Horn fly resistance to pyrethroids

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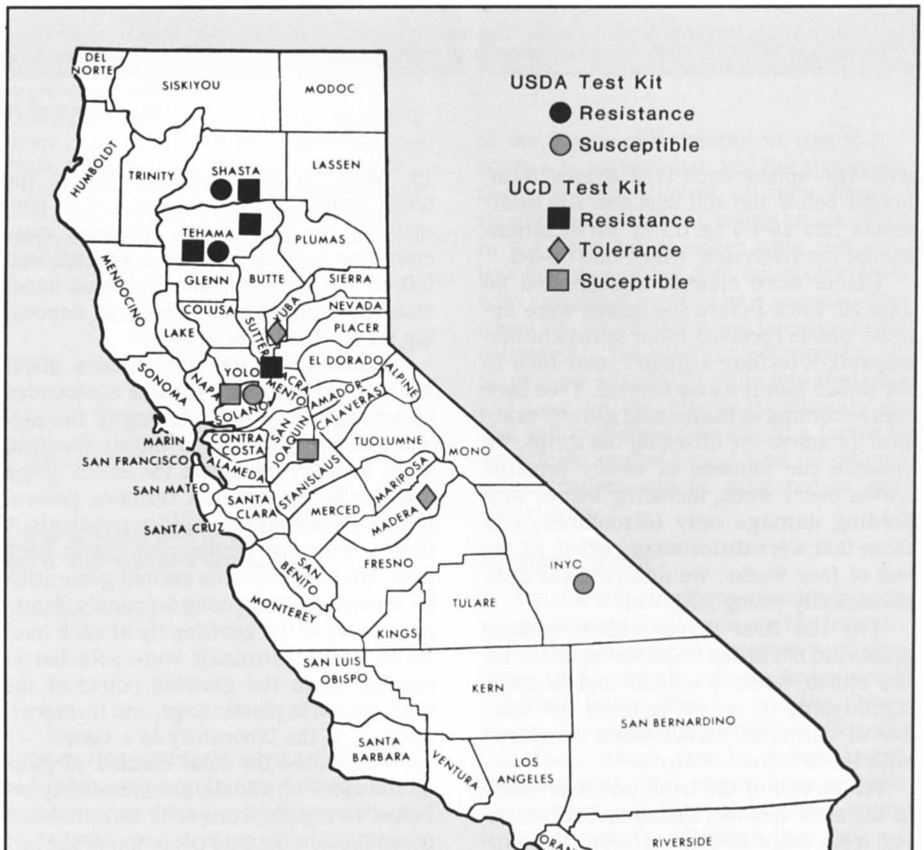
Horn flies are permanent blood-sucking parasites that, in dense numbers, annoy cattle. Economic damage may result from decreased weight gains and milk production. Early control measures commonly relied upon frequent insecticide sprays or hand-dust applications and the use of self-treatment methods, such as insecticide-charged back-rubbers or dust bags. Since 1980, however, pyrethroid-impregnated cattle ear devices have been widely used to provide seasonal fly control without the necessity for repetitive roundup of cattle or the maintenance of back-rubbers or dustbags.

A variety of such devices are registered for control of horn fly, *Haematobia irritans:* 8 percent fenvalerate and 7.5 percent flucythrinate in plastic ear tags, and 10 percent permethrin in a plastic ear tag, a plastic ear strip, and a tape holding a small vial of the active ingredient for application to an existing cattle identification ear tag.

Studies conducted in 1983 by research entomologists at the U.S. Department of Agriculture (USDA) Livestock Insects Laboratory, Kerrville, Texas, demonstrated fenvalerate and permethrin resistance in horn flies from certain areas of Florida, Georgia, Kansas, Louisiana, Oklahoma, and Texas. The researchers used a USDA laboratory test kit to expose field-collected flies of mixed sexes to different concentrations of pyrethroid-treated muslin cloths covering plastic cups through which flies fed on citrated beef blood pads placed atop the cloths; mortality was recorded after 24 hours of exposure (as reported by Schmidt *et al.*, 1985, *Journal of Economic Entomology*). Lethal concentration values (LC_{50} and LC_{90}, or concentrations required to kill 50 or 90 percent, respectively, of the test population) for field-collected flies were compared with similar values for colony-reared flies maintained free of insecticide exposure (susceptible) for 18 years at the USDA laboratory.

In cooperative studies using the USDA test kit during 1984 and 1985, state university and USDA entomologists found resistance to the same pyrethroids in horn flies sampled from some herds in Alabama, Arkansas, California, Hawaii, Illinois, Iowa, Kentucky, Nebraska, and New Mexico. Pyrethroid resistance in the horn fly now has been confirmed in 15 states, and suspected resistance has been reported to the USDA laboratory at Kerrville by entomologists in Mississippi, Oregon, and Tennessee. Tests have not been conducted in other states, where pyrethroid-impregnated cattle ear devices have continued to provide seasonal control of horn flies.



Areas of California in which horn fly resistance to pyrethroid cattle ear devices was reported in 1984-85.

UC field studies

In the summer of 1983, California cattle ranchers and University of California livestock advisors in some counties reported that pyrethroid ear devices were not controlling horn flies as they had in past years. Since horn fly resistance had been proved in other states, we conducted field studies in 1984 and 1985 to determine the status of horn fly susceptibility to pyrethroids in California. Horn flies were tested in 1984 with USDA laboratory kits supplied by researchers at Kerrville and an on-farm test kit (UC Davis kit) designed by the senior author. The UCD test kit procedure consisted of immediate aspiration of field-collected flies into glass tubes that had been treated previously with pyrethroid solutions, with mortality recorded after a four-hour exposure.

An average of 41 flies (range, 21 to 50) were exposed to three replicates of ten concentrations of permethrin-treated cloths in the USDA test, and an average of 28 flies (range, 22 to 37) were exposed to three replicates of seven concentrations

TABLE 1. Responses to pyrethroids by horn fly populations from locations in California, 1984-85

Location	LC_{50}	(95% CL)†	LC_{90}	(95% CL)†	RR* LC_{50}	RR* LC_{90}	LC_{50}	(95% CL)†	LC_{90}	(95% CL)†	RR* LC_{50}	RR* LC_{90}
A. 1984 — Permethrin (August 8 - September 9)												
	USDA laboratory test kit						UCD on-farm test kit					
	$\mu g/cm^2$				RR*		Percent active ingredient				RR*	
TX lab‡	.14	(.12 - .17)	.41	(.34 - .53)	—	—						
Inyo	.06	(.05 - .07)	.12	(.10 - .15)	.43	.29						
Sacramento							.002	(.001 -.002)	.006	(.005-.007)	33	.75
Shasta	3.7	(3.2 -4.3)	23	(18 - 32)	26	56	.013	(.011 -.015)	.044	(.034-.059)	216	5.5
Solano	.37	(.31 - .45)	5.2	(3.9 - 7.3)	2.6	13.9	.00006	(.00004-.0002)	.008	(.005-.021)	—	—
Sutter							.004	(.003 -.005)	.026	(.019-.038)	66	3.2
Tehama-TQ	4.3	(3.2 -6.1)	184	(84.6 -512)	31	449	.0089	(.007 -.01)	.141	(.078-.312)	148	18
Tehama-CN							.006	(.005 -.007)	.016	(.013-.022)	100	2
B. 1985 — UCD on-farm test kit (July 30 - August 8)												
	Fenvalerate, % a.i.						Permethrin, % a.i.					
San Joaquin	.0005	(.0002- .0009)	.009	(.006- .017)	—	—	.0004	(.0001 -.0007)	.0078	(.005-.015)	—	—
Madera	.0008	(.0005- .001)	.012	(.007- .02)	1.6	1.3						
Sutter	.013	(.009 - .02)	.411	(.169- 1.45)	26	46	.0047	(.004 -.005)	.017	(.013-.021)	11.8	2.2
Yuba	.0013	(.0009- .002)	.026	(.016- .05)	2.6	2.9	.0009	(.0006 -.001)	.023	(.014-.042)	2.2	2.9
Tehama-CN	.003	(.002 - .004)	.237	(.09 - 1.04)	6	26						

* Resistance ratio.
† 95% confidence limit.
‡ U.S. Department of Agriculture Livestock Insects Laboratory, Kerrville, Texas.

of permethrin- or fenvalerate-treated glass tubes in the UCD test. We used the UCD test kit exclusively during 1985, since the procedure eliminated the need to transport flies long distances to the laboratory and to use blood meals.

Potentially susceptible horn flies were collected from herds where operators reported that they had not used any insecticides for fly control during the previous five years (1980-85): Inyo, San Joaquin, and Solano counties. Potentially resistant horn flies were collected from herds where operators had treated all animals with pyrethroid ear devices or sprays (with the exception of Yuba County): Madera (permethrin tapes and tags 1982-85); Sacramento (permethrin tags and strips 1981-84); Shasta (permethrin sprays in experimental use 1977-79, fenvalerate and permethrin tags 1980-84); Sutter (fenvalerate tags 1982-83, permethrin tags 1984); Tehama-TQ (fenvalerate tags 1982-84); Tehama-CN (fenvalerate and permethrin tags 1981-84); Yuba (permethrin sprays and dust in experimental use 1977-79, stirofos tags 1980-82, fenvalerate tags and permethrin tags and tapes 1983-84, phosphate sprays, dust and tags 1985 — with less than 100 percent of the animals treated in any one year).

Concentration and mortality data were analyzed by entomologists at the USDA laboratory in Kerrville, using statistical methods of probit analyses. The lethal concentrations (LC_{50}, LC_{90}) in the USDA test kit procedure were calculated on the basis of micrograms active ingredient per square centimeter of cloth (table 1). Colony-reared flies at the Kerrville laboratory were used as a reference population to determine resistance ratios. The LC values in the UCD test kit procedure were calculated on the basis of percent concentration of active ingredient solutions used to coat the inside surfaces of the glass tubes; the most susceptible field-collected horn flies found each year were used as a reference population to determine resistance ratios.

USDA research entomologists at the Kerrville laboratory have found that a resistance ratio at or above three indicates a high enough resistance level to explain failure of horn fly control following repeated exposure to pyrethroid-impregnated ear devices. The LC_{50} and LC_{90} values determined from the USDA test showed that the Inyo flies and, to a lesser extent, the Solano flies were more susceptible to permethrin than those from Shasta and Tehama-TQ. Resistance ratios (LC least susceptible ÷ Texas lab susceptible) were related to the history of not using insecticides for flies in Inyo and Solano as opposed to pyrethroid exposure of flies in Shasta and Tehama-TQ. The lower LC_{50} and LC_{90} values shown by the Inyo flies compared with those of the Texas lab strain are within the range of 95 percent confidence limits. The resistance ratios of the Solano flies suggest a level of tolerance at LC_{50} but resistance at LC_{90}. The LC values from the UCD test showed that the Solano flies were more susceptible than flies exposed to pyrethroid treatments on herds from Sacramento (except for Sacramento LC_{90}), Shasta, Sutter, Tehama-TQ, and Tehama-CN.

The 1985 UCD test data showed that the San Joaquin flies were more suscept-

The red tapes on yellow identification tags contain pyrethroid to provide seasonal horn fly control. Development of horn fly resistance has made the devices less effective.

ible to fenvalerate and permethrin than those from the other counties tested. The resistance ratios for fenvalerate suggest a tolerance level in the Madera and Yuba flies and resistance levels in flies from Sutter and Tehama-CN. The resistance ratios for permethrin indicate potential tolerance in the Yuba flies and a level of resistance in the Sutter flies. The use of different pyrethroid and phosphate compounds by various delivery systems from 1977 to 1985 for the Yuba cattle may be responsible for the fly response at a tolerance level.

Conclusions

The results of these field test bioassays support the assumption that certain horn fly populations have developed levels of tolerance or resistance to fenvalerate and permethrin while other populations remain susceptible (fig. 1). The results also correspond to the success or failure in fly control from the use of pyrethroid-impregnated cattle ear devices found in our routine monitoring of horn fly populations on cattle in Inyo, Madera, Shasta, Sutter, and Yuba areas.

The ability of the horn fly to develop resistance to pyrethroids is well established although the levels of resistance are different in different herds, and resistance is not common throughout all areas of cow/calf production. It is apparent, however, that once flies become resistant to one pyrethroid, the same population may be resistant to another pyrethroid. Changing types of ear devices will not overcome the resistance problem since all registered pyrethroid compounds may be affected reciprocally by cross-resistance.

Specifically, then, the recommendation is to not use pyrethroid-impregnated ear devices on cattle where horn flies show resistance to those compounds. Pyrethroid ear devices may be used in areas where resistance has not developed, but alternating pyrethroids seasonally with phosphate compounds is suggested to help delay or reduce the development of resistance in horn flies.

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Uniformity of continuous-move sprinkler machines

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Continuous-move sprinkler machines, both linear-move and center-pivot systems, are normally evaluated for uniformity of applied water with catch cans along the lateral only. High uniformity along the travel path is assumed, and so is not measured.

Although these machines are classed as continuous-move, in reality, they move in a series of starts and stops controlled by a guide tower. The movement of the guide tower controls the system revolution rate, and the other towers follow with a start/stop sequence that may be considerably different from that of the guide tower. Uniformity of water applied along the travel path may depend on a particular start/stop sequence. We investigated uniformity-movement relationships for a linear-move and a center-pivot machine.

Systems tested

The linear-move machine, driven by electric motors, consisted of nine spans. The first six were each 42 yards long, and the rest were each 60 yards. Spray nozzles with serrated deflector plates were spaced every 9 feet and were suspended about 4 feet above the ground. Time-averaged travel speed of the system was 2½ feet per minute, and the system pressure was 30 pounds per square inch (psi).

The center-pivot machine, also an electric drive, consisted of 10 spans each 42 yards long. Spray nozzles were spaced every 10 feet and were suspended about 5 feet above the ground. Time-averaged travel speed of the machine was 6½ feet per minute. The pivot-point pressure was 14 psi.

We installed transects of catch cans with a 1-foot spacing along the travel path near the guide tower and the midpoint tower. Distance per move, on-times, and off-times were recorded for the tower nearest the transects. Catch cans were also installed in transects along the lateral length (can spacing of 10 feet) and across several individual spans (spacing of 2 feet).

We analyzed the data using both the traditional Christiansen's coefficient of uniformity (CU) and time series statistics. The time series analysis indicated any nonuniformity in the can data along the travel path related to the tower movement.

Results

Catch-can data from the transects along the travel path of the linear-move system showed no obvious patterns, but the transect near tower 5 (midlateral) showed much higher variability than the transect near tower 9 (guide tower) (fig. 1). Statistical analysis indicated greater uniformity (CU) near the guide tower than near the lateral midpoint (table 1).

Movement was quite constant at the guide tower but was very irregular at the lateral midpoint (fig. 2 and 3). Distance per move of tower 5 ranged from 10 inches to 9 feet, while on-time ranged from 0.17 to 1.17 minutes and off-times from 0.08 to 2.72 minutes. Generally, relatively large distances per move and long off-times were followed by relatively