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

Uniformity of water application of both center-pivot sprinklers and linear-move systems, such as that above, was high near the guide towers and low near the midlateral towers. At left is the engine-powered pumping plant on a 1,300-foot linear-move machine.

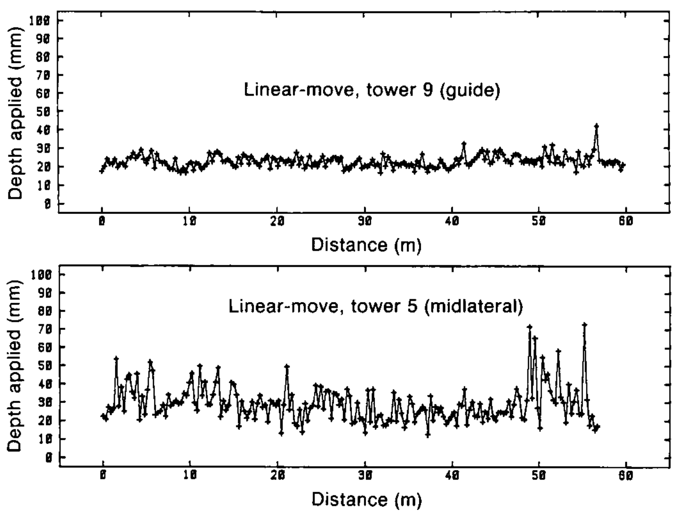

Fig. 1. Uniformity of the linear-move machine varied more near midlateral tower (lower graph) than near guide tower (upper).

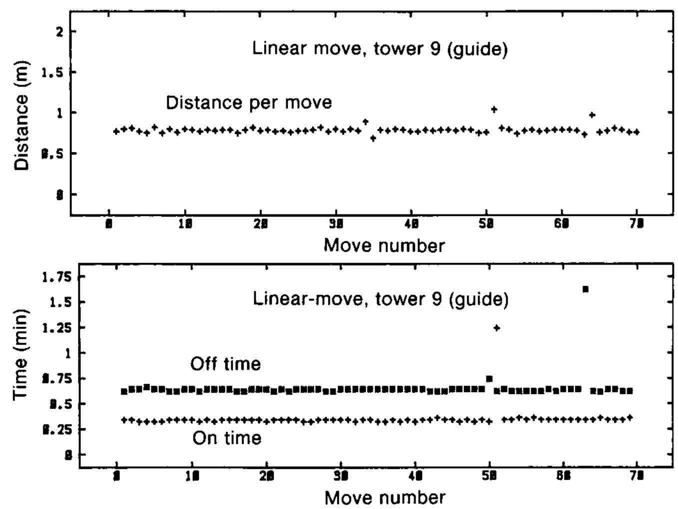

Fig. 2. Distance per move and on- and off-times of the linear-move machine showed guide tower movement to be quite constant.

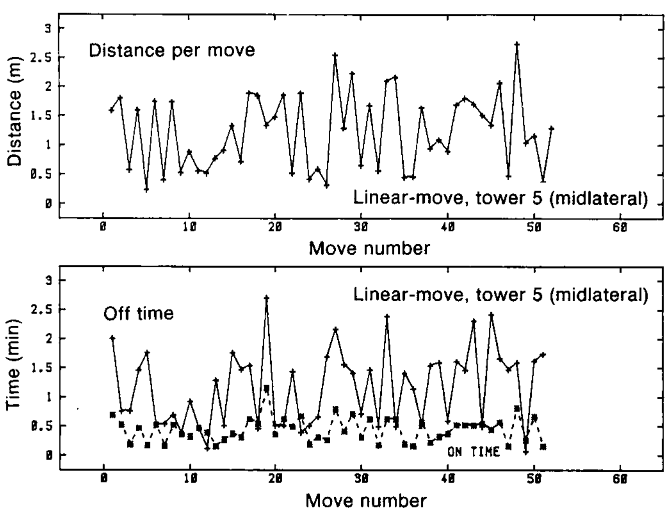

Fig. 3. Unlike pattern in fig. 2, movement of the midlateral tower of the linear-move machine was very irregular.

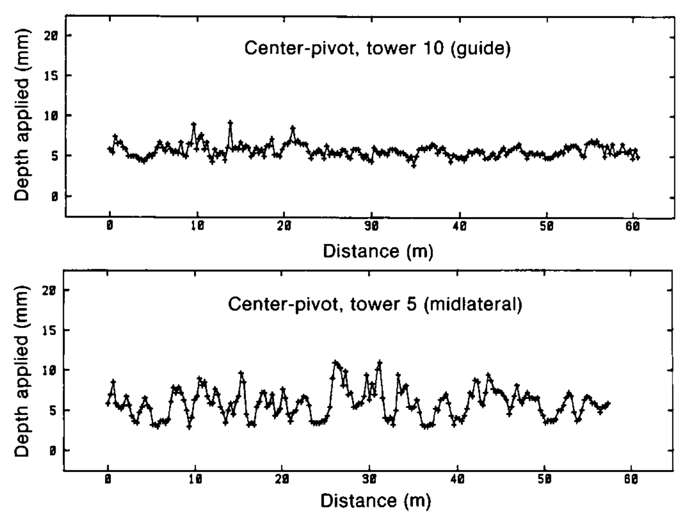

Fig. 4. Center-pivot machine showed little variability near the guide tower but repeating peaks and valleys near the midlateral.

TABLE 1. Statistical analysis of catch can data

Location	Mean*	SD†	CV‡	CU§
LINEAR-MOVE	------------ inches ------------		--------- % --------	
Inside tower 9 (guide), along travel path	0.98	0.14	14	89
Inside tower 5 (midlateral), along travel path	1.26	0.41	32	75
Along lateral length	0.95	0.32	34	73
Across span 5	0.72	0.37	51	59
Across span 9	0.79	0.24	31	76
CENTER-PIVOT				
Inside tower 10 (guide), along travel path	0.24	0.03	12	90
Inside tower 5 (midlateral), along travel path	0.25	0.08	30	76
Along lateral length	0.38	0.19	50	77
Across span 2	0.35	0.16	46	67
Across span 5	0.23	0.08	37	70
Across span 10	0.32	0.10	32	71

* Average depth of water caught.
† Standard deviation.
‡ Coefficient of variation.
§ Coefficient of uniformity.

TABLE 2. Statistical analysis of distance per move and on- and off-time

Item	Distance per move	On-time	Off-time
	feet	------------minutes-----------	
LINEAR-MOVE			
Tower 5 (midlateral)			
Mean	4.0	0.45	1.18
SD	2.1	0.21	66
CV (%)	53	47	56
Tower 9 (guide)			
Mean	2.6	0.36	0.66
SD	0.13	0.11	0.12
CV (%)	6	30	18
CENTER-PIVOT			
Tower 5 (midlateral)			
Mean	12.2	1.55	2.25
SD	2.6	0.4	0.4
CV (%)	21	25	19
Tower 10 (guide)			
Mean	3.2	0.38	0.12
SD	0.6	0.0024	~0
CV (%)	19	0.6	~0

small distances per move and short off-times.

These results suggest a relationship between application uniformity and tower movement, since uniformity was high where tower movement was constant and low where tower movement was highly variable. The time series analysis, however, showed little variability in the can data that was directly related to the tower movement. Also, we found a weak correlation between off-time and distance per move of tower 5, which was unexpected.

Most of the nonuniformity in the data for the individual spans (table 1) resulted from sprinkler overlap. Reasons for the particularly low value for span 9 are unknown.

With the center-pivot machine, much higher variability was apparent near tower 5 (midpoint along the lateral) than near tower 10 (guide tower) (fig. 4). No pattern of variability appeared near tower 10, but the data taken near tower 5 showed a repeating pattern of valleys and peaks. The statistical analysis (table 1), indicated high uniformity near tower 10 and low uniformity near tower 5.

Movement of the guide tower was very constant (table 2). Tower 5 moved irregularly, however; distances per move ranged from 8 to 16 feet.

As with the linear-move machine, application uniformity of the center-pivot machine was high near the guide tower, which had a constant movement, and lower near tower 5, which had highly variable movement. Statistical analysis of the can data near the guide tower revealed no nonuniformity directly related to the tower movement but, instead, revealed a significant repeating pattern, or periodicity, every 16 feet. The reasons for this periodicity are unknown, since no such behavior was found in the tower movement. Analysis of the can data near tower 5, however, showed most nonuniformity to be directly related to the tower movement, with the periodicity occurring over an average distance of 12 feet (equal to the average distance per move).

Conclusions

In this study, we found that uniformity was high near the guide towers and low near the midlateral towers of both machines. Although the coefficients of uniformity were similar for both machines, the patterns of nonuniformity were different. Near the midlateral tower, nonuniformity occurred over relatively small distances with the linear-move machine, and over relatively large distances with the center-pivot machine.

In both machines, movement was constant near the guide tower and variable near the midlateral tower, but no direct correlation between uniformity and tower movement was evident except near the midlateral tower of the center-pivot machine. There was no correlation between nonuniformity along the lateral length and variability in nozzle discharges of either machine.

These analyses of both machines suggest a relation between uniformity along the travel path and the tower movement, yet we only found a direct correlation in the one instance. One reason for the lack of correlation may have been the relatively small distances per move and overlapping of spray patterns along both the lateral and the travel path. Where distances were small compared with the wetted patterns, overlapping apparently caused a complex periodicity that obscured any direct correlation. Where distances per move were larger, as at the midlateral tower of the center-pivot machine, there was less interference from overlapping, and a direct correlation was found.

Catch can data revealed unexpected behavior along the lateral length of the center-pivot machine. Starting at about 190 yards from the pivot point, an obvious pattern of valleys and peaks occurred about every 50 yards. One might expect this pattern to be related to variability in the nozzle discharge, but no such relationship existed, as verified by statistical analysis of both nozzle discharge and catch-can data. We believe the repeating pattern was caused by the movement of the machine. Conceivably, such behavior could occur if a tower moved a considerable distance before an adjacent tower also moved a considerable distance. Uniformity along both the travel path and the lateral may thus be affected by the machine's movement.

The effect of nonuniformity on crop production depends on factors such as the distance over which the nonuniformity occurs, lateral water redistribution characteristics of the soil, the depth applied per irrigation, the seasonal uniformity due to subsequent irrigations, and the crop's response to water stress resulting from nonuniform application at any given time. Nonuniformity of the linear-move machine occurred over relatively small distances and thus might have little effect on yield. Characteristics of the center-pivot machine could affect crop yield, however: even though the coefficients of uniformity were the same as for the linear-move machine, the nonuniformity occurred over a fairly large distance.

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