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APPLICATIONS OF INSECT GROWTH REGULATORS FOR CONTROL OF ANGORA GOAT BITING LICE[a,b]

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ABSTRACT

More than 90% control of the Angoragoat biting louse, Bovicola limbatus (Gervais), was obtained 3-10 wk after Angora goats were sprayed at 3 wk after shearing with 0.1% Thompson-Hayward TH6040 (N-(4-chlorophenyl)-N'-(2,6-difluorobenzoyl)urea), 0.2% hydroprene (ethyl (E,E)-3,7,11-trimethyl-2,4-dodecadienoate), or triprene (S-ethyl (E,E)-11-methoxy-3,7,11-trimethyl-2,4-dodecadienethioate). When the hydroprene was applied earlier, 2 applications 3 wk apart were necessary to obtain the same control. Pourons of 50 ml of 0.5 or 1.0% hydroprene applied 7 wk after shearing also gave control. The effect of hydroprene was shown to be hormonal by the presence of nymphoid 4th-stage lice, a stage normally the adult. Other materials showing promise were: Ciba-Geigy CGA-13353 (ethyl 3-methyl-4-[4-(phenylmethyl)phenoxy]-2-butenoate) and Stauffer HS-103 ((E)-5-[(3,7-dimethyl-2,6-octadienyl)oxy]-2-ethylpyridine).

RESUMEN

Mas de 90% de control fue obtenido sobre el piojo que muerde a las cabras Angora (Bovicola limbatus (Gervais)), durante un periodo de 3-10 semanas despues de que las cabras Angora fueron banados por aspersion tres semanas despues de haber sido trasquiladas, con 0.1% Thompson-Hayward TH6040 (N-(4-chlorophenyl)-N'-(2,6-difluorobenzoyl)urea), 0.2% hydroprene (ethyl (E,E)-3,7,11-trimethyl-2,4-dodecadienoate), or triprene (S-ethyl (E,E)-11-methoxy-3,7,11-trimethyl-2,4-dodecadienethioate). Cuando la hydroprene fue aplicada antemano, dos aplicaciones tres semanas aparte fueron necesarias para obtener el mismo control. Aplicaciones vertidas de 50 ml de 0.5 o de 1.0% de hydroprene aplicados siete semanas despues de trasquilarse, tambien dieron control. El efecto de hydroprene enseno ser hormonal, por la presencia de piojos como ninfa en el estado cuarto, estado normalmente adulto. Otros materiales que ensenan promesa son: Ciba-Geigy CGA-13351 (ethyl 3-methyl-4-[4-(phenylmethyl)phenoxy]-2-butenoate) y Stauffer HS-103 ((E)-5-[(3,7-dimethyl-2,6-octadienyl)oxy]-2-ethylpyridine).

[a]Mallophaga:Trichodectidae.

[b]This paper reflects the results of research only. Mention of a proprietary product or a pesticide in this paper does not constitute a recommendation for use by the USDA nor does it imply registration under FIFRA as amended.

Previously (Chamberlain and Hopkins 1971), we presented preliminary data which showed that the Angoragoat biting louse, Bovicola limbatus (Gervais), could be controlled in field conditions with the synthetic juvenile hormone (SJH)(methyl 10,11-epoxy-7-ethyl-3,11-dimethyl-2,6-tridecadienoate). These studies also showed that the population of lice on Angora goats declined slowly after treatment with an insect growth regulator (IGR) and that more than 1 application of the IGR was needed to obtain more than 90% control.

We have continued our efforts to further define the number of applications, the timing of applications, and the effectiveness of several IGR's and formulations. Our results are reported here.

EXPERIMENTS AND RESULTS

The female Angora goats used in the tests were obtained at auction and ranged in age from 1 to ca. 8 yr. The animals were classified as to the number of lice present by parting the hair in 5 places and counting the number of lice along a 3.0-cm length of the part. An infestation was considered light if the average number per 5 parts was 1-5, medium if it was 6-25, and heavy if it was over 25. Treatment groups were then made up with equal numbers of animals with light, medium, and heavy infestations. The goats were held in outdoor isolation pens. Each pen had an 8X8-ft covered area for shelter, but the goats did not always use it during rainy weather. All sprays were applied with a power spray operated at a pressure of 150 psi.

Experiment 1--Experiment 1 was made to determine the degree of control obtained with 1 and 2 spray applications of SJH and also to compare concentrations of 0.1% and 0.2%. The EC was prepared with 25% A.I. in a base of xylene and Triton® X-100, and 900 ml of the aqueous emulsion was applied to each animal. Each treatment group consisted of 5 animals. The 1st application was made 2 days after shearing; the 2nd application was made 2 wk after the first. The control treatment consisted of 2 applications of a 0.6% mixture of 65-10 xylene-Triton X-100. The effect of the solvent-emulsifier mixture was determined because biting lice of goats are often affected by petroleum materials though they usually recover after several weeks. The effect of the treatments was determined by parting the hair in 5 places and counting the lice along 3.0 cm of the part.

The results are shown in Table 1.

TABLE 1.--Effect of Concentration and Number of Applications of the SJH on Control of B. limbatus on Angora Goats.

% concn of hormone	No. of applications	Total no. of lice per goat (5 sampled areas) at indicated week posttreatment				
		0	2	4	8	12
0.1	2	22.4	26.0	2.0	0.6	0
.2	1	40.6	30.0	24.2	29.6	41.8
.2	2	28.2	17.0	1.6	0	0
Spray control	2	53.6	46.6	30.2	38.8	45.4

With 2 applications of either 0.1 or 0.2% SJH, we obtained better than 90% control within 4 wk of the initial treatment, but a single application of 0.2% was not satisfactory. The results of this experiment confirmed the earlier observation (Chamberlain and Hopkins 1971) that the effect of the SJH is manifested gradually.

Experiment 2--In experiment 2, we investigated the control of natural populations of the biting lice on goats of materials that had been effective in laboratory tests and also the timing of spray applications. The test compounds were the SJH; Hoffman-LaRoche RO-8-4314 (ethyl 10,11-epoxy-3,7,10,11-tetramethyl-2,6-dodecadienoate); ARS compound AI3-34455 (12,13-epoxy-5,9,13-trimethyl-4,8-tetradecadien-3-one); and hydroprene (ethyl (E,E)-3,7,11-trimethyl-2,4-dodecadienoate). The first 3 compounds were 50% EC with a xylene-Triton X-100 base; the hydroprene was an 81% concentrate with an unknown solvent-emulsifier combination. All sprays were tested at 0.1 or 0.2% with 1 or 2 applications of 450-500 ml of spray/goat (4 goats/treatment). When 2 applications were made, the 1st occurred 1 wk after shearing, and the 2nd 2 wk later; the single spraying was done 3 wk after shearing. The spray control consisted of 0.2% of the xylene-Triton X-100 solvent mixture. There was also an unsprayed control. The animals in this test had heavy infestations, 46 lice/5 sampled areas/animal. The effect of the treatments was determined as in experiment 1.

The results are recorded in Table 2.

TABLE 2.--Comparison of IGR's Used to Control B. limbatus on Angora Goats.

Material	% concn of material	No. of applications	Total no. of lice per goat (5 sampled areas) at indicated week posttreatment					
			4[a]	6	8	10	12	16
SJH	0.1	2	34.3	25.8	48.0	79.0	96.8	76.7
	.2	2	18.5	14.5	15.2	28.5	43.3	47.3
	.2	1	49.3	62.0	55.2	69.0	67.8	56.3
RO-8-4314	.2	2	22.0	60.8	71.0	76.5	77.3	68.5
	.2	1	51.3	66.5	121.5	133.8	135.5	116.5
AI3-34455	.1	2	32.7	64.5	78.8	109.0	118.0	160.5
Hydroprene	.1	2	20.8	7.0	6.0	2.2	0.4	0.7
	.2	2	31.8	14.5	16.0	5.8	1.6	3.5
	.2	1	21.8	41.5	28.0	5.0	7.0	25.7
Spray control	.2	2	51.0	58.5	80.2	99.2	94.8	89.5
Unsprayed	-	-	90.3	129.7	187.0	198.8	167.7	244.3

[a]The test goats averaged 46 lice before treatment.

With 2 applications of the SJH at 0.2%, the population of the lice was reduced to less than 1/2 the initial number at 6 wk posttreatment; therefore, with a heavy population, control was not completely satisfactory. Two applications of both concentrations of hydroprene gave satisfactory control, and even 1 application of 0.2% hydroprene gave more than 90% control between the 10th and 12th wk. The other materials did not affect the populations.

We also determined the morphological types of lice on the goats at 7, 8, and 12 wk after the 1st treatment to determine the degree of juvenilization of the adults (Hopkins et al. 1970). At 7 and 8 wk, Type II and III (moderate effect) lice were seen on the goats treated with the SJH; only Type I (normal) lice were found on goats treated with RO-8-4314 or AI3-34455; Type IV (severely affected) lice were found at 8 wk posttreatment with hydroprene, and Types II and III were seen at 12 wk. All other goats had Type I lice at 12 wk. The observed effects were hormonal since the types of lice found were those that result from juvenile hormone activity.

Experiment 3--In experiment 3, we evaluated the effects of timing of spray applications of SJH and hydroprene. The tests were conducted during the spring, and 500 ml applied to each goat. Spraying schedules were set up for

1 or 2 applications, with the 1st spray applied varying from the day of shearing to 6 wk after shearing and interval between the 1st and 2nd spray ranging from 2 to 4 wk. Each treatment was applied to 4 aged goats; the unsprayed and spray control groups consisted of 3 animals. Sampling was done as before.

The results are shown in Table 3.

TABLE 3.--Effect of Timing of Sprays of IGR's on the Control of B. limbatus on Angora Goats.

Material	Time of spraying (weeks after shearing)	% concn of material	Total no. of lice per goat (5 sampled areas) at indicated week postshearing 2	4	6	8	10	12
SJH	0,3	0.2	8.0	8.3	5.3	2.3	6.8	
	0,2	.2	9.3	3.8	3.0	3.5	4.5	
	1,5[a]	.2	15.8	3.0	4.5	2.2	1.7	
Hydroprene	0	.1	8.0	2.3	2.3	0.7	2.3	
	0,3	.1	9.0	7.0	4.0	1.7	0	
	2	.1		7.5	10.0	6.0	2.8	
	2,5	.1		5.7	6.5	2.5	.5	
	2	.2		8.0	6.3	3.3	1.5	
	4	.1			11.8	6.0	1.2	
	4	.2			5.3	2.0	1.2	
	6	.1				14.0	3.0	5.6
Spray control	0,3	.2	15.3	13.3	14.0	8.7	7.3	
Unsprayed	-	-	35.3	27.0	15.3	9.0	6.7	10.5

[a]Readings on number of lice for this treatment were taken at 3,5,7,9, and 11 weeks after shearing.

The populations of lice on the controls were low and declined during the experiment, which often happens in the spring, presumably because of the increasing average daily temperature as summer approaches. With SJH, 2 applications at 1 and 5 wk gave 70-75% control at 8-10 wk after shearing. With hydroprene (at these low natural populations of lice), nearly all the single treatments except at 2 and 6 wk gave slightly better than 50% control. The 2 applications at 0 and 3 wk gave 100% control, and the 2 at 2 and 5 wk gave better than 90% control at 10 wk after shearing.

Experiment 4--In experiment 4, we compared the effectiveness of pouron application and spray application. During the late fall or winter it is often inadvisable to spray Angora goats because they are susceptible to pneumonia, so spraying during very cold, wet weather may cause high mortality. Also, pourons may be more convenient in some situations.

Each treatment group consisted of 4 aged does. The sprays (600 ml/hd) were prepared and applied as in previous experiments. The pourons were prepared by diluting the EC with mineral oil (white oil) to the desired concentration. Thus, the EC for hydroprene, the SJH, and Stauffer R-20458 ((E)-6,7-epoxy-1-(p-ethylphenoxy)-3,7-dimethyl-2-octene) contained 50% A.I.; and that for the mixed isomers of Hoffman-LaRoche RO-7-9767 ((E)-4-[(6,7-epoxy-3-ethyl-7-methyl-2-nonenyl)oxy]-1,2-(methylenedioxy)benzene) contained 25% A.I. The solvent controls were: a solvent-emulsifier furnished by Zoecon, a mixture of 65 parts xylene and 10 parts Triton X-100, and 12% of the xylene-Triton X-100 plus 88% mineral oil, all equal to the amounts of solvents found in the test sprays or pourons. The pouron treatments consisted of 50 ml applied along the backline of each goat.

The results are recorded in Table 4.

TABLE 4.--Comparison of Sprays and Pourons of IGR's for the Control of B. limbatus on Angora Goats.

Material	Treatment	Time of treatment (weeks) after shearing	Avg total no. of lice per goat (5 sampled areas) at indicated week postshearing 3	5	7	9	11	13	17
Hydroprene	0.1% spray + 1.0% pouron	1,7	4.8	1.5	0.5	0	0.2	0	0
	0.1% spray + 0.1% spray	1,7	15.8	1.8	1.7	1.7	.7	1.3	1.3
	1.0% pouron	7				13.0	13.0	7.0	1.2
	0.5% pouron	7				16.7	16.5	6.5	3.5
SJH	2.0% pouron	7				11.5	17.5	6.5	5.5
RO-7-9767	4.0% pouron	7				28.2	29.7	19.8	18.0
	0.4% spray + 4.0% pouron	1,7	8.5	5.5	6.0	11.5	24.5	15.5	16.7
R-20458	4.0% pouron	7				16.5	27.7	30.3	42.0
	0.4% spray + 4.0% pouron	1,7	10.5	5.2	8.5	11.7	17.7	9.5	21.0
Spray control:	0.1% Z-s-e[a]	1	15.8	28.7	31.0	28.7	35.5	32.8	53.0
Spray control:	1.2% x-tx 100[b]	1	17.8	19.5	14.0	31.2	40.7	33.5	69.5
Pouron control[c]		7				16.2	15.2	16.5	27.3
Untreated			29.9	21.0	33.1				

[a]Zoecon solvent-emulsifier mixture.

[b]Xylene-Triton X-100 solvent-emulsifier mixture.

[c]Mineral oil-xylene-Triton X-100 equal to that in the test pourons.

Hydroprene was the most effective compound; either 2 sprays or a spray followed by a pouron gave better than 90% control from 5 to 17 wk after shearing. A single pouron of 1.0% hydroprene also gave more than 90% control, and control with 0.5% hydroprene was only slightly less than 90%. The percentage control with the pouron of SJH was about 80%. RO-7-9767 as a spray plus pouron or as a pouron only gave less than 10% control. R-20458 was ineffective as a pouron even though the concentration was 8 times the effective dose of hydroprene.

Experiment 5--Our purpose in experiment 5 was to compare the effectiveness of Thompson-Hayward TH6040 (N-(4-chlorophenyl)-N'-(2,6-difluorobenzoyl)urea) with that of hydroprene and triprene (S-ethyl (E,E)-11-methoxy-3,7,11-trimethyl-2,4-dodecadienethioate). Since TH6040 interferes with the transformation from one stage of the insect to the next by interfering with the formation of chitin (Mulder and Gijswijt 1973), any effect should be visible sooner than with compounds having typical JH activity.

Single sprays were applied to goats sheared 3-6 wk previously that had an average population of 48 lice/goat by our standard method of measurement. Each treatment group consisted of 5 animals. The sprays of hydroprene and triprene were prepared from 50% EC, the TH6040 spray was prepared from 25% W.P., and the control spray was prepared from the Zoecon solvent-emulsifier mixture used in preparing the EC formulation of hydroprene and triprene. Each animal received 600-700 ml of test spray material.

The results are shown in Table 5.

TABLE 5.--Comparison of TH6040 with Other IGR's for Control of B. limbatus on Angora Goats in the Field.

Material	Treatment (spray)	Avg total no. of lice per goat (5 sampled areas) at indicated week posttreatment						
		2	4	6	8	10	12	14
Hydroprene	0.1%	34.4	29.2	21.0	12.2	11.8	18.0	33.6
	.2%	13.0	21.6	11.6	6.6	3.8	13.0	19.6
Triprene	.1%	44.2	22.2	18.8	17.6	40.8	37.6	63.0
	.2%	21.4	16.8	11.8	7.8	6.2	8.2	8.4
TH6040	.1%	8.0	0.8	0	0	0	0	0
	.2%	3.2	1.4	.6	.2	0	0	0
Spray control	.2%	57.8	41.2	61.0	75.5	64.5	74.0	74.5
Untreated		60.6	35.2	65.0	112.8	124.6	93.4	121.6

All materials tested suppressed populations of lice on the goats, but the effect of TH6040 was apparent much sooner since we recorded 95% control within 2 wk of treatment with the 0.2% concentration, and the treatment continued to suppress the populations through the remainder of the test period. Also the 0.1% concentration was as effective at 4 wk as the 0.2% concentration. The minimum populations of lice on animals treated with the hydroprene and triprene occurred at 8-10 wk posttreatment, but the populations then increased slowly. The 0.2% concentration of both hydroprene and triprene was more effective than the 0.1% concentration. In this experiment, the animals may well have been exposed to heavy rains during the 4 wk posttreatment----0.38 cm fell at 3 days, 2.16 cm at 6 days, 1.30 cm at 10 days, 4.04 cm at 20 days, 0.69 cm at 21 days, 5.87 cm at 23 days, and 0.53 cm at 24 days. This relatively heavy rainfall may have influenced the results. This was the only experiment of the series when considerable rain fell shortly after the treatments were applied to the goats.

Experiment 6--Our previous experiments showed that a single application of hydroprene at 3-4 wk after shearing controlled the Angoragoat biting louse. Therefore, experiment 6 was made to confirm the effectiveness of hydroprene and also to compare hydroprene with several new IGR's. All the goats in this test were sheared 3 wk before spraying. Only 1 application of spray was used, about 750 ml of emulsion, during the fall of the year. The average population was 25 lice/goat.

The test materials were hydroprene, Cheminova HS-2 ((E)-5-[(3,7-dimethyl-2,6-octadienyl)oxy]-2-methylpyridine), Stauffer HS-103 ((E)-5-[(3,7-dimethyl-2,6-octadienyl)oxy]-2-ethylpyridine), and CIBA-GEIGY CGA-13353 (ethyl 3-methyl-4-[4-(phenylmethyl)phenoxy]-2-butenoate). All were prepared as 50% EC's with the Zoecon solvent-emulsifier mixture and were applied to the goats as 0.2% emulsions. The spray control was a 0.2% emulsion of the Zoecon solvent-emulsifier mixture. Five Angora goats were untreated or treated with the spray control, HS-2, and hydroprene, but only 3 goats were treated with HS-103 and 2 with CGA-13353 because of limited material.

The results are recorded in Table 6.

TABLE 6.--Comparison at 0.2% Sprays of New IGR's with Hydroprene for the Control of B. limbatus on Angora Goats.

Material	Avg total no. lice per goat (5 sampled areas) at indicated week posttreatment					
	2	4	8	10	14	18
HS-103	23.7	13.0	3.0	5.5	5.5	1.0
CGA-13353	25.0	7.0	1.5	0	0	0
Hydroprene	21.0	25.4	0.8	0.2	0.4	0
HS-2	18.0	10.2	13.2	14.6	19.0	19.6
Spray control	21.6	14.0	34.8	24.6	28.4	27.8
Unsprayed control	37.6	35.6	60.5	68.2	52.6	80.6

When moderate populations of biting lice were present on the goats, a single spray of HS-103, CGA-13353, or hydroprene applied 3 wk after shearing was effective in controlling lice. These materials reduced the populations of lice to essentially zero before the 8-wk examination, and the populations remained low through the rest of the test period. However, CGA-13353 was used on only 3 goats, and one of these died before the 8-wk examination for reasons not attributed to the test material. Also, only 2 goats were treated with HS-103. Future tests with these 2 materials may show greater variation in results. The experiment was terminated after 18 wk because the time for the spring shearing of Angora goats was approaching. Cheminova HS-2 gave only about 60% control when compared to the spray control.

DISCUSSIONS AND CONCLUSIONS

Since IGR's usually affect the insect during the penultimate stage, the susceptible stage of hemimetabolous insects is the last nymphal instar; in holometabolous insects, the young pupa is most sensitive. Thus, when the adult insect, young larvae or nymphs, or eggs are treated, an IGR will usually have no effect unless a higher concentration is used. The present exception is TH6040: all stages are susceptible to this material. This order of effect was clear in the field tests of the IGR's against the biting lice of goats. The life cycle of the louse is about 30 days, and the adult female lives an average ca. 20 days. These lengths of life cycle and adult life correspond well with the fact that the observed maximum effect of treatment with most IGR's occurs about 6-8 wk posttreatment. Also, the 1st form to show a decline in numbers was the adults; this was followed by a decrease in the number of eggs. Then if the IGR is not active long enough, some of the nymphs resulting from the eggs of the last adults may escape exposure to sufficient concentrations of the IGR and become viable adults. The population then increases slowly, which was exactly what we observed in many of our tests.

We saw 2 general effects of our test compounds. The first was the slow decline in the population that occurred with most IGR's. The other was the rapid decline in the population that occurred with TH6040. The slow decline also produced lice the size of adults within 2-4 wk after treatment that lacked the normal pigmentation of adult lice. This did not occur with TH6040.

Timing of the spraying appeared to be critical. When the goats were sprayed almost immediately after shearing, as in some of our 1st tests, a single application of the most effective material (hydroprene) gave poor control. In later tests, the same concentration of hydroprene applied 3 or 4 wk after shearing gave good control. After 3 or 4 wk, the hair is about 2.5 cm long,

and we surmise that this longer hair retains the IGR better than short hair and skin. Also, the hair probably protects the IGR from the degrading effect of ultraviolet light. In fact, when a 1st application of spray was made early, the populations declined, but a 2nd application was needed 3 or 4 wk later, even with moderate population pressure.

Our tests with pourons of IGR's showed that they may have a place in a control program. Since sprays may be inadvisable in winter, the pouron treatment could be substituted. Although the results are essentially the same as those obtained with sprays, the results are slower, presumably because the small volume of oily material spreads only part way down the sides of the animals, and the lice that are on the lower body areas at the time of application may not make contact with the IGR for some time.

The choice of sprays versus pourons will probably depend on economic considerations and rancher acceptance. Ranchers who practice good husbandry usually spray with an insecticide immediately after shearing and often make one or more applications later in the season. However, with the possible exception of TH6040, the IGR's would not be effective as a single spray at shearing if the goats have moderate to heavy populations of lice. Thus, if IGR's are used for louse control, the rancher would have to choose between spraying more than once, delaying spraying, applying a pouron when he noticed moderate populations of lice, or spraying in the winter during warm dry weather.

Low, medium, and heavy populations of lice plainly affected the results of our tests. Only one experiment was conducted during the spring. In that case, populations of lice at the time of treatment were no more than medium and declined naturally to low levels. Thus, nearly any treatment, even the solvent-emulsifier, reduced populations to light infestations. Spring treatment of goats for control of biting lice in this area may therefore be unnecessary if this natural reduction is the usual situation in spring. At other times, when the population pressure was extremely heavy, as in the 2nd experiment, a single application gave only temporary control, even when hydroprene was applied at 0.2% at 3 wk after shearing.

Although our experiments were conducted on Angora goats for the control of biting lice, the information obtained on effective materials, formulation, and timing of application is probably equally applicable to the control of biting lice of sheep.

We conclude that a single spray or pouron of hydroprene or a single spray of TH6040 (and possibly of triprene) will give complete control of light to moderate infestations of the Angoragoat biting louse on Angora goats if the application is timed correctly. Even heavy population temporarily can be reduced to light infestations.

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