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THE PROTECTION OF SHEEP AGAINST BLOWFLY STRIKE. V. THE DURATION OF PROTECTION OF CERTAIN INSECTICIDES UNDER FIELD CONDITIONS.

S. STAMPA, O. G. H. FIEDLER AND R. DU TOIT, Onderstepoort Laboratory.

CONTENTS.

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Introduction.

It has been demonstrated in previous articles of the current series (parts I to IV) that insecticidal compounds must possess certain definite physico-chemical properties besides being efficient larvicides, to exert long-term protection against blowfly strike under conditions that prevail in the fleeces of woolled sheep. A bio-assay method was developed to ensure the accurate assessment of potential protecting agents which are making their appearance in ever-increasing numbers (Fiedler and du Toit, 1951). Under these conditions four compounds were selected from the large range of synthetic insecticides available which best appear to fulfil the requirements of an efficient protecting agent, namely B.H.C., Diazinon, Aldrin and Dieldrin.

The aim of the present paper is to present an assessment of the value of these four insecticides mentioned, under typical field conditions. Under natural conditions, as met with in the field, a variety of factors are encountered which did not operate in the previous tests of this series. The determination as well as an analysis of these factors played an essential part in the present study.

The Graaff-Reinet and Middelburg districts of the Cape Midlands were selected as representing areas in which it was possible to obtain farms for experimental purposes on which a relatively low incidence of blowflies existed in close proximity to properties where these ectoparasites play so important a role that sheep farming is feasible only if appropriate protective measures are adopted.

A comparison of the relative value of the different formulations in which the insecticides tested were available was undertaken, special attention being paid at the same time to the most suitable means of applying them to the fleeces of living sheep.

An attempt was made, furthermore, to reach a definite conclusion on the value of the Mule's operation in areas that normally experience a high incidence of blowflies.

Finally, certain aspects of the biology of blowflies were investigated.

Field Experiments.

Field trials conducted in former years had shown that conclusive results could be expected only if adequate supervision was provided during the entire course of the experiments and to ensure such supervision the number of experimental animals had to be limited. For the same reason so-called "user trials" with an impressive number of flocks, not regularly inspected individually, in which the sheep farmer is called upon to report on the results of insecticides issued to and applied by him, were not undertaken in order to ensure the recording of the various factors likely to influence the duration of protection. It was found to be essential that every sheep of all the experimental flocks be inspected thoroughly twice per week, and that the experimental farms be chosen with the view to the inclusion of all possible factors liable to influence the conclusions ultimately arrived at.

Altogether 8,631 Merino sheep on eight farms were subjected to 78 individual trials, and adequate control animals were included in each experiment. The trials of the various types of insecticides covered a diversity of pastures, lengths of wool, as well as various densities of blowfly population.

Factors Rendering Sheep Susceptible to Strike.

Opportunities were afforded during the course of the trials to investigate the factors responsible for those changes in the fleeces of living sheep which render animals susceptible to strike.

This attractiveness of sheep to blowfly females is brought about by specific conditions which fall into three different categories, namely, wetting, soiling of the wool, and skin lesions. Wetting and soiling have more or less the same effect on the wool. Both stimulate bacterial growth, produce dermatitis and damage to the upper layers of the skin which eventually lead to fleece rot and the production of odours strongly attractive to primary blowflies. Similar attractiveness is produced by any fresh skin lesion or open wound, and this may be further enhanced by inflammatory or necrotic changes of the skin.

The biological and environmental factors inducing changes in the fleece favourable to blowfly attack are given below.

1. *Wetting of the Wool.*

Four different sources of moisture were found to be responsible in enhancing the attractiveness of woolled sheep, viz.:—

(*a*) *Rain*.—Excessive downpours during the summer season, which soak the wool staple down to skin level, create conditions ideal for body strike in certain parts of the coastal region, especially when accompanied by overcast weather for a succession of days.

(*b*) *Dew*.—Body strikes can also be expected in the coastal belt under conditions of high humidity of the air and the formation of dew at night. Animals grazing in thick bush or underneath trees heavy with dew may collect enough moisture in their wool to render them readily prone to strike.

These first two factors, however, were not observed under Karoo conditions, where the formation of heavy dew is rare and of short duration, and where rains normally are accompanied by cold spells which reduce the activity of blowflies very considerably.

(*c*) *Saliva*.—Irritation of the skin very often causes animals to bite and chew at the wool over those parts of the body which they can reach. Such irritation may be due to ticks, keds, or the pointed seeds of certain grasses, infestation with lice, or infectious itch (*Psorergates ovis* Womersley). In the case of the itch mite particularly where constant irritation seems to be present, the animals are inclined to keep the wool constantly wet over the affected parts by continuous chewing of the fleece. Strikes along the flanks play an important role amongst flocks infected with itch mites, as was observed in several parts of the Karoo.

(*d*) *Urine*.—By far the most common factor responsible for strikes in the crutch region is wetting of the wool by urine, especially in ewes. Decomposition of organic matter in wool moistened by urine renders these parts highly attractive to blowfly females. Wetting of the surrounding wool takes place when the bare region around the vulva is rather narrow, or when deep skin folds are present which tend to lead part of the excretions into the surrounding wool. Furthermore, damage to the vulva by shearing cuts can result in constant wetting of certain portions of the neighbouring wool. In rams and hamels wetting of the fleece was only observed when the wool was long, and sheath strikes are then not uncommon.

2. *Soiling of the Wool.*

Two different causes of soiling were observed which are responsible for attracting blowfly females, namely:—

(*a*) *Liquid faeces*.—Soiling of the wool by diarrhoeic faeces plays by far the greatest role. Diarrhoea may be due to worm infestation which is frequently observed. An equally common cause of liquid faeces in the Karoo, is the running of sheep on green and succulent pastures such as lucerne, or their access to "brak" plants, (perennial halophytes) and "opslag" (annual herbs of a succulent nature which make their appearance after rain). These are the main causes of disturbing digestion of sheep in normally arid areas (Acocks, 1953).

Animals are more susceptible to strikes if they possess well-developed skin folds on both sides of the perineal region.

(*b*) *Droppings of birds*.—An interesting predisposing cause of body strikes was noted on several farms in the Karoo. Sheep, resting underneath trees occupied by gregarious types of small birds became soiled by their droppings to such an extent that they proved to be highly attractive to blowflies. This form of soiling was only of importance in limited parts of certain farms.

3. *Skin Lesions.*

Fresh open wounds and lacerations of the skin are readily attacked by blowflies, especially when the incidence of flies is high. Strikes on docking and castration wounds are a serious problem in many parts, and these operations, therefore, are mostly performed during the winter or mid-summer season when the blowfly activity is at its lowest. Any alteration of the routine governing these operations, however, may adversely influence the lambing season which should rather correspond with the abundance of fresh and nutritious pasture than with the period of minimum blowfly activity. Special attention was directed during the course of this study to the application of insecticides as a means of preventing strikes following docking and castration.

Head wounds in rams due to fighting, which normally lead to poll strikes, occupy a second place amongst the skin lesions. Tick bites, mainly caused by *Hyalomma* spp., shearing cuts and accidental wounds, due to barbed wire injuries, dog bites, etc., follow in the order of importance.

Development of Strikes in Sheep Treated with Insecticides as Compared with Unprotected Animals.

The young blowfly larvae normally remain close to the site where the egg batches are deposited, and attack the superficial layers of the skin in the immediate vicinity. The tendency to migrate into adjoining parts of the fleece can only be observed after they have reached the second instar.

As shown by Fiedler (1951) the maggots of primary blowflies live mainly on the lymph exuding from superficial lesions of the skin. Granulating tissue must be removed constantly in order to ensure a constant flow of the nutritional medium and the tendency to spread into surrounding parts of the fleece develops in accordance with the increasing demand for food as the larvae grow. Healthy skin, covered by dry wool is attacked from now on as can be noticed by the wool becoming wet due to soaking with exudate from the lesions underneath.

Blowfly larvae are negatively phototropic from the second instar onwards and, therefore, will not attack bare portions of the skin. As soon as the wool over the affected area starts to fall out due to the activity of the maggots, they are forced to migrate to new sites.

Since strike wounds are particularly attractive to gravid blowfly females, further egg clusters are soon deposited on the affected area. It was observed that young larvae hatching from the secondary strikes show hardly any tendency towards gregarious feeding and commence migrating into the adjacent wet wool almost immediately, especially when they encounter competition from older larvae. From now on at an early stage of development they are inclined to invade fresh dry areas.

Three progressive stages can be distinguished during the normal development of a strike on sheep not protected by insecticides, namely:—

(1) A localized strike of first, and possibly second instar larvae around a comparatively small skin lesion.

(2) Spread into adjacent wet areas by second instar and also by first instar larvae originating from egg batches deposited at a later date.

(3) Invasion of originally dry portions of the fleece.

This normal developmental cycle is interfered with when sheep are treated with a protecting agent. The observations described below were made on animals treated with one of the modern synthetic insecticides. According to the efficacy of the active ingredient and the concentration present in the wool, the interference of development occurs at different stages of the cycle. The following effects on the parasite were observed in protected crutches:—

(1) Gravid females are repelled, and no deposition of eggs occurs. This phenomenon was seen in sheep freshly treated with D.D.T.

(2) Females are repelled from the treated wool and deposit their eggs on the bare parts or at the fringes of the fleece. Larvae may commence developing in folds of the bare skin but are killed when they migrate into the woolled portions.

(3) Females are not repelled by the insecticide and deposit their egg clusters on the treated zone, but the young larvae are killed soon after hatching and never reach maturity. (Up to this stage the treated wool is fully protected by the insecticide and none of the larvae completes development. From now onwards a certain degree of larval development becomes possible and the conditions in the wool change gradually in favour of the parasite until total breakdown of protection occurs. The period of decreasing resistance can be designated as partial protection).

(4) Larvae after hatching no longer succumb instantly but their development is retarded. They are killed as soon as they commence invading neighbouring parts of the fleece, but some remain localized and reach maturity to produce a so-called localized strike.

(5) Many larvae develop in the wet wool of the original area of the strike. Those larvae invading the surrounding dry wool, however, are killed off. A slightly larger localised strike results in this case.

(6) Finally, normal larval development becomes possible and only those maggots succumb at a later stage which invade areas where the insecticidal concentration is still lethal to them and a diffuse strike is the result.

The different stages of development were observed in all cases where insecticides of the chlorinated hydrocarbon or phosphorus type, with a high power of diffusion along wool fibres, were employed as protecting agents. Depending upon the physico-chemical properties of the compounds used some of the intermediate stages of breakdown are of longer or shorter duration.

Larvicidal Value of the Insecticides under Test.

The insecticidal compounds included in the present field trials did not show the pronounced repellent action on blowfly females which was observed in the case of D.D.T. In the case of Diazinon especially, no repellent action was noticeable and treatment with this insecticide did not appear to influence the natural attractiveness of soiled and wet crutches. Those areas were literally covered with egg clusters, which hatched successfully but the resulting larvae succumbed instantly without reaching their feeding grounds or doing any damage. For this reason an insecticide of this type must be regarded as superior to compounds of the D.D.T.-group, where gravid females are repelled and forced to search for animals or carcasses more suited to their purpose. Insecticides possessing no repellent action, therefore, are of greater value for a campaign against blowflies in general, as eggs are readily deposited on treated sheep and only very little propagation is possible. Regular treatment of all flocks should, therefore, result in a substantial reduction of the blowfly population in a particular area.

The larvicidal properties of the insecticidal compounds tested can be characterised as follows:—

(1) *Gamma-B.H.C.*—This insecticide is lethal to first instar larvae at a concentration as low as 4 p.p.m. It possesses excellent diffusion properties in wool but decomposes rather rapidly in soiled wool The protection of sheep breaks down fairly quickly, therefore.

(2) *Dieldrin* is a slightly more potent larvicide and kills first stage maggots at a concentration of 1 p.p.m. Its diffusion power surpasses that of B.H.C., it is more stable in soiled wool and gives more prolonged protection than B.H.C. It breaks down slowly and gradually. Localized small strikes occur, to start with, and these progressively increase in number and size until the last trace of protection has vanished.

(3) *Aldrin.*—Its insecticidal effect is slightly inferior to that of Dieldrin and equivalent to gamma-B.H.C. The diffusion power along the wool fibre, however, is superior to that of Dieldrin. It is also very stable and the mode of breakdown is similar to that of Dieldrin.

(4) *Diazinon* is a potent and quick-acting larvicide and is lethal to newly-hatched maggots at a concentration of 0·25 p.p.m. Its diffusion power is superior to those of the other compounds cited. It is stable in soiled wool, but when decomposition occurs this happens rather suddenly and rapidly. On account of these properties Diazinon confers a long period of absolute protection, followed by a comparatively short interval during which small strikes occur. This period is terminated by a rapid and complete breakdown of protection. Very few maggots only can succeed in completing their development before complete decomposition occurs and normal development takes place thereafter.

Factors Influencing the Duration of Protection.

A number of factors which influence the duration of protection to a greater or lessor degree, was observed under field conditions. These influential factors may be introduced either by the protecting agent itself, by the sheep, or by the parasite.

The assessment of the effect of a certain factor is possible only if all other conditions are identical or at least so similar that the particular factor can manifest itself. It was necessary to conduct a large number of parallel trials in order that those effects could be selected which diverge in respect of one factor only.

Factors Introduced by the Proctecting Agent.

The actual larvicidal efficacy of the compounds under test had been established previously (du Toit and Fiedler, 1952, 1953) and, therefore, will not be considered here. It was found, however, that the type of formulation, the mode of application, as well as the quantity applied play an important part in determining the duration of protection.

(*a*) *The Formulation of the Insecticide.*

It was demonstrated by Fiedler and du Toit (1954) that the type of formulation had a profound effect on the duration of protection. A dust and a wettable powder of B.H.C. proved to be superior to an emulsion when applied at equal quantities to the dry and unsoiled wool of the rump. The experiments indicated clearly that the active ingredient tends to combine more readily with the wool grease when brought into the wool as minute particles, mechanically bound to particles of an inert carrier, rather than being dissolved in a hydro-carbon solvent.

It must be borne in mind, however, that these results were obtained in tests in which a very important natural factor, the soiling of the crutch region, was excluded. In order to compare the potency of the different formulations in the field the same concession had to be made and only those trials are considered here where the crutch region was clean at the time of treatment. The influence of dirty wool will be discussed later.

The results of the field tests differed for the wettable powders and dusts from those conducted under semi-laboratory conditions. It could be demonstrated that for Dieldrin, Diazinon and gamma-B.H.C. wettable powders gave a longer protection than dusts. Table 1 shows the results of three groups of parallel experiments with these two formulations and two of the above-mentioned insecticides, each pair of which was conducted under identical conditions.

There are no results available to compare the lasting properties of an emulsion in clean dry wool.

It is not feasible to compare the data for Dieldrin and Diazinon presented in Table 1 as indicating the superiority of Dieldrin, as all three trials were carried out at different places and under different conditions, as will be explained later.

Furthermore, it must be stated in this connection that the effect of the formulation itself is very often obscured in the field by the physical conditions prevailing in the crutch region at the time of application, and this appears to exert a profound influence upon the resulting period of protection.

(*b*) *The Mode of Application.*

The maximum period of protection can only be expected from any insecti-prevailing in the crutch region as the time of application, and this appears to skin level. The reason lies in the fact that the insecticide is best able to diffuse along the new growth of wool fibres, apparently when the newly secreted wool grease is still in a liquid state and is able to dissolve a portion of it and thus serve as a carrier.

Certain insecticides applied to the surface of the fleece can, however, diffuse along the wool fibres to a greater or lesser extent depending upon the diffusion properties possessed by them.

In the following experiment conducted in small camps in the open at Onderstepoort an attempt was made to assess the diffusion properties possessed by Diazinon, Dieldrin, Aldrin and B.H.C.

Thirty Merino sheep with a fairly uniform growtth of wool of $2\frac{1}{2}$ inches in length were divided into five groups of six sheep each, each group being kept in a separate camp.

The test insecticides were sprayed on to the rump region over an area of 10 inches in diameter by means of a stirrup pump giving a finely atomized spray at the rate of 750 cc. of a 0·15 per cent concentration of the active ingredient per sheep. This was sufficient to wet the surface of the wool without run-off. On subsequent examination of the fleece over the sprayed region it was noted that the wool was wetted to a depth of not more than one-quarter of an inch.

TABLE 1.

No. of Exp.	Wettable Powder.				No. of Exp.	Dust.			
	Insecticide.	Quantity of a.i. applied in gm.	First Small Strike after (Days).	First Large Strike after (Days).		Insecticide.	Quantity of a.i. applied in gm.	First Small Strike in Days.	First Large Strike in Days.
(3)	Dieldrin...	0·5	129	129	(1)	Dieldrin..	0·5	70	80
(4)	Diazinon..	0·61	64	98	(8)	Diazinon	0·55	44	84
1 b	Diazinon..	0·625	64	92	II b	Diazinon	0·625	53	56

Commencing eight weeks after the application of the insecticides samples of wool were snipped from the treated areas at weekly intervals, care being taken to sever the wool as close to the skin as possible. From each sample the half inch of wool nearest the skin was cut and tested by the "in vitro" method described by Fiedler and du Toit (1953), namely, by the addition of fresh serum and the implantation of first instar larvae of *Lucilia cuprina* in glass tubes.

Observations were carried out each week for a period of 24 weeks when no further protection of wool could be demonstrated and the average length of wool of all the sheep had reached four inches.

In the case of Diazinon which was applied in the form of a miscible oil on one group and as a wettable powder on another the average period of protection for the former group amounted to 17·8 weeks and for the latter 13·8 weeks. None of the other insecticides tested under these conditions gave protection for a period exceeding eight weeks.

The results are not reported in detail as the variation per sheep was too great to allow of statistical analysis and repetitions will be necessary.

The fact remains, however, that diffusion of Diazinon down the wool fibres from surface to skin level had occurred and in the case of one sheep complete inhibition of larval development at skin level was demonstrable in the case of the miscible oil treatment until the 23rd week when protection broke down. This indicates that the insecticide had diffused along the wool fibres for a distance of $2\frac{3}{4}$ inches at the time of the first test and thereafter another inch along the newly-grown wool between the 8th and 24th week, a distance of $3\frac{3}{4}$ inches in all.

The insecticide can be applied to the fleece in different ways. The liquid formulations were applied by hand (hand-dressing), as high volume sprays, and as low volume sprays. In the case of dusts the mode of application was confined to dusting by hand and to power dusting. In order to ensure thorough treatment of the crutch region the sheep have to be held by a labourer in a sitting position, and the treatment is then carried out by a second person.

Liquid Formulations.

The usual method of applying the protecting agent to the crutch region is by hand-dressing. A measured quantity of the fluid, usually about a pint, is poured slowly from a container, usually a tin can, on to the wool of the crutch. The operator at the same time parts the wool fibres over the area of application with the fingers and then squeezes the wool with his other hand in order to effect even distribution of the insecticide. In this way 60-80 sheep can be treated per hour by a team of three or four labourers. The method is rather slow but ensures on the other hand that equal quantities of insecticide are applied to each sheep.

A large number of sheep can be treated if the insecticide is applied by hand pump and by this means about 100 animals can be handled within an hour. This method, however, entails the danger that too little or too much insecticide is applied, as the measurement of the correct amount is left entirely to the skill of the operator.

The third type of application is that of low volume power spraying. It was found that the most suitable type of apparatus for this purpose consists of a unit whereby the fluid is driven by compressed air at a pressure of from 50-80 lb. per square inch into the fleece. A venturi-type nozzle such as is used for sand blasting connected with a compressed air unit capable of delivering approximately seven cubic feet of air at the desired pressure per minute gave excellent results (Fig. 1). The advantage of this arrangement is that the air stream which carries the fluid particles forces the wool fibres apart and drives the protecting agent down to skin level. From 250 to 300 animals can be treated per hour by using a single nozzle as it takes only about 10 seconds to handle each sheep. As a comparatively small amount of fluid is sprayed into the fleece by this means the concentration of insecticide in the wash must be increased in order to obtain a deposit of the protecting agent equal to that of hand-dressing or high-volume spraying. It was found that in the case of the unit used in the trials, which delivered about 110 ml. per 10 seconds, the insecticidal concentration of insecticide had to be five times that for hand application.

FIG 1.—Power spraying.

Field experiments have shown that under otherwise identical conditions a more or less equal duration of protection is achieved by all three methods. The protection in the case of low-volume power spraying can, however, be seriously influenced by faulty application in that certain circumscribed areas remain either untouched by the insecticide or are not treated to skin level. In this way the method is more liable to faults than the hand-dressing method, as the treatment of each sheep is carried out in so short a time. In the hands of a skilled and reliable operator, however, it represents the most economical method of treatment, as it saves time and labour.

Furthermore, there is practically no run-off and hence no wastage of insecticide as compared with the tin can or hand-spraying methods where about 15-20 per cent of the fluid applied runs off in long-woolled sheep and 20-30 per cent from sheep with short wool.

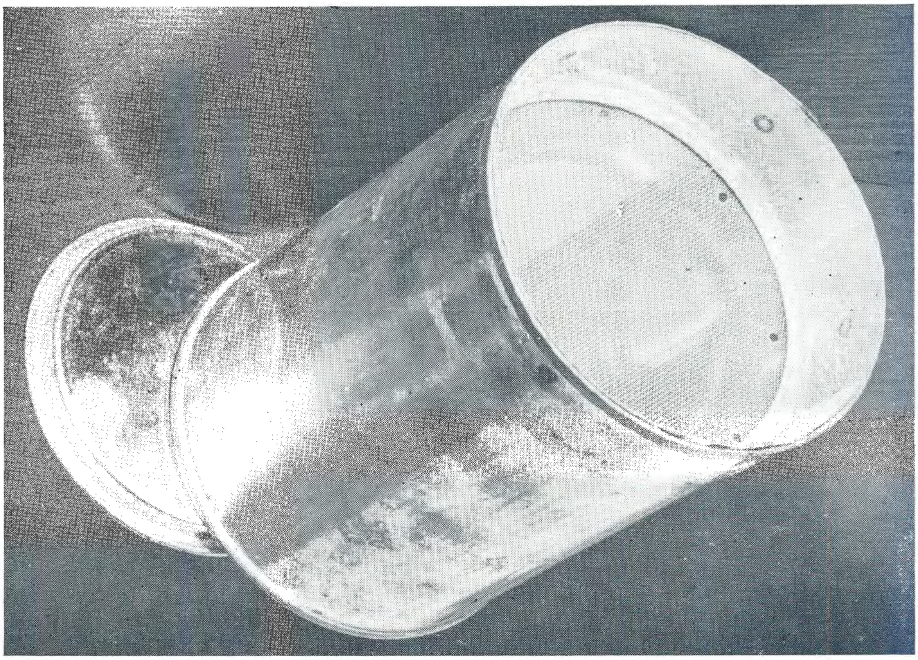


FIG. 2.—Tin can fitted with brass wire screen.

Dusts.

The trials reported upon represented the first time that insecticides in the form of dusts containing 1 per cent of the active ingredient had been used to protect sheep against blowfly strike and extensive initial experimentation was necessary in order to find a suitable means for field application. Two methods were decided upon which warranted testing in practice, namely, application by hand for small flocks and the use of power dusters for larger flocks.

In the first instance the apparatus consists of a tin can with a tight fitting lid from which the bottom has been removed. This is fitted with a fine brass wire screen of 32 meshes to the inch fixed to the inside about one inch from the lower rim. The rim protects the sieve against dirt in the wool and prevents clogging and furthermore, opens the wool when the apparatus is rubbed over the fleece and thus allows the dust to fall between the fibres. About 40 to 60 animals can be treated per hour employing one tin can and two or three labourers (Fig. 2).

The same type of air compressor unit as used for the liquid formulations was found suitable for power-dusting of large flocks. The treatment per sheep occupies about 12 seconds, thus about 250 animals can be treated per hour with one nozzle and four or five labourers. As a certain amount of dust escapes into the air labourers should be protected by means of respirators. The operation is less unpleasant when there is some air movement and the operation is so conducted that the breeze blows from one side.

The duration of protection obtained by hand-dusting proved inferior to that obtained by power-dusting throughout the field trials. As an example a comparison between two series of parallel experiments is given in Table 2.

TABLE 2.

Protection in Days with Dust Applications Applied by Power and Hand.

Experiment	1	2	3	—
Power	93	93	84	—
Hand	61	71	56	—

The explanation appears to lie in the fact that a more even distribution of insecticide in the fleece is obtained and the insecticidal particles are brought into more intimate contact with skin by the air stream from the compressor unit.

Hand-dusting, therefore, is not to be advocated as a prophylactic treatment of large flocks against blowfly strike. It has proved very useful, however, and superior to liquid formulations for the treatment of strike wounds on individual sheep as well as for castration and docking wounds. The advantage of the dust is that bleeding is stopped rapidly and the dust combines readily with the secretions from the wound thus forming a thick protective layer. In this way it promotes drying and subsequent healing of the wound and protects against further strikes at the same time.

(*c*) *The Quantity Applied.*

Experiments at Onderstepoort have shown that the period of protection stands in direct relation to the quantity of insecticide applied to a certain quantity of wool. When equal amounts of different concentrations of a B.H.C. suspension were applied to a limited area of dry and clean wool of equal length on the rumps of sheep and tested by the bio-assay method developed by Fiedler and du Toit, it was found that a greater insecticidal deposit resulted from the higher concentrations and effected a longer duration of protection. This is shown in Table 3.

TABLE 3.

Period of Protection Afforded by Different Concentrations of a Gamma-B.H.C. Suspension on the Rump of Sheep. Averages of 6 Sheep Each.

Gamma Concentration	0·5%	0·4%	0·3%	0·2%	0·1%	0·05%
Period of full protection. (Weeks)	39·0	35·5	29·2	26·2	21·0	17

It was practically impossible, however, to demonstrate the influence of the quantity of insecticide during the field trials, although a wide range (from 0·425 to 2·84 gm.) had been applied per sheep. The resulting periods of protection were not always in strict accordance with the insecticidal deposit. It had to be deduced, therefore, that other factors were obscuring the efficacy of the different levels of deposit and were of greater importance as regards period of protection than the amount of protecting agent present in the wool. Conditions in the crutch region and the prevalence of blowflies represent such potent factors. This will be demonstrated later.

Furthermore, it does not seem to be of any consequence whether a small amount of a high concentration is administered or a large amount of a low concentration, as long as the deposit is evenly distributed in the wool.

It is of far greater importance from the practical point of view to ensure the optimum deposit as judged by the standard of economy. The present trials indicate that between 0·8 and 1·1 gm. of the active ingredient of either Diazinon, Dieldrin or Aldrin per crutch fulfils this demand. This is achieved when one pint of a suspension or emulsion of the particular insecticide containing between 0·15 and 0·2 per cent of the active ingredient is administered per sheep by means of the tin can method or by hand-spraying. If low-volume spraying is applied the concentration should be increased in accordance with the rate of delivery and the quantity of fluid per sheep. A concentration of between 0·75 and 1 per cent is recommended when only about 100 ml. per sheep are applied.

Factors Introduced by the Sheep.

The analysis of the results obtained from the different field trials demonstrated clearly the existence of certain factors influencing the duration of protection which are introduced by the sheep. These may be stated to comprise the length of the wool fibres, the condition in the crutch region, and the age of the animal.

(*a*) *The Length of the Wool.*

It was shown by du Toit and Fiedler (1954) that the length of the wool at the time of treatment influences the duration of protection which stands in direct proportion to the length of the fibre.

The present trials revealed that these findings are equally applicable to conditions in the field as is illustrated in the following experiments. In Table 4, where the halves of two flocks with three-and-a-half and one month's wool were treated with Diazinon wettable powder (1 pint at 0·25 per cent) and dust (50 gm. at 1 per cent) respectively, and kept under identical conditions, 43 per cent strikes were encountered amongst the control sheep during the period of observation of 116 days. All the strikes, encountered in the treated flock were confined entirely to the short-woolled sheep, and the sheep with the longer wool did not experience a single strike.

Furthermore, it was noted during the course of field trials, where gamma-B.H.C. was employed as the protecting agent, that most of the strikes occurred in crutches with short wool, i.e. where the wool had been clipped away close to the skin in order to remove the faeces-impregnated lumps of wool or "dags" prior to treatment.

TABLE 4.

Comparison of the Protection by Diazinon Dust and Wettable Powder in Long- and Short-woolled Sheep.

Experimental group	33/a/1	33/a/2	34/a/1	34/a/2
Formulation	Dust	Dust	W.P.	W.P.
Length of wool. (Months growth)	3½	1	3½	1
Days to first small strike	*116	97	*116	97
Days to first big strike	*116	97	*116	116
Small strikes as per cent	0	9·7	0	6·7
Big strikes as per cent	0	12·9	0	3·3

* Not within this period.

According to these findings it appears to be inadvisable to crutch dirty sheep prior to treatment with insecticide, even if the crutch region is grossly soiled with faeces.

(*b*) *The Conditions in the Treated Area.*

The area that requires treatment with the insecticide, namely, the crutch region, may be subjected to certain conditions which can have a bearing on the lasting properties of the protecting agents applied. The factor mainly responsible is undoubtedly the state of soiling of the breach. Two distinct sets of conditions may be observed. In the first instance, the region can be clean and dry at the time of treatment but may become soiled and wet later on account of a change in diet or because of some other cause which results in diarrhoea. Secondly, the breach may already be in a soiled state when the protecting agent is administered.

The influence of soiling is not very pronounced in the first case cited, especially with Diazinon, Dieldrin and Aldrin. As these compounds possess a certain degree of stability and are protected by being dissolved in the wool grease, their larvicidal properties seem to be only slightly affected. Nothing appears to affect Diazinon, where, theoretically speaking, slow hydrolysis of the active ingredient would be expected on account of its molecular structure, but the duration of protection afforded by it does not seem to be curtailed where soiling after application occurs, compared with the theoretically more stable compounds of the Dieldrin group.

The length of the protection period, however, decreases considerably, if the crutch is already soiled at the time of treatment. In cases where dried faeces form a solid mass with the wool, penetration of the protecting agent is impeded mechanically and essential areas remain untreated. In crutches soiled with more liquid excretions a less severe mechanical obstacle results. If, however, soiling with liquid faeces has occurred over a considerable period prior to treatment appreciable amounts of wool grease, which alone can absorb and hold the protecting compounds, are removed and this will permit of a smaller insecticidal deposit. A shorter period of protection will result in both cases. The first diffuse strike will occur fairly soon after application, (Table 5), and consequently, more strikes will be recorded during the observation period in sheep with soiled crutches than in animals that remain clean (Table 6).

TABLE 5.

Occurrence of the First Diffuse Strike in Flocks Carrying 3-4 Months Wool, Clean and Soiled, at the Time of Treatment.

Insecticide. (1% Dust.)	Clean Crutch.	Soiled Crutch.
	Days after Treatment.	Days after Treatment.
Dieldrin	93	38
Lindane	30	25

TABLE 6.

The Number of Accumulated Strikes During the Period of Observation of 13 Weeks for Long-Woolled Sheep, Clean and Soiled at the Time of Treatment.

Insecticide.	Clean.			Soiled.		
	Number of Sheep.	Strikes.	Percentage Strikes.	Number of Sheep.	Strikes.	Percentage Strikes.
Controls	16	43	269	29	183	631
B.H.C.	13	19	146	35	119	340
Dieldrin	20	2	10	28	30	107
Diazinon	25	2	8	22	17	77

It is interesting to note that the decrease in duration of protection applies not only to compounds which are known to be rather unstable, like B.H.C. but also to insecticides such as Dieldrin, which are considered to be very stable under a variety of conditions. This indicates that it is not the chemical properties which have been affected but that the soiling itself, by forming solid masses in the wool, has presented a physical obstacle to thorough penetration.

The various formulations react differently to these conditions. Whereas in clean and slightly soiled crutches the best results are obtained with wettable powders and emulsions, and dusts take a second place, it is the emulsion that is relatively superior to wettable powders in very soiled wool on account of its better powers of penetration. The most inferior results are obtained with dusts in these cases.

These contentions appear to contradict the conclusions arrived at above where it was stated to be more advantageous to treat very soiled crutches than to "crutch" the area and remove the caked wool prior to treatment. When, however, the duration of protection in an extremely soiled breech with long wool is compared with that of a crutched animal, where the remaining wool is very short, it will always be found that better results are obtained with the long and soiled wool, especially when emulsions are used. In other words, longer protection results in soiled wool of suitable length than in clean, very short wool. In both cases, however, protection is inferior to that experienced with clean wool of a length of one-and-a-half inches and over.

These findings explain the complaints frequently raised by sheep farmers that the insecticides Diazinon, Dieldrin and Aldrin, fail to give protection for three months and over, as claimed on the labels. It must be borne in mind, however, that these claims are justified under normal conditions only and do not apply where extremes are encountered. In general it must be emphasized that soiling of the breech has a profound effect on the duration of protection in the length of one-an-a-half inches and over.

A further point in this connection should be mentioned which is responsible for aggravating the effects of wool soiling and this is the effect produced by skin folds in the region of the breech. Table 7 shows the number and percentage of strikes encountered in sheep of the same flock with slight and well-developed skin folds after application of different insecticides.

TABLE 7.

The Number and Percentage of Blowfly Strikes Amongst Long-Woolled Sheep Treated with Different Insecticides Applied as Wettable Powders at 0·5 *Per Cent a.i. During the* 13 *Weeks Following Treatment.*

Insecticide.	Development of Breech Folds.					
	Slight.			Well-developed.		
	Number. of Sheep.	Number of Strikes.	Percentage Strikes.	Number of Sheep.	Number of Strikes.	Percentage Strikes.
Controls................	39	200	513	12	59	492
B.H.C..................	29	79	272	18	55	306
Dieldrin................	31	17	55	18	16	89
Diazinon................	33	8	24	14	11	79

The results demonstrate that the presence of well-developed skin folds exerts an effect particularly in the case of the more active compounds, e.g. Dieldrin and Diazinon, whereas their effects are virtually inapparent in the case of untreated sheep or on those treated with a less potent agent. The explanation appears to lie in the fact that in animals treated with insecticides prone to rapid breakdown, as also in untreated sheep, such adverse conditions have been encountered that the situation cannot be further aggravated by the additional presence of skin folds. A different situation, however, is met with in the case of the more potent agents. It may be deduced from Table 6 that soiling has a greater effect proportionally on Diazinon and Dieldrin than on B.H.C. About 10 times more strikes expressed as a percentage were encountered on very soiled sheep treated with Dieldrin or Diazinon compared with slightly over twice as many where B.H.C. was used. Since excessive development of skin folds results in a larger and more thoroughly soiled area, these otherwise valuable and well-suited compounds may encounter conditions where the profound influence exerted by skin folds commences to show up distinctly on a proportional basis.

(*c*) *The Age of the Sheep.*

During the course of the field trials many farmers in the experimental area maintained that the modern insecticides, though producing spectacular results in adult sheep, gave only very short protection in the case of lambs. A number of comparative experiments was conducted with lambs and fully-grown sheep to test the validity of this contention.

As a pilot test a number of lambs, one month of age together with their dams, was treated in the crutch region with a wash containing 0·25 per cent Dieldrin in the form of a wettable powder. Blowflies were very prevalent at the time and the first diffuse strikes amongst the lambs occurred a fortnight after treatment, whereas no strike was observed amongst the ewes. Additional results from parallel experiments conducted under the same conditions are given in Table 8.

TABLE 8.

The Protection Given by Insecticides to Adult Sheep as Compared with Lambs 3-4 Months Old.

Protecting Agent.	Dieldrin Dust.		Dieldrin W.P.		Diazinon W.P.	
Type of Sheep.	Lamb.	Ewe.	Lamb.	Ewe.	Lamb.	Ewe.
Length of wool in months	3–4	$3\frac{1}{2}$	4	2	4	2
Days to first localized strike	30	58	36	71	134	Over 198
Days to first diffuse strike	58	93	Over 71	Over 97	Over 198	Over 198
Percentage strikes for this period................	10·7	2·4	10·0	6·5	5·3	0*

* No strikes were encountered in the Diazinon-treated ewes during the observation period of 198 days.

Young lambs were protected for a shorter period than adult sheep in all the experiments conducted and this increased susceptibility to strikes is still very evident in four months old lambs. There seems to be a direct correlation between the duration of protection and the age of the animal up to the time of the first shearing.

The underlying cause of this phenomenon has not yet been fully investigated but may lie in the fact that the fleece of lambs differs substantially in density and structure from that of mature sheep and appears to be incapable of building up and retaining an insecticidal residue sufficiently high to effect a long duration of protection. Since young lambs can be protected for only comparatively short periods even with the most potent insecticides such as Diazinon and Dieldrin, they must be closely watched during periods of great activity of blowflies in order to avoid losses from strikes.

Factors Introduced by the Blowfly.

When a comparison was drawn between protection periods afforded by particular insecticides conducted to all intents and purposes under identical conditions, a considerable variation in the lengths of protection was noted. Double and even three times the duration of protection was observed in certain instances, and this variation could not be attributed to any of the factors demonstrated previously. A satisfactory explanation of this phenomenon was forthcoming, however, when the prevalence of blowflies in the different localities was taken into consideration. It could be shown in all the field experiments that the density of the fly population had a profound bearing on the length of protection exerted by any of the insecticides under test. This factor, which is here designated the " fly population pressure ", was found to exert so marked an influence that it overshadowed all other factors. For this reason any figures expressing the duration of protection should always be accompanied by a statement on the fly population pressure or otherwise it is not possible to assign to them either scientific or practical significance.

The duration of protection in terms of field trials must be terminated by an arbitrary end-point arrived at by practical considerations. Equal status should always be given to the fly population pressure. As has been the practice throughout this investigation the occurrence of the first diffuse strike amongst the treated flock is the arbitrary point decided upon to mark the end of protection in the following calculations. Since a number of localized strikes is found to occur with all protecting agents before this end point is reached, the period of protection can be further subdivided. The time between treatment and the occurrence of the first localized strike is considered as the " period of full protection ", whereas the time lapse between the first localized and the first diffuse strike is designated the " period of partial protection ". Full and partial protection together make up the " total period of protection " which is the time limit set during which, in practice, no threat to the life of treated animals exists.

Furthermore, for purposes of this investigation the fly population pressure is expressed in terms of the percentage of accumulated strikes amongst the control animals during a given period, which is of equal length for all experiments. The period of twelve weeks following treatment was chosen as the standard for all the trials for the sake of uniformity, as this was the shortest period of observation ever applied. In this way, the fly population pressure represents the average figure for this period and makes a straight comparison possible between the results of the different trials. Table 9 shows the empirical figures of the periods of protection in days obtained with different insecticides as well as the corresponding fly population pressure in a number of field trials.

TABLE 9.

Periods of Protection Obtained with Different Insecticides and the Corresponding Fly Population Pressures.

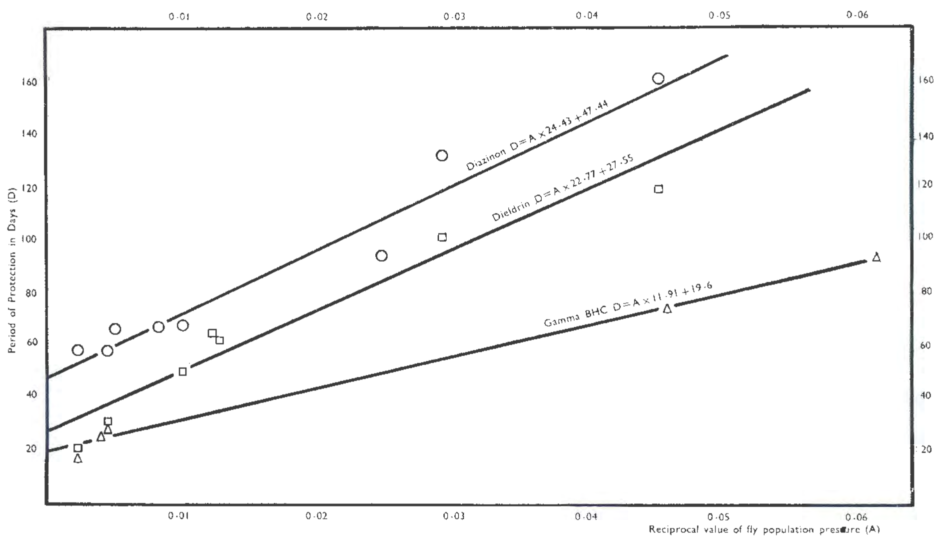
Number of Experiments.	Period of Full Protection in Days (First Localized Strike)	Total Period of Protection (First Diffuse Strike).	Fly Population Pressure.	Reciprocal Value thereof.	Conditions of the Crutch Region.
Gamma B.H.C.					
1/53..........	93	103	16·3	0·0615	Soiled.
2/53..........	74	Over 76	21·6	0·0461	Clean.
2.............	30	30	222·2	0·0045	Clean.
12............	25	25	249·2	0·0040	Soiled.
II............	17	34	439·7	0·0023	Soiled.
Dieldrin.					
3c............	119	Over 161	22·0	0·0455	Soiled.
(1)...........	73	80	33·9	0·0295	Soiled.
(3)...........	129	129	33·9	0·0295	Clean.
(25)..........	80	80	79·0	0·0127	Soiled.
(26)..........	46	80	79·0	0·0127	Soiled.
111b..........	64	92	80·4	0·0124	Clean.
(12)..........	50	Over 98	92·4	0·0108	Clean.
3.............	30	93	222·2	0·0045	Clean.
III...........	21	90	439·7	0·0023	Soiled.
Diazinon.					
4c............	Over 161	Over 161	22·0	0·0455	Soiled.
(2)...........	Over 149	Over 149	33·9	0·0295	Clean.
(4)...........	115	Over 149	33·9	0·0295	Clean.
33............	93	93	40·0	0·0250	Clean.
(11)..........	65	Over 98	92·4	0·0108	Soiled.
30............	70	Over 77	92·4	0·0108	Soiled.
(21)..........	67	Over 109	120·0	0·0083	Soiled.
33b...........	61	71	198·2	0·0051	Soiled.
34b...........	71	Over 91	198·2	0·0051	Soiled.
4.............	58	Over 93	222·2	0·0045	Clean.
I.............	58	77	439·7	0·0023	Soiled.

TABLE 10.

	Period of Full Protection (to first small strike).		Total Period of Protection (to first diffuse strike).	
	„d"	„k"	„d"	„k"
Diazinon.....................	47·44	2443	74·65	1195
Dieldrin.....................	27·55	2277	75·24	1420
B.H.C........................	19·6	1191	25·2	1714

When the figures for the duration of full protection as well as for the total period of protection, respectively, are plotted against the corresponding figure for the fly population pressure, a curve is obtained which closely resembles a hyperbola (Graph 2). The equation of a hyperbola is $D \times B = K$, where $D =$ Time of Protection and $B =$ Fly Population Pressure. This means that the product of the duration of protection and the fly population pressure must always be constant, if this type of correlation applies. It has to be assumed that a certain minimum period of protection (d) is achieved at an infinitely high fly population pressure, which means, that the hyperbola will become parallel to the B axis at the distance from the latter $= (d)$. It can be expected furthermore that the period of protection is infinite at a fly population pressure $= 0$, which means, that the hyperbola will touch the D axis. The formula of the hyperbola from this assumption is, $(D - d) \times B = K$. The values for d and K can be found when using the reciprocal value of B, the fly population pressure, by using the method of the least squares. The values for d and k as found by this method for the three insecticides Diazinon, Dieldrin and B.H.C. are given in Table 10 and Graph 1.

GRAPH 1.



The hyperbolas for full protection can be based on the following equations:—

$$\text{I. Diazinon: } B = \frac{2443}{D - 47 \cdot 44}$$

$$\text{II. Dieldrin: } B = \frac{2277}{D - 27 \cdot 55}$$

$$\text{III. Gamma B.H.C. } B = \frac{1191}{D - 19 \cdot 60}$$

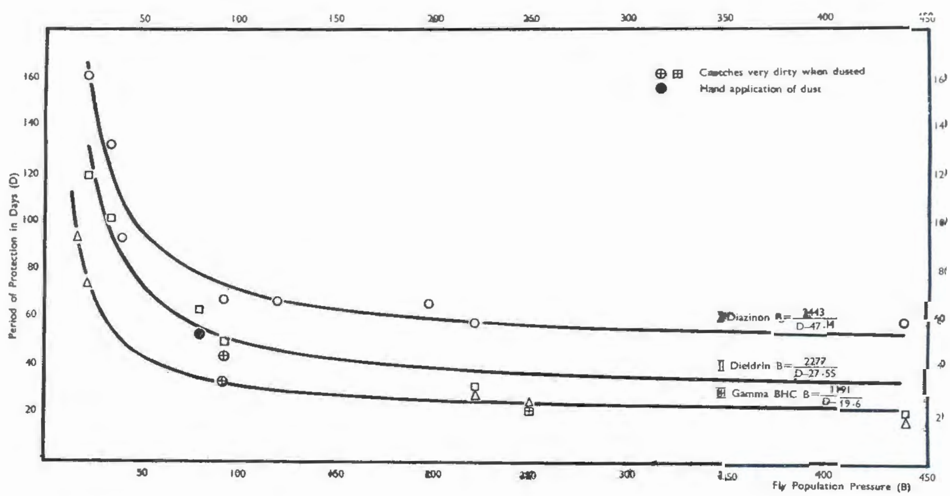
B represents the fly population pressure and D the period of full protection. The different points of the hyperbola, are given in Table 11, whereas the graphs are shown in Graph 2.

TABLE 11.

Correlation between the Fly Population Pressure (B) and the Period of Full Protection (D) for Diazinon, Dieldrin and Gamma B.H.C.

I. Diazinon.		II. Dieldrin.		III. Gamma B.H.C.	
B.	D.	B.	D	B.	D
493	53	460	32·5	496	22
372	54	353	34	350	23
285	56	241	37	221	25
211	59	183	40	127	29
157	63	138	44	73	36
113	69	101	50	49	44
83	77	70	60	34	55
62	87	48	75	24	70
46	100	31	100	17	90
34	120	22	130	12	120
24	150	15	180	9	150
18	180	—	—	7·5	180

GRAPH 2.



Graph 2 demonstrates that the results of the field trials fall well within the limits of a hyperbola thus proving that the correlation is applicable under natural conditions in the field. Three examples for Diazinon and one for Dieldrin are quoted, however, where the relationship does not conform with this standard due to other factors strongly influencing the results, such as very soiled crutches and the application of dust by hand respectively. All the other empirical points represent the results obtained with sheep, as normally encountered under field conditions in the Karoo. The graph shows that Diazinon gave the longest full protection followed by Dieldrin and Gamma B.H.C, Dieldrin occupying an intermediate position between the other two. The difference between the three curves is significant. The question as to whether the relation between the period of full protection and the fly population pressure does follow the trend of a hyperbola and not that of a straight line can be tested. The sum of the squares of the distances of the points of observation from a straight line and from a hyperbola shows clearly that the trend between fly population pressure and period of full protection follows that of a hyperbola as is given in Table 12.

TABLE 12.

Sum of the Squares of the Distances of the Observed Points from a Connecting Hyperbola and a Connecting Straight Line.

	Hyperbola.	Straight Line
Diazinon	657·9	5859·6
Dieldrin	496·01	2541·2
B.H.C.	54·62	698·7

When the position for the total period of protection is considered, the picture is somewhat different. The equations in this case are:—

I. Diazinon: $B = \dfrac{1195}{D - 74 \cdot 65}$

II. Dieldrin: $B = \dfrac{1420}{O - 75 \cdot 24}$

III. Gamma B.H.C. $B = \dfrac{1714}{D - 25 \cdot 20}$

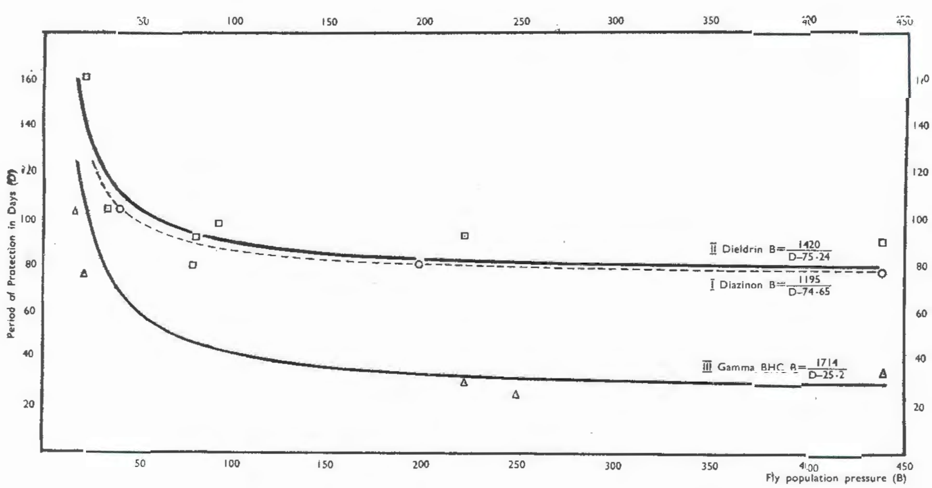
Again it is seen that the resultant trends are those of hyperbolas as is shown in Table 13 and Graph 3.

TABLE 13.

Correlation between the Fly Population Pressure (B) and the Total Period of Protection (D) for Diazinon, Dieldrin and Gamma B.H.C.

I. Diazinon.		II. Dieldrin.		III. Gamma B.H.C.	
B.	D.	B.	D.	B.	D.
509	77	—	—	45	29
357	78	449	79	357	30
275	79	275	81	252	32
163	82	174	84	175	35
105	86	117	88	124	39
73	91	83	93	87	45
51	98	61	99	64	52
38	106	47	106	49	60
30	115	37	114	38	70
24	125	29	124	29	85
16	150	21	144	23	100
11	180	17	160	17	125
—	—	—	—	11	180

GRAPH 3.



The curves possess a zero line, i.e. the minimum period below which no diffuse strike can be expected under any circumstances, about 74 days in the case of Diazinon, 75 days for Dieldrin, and 25 days for gamma B.H.C. The difference between Diazinon and Dieldrin is not significant, but there is a significant difference between gamma B.H.C. and the other two.

Furthermore, Graphs 2 and 3 reveal another significant point and afford an explanation of the phenomenon that an extremely long duration of protection is sometimes observed with compounds of only mediocre efficacy like B.H.C. The duration of protection increases rapidly on the left side of each hyperbola and eventually becomes infinitely long, which signifies that a low fly population pressure results in a very long period of protection in spite of an inferior insecticide. The validity of this deduction was demonstrated in the case of two experiments with Lindane dust, (No. 1/53 and 2/53), where full protection of 93 and 74 days respectively was recorded, and a total protection of 103 days in the case of Expt. No. 1/53 (see Table 9).

As to the fourth compound under test, namely Aldrin, it can be stated that it behaved in a very similar manner to Dieldrin. Although a smaller number of trials was conducted with Aldrin wettable powder, no significant differences could be detected between the protection afforded by it and that of Dieldrin with the same formulation, when the fly population pressure was taken into consideration. Table 14 is given as an example.

TABLE 14.

Degree of Protection by Dieldrin and Aldrin. (Sheep of the two Groups Grazea as one Flock.)

Weeks after Treatment.	Degrees of Protection, Percentages.	
	Dieldrin.	Aldrin.
1	100	100
2	100	100
3	100	100
4	100	100
5	99·88	100
6	99·7	99·45
7	97·38	95·93
8	96·48	95·28
9	95·29	94·52
10	95·29	94·52
11	92·97	93·41
12	60·99	42·8

Difference of 1·2 per cent in favour of Dieldrin is not significant.

PROTECTING PROPERTIES OF THE INSECTICIDES UNDER FIELD CONDITIONS.

The following conclusions regarding the efficacy of the compounds under test as protecting agents against blowfly strike can be drawn from the field experiments. Three of the four insecticides, namely Diazinon, Dieldrin and Aldrin can be regarded as excellent, whereas gamma B.H.C. has proved to be inferior. Since the duration of protection depends to a large extent on factors such as the fly population pressure, the condition in the crutch region at the time of treatment. etc., as was discussed previously, it is scarcely possible, even with a large number of trials, to produce evidence sufficiently detailed to warrant a proper classification of the compounds under test. It should be stated rather that each of the compounds has its advantages and disadvantages and that the differences between them were so slight, except in the case of B.H.C. as to be regarded as insignificant. In any event it became apparent that it was not possible to express the biological results in terms of figures which would indicate the absolute duration of protection exerted by each compound, due to the many factors discovered during the course of the investigation which influenced the picture and had not been considered in previous publications. As the fly population pressure has proved to be the dominant influence any statements on the duration of the period of protection are of value only if accompanied by an evaluation of this factor. Furthermore, the efficacy of different compounds can be assessed only if the fly population pressure as well as the other factors, having a bearing upon the question, are more or less constant and this occurs only under field conditions when the comparison is made within a single flock.

Another way by which it seems possible to determine the value of insecticides is to exclude, by careful selection of sheep, those factors having a minor effect only, and to establish the correlation between the fly population pressure and the duration of protection by means of properly and regularly controlled experiments in a diversity of localities. In this way reliance may be placed on results such as are given in Graphs 2 and 3, where the protection can be compared at equal values of fly population pressure. With this in mind the insecticides under test can be classified for their value in practice as follows:

(1) *Diazinon.*

This compound acts somewhat differently to the hydrocarbon insecticides, Dieldrin and Aldrin, in that it produces a significantly longer period of full protection at any degree of fly population pressure. This property, however, has little bearing on the practical value of the compound. When consideration is given to the total period of protection there is no difference between Diazinon and compounds of the Indene group. A breakdown of its protecting property will occur eventually within the limits imposed by its molecular structure even if the fly population pressure is negligible.

(2) *Dieldrin.*

Theoretically speaking this compound is in certain respects slightly inferior to Diazinon as its period of full protection is significantly shorter. The early occurrence of localized strikes which constantly increase in size and number may soon demand the attention of the farmer. Its total period of protection, however, is the same as that of Diazinon.

(3) *Aldrin.*

No significant difference could be demonstrated between the protecting properties of Dieldrin and Aldrin at equal fly population pressures. There are indications that it might break down slightly sooner than Dieldrin, and in this way it resembles Diazinon at low fly pressures.

(4) *Gamma B.H.C.*

This compound must be regarded as inferior to the others under conditions normally encountered in the Karoo. One interesting fact, however, is that this compound is not much inferior to the other three under conditions where wool has not undergone soiling.

At medium or high fly pressures, which occur in many parts of the Karoo, Diazinon, Dieldrin and Aldrin are the insecticides of choice at the present stage of our knowledge. B.H.C. preparations, on the other hand, are unstable in the presence of soiled fleeces and can be recommended only where sheep are clean and dry.

The Efficacy of the Mule's Operation as Compared with Insecticides.

The Mule's operation in its original and modified form was designed to eliminate by surgical means all skin folds in and around the crutch region, and in this way produce a sheep less susceptible to blowfly strike. This method, although very popular in Australia, has not found many followers in South Africa.

To evaluate the merits of this method of protection and to compare its efficacy with the protection achieved by chemical means, two trials were conducted where " muled " sheep of the same type were exposed to natural strikes together with other groups treated with insecticides such as Dieldrin, Diazinon and B.H.C. as well as untreated controls.

A flock of 250 sheep, obtained as culls from Merino breeders because of their excessive development of skin folds, was divided into 5 equal groups, one of which was selected at random and subjected to the Mule's operation.* A second group remained untreated and served as controls, whereas the other three groups were treated with either Diazinon, Dieldrin or Gamma B.H.C. respectively, each sheep receiving one pint of a suspension containing 0·25 per cent of the active ingredient. In the first experiment the sheep were carrying about nine months wool and in the second the treatment was applied two months after shearing, so that long wool could be compared with short wool. The results were more pronounced in the first trial, but the two tests simulated each other so closely that a statistical analysis was possible.

The fly population pressure was very high during the first 12 weeks of the first experiment (439·7) and moderately low during the second (80·4).

Observations made during the course of the trials showed that the " muled " sheep were considerably cleaner than the other groups, but that soiling was not entirely absent. Despite the fact that the Mule's operation had been carried out very well three sheep of the group had to be classed as " very dirty and very wet ". As could be expected, the protection afforded by the Mule's operation to animals like those that became very dirty and wet, was practically nil.

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* The authors wish to thank Mr. A. de Vries and other staff members of the Agricultural College, Grootfontein, C.P., for the classification of the sheep into the 5 groups and for the performance of the Mule's operation.

The results of the two experiments are recorded in Table 15.

TABLE 15.

Percentage of Strikes Occurring Amongst "Muled" Sheep as Arranged Against the Corresponding Fly Population Pressure.

Weeks after Treatment (second experiment in brackets).	Fly Population Pressure.	Percentage of Strikes "Muled" Sheep.
1, 2, 3, (1), (6), (18)	0	0
(20)	1·9	0
(7), (15), (19)	3·9	0
(9), (17)	5·9	0
(10)	7·8	0
(12)	9·8	0
(11)	13·7	0
(14)	21·6	0
4, 6, 7	23·5	2·1
5	27·4	0
(13)	29·5	2·2
(16)	31·4	4·7
13	36·0	0
10, (8)	41·1	0
8	54·9	6·2
12	54·9	10·4
14	66·0	6·2
11	80·4	16·7

This table indicates that the occurrence as well as the abundance of strikes amongst "muled" sheep is closely dependent on fly population pressure, and that this relationship, is statistically significant. The decline in the protective capacity of the operation can be estimated by the method of least squares, and is demonstrated in Graph 4.

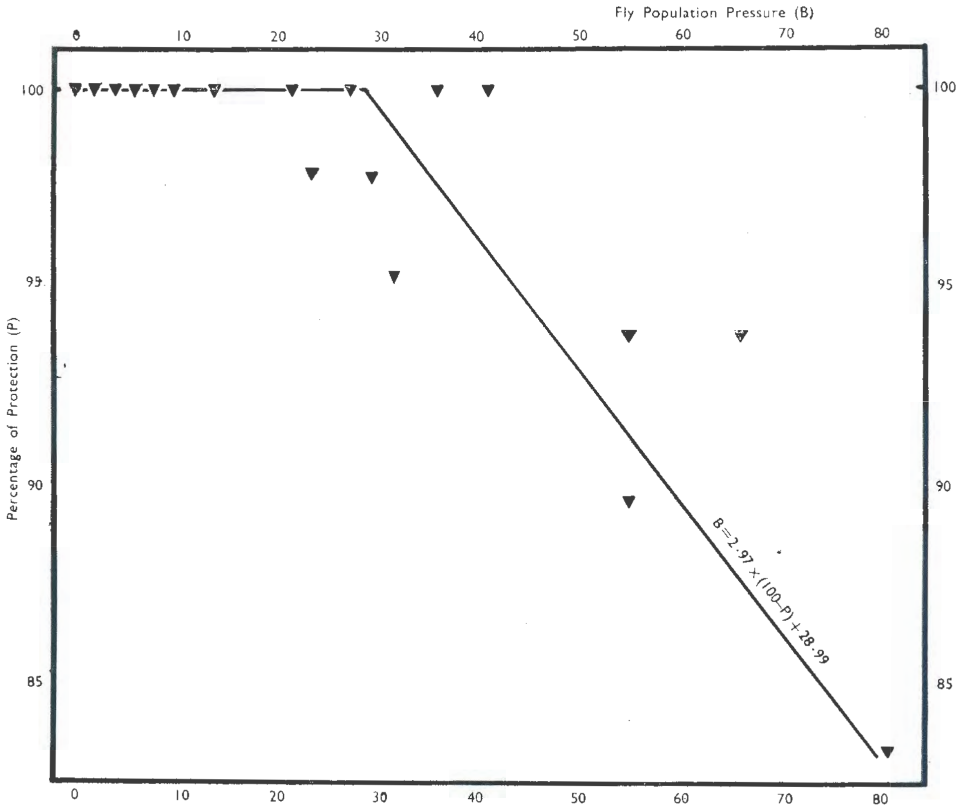
It is interesting to note that up to a fly population pressure of about 29, almost no strikes will occur amongst the "muled" animals but that beyond this point strikes can be expected in increasing numbers. The Mule's operation, therefore, affords full protection up to a moderate fly population pressure, and beyond this point "muled" sheep are as susceptible as animals left entirely untreated. In comparison with the protection afforded by insecticides, Graph 2 demonstrates that Diazinon and Dieldrin give a total protection of 55 and 35 days, respectively even at very high fly population pressures.

Furthermore, it can be stated that the length of wool has an adverse effect on the efficacy of the Mule's operation in that it tends to become soiled in spite of this operation.

When comparing the protection afforded by the Mule's operation with that of chemical agents, and the incidence of strikes amongst untreated animals, as demonstrated in Graph 5 for the first experiment, it can be seen that the number of strikes per week in the "muled" group follows closely the trend of the controls.

The same applies to an insecticide of inferior potency such as B.H.C., before its protecting properties fade out entirely, whereas compounds like Dieldrin and Diazinon seem to be unaffected by the level of weekly fly incidence throughout the total period of protection attributable to them.

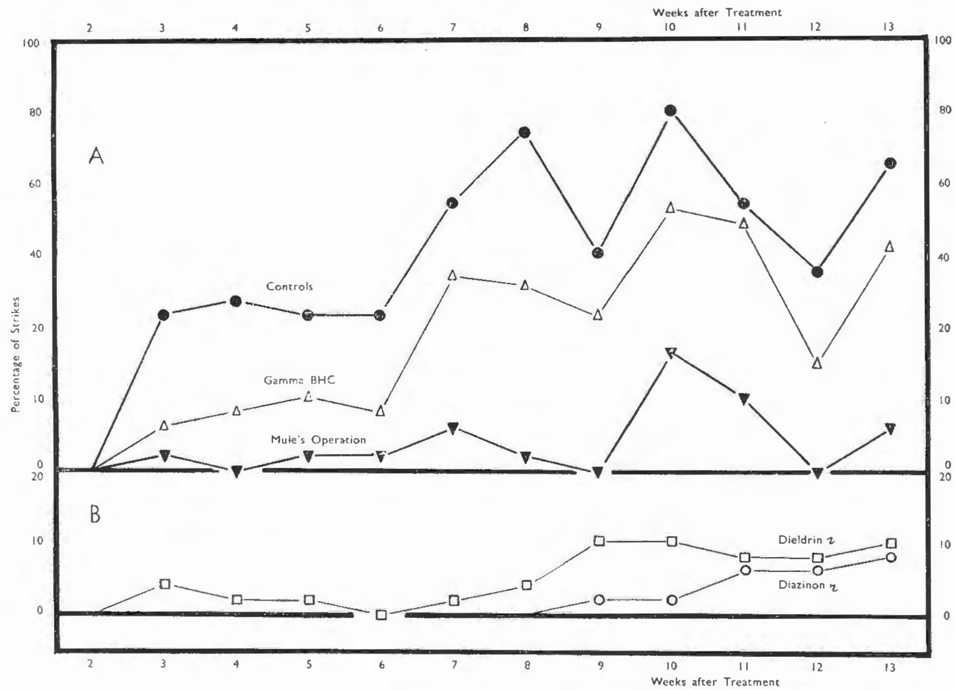
GRAPH 4.



The greatest disadvantage of the Mule's operation, however, is that all strikes usually are diffuse strikes and are unrestricted in their development as is the case in untreated animals. It is for this reason that farmers, relying entirely on the efficiency of the Mule's operation, may be faced with severe losses during periods of great blowfly activity, especially in bushy country where regular inspections of flocks are difficult.

The Mule's operation, therefore, can only be regarded as an efficient means of protection when the incidence of blowflies is low or the wool is not too long. In areas where fly activity is always high, as is experienced in many parts of the Union, an insecticide should be applied in addition to the Mule's operation in order to avoid losses.

GRAPH 5.



CONCLUSIONS.

The large number and diversity of the field experiments conducted in areas of the Karoo, well-known for a high degree of blowfly activity, in which four insecticides originally selected for their larvicidal properties by "in vitro" and "in vivo" tests, have made possible their accurate evaluation. A number of factors adversely affecting the efficacy of these protecting agents was shown to be operative as a result of this investigation.

The adverse factors can be divided into two groups some of which, firstly, are operative at the time of application of the insecticide and, secondly, others which manifest themselves later. In both cases the effect is a reduction in the duration of protection afforded by the particular insecticide applied.

Factors belonging to the first group include:—

(1) formulation of the insecticide;
(2) mode of application;
(3) length of the wool;
(4) soiling of the wool.

A factor that produces its effect later is the density of the blowfly population, here expressed as fly population pressure.

If animals can be treated under optimal conditions (medium long, dry wool thoroughly wetted down to skin level by a suspension) the greatest period of protection consistent with the fly population pressure will result. The fly population pressure constitutes the factor of the greatest imporance and can be responsible for a considerable decrease in the degree of protection. For this reason, any figures concerning the duration of protection must be correlated with the fly population pressure in order that the protecting properties of a particular compound can be compared with those of others. Failing this, a statistical assessment is not possible.

The fly population pressure is dependent upon geophysical and climatic conditions and cannot readily be affected by control measures and thus excluded, whereas most of those factors exerting their influence at the time of insecticide application can be eliminated or mitigated. In this way, the significance of the second important influence listed, the degree of soiling of the breech, will be diminished by selecting the correct formulation of the insecticide. Dusts, in such cases, are of limited value only and wettable powders or emulsions should be used. In cases of extremely soiled breeches, where the wool is extensively matted, emulsions will afford a longer period of protection than wettable powders due to their greater powers of penetration, whereas, better results are observed with wettable powders when soiling is less pronounced.

Of the compounds tested as protecting agents against strike in this investigation it may be said that Diazinon, Dieldrin and Aldrin are the only safe insecticides at present known that are least influenced by adverse factors and thus will afford protection of considerable duration even in the presence of a high fly population pressure. A protection lasting for two and a half months can be expected under all circumstances, provided a sufficient amount of the active ingredient has been applied thoroughly.

The differences in duration of protection obtained with the three compounds are statistically not significant. It is not possible, therefore, for practical purposes to pronounce any one as the absolute best although Diazinon shows certain properties at high fly pressure which points to its being slightly superior. Although flocks could be protected with any of the three compounds for four to five months at a very low fly population pressure, none of the insecticides was able to protect them for an entire blowfly season. Sheep should be treated twice and even more often per season to ensure a sufficient degree of protection.

Regarding the value of B.H.C. it was concluded that its stability is insufficient to afford adequate protection with the fly incidence normally encountered in the typical blowfly areas.

Summary.

A large number of field trials under close supervision was conducted in the blowfly areas of the Karoo to investigate certain biological aspects of blowfly strike as well as the protection afforded to sheep by the insecticides Diazinon, Dieldrin, Aldrin and B.H.C. under natural conditions.

(1) The biological factors rendering sheep susceptible to blowfly strike are reviewed.

(2) Observations on the development of strikes in sheep treated with an insecticide as compared with unprotected animals are reported.

(3) The larvicidal value of the compounds tested are discussed, as well as the factors influencing the duration of protection afforded by them.

(4) Dusts and wettable powders gave longer protection than emulsions in sheep with clean and dry crutches, whereas emulsions and wettable powders gave better results in soiled sheep.

(5) The protecting agent must be evenly distributed throughout the vulnerable areas of the fleece right down to skin level to ensure the maximum degree of protection.

(6) No significant difference in duration and degree of protection was observed with quantities of between 0·45 and 2·85 gm. of the active ingredient per crutch region. This is probably due to this factor being overshadowed by others.

(7) Insecticides gave better protection when applied to long wool than to short wool. The crutching of soiled breeches is discouraged, therefore.

(8) Soiled crutches exercise an influence upon the uniformity of the application and, consequently, upon the duration and the degree of protection. This is particularly evident in the case of B.H.C. No significant differences could be detected between Diazinon, Dieldrin and Aldrin.

(9) All insecticidal compounds afford a considerably shorter period of protection on young lambs than on adult sheep with an equal or even shorter length of wool.

(10) The incidence of blowflies (fly population pressure) exercises the most significant influence upon duration of protection afforded by any of the insecticides. The relationship between fly population pressure and duration of protection follows the equation of a hyperbola.

(11) The duration of protection afforded by Diazinon, Dieldrin and Aldrin showed no significant differences under equal conditions, whereas B.H.C. was markedly inferior.

(12) The Mule's operation affords adequate protection as long as the incidence of flies is low and the wool fairly short. With higher fly population pressures the resistance of "muled" sheep to fly strike decreases rapidly.

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