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The Eradication of the Sheep Tick

By L. D. SWINGLE

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The Eradication of the Sheep-Tick

(By *LEROY D. SWINGLE.*)

In a recent bulletin (No. 99) the results of my work on the life-history of the sheep-tick were published. Those results, together with more recent data obtained regarding the action of sheep dips upon the ticks, serve as a basis for determining efficient methods of eradicating this pest.

Errata:

BUL. 105, ERADICATION OF THE SHEEP-TICK.

Page 29, line 1, "objects" should read "object."

Page 33, line 27, "quite" should read "quiet."

Page 35, line 10, "immerser" should be "immersed."

Page 36, line 8, "Coopers's" should be "Cooper's."

Page 42, line 14, should read: "before any will have laid pupae."

Page 42, line 17, "dippins" should be "dippings."

Page 46, line 2, under (d), "wark" should be "work."

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out and infect the whole flock.

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In a recent bulletin (No. 99) the results of my work on the life-history of the sheep-tick were published. Those results, together with more recent data obtained regarding the action of sheep dips upon the ticks, serve as a basis for determining efficient methods of eradicating this pest.

It is common knowledge that all the ticks on a flock of sheep can be destroyed by any one of several sheep dips. Every one also knows that after a few months the sheep are found to be reinfested. The owner often attributes this to the sheep's picking up stray ticks from bedding or vegetation of the pasture. This error is doubtless due to the fact that he does not distinguish between the sheep-tick and the *true* tick, which may live for a long time off its host. The sheep-tick will live but a short time, generally but three or four days, off the sheep and is not prone to leave its host. The true explanation of reinfestation lies in the fact that none of the sheep dips are effective in destroying all of the pupae (eggs) present in the wool at the time of the dipping. And, therefore, in a few days after dipping, young ticks hatch out and infect the whole flock.

If a dip were available that would absolutely kill not only all of the ticks but all the pupae without injury to the sheep or wool, the problem of complete eradication of the sheep-tick would be easily solved. Yet, though such a dip is doubtless not to be had, it is still perfectly

possible to eradicate the tick not merely from a few flocks of sheep but as well from the whole state or even the United States.

In discussing the eradication of the sheep-tick the following important questions must be considered:

1. What is the effect of sheep dips upon the pupae (eggs)?
2. Does dipping of the pupae modify their incubation period?
3. What is the effect of various dips upon the tick?
4. Which are the best dips to use?
5. How many dippings are necessary, and when should they be made, in order to eradicate the tick?

In solving these problems it was not expedient to try all of the sheep dips that are on the market. Some of the dips having a good reputation were used. There may be other dips as good or perhaps better. But the main object was to find a dip that would certainly kill the ticks and accomplish this result without much injury to the sheep and the wool, and without excessive cost and inconvenience.

In the experiments to determine the effect of dips upon the pupae and ticks, the element of time was considered important.

In dipping for sheep-ticks only, it was considered impractical to leave the sheep in the bath more than one minute unless no dip could be found that would be effective in that time. However, in case a very long vat is used the sheep would naturally remain in the bath more than one minute. This would also be true if the sheep were being dipped not only for ticks but also for scabies because in dipping for the latter it is the practice to leave the sheep in the bath longer in order to soak up the scabs. Since in these experiments only the sheep-tick was being considered, the pupae and ticks were generally immersed only one minute.

In the first experiments on the pupae the only objects was to determine whether pupae would hatch after being treated with sheep-dips. The percentage of pupae killed was considered in some of the later experiments. The first four experiments were carried out on lambs, and the dips used were Cooper's powder, Zenoleum, crude carbolic acid and the official lime and sulphur dip. In every case pupae hatched readily. In the case of the lime and sulphur dip even the ticks themselves were not killed.

Some laboratory tests were then made with several other dips. In each case several pupae were placed in the center of a handful of wool, which was then immersed in the dip. The wool was removed after one minute and allowed to drain and dry, much as in the case of actual dipping. The following dips were tried: Chloroleum 1:63, Carboleum 1:100, Cooper's Fluid Dip 1:150, Kreso 1:75, Chloro-naphtholeum 1:50, Zenoleum 1:50, and kerosene emulsion, the quantity of kerosene being 25 per cent. Many pupae from each group, except that dipped in kerosene, hatched.

It is therefore seen that none of these dips, except kerosene, will kill all the pupae. But kerosene in 5 per cent strength will not kill all of them and in a higher percentage it is impractical. Even Zenoleum in 2 per cent. strength will not kill all of the pupae.

In some other laboratory tests the relative killing action of several dips on pupae was considered. At first no controls were kept but it soon became apparent that they were necessary in order to give an accurate estimate of the killing power. From these experiments the relative killing action may be indicated by the following tabulation in which the strongest is placed first and the weakest last: *

**"Black Leaf 40" was also used in these tests, the results being represented by 11.1 units. It is claimed that Black Leaf is slower in its action and hence the directions demand that the sheep be kept in the bath two minutes. In this test the pupae were immersed only one minute.

Kreso 1:75	48.9
Sanitary Fluid (Betz) 1:200	48.1
Zenoleum 1:100	45.8
Crude Carbohc Acid (drug store sample) 1:200	41.4
Crude Carbohc Acid (drug store sample) 1:800 and Kerosene 1:20 plus 1 per cent. soft soap	40.3
Zenoleum 1:100	28.0
Minor's Fluid 1:80	28.0
Chloroleum 1:63	23.2
Sanitary Fluid (Betz) 1:100 plus 1/2 per cent. hard soap	14.0
Crude Carbohc Acid (drug store sample) 1:400 plus 1/8 per cent hard soap	12.9

It will be seen that there are variations even in the action of the same dip and hence not much reliance can be placed upon these results except when they are confirmed by other experiments.

There are evidently some unknown factors involved.* In every instance but one the pupae of the controls began to hatch before those that had been dipped. This probably is due largely to the cooling action of the wet wool rather than to the possible fact that the pupae which were about ready to hatch were killed by the dips. Another important fact is that the controls continued in every case to hatch for several days after all hatching had ceased among the groups that had been dipped. This means that all of the youngest pupae were killed by the dips, and this conclusion is supported by other data. These experiments indicate that more than one dipping must be made if the tick is to be eradicated.

*Some later experiments which are not reported in this paper indicate that there are certain physical or chemico-physical factors involved in the action of dips upon ticks. Further experimental work, which is being prosecuted along these lines, must be completed before the facts can be presented.

In using the life-history as a basis for determining when the last dipping should be made in order to eradicate the tick, it is necessary to know whether the first dipping lengthens the incubation period of the pupae that are not killed. Since the dips will not kill all of the pupae, it is necessary to place the last dipping after every pupa has hatched. In the summer time the normal incubation period may reach 23 days, so that the last dipping could not be made till 23 days had elapsed after the first dipping. But, if the first dipping should have such effect upon the pupae as to delay their hatching, it would be necessary to delay the second dipping proportionately, unless it can be shown that the last dipping, falling 23 days after the first dipping, will kill those pupae that have not yet hatched. Experiments show that the last dipping will not kill such pupae. Therefore, it is necessary to know whether the incubation period of pupae is prolonged by the first dipping.

Several experiments were made to determine this point. The method employed was to collect several female ticks which were ready to lay their pupae and confine them on a sheep in an area of wool which had been freed from pupae. The next day, the pupae which they had laid during the night were collected and divided into two groups. One group was dipped in Zenoleum 1:100 and the other kept as a control. Both groups were placed under exactly the same conditions either on a sheep or in the laboratory. It was found that, if the pupae were dipped before they were about four days old they were killed, instead of the incubation period being prolonged. But when dipping was delayed four days, only part of the pupae were killed. In one of the experiments there was indication that the period might be prolonged four days. But since the pupae that are less than four days old are killed by the dip, a prolongation to the extent of four days of the incubation period of pupae over four days old does not prevent their hatching within 23 days after the first dipping, altho their whole incubation period might reach 27 days. And so we conclude that the possibility of a prolongation of

the incubation period by the first dipping need not be considered in determining when the last dipping should be made.

The third question for consideration is:

“What is the effect of the various dippings upon the ticks?”

In testing the action of dips upon ticks it was necessary to divide the dips into two groups, namely, those whose action is immediate because they are absorbed, and those whose action is more or less remote, owing to the fact that they are but slightly absorbed, their killing power being due largely to their being ingested. The coal tar and cresol dips and “Black Leaf 40” belong to the first group and Cooper’s Powder Dip to the second. The first group admit of laboratory tests, while the second group had to be tested by actual dipping experiments.

It is more difficult to determine the relative effects of different dips upon the ticks than one would anticipate. The ticks may be stupefied so that they are apparently dead. But if they are removed from contact with the dip they may revive. The matter of time is an important factor to be considered in determining the killing power of a dip. Generally it would not appear practical in dipping a large flock of sheep to leave them in the vat over a minute, except, as stated before, when the vat is very long so that the movement of the sheep needs not be retarded, or when the sheep are being dipped for scab also. And so in testing the dips the ticks were immersed only one minute. It is true that according to directions with some dips the sheep should be left in as long as two minutes. But generally in comparing such dips I left the ticks in only one minute, the same as with other dips. It might also be held that it would not be fair to compare the dips without using them in uniform strength even though directions with one dip may demand that it be used in solution five times as strong as

another. But this is an entirely different question. For example, if "Black Leaf 40" were to be used in a dilution of 1:50 as Kreso is used, it would probably kill the sheep and would cost about twenty times as much. It would without question be stronger than Kreso and would also be much stronger than would be necessary. We see, therefore, that there are other factors such as the effect upon the sheep and the cost of the dip that are involved when the strength of the dip is considered.

At first it appeared reasonable that the killing power and hence the relative value of a dip could be determined by holding ticks under the dip and noting the time required for all movements to cease. It is plain that in the case of ticks external movement is the only indication of life, or at least the only practical indication that could be used in these experiments. Yet this sign is not entirely satisfactory inasmuch as all external movements may cease for a long period while the tick is under the influence of the drug, and then return when the drug is removed, indicating, of course, that the tick was not quite dead. Still in the absence of any more practical and fundamental sign of life, this one had to be used. It was found best not to depend upon the cessation of voluntary movements, but to determine when artificial stimuli would no longer evoke movements. This was necessary because ticks may become quite spontaneously unless irritated.

The dips used in the laboratory tests on ticks were (1) Zenoleum; (2) Chloroleum; (3) Chloro-Naptholeum; (4) Kreso; (5) Minor's Fluid; (6) Sanitary Fluid*; (7) Pyxol**; (8) Crude Carbohc Acid; (9) Carbohc Acid; (10) B. & C. Cresol; (11) Cooper's Fluid Dip (Cresol); (12) "Black Leaf 40." The first eight appear to be very similar coal-tar compounds and when mixed with water make a white, milky fluid. Crude car-

*Sanitary Fluid may be obtained from the F. S. Betz Co., Hammond, Indiana.

**Pyxol is put out by the Barrett Manufacturing Co., 17 Battery Place, New York City.

carbolic acid will not mix with water without the addition of soap and if the water is hard, a softener. Tests show that the first five dips when used according to directions are very effective killers of sheep-ticks. Betz's Sanitary Fluid and Pyxol have not been advertised or used as sheep-dips and so no directions regarding their use as such accompany them. Experiments indicate that Sanitary Fluid in the proportion of 1:100 and Pyxol 1:200 are very effective. There is evidence that Pyxol is much more poisonous to sheep-ticks than carbolic acid, and it need not be used in greater strength than 1:200. The best crude carbolic acid, which was tested, is the Denver Fire Clay Company's (50-60 per cent. quality containing naphthalene). This, used in the proportion of 1:200, with $\frac{1}{2}$ per cent. soap and $\frac{1}{8}$ per cent. sal soda, is a very effective dip. I regard the action of B. & C. Cresol and Cooper's Fluid (Cresol), when used in the proportions called for by the directions, as less certain than some of the coal tar compounds. They were not tried in actual dipping experiments. They may possibly kill all the ticks, but I believe with less margin to spare than is the case with the best coal-tar dips when used in the strength indicated by their directions. "Black Leaf 40" proved inferior to the coal-tar dips in the laboratory tests, even when used according to directions, which call for the conditions that the ticks remain in the bath 2 minutes, and the bath be of 100 to 105 degrees. Similar results were obtained by two actual dippings, but in one of the tests the dip was used cold and the sheep were not left in it longer than in the case of Zenolum (probably one minute).

It is worth while to mention in detail some of the tests that were made in the laboratory. I will select Pyxol and Cooper's Fluid Dip. According to directions the latter is to be used in the strength of 1:200. At first Pyxol was used in the ratio of 1:150. Ticks were placed in the center of a handful of wool which was immersed in the Pyxol bath for one minute. It was then removed and allowed to drain for five minutes. The ticks were left undisturbed in the wet wool. These conditions simulated the conditions that prevail in actual dipping.

Eighteen minutes after the wool was immersed the ticks were examined. Only one showed voluntary movements. Twelve minutes later none showed voluntary movements and a minute later only one showed movements under irritation and that almost imperceptible. Another group of ticks were similarly treated with Cooper's Fluid 1:200. While the wool was draining some of the ticks crawled out on the surface of the wool. They were placed back in the center. Eighteen minutes after the wool was immersed it was opened and the ticks were examined. Four of them showed voluntary movements. Fifteen minutes later one was very irritable and five others showed slight response under stimulation. These facts indicate that Cooper's Fluid 1:200 is inferior to Pyxol 1:150.

A comparison exactly like the above was made between Pyxol 1:200 and Cooper's Fluid. In the case of Pyxol, fifteen minutes after dipping began no voluntary movements were present. Twenty minutes later practically no response could be evoked by stimulation. In the case of Cooper's Fluid, sixteen minutes after dipping began six of the ticks were found crawling in the wool. Nineteen minutes later voluntary movements were still present in several. This indicates that Pyxol 1:200 is superior to Cooper's Fluid 1:200

The above results were confirmed by tests of a different nature. The ticks were divided into groups of ten each. The groups were immersed for varying lengths of time in the dips and then removed to open boxes. In the first experiment one group was immersed for two minutes in Pyxol 1:150, and another for the same time in Cooper's Fluid 1:200. In the former case only one showed voluntary movements 100 minutes after dipping, while in the latter case all were much more lively. Six hours after they were dipped, the first group showed very slight movements under irritation, while the latter group were as lively as if they had not been dipped. Twelve hours later those dipped in Pyxol were all dead, while those dipped in Cooper's Fluid were as lively as ever. A similar comparison was made between Pyxol

1:200 and Cooper's Fluid 1:200. The ticks were dipped for eight minutes in each case. Four hours after dipping there were no movements under irritation in either group. Twelve hours later those dipped in Cooper's Fluid had revived and become very active, while those from Pyxol were all dead. I will not record the remaining experiments but only add that they confirmed these results, namely, that Pyxol 1:200 is superior to Cooper's Fluid 1:200.

In order to determine the value of Cooper's Powder Dip, which is an insoluble arsenic compound, actual dipping experiments were made. It was found that one dipping with it would come nearer to destroying the ticks than one dipping with Zenoleum. Yet the fact that one female tick and two live pupae were found on one of the lambs four months after the dipping had taken place, would indicate that one dipping cannot be relied upon to absolutely eradicate the ticks. That ticks may be found on the lambs for a month after the dipping is not an indication that the dip is not effective, for the pupae may be hatching for three weeks or more after the dipping and several days may elapse before they eat enough poison to kill them. Sufficient powder remains in the wool to kill most of the ticks, as was shown by the following experiment.

A sheep having wool about two inches long was dipped according to directions in Cooper's Powder and allowed to dry for three days. Then fifty ticks were placed in the wool. The following day most of the ticks were gone. But some of them were still alive and others were found dead in the wool. After about three days no live ticks could be found. Then fifty more live ticks were placed on the sheep. The same conditions were repeated. This sheep was later turned in with infested sheep and remained comparatively free from ticks for some time.

On June 21st, a flock containing 75 sheep and their lambs were dipped according to directions in Cooper's Powder. The sheep had been sheared about a month earlier. On July 29th two or three ticks could readily be

found on a lamb, but none could be found on the sheep. On this date they were dipped again in Cooper's Powder. A month later no ticks could be found. On January 5th, about 6½ months after the first dipping, no ticks were present.

On June 21st, another group containing 17 sheep with long wool and 13 lambs with very short wool were dipped in the same Cooper's Powder mixture that was used in the first dipping of the preceding experiment. Thirty-eight days after the first dipping, this group was dipped again. After dipping the preceding group in Cooper's Powder there remained 250 gallons of dip in the vat. To this were added two gallons of Zenoleum. In this mixture, the group were dipped. Thus, the slow but prolonged action of Cooper's Powder was combined with the rapid killing action of Zenoleum. Frequent examinations during the six subsequent months failed to reveal any ticks.

I have seen large flocks of sheep practically, if not entirely, freed from ticks by a yearly dipping in Cooper's Powder Dip. The shearers testified that they did not find a tick. The conclusion is justifiable that two dippings with this preparation is certain to eradicate the ticks absolutely. There is evidence that one dipping cannot be depended upon to eradicate them. No chances should be risked and so a margin of safety as wide as is practical should be maintained, though a little extra expense may be involved. The expense will never have to be repeated, if the work is done rightly in the first place.

Some actual dipping tests were made with certain other dips. On June 15th, three sheep and five lambs were dipped in Chloroleum 1:80 (the directions call for the proportion 1:75). After the adults were dry they were sheared. Twenty-eight days after the first dipping, although a hasty examination revealed no ticks, we dipped the group in Chloro-naptholeum 1:75. About two months later and again in about six months they were carefully examined, but with negative results.

On June 21st, a group of 27 large wethers, with a half year's growth of wool, were dipped in Zenoleum 1:100. Thirty-one days later, altho no ticks were noticed, they were dipped with Zenoleum 1:100. Six months later they were sheared, but no ticks were found.

A group of thirteen sheep (having one year's growth of wool) and nine lambs were dipped in the fluid that remained after the wethers were dipped. Ticks were present on the lambs twenty-three days later, and so they were dipped again in Zenoleum 1:100. These dippings destroyed the ticks and the group was still clean six months later.

Another group containing 15 sheep (with one year's growth of wool) and 14 lambs, were dipped June 23rd in "Black Leaf 40", strength 1:686. The bath was used cold. Four pounds of sal soda were added to each 100 gallons of water. The sheep and lambs were left in the dip about the same time as was the case with the other dips. On July 1st, ticks were present on the lambs. On the 14th they were present on the sheep and numerous on the lambs. On the 16th, 23 days after the first dipping, the group were dipped again in "Black Leaf 40", 1:686, cold. The lambs were left in much longer this time. On July 22nd ticks were present on the lambs. Another examination was made August 22nd, and the ticks still being present, we dipped the group in Zenoleum 1:100. These three dippings destroyed the ticks and at the last examination, about five months later, no ticks could be found.

We may now consider the next question, "Which is the best dip to use?" Our decision must take in account at least five factors: (1) The killing power. (2) The effect upon the sheep. (3) The effect upon the wool. (4) The cost. (5) The ease with which the dip can be prepared. It is apparent that some of these factors are more important than others, and hence must be given more weight. Of greatest importance is the first. We must select a dip that will certainly kill the ticks, even though it might cost more, require more effort in its

preparation, or even be more injurious to the sheep and wool than another dip that may be better in respect to the last factors but will not kill the ticks. But between two dips that have equal killing power we should choose the one that is best in respect to the less important points.

Since the work on the sheep dips has not been extensive enough to draw sharp comparisons between them, I will merely indicate some of the dips that when used as recommended, will certainly destroy the ticks. They are: Chloroleum, Chloro-naphtholeum, Kreso, Zenoleum, Minor's Fluid, Sanitary Fluid (Betz) 1:100, Pyxol 1:200, Crude Carbohc Acid (50-60 per cent. quality, Denver Fire Clay Co.) 1:200 or 1:300, and Cooper's Powder Dip. In the comparisons between "Black Leaf 40" and the other dips, Black Leaf was not generally used according to recommendations. Its effectiveness would undoubtedly be increased by such conditions.

In respect to the effects upon the sheep and wool, and in respect to ease of preparation, there is not much difference between the different coal-tar dips mentioned, except crude carbolic acid, which blackens the wool more and is hard to prepare. Therefore, with the exception of crude carbolic acid, the only question to be considered in selecting a dip from this group of coal-tar dips is the cost. From quotations on large quantities of dips, I can give the cost per one hundred gallons of mixture ready for use: Kreso, \$1.00 to \$1.30; Zenoleum, 90c.; Chloro-naphtholeum, \$1.00; Chloroleum, 1:75. \$1.13; Pyxol, 1:200, 75c., f. o. b. Philadelphia; Sanitary Fluid 1:100, 75c., f. o. b. Hammond, Ind. As prices may change and concessions may be made, the sheepmen should not depend upon these quotations. Crude carbolic acid, including soap and sal soda, will cost about 40c. While it is much cheaper, still the trouble of making it up stands in the way of its general use.

Cooper's Powder Dip must be considered by itself. It answers the first requirement. Altho its action is slow, yet it has the compensating quality of remaining in the wool as a continuous and active poison. On account of this, one dipping with it apparently comes nearer to eradicating the tick than one dipping with the coal-tar dips. Regarding its action on the sheep, it must be said that it will take the skin off if it is not properly used. However, I have never seen any such effects when it is used properly in a swimming vat. It must be remembered that the dip contains arsenic which is very poisonous to the sheep and other animals, so that proper precautions must be exercised against its being ingested by the sheep, either by drinking the bath or by eating material upon which they may have been allowed to drain. The latter possibility should be prevented by keeping the sheep in barren pens until they have drained. Care must be exercised in discarding the dip that remains after dipping has been finished. If reasonable care is exercised there is no reason why poisoning should result. However, it must be admitted that, other things being equal, the fact that the dip is highly poisonous to the higher animals, stands against its use, especially by people who have never been trained to exercise care in such matters. It will be objected that a preparation is worthless as a sheep-dip if it is not poisonous, the idea being that the ticks will not be destroyed. Yet this idea is not necessarily true, for it is found that some drugs, such as coal-tar products, may be more poisonous to the lower animals than to the higher. Hence ticks may be destroyed by solutions so weak that comparatively larger quantities of them may be taken by sheep without damage. But, the fact is that the so-called non-poisonous dips are really poisonous even to sheep and proper care must be exercised against their being imbibed.

There have been reported ill effects upon the wool from the use of arsenic compounds. On the other hand, I have seen prize show-sheep dipped in it. And besides, there are show-sheep owners who prefer it to the coal-tar dips, because they think it has less injurious effect

upon the wool than the coal-tar dips. While it is my opinion that there is little ground for thinking it is injurious, providing the dipping is carried out according to directions, yet this point should be determined by careful, systematic experimentation.

The cost of dipping with Cooper's Powder is about twice as great as with the coal-tar dips. It is also harder to prepare the dip for use.

In the light of these facts it is impossible to decide whether Cooper's Powder is preferable to the coal-tar dips. Both will do the work. Yet is desirable to have as wide a margin of safety as is possible and at the same time practical. The fact that Cooper's Powder will remain in the wool exercising its killing power for months is a distinct point in its favor. For this reason, I would suggest that a most effective dip may be obtained by mixing with Cooper's Powder one of the coal-tar dips in about half or one-quarter the strength recommended for their use. In this way the quick action of the coal-tar dip is combined with the prolonged action of the arsenic and a dip ideal in killing action is obtained. This, however, increases the cost considerably. The first dipping could be made with Cooper's straight or with a coal-tar dip straight and the last with the combination mentioned. In this way the cost would be kept down while the margin of safety would remain wide. Still I would add that there is almost no doubt that two dippings, either with the coal-tar dips or with Cooper's Powder, will absolutely destroy the ticks.

The decision may be left with the sheep men, believing that they will get the desired results whichever method they use, provided reasonable care is exercised and the cautions to be mentioned later are observed.

The last question propounded is, "How many dippings are necessary and when should they be made in order to eradicate the sheep-tick?" ,

It is certain that one dipping cannot invariably be depended upon to eradicate the tick. Judging from the

facts obtained regarding the normal life-history of the tick and the data concerning the action of sheep dips, at least three dippings would be necessary to make the eradication absolutely certain in all cases; these dippings to be made about fourteen days apart. This conclusion is based upon the facts that in warm weather the pupae require from 19 to 23 days to hatch and a young tick may reach sexual maturity and lay its first pupa in 14 days. Thus it is plain that the second dipping, 14 days after the first, will kill any young tick which may have hatched after the first dipping, before it has had time to lay a pupa. And the third dipping being placed about 12 or 14 days later will occur after all the pupae have hatched and before will have laid pupae. Thus all the ticks will *certainly* be destroyed.

Nevertheless, although the normal life-history indicates that at least three dippings are necessary to insure absolute eradication, there are reasons for believing that the same can be accomplished with two dippings. The eradication of the sheep-tick will be a much lighter burden if it can be accomplished with two dippings.

As a matter of fact, the *normal* life-history should not be used as a basis for determining how many dippings are necessary, because the first dipping modifies the *normal* life-history. The modifications may be set forth as follows: (a) None of the pupae hatch for a couple of days after they are dipped, and if they did, they would be killed in the wet wool; (b) many of the pupae are killed by the first dipping and some are so weakened that the young ticks hatching out never mature. Therefore, the number of pupae hatching out and maturing in a flock during the first two weeks following the first dipping is very small; (c) since the number is small, the chances for a female to become fertilized soon after hatching are slight. It can be shown that these conditions are unfavorable to an early deposit of pupae after the first dipping. Since at least 14 days are required for a young tick to mature and lay its first pupa under the most favorable conditions where males and females are kept together in a small area on a sheep, it is highly prob-

able that at least three weeks would be required under the conditions that follow the first dipping. It has been shown that pupae under four days of age are killed by dipping. Therefore, if a young tick should manage to lay a pupa three days before the last dipping took place, it would be killed. It appears, therefore, that if the second (or last) dipping be placed (in warm weather) 24 days after the first, all ticks will be destroyed.

These theoretical results are supported by some actual dipping tests. In one experiment with Zenoleum two dippings 23 days apart eradicated the ticks. In another experiment with Zenoleum two dippings 31 days apart destroyed the ticks. In a test with Chloroleum and Chloro-naphtholeum, two dippings 28 days apart were successful. Two dippings with Cooper's Powder, 38 days apart, were effective. Likewise, one dipping in Cooper's Powder followed in 38 days by a dipping in a combination of Cooper's Powder and Zenoleum destroyed the ticks. We conclude, therefore, that during warm weather the most favorable interval between the first and second (last) dipping is 24 days. If the dipping is done before May or after September the eradication will be less certain and a more favorable interval would be 26 days. While the tick may be destroyed by two dippings with Cooper's Powder 38 days apart, yet the most favorable interval would be that mentioned above.

In regard to the time of year when dipping should take place, it appears that the early fall is the most acceptable. On account of lambing and shearing the spring is unfavorable. It is bad to dip just before lambing or shearing, or just after. If dipping takes place after lambing and shearing it is much harder to eradicate the ticks because of the short wool on the lambs and sheep. In the fall the wool will be long enough on both to hold sufficient dip to make the destruction of the ticks certain. Therefore, marketing time, say the month of September, is the most favorable time for cleaning up the ticks. It is certain that during this next September every sheep-tick in the state could be destroyed so that in the following spring lambs would not face a tick. If the ticks are

once eradicated from a flock of sheep, the flock will remain absolutely free as long as they are not contaminated by ticky sheep.

The question of compulsory dipping for sheep-ticks is a live one and perhaps ought to receive some consideration in this paper. At this time, when personal liberty is being curtailed on every side by law, it is hard to say whether dipping for sheep-ticks should be made compulsory. There are certainly two sides to the question. Yet, were it not for the fact in this case that the permission of the personal liberty of one sheep-owner to raise sheep-ticks on his sheep may take away the personal right from a neighbor, or more correctly *several* neighbors to maintain their sheep free from sheep-ticks, we would at once say that compulsory dipping is not justifiable. But a flock of sheep infested with sheep-ticks is ever a menace to the flocks that have been freed from this pest, and in a civilized state, it, therefore, becomes the duty of the government out of justice to those who wish to maintain clean flocks either to compel those who own infested flocks to eradicate the pest or to keep their sheep off the public domain and away from clean flocks.

It is probably true that the sheep men are more apt to look at this question from the financial standpoint than that of personal liberty. If so, there can be little doubt as to where everyone ought to stand. Will it pay the sheepmen? Will the cost of eradicating the sheep-tick be as great or greater than the damage done by the tick each year, plus the expenditure that is already being made every year in dipping with only a *partial* eradication? As it is now, all up-to-date sheepmen are spending something every year in dipping and must continue to do so unless every owner will decide voluntarily, or is compelled, to eradicate the tick once and for all time from his flock. If those who do not dip were compelled to, and those who are dipping would voluntarily clean up all their ticks this year, the latter class would be saved all the yearly expense of dipping, while the former class would be gainers also in escaping the damage the sheep-tick is doing in their flocks. There can be no doubt

that the sheep-tick does more damage in a year to a flock of sheep than it would cost to give the flock two dippings. And so in ten years the saving would be almost ten times the cost of giving the sheep the two dippings the first year; for they would not need dipping again, provided the neighbors were compelled to remove their menace. The consensus of opinion is that the sheep-tick does more damage in a year to a flock of sheep than the cost of giving the flock two dippings. Since the cost of eradication of the sheep-tick is unquestionably less than the loss sustained on account of its presence, and since history and present observation indicate that there will be some careless individuals who will not volunteer to clean up their flocks, it would seem advisable for the government to compel proper dipping. Moreover, the government would be especially justified because it would be attempting a perfectly practical and possible work. The task is different from that of eradicating scab and the *true* tick, because the sheep-tick does not spread so insidiously and can be destroyed much more easily. The sheep-tick is not lurking around in crevices, in the bedding and vegetation as is the case with the scab mite and the *true* tick. In fact, altho it is not advisable to do so, the sheep after being dipped may be turned back into the same pens which they occupied before dipping. In all those experiments in which the sheep-tick was eradicated, the sheep were returned immediately after dipping to their old pens.

And so, seeing what has been accomplished by the fight against scab, we are convinced that the sheep-tick can be utterly eradicated from the state within one year after the work has been initiated and systematized. The ticks having been once eradicated from a flock, there is no reason why the owner should be compelled to dip again, unless his flock should become re-infested. And this will not occur if they are kept away from ticky sheep.

Directions for Dipping.

(a) Where a large number of sheep are to be dipped, a swimming vat is indispensable. Directions for building a vat may be obtained from the U. S. Department of Agriculture, Bureau of Animal Industry, Washington, D. C. The sheep should be allowed to swim thru the vat and should be completely submerged twice. In case any extremely poisonous dip, such as arsenic, is being used, care should be taken that the sheep do not get under and swallow it. If the proper care is exercised, there is no excuse for sheep becoming poisoned. Some sheepmen object to dipping, saying that the loss from poisoning more than balances the gain from destroying the tick. Such results must be due to gross carelessness.

(b) After the dipped sheep have drained well, they should be turned into a yard where no fodder can be contaminated with the poison. This applies especially to arsenic dips. Equal care must be exercised in the disposal of arsenic dips.

(c) During the dipping the strength of the bath should be kept as nearly constant as possible. Undoubtedly baths, whether they be emulsions, solutions or suspensions become weaker and weaker as dipping progresses. In the case of emulsions and suspensions, drops and particles of the active agents are filtered out by the wool so that the bath becomes weaker and weaker. And surely even solutions are weakened by the grease from the wool and by organic material (manure) which collects in the bath. At present there are no data upon which to base a rule for correcting this difficulty. It may be said that the bath should be frequently replenished.

(d) In making up the bath and in replenishing it, no guess work should be allowed. The water and the dip should be carefully measured and used in the proper proportions.

(e) The dipped sheep should be kept absolutely separated from the undipped. They must not be allowed around the shearing grounds or to come in contact with shorn fleeces, which contain pupae that will be hatching for a month.

(f) It is best not to turn the dipped sheep back into the pen, where they were before dipping, within four days.

(g) An attendant should not go amongst dipped sheep after being with the undipped. Ticks might be carried on the clothing. Likewise, dogs should not be allowed to go from undipped to dipped sheep. And moreover, the dogs themselves ought to be dipped along with the sheep.

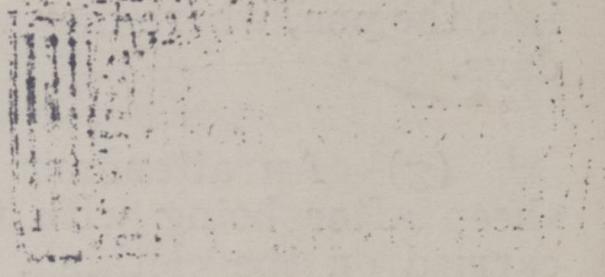
(h) If sheep are bought or borrowed from another flock, they should be properly dipped before being turned in with clean sheep, unless proper proof that they are clean can be secured.

(i) A record should be kept of the groups of sheep dipped and the day on which each group was dipped, so that no mistakes will be made regarding the interval between dippings.

(j) Dipping should be finished as soon as possible after it has been begun so as not to have on hand for a long time any undipped sheep, which may be a source of infection.

If each person will do his part, in one year the sheep-tick may be eradicated from the state, or for that matter, from the United States. It is, therefore, the duty of everyone, if for no reason other than kindness to the sheep, to eradicate the tick from his flock.

I am indebted to my successor, Dr. J. W. Scott, for inspecting some of the dipped sheep after I left the Experiment Station.



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