale Westmorland	18 ,,	,,	80	0	0	0	Severe
10	Gaisgill Westmorland	9 ,,	,,	270	50—100	50—100	5—50	Light
11	Ambleside Westmorland	14 ,,	Swale Herdwick	2,400	5—50	0—50	0—50	,,
12	Carter Bar Northumberland	12 ,,	Black Face	450	0	0	0	Moderate
13	Aberfeldy Perth	10 ,,	,,	700	0	0	0	Light
14	Castleton Derbyshire	12 ,,	Swale	250	0—5	0—50	0—50	Moderate
15	Croglin Cumberland	10 ,,	,,	300	0	0	0	,,

TABLE II
WOOL AND LICE EXPOSED TO *In vitro* IMMERSION

Expt. No. relevant to Table 1	Location	Concentration of gamma-BHC in total staple from which lice removed p.p.m.	Per cent. survival of lice after 24 hour exposure to wool soaked in 100 p.p.m. gamma-BHC
4	Appleby Westmorland	50	100
7	Hawes N. Yorks	0	100
9	Meggerscale Westmorland	5	100
11	Ambleside Westmorland	50	100
12	Carter Bar Northumberland	0	50
13	Aberfeldy Perth	25	100
14	Castleton Derbyshire	50	90
15	Croglin Cumberland	0	100
Not listed	Gamblesby Cumberland	Not available	20

TABLE III
RANGE OF LENGTHS OF MALE AND FEMALE "RESISTANT" LICE COMPARED WITH THOSE OF "NORMAL" LICE

	Length of lice in mm. range for 400 resistant and 46 normal type		Ratio ♂—♀
	Male	Female	
Resistant lice	1·3—1·5	1·4—2·0	1 : 3
Normal lice	1·2—1·5	1·5—2·0	1 : 5

Field Tests

Severe to moderate lice infestations were confirmed in three flocks, all previously dipped within eight weeks in a gamma-BHC dip giving a bath strength of 0·016 per cent. These flocks were then each re-dipped in concentrations of 0·016, 0·036 and 0·072 per cent. gamma-BHC respectively. The dippings were carried out on a commercial scale and the initial wash concentration was accurately determined.

The first sheep dipped at each strength was picked out as being exceptionally lousy, and the two dipped

at 0·016 and 0·036 per cent were removed to the field laboratory for intensive observation. Since the complete flocks could not be intensively examined after dipping, five random sheep in each flock were studied intensively at three-week intervals, and wool samples were removed from the first dipped and the five random studied sheep for assay of gamma-BHC at the same time.

The results for the first dipped sheep are shown in Table IV and for the five random studied sheep in Table V.

Results

Laboratory Tests

Table I shows that, on 10 of the 15 farms examined, lice were present on sheep where the gamma-BHC concentration fell within the range of 5 to 100 p.p.m. in one of the three segments of wool bio-assayed, and in experiment 3 a severe infestation where the gamma-BHC concentration was 50 to 100 p.p.m. is recorded.

In Table II, lice removed in each case from nine farms showed a survival rate, when exposed to 160 p.p.m. gamma-BHC for 24 hours, in the range 20 to 100 per cent, compared with total mortality within six hours for normal lice.

Table III shows that there is no difference in length between the two types of lice examined, but the significant difference in male to female ratio may not stand up to statistical evaluation.

Field Tests

Tables IV and V show the depletion of gamma-BHC over a period of 15 weeks. The point at which a reinfestation was observed for the flock dipped at 0·036 per cent. suggests that, in fact, a failure to eradicate occurred, and that forms, non emergent at the time of dipping, were able to hatch and to develop in a background of 250 p.p.m. gamma-BHC.

Discussion

In laboratory tests of wool samples taken from

TABLE IV
RESULTS FOR THE FIRST DIPPED SHEEP

	Concentration of gamma-BHC as p.p.m. in the "tip" "middle" and "lower" segments of wool, from the first sheep dipped in the three concentrations, 160 p.p.m., 360 p.p.m., 720 p.p.m., gamma-BHC																		Point after dip when positive infestation established
	Pre-dip			3 weeks post dip			6 weeks post dip			9 weeks post dip			12 weeks post dip			15 weeks post dip			
	tip	mid	lower	tip	mid	lower	tip	mid	lower	tip	mid	lower	tip	mid	lower	tip	mid	lower	
First sheep dipped at 160 p.p.m. g-BHC	5	0	5	75	75	5	50	50	50	5	50	5	25	5	5	5	25	0	8 weeks
First sheep dipped at 360 p.p.m. g-BHC	0	0	0	250	250	75	40	40	400	25	25	50	5	5	25	5	0	0	4 weeks
First sheep dipped at 720 p.p.m. g-BHC	100	100	25	600	600	300	300	300	300	250	250	250	5	40	40	5	25	25	Negative to 20 weeks

TABLE V
RESULTS FOR THE FIVE RANDOM STUDIED SHEEP

	Concentration of gamma-BHC, as p.p.m. at indicated intervals before and after dipping in "tip," "middle" and "lower" segments of wool from five random sheep in flocks dipped at 0·016%, 0·036%, 0·07%																		Point at which lice confirmed after re-dipping
	Before dip			3 weeks after			6 weeks after			9 weeks after			12 weeks after			15 weeks after			
	tip	mid	lower	tip	mid	lower	tip	mid	lower	tip	mid	lower	tip	mid	lower	tip	mid	lower	
Range for 5 results from sheep dipped at 0·016%	0-5	0-20	0-5	50-100	50-100	20-50	20-100	5-100	5-100	20-100	5-75	0-5	5-20	5-50	5-50	0-5	0-20	0-5	8 weeks
Range for 5 results from sheep dipped at 0·036%	0	0	0	250-300	250-300	75-250	30-40	30-40	40-300	Not available						5-20	5-20	5-20	3 weeks
Range for 5 results from sheep dipped at 0·072%	50-150	20-100	5-75	Not available			40-600	600-600	40-600	Not available						5 (1 sheep)	25	25	Negative to 20 wks.

flocks over a wide area of the North of England where lice infestations were confirmed, lice were shown to be present in comparatively high concentrations of gamma-BHC in the fleece, certainly in concentrations of a magnitude hitherto thought to be lethal to this parasite. The high survival rate of lice removed from nine flocks when exposed to a concentration of 160 p.p.m. gamma-BHC for 24 hours is compared to total mortality within six hours for normal lice similarly exposed.

In field tests, lousy flocks were found reinfested within three weeks of dipping in 0·036 per cent. gamma-BHC, within eight weeks of dipping in 0·016 per cent., but no reinfestation occurred after the dipping in 0·072 per cent. These results suggest a differential resistance of lice between flocks and also between sheep.

The depletion of gamma-BHC after dipping, as shown in Tables I, IV, and V, suggests the possibility of sub-lethal doses existing in the fleece from approximately eight weeks after dipping in 0·016 per cent. gamma-BHC. After dipping, the problem of low concentrations in the wool would be greater where the bath was inaccurately calibrated, or where insufficient replenishments of concentrate were made, or where the sheep were ineffectively dipped.

It is of interest to speculate as to the origin of the resistant sheep lice, or "Westmorland Lice" described by Page, Brown and Flanagan (1965). Gamma-BHC has been used in Britain for about 20 years to control ecto-parasites of sheep and it has commonly been employed in conjunction first with DDT, and later with aldrin and dieldrin. It is usual for farmers to dip with gamma-BHC only in the autumn on economic grounds, and, in the fells, it is not easy to arrange a complete muster of sheep. In this respect even less care has been evident since the sheep scab dipping order was relaxed.

Sheep which have been missed in the autumn muster are likely to be lousy in the period between then and clipping and it is possible that lice from such sheep may be transferred to dipped sheep. Towards the end of the period the dipped sheep would carry sub-lethal amounts of insecticide, so that lice transferred to them would be exposed to small amounts and this would tend to select out strains of lice whose progeny would be able to withstand slightly higher concentrations of insecticide the following season.

Young ewes from flocks where the general level of gamma-BHC resistance in lice is high, when sold to other farms could be widely distributed, and this might perhaps account for the widespread occurrence of resistant lice. There could also be an opportunity for the simultaneous development of resistance in several fell areas and the production of resistant lice might be expected in Scotland and Wales. This condition may already exist although undetected.

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BRUCELLOSIS ERADICATION AND PIG HEALTH SCHEMES TO BE INTRODUCED

Following a Parliamentary Question on July 26th the Minister of Agriculture gave a reply which is of major interest to the profession.

Mr. Kitson asked how soon he intends to introduce the pig health scheme announced by the Joint Parliamentary Secretary on February 2nd last; and when he proposes to make a start on eradicating brucellosis.

Mr. Peart said: "My right hon. Friend the Secretary of State for Scotland and I propose, as a step in our declared policy of promoting preventive veterinary medicine, and as a contribution to the increase in agricultural productivity called for by the National Plan, to introduce a pig health scheme for herds ranked as 'accredited' by the Pig Industry Development Authority. Subject to Parliamentary approval, the scheme will start as soon as possible and discussions are taking place with the industry."

Brucellosis Eradication

The Minister went on: "We have also decided to introduce a scheme aiming to eradicate brucellosis over a period of some years. This will not only serve the interests of human and animal health, but will also improve agricultural productivity and enable us to maintain and increase exports of livestock.

"The first essential is to build up a register of brucella-free herds on a voluntary basis to provide a reservoir of disease-free replacements. The second stage, which can only be introduced when the voluntary response is large enough, will consist of a plan of eradication, area by area, in which all animals reacting to diagnostic tests will be slaughtered, with payment of compensation. Various aspects of the plan have yet to be discussed with the National Farmers' Unions and other interests concerned, but we intend to make a start as soon as possible."