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COMPARATIVE EFFECTIVENESS OF FULL-FIELD AND FIELD-EDGE BAIT APPLICATIONS IN DELIVERING BAIT TO ROOF RATS IN FLORIDA SUGARCANE FIELDS

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ABSTRACT

Current rodent control measures in Florida sugarcane emphasize the placement of toxic baits at field perimeters, either by aerial application, in bait stations, or both. In a 2-phase study involving 16 fields, we determined that perimeter bait applications, although providing greater bait density, were less effective than whole-field applications in delivering bait to roof rats living in field centers. Removal of rats (by trapping) from the edges of perimeter-treated fields to simulate bait-induced mortality did not result in a major shift in rat movements toward field perimeters. Further work is needed on registration of effective rodenticides for application in sugarcane and on optimal bait distribution patterns to provide cost-effective rodent control.

INTRODUCTION

Rodent damage to sugarcane has been estimated to amount to $10 million in one year for one large grower-processor in Florida (6). Current rodent control measures in Florida sugarcane emphasize the placement of toxic baits in field edges by aerial application or in bait stations. These methods have evolved for several reasons: the difficulty of penetrating maturing sugarcane, the belief that rats are killed or leave fields at harvest and reinvade fields from surrounding areas, the expense of whole-field bait application, and the fact that until recently, no bait was registered for in-field use in Florida sugarcane. The need for in-field treatment to reduce rodent populations in Hawaiian sugarcane fields has long been recognized (3,12). Data are lacking on the comparative effectiveness of whole-field versus field-edge applications in delivering baits to rats inhabiting Florida sugarcane fields. The primary targets of aerially-applied rodent baits in Florida sugarcane are the cotton rat (*Sigmodon hispidus*) and the roof rat (*Rattus rattus*). Movement data obtained in earlier studies (4) indicated that only a small percentage of cotton rats occupying a field would encounter baits placed at the field edge. Very little information is available on roof rat movements in Florida sugarcane, however rats have been trapped throughout fields.

In Hawaii, roof rats (= black rats) are seldom captured in sugarcane fields, and primarily occupy the large non-crop areas surrounding fields, e.g. gulches or wastelands (11,13). Lindsey et al (9) concluded that in Hawaiian sugarcane, perimeter bait stations may be effective for roof rats because 78-93% of roof rats captured along field edges had consumed bait station oat groats treated with a marker. Hawaiian sugarcane field rodent populations (primarily the Polynesian rat, *Rattus exulans*) are drastically reduced by harvest operations, and rats that survive leave the fields (10). In Florida, many rats survive harvest and continue to live in the fields. Following a 1983 field test (7), the fate of 49 radio-collared roof rats in four fields was determined immediately after the fields were burned, and 27 radio-collared roof rats in three fields were tracked through loading of cut cane (all fields were hand-harvested). Only six rats (12%) died as a direct result of the burn, and eight (30%) were apparently crushed or suffocated in their shallow nests, usually located under cane stools, by mechanical loaders. Thus roof rat mortality directly related to harvest was less than 50% of field populations. Two radio-collared rats that were not recovered immediately after harvest were still living in the field one month later. In May 1982, 20 roof rats were radio-tracked over a 2-week period in two harvested sugarcane fields (8). Only one rat left the field where it was tagged and moved to an adjacent ditch-bank, despite the fact that the resprouting cane in this field was approximately 60 cm in height and provided relatively little cover. During a 2-year livetrapping study (5) roof rats were captured in the field in almost every month, including those following harvest.

Apparently, roof rats in Florida sugarcane fields behave quite differently than those in Hawaiian sugarcane, which is perhaps not surprising considering the great differences in physical features and cultural practices of these two regions. Nevertheless, field-edge baiting could provide crop protection in Florida sugarcane if roof rats living in field interiors frequently visited field edges, or if bait-induced mortality at perimeters caused a rapid (while bait was still available) shift in rat movements toward field edges.

We compared the effectiveness of full-field and field-edge baiting in delivering baits to roof rats throughout fields and determined whether or not rats move to the field edge and consume bait in response to a population reduction at the edge.

METHODS

Phase I - No population reduction along edge - Eight sugarcane half-fields (7.3 ha in size), in which at least six roof rats had been captured in 24 trap-nights, were selected in September 1982. Traps were Haguruma (Japanese) wire-mesh live traps (Honolulu Sales, Ltd., Honolulu, HI) baited with apple.

Study half-fields were stratified into edge and center (Figure 1). The middle ditch, a 1.3 x 1.3 m irrigation ditch, was considered as field-edge because current baiting procedures include applying bait along it. Four of the selected fields were randomly assigned to edge-treatment and four to full-field treatment. The proportion of trapped rats that consumed bait was determined for each stratum within fields.

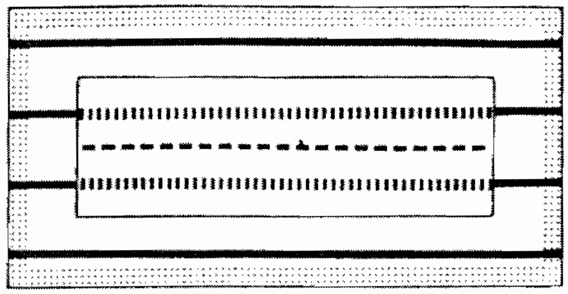

Figure 1. Field-edge treated field, showing location of trapping transects. The layout of whole-field treated fields was identical, however the same quantity of demeclocycline hydrochloride-treated bait was distributed over the whole field. All fields were approximately 7.3 ha.

Slightly-crimped oat groats were treated with 1% demeclocycline hydrochloride (DMCH) by weight in an acetone slurry. (Demeclocycline hydrochloride was formerly named demethylchlortetracycline, abbreviated DMCT). After evaporation of the acetone, the treated oat groats were overcoated with 6% by weight 1:9 Rhoplex AC-33 and water. DMCH induces a golden-yellow fluorescence in bones and teeth under long-wave ultraviolet light (3,600-3,700 Å) (2). It has been used as an effective rodent marker for bait consumption studies (9,11).

Treated oat groats (4.5 kg) were applied to each test field by aerial application. In full-field applications, bait was evenly distributed over the entire field (5.6 kg/ha, or 5 lb/A). In field-edge applications, bait was applied in a swath just inside the field edge (Figure 1), in the same manner as is currently practiced by some Florida sugarcane growers. Consequently the bait density in the treated swaths of field-edge treated fields was several times that of whole-field applications; this insured that the same total quantity of bait was available to rats in both types of treatments. The test was conducted in two stages, three days apart, each stage including two full-field and two field edge treatments. Rats were allowed to consume treated oat groats and become marked for six days following application. Four trapping transects (370 m long) were established by cutting paths through each half-field. Rat snap traps baited with apple chunks were placed at intervals along each transect for two consecutive nights (Figure 1). The trap interval was 5.5 m in the field-center stratum and 9 m in the field-edge stratum, so that trapping effort was similar in each stratum per field. A buffer zone of 30 m with no traps was established between edge and center strata.

Mandibles from all trapped rats were examined independently under long-wave UV light by two evaluators for presence or absence of fluorescence. Several mandibles from roof rats not exposed to DMCH were available as references. Mandibles which were scored positive for fluorescence by one evaluator and negative by the second were examined by a third evaluator. The score given by the two evaluators in agreement was considered correct. The sample evaluated by the third evaluator always included additional mandibles to those in question.

Variation in proportions of rats marked per stratum was tested using a 2-factor split-plot design, in which plots are fields with bait treatments representing whole plot effects and strata representing subplot effects. Untransformed and arcsine transformed proportions of rats marked were analyzed using the ANOVA Procedure of the Statistical Analysis System (SAS) software package at the Northeast Regional Data Center, University of Florida. An _a priori_ contrast was used to compare the mean proportion of rats marked in the centers of edge-treated fields with the means of the other three treatment x stratum combinations using a constructed error term and adjusted _t_-statistic (1). The accepted significance level was $P \leq 0.05$.

Phase 2 - Population reduction along edge - Eight additional study fields were selected in October 1982 and randomly assigned to edge or full-field treatment as in Phase 1. Strata and transects were established as in Phase 1, with an additional transect in the center stratum (Figure 1). Japanese live traps baited with apple chunks were set at 15-m intervals along the three center stratum transects for three consecutive nights. All rats trapped were marked with numbered Monel® ear tags.

Oat groats treated with DMCH were then applied to the study fields as in Phase 1. Six days following bait application, rats were trapped for six consecutive days with live traps placed at 15-m intervals along edge transects (Figure 1). In perimeter-treated fields, rats were killed, removed and frozen. All rats were examined for presence of an ear tag. In full-field treatment fields, rats were ear-tagged and returned to the fields. Live traps were removed and snap traps were placed (the same day) at 7.6-m intervals on all portions of all transects except the center transect (Figure 1) for three consecutive nights. The 6-day period during which rats could have dispersed to field edges was considerably longer than the period (two days) over which oat groats have been observed to persist on the ground before being consumed.

Rat mandibles were examined for DMCH fluorescence as in Phase 1. Variation in proportions of rats marked was analyzed as in Phase 1.

RESULTS

Phase 1 - No population reduction along edge - Roof rats [442] were captured from the eight test fields post-treatment($\bar{x}$ = 56.0 from full-field and 54.5 from field-edge treated fields). Since the ANOVA results for untransformed and transformed proportions of rats marked per strata were essentially the same, and the distribution of residuals of untransformed data was close to normal, only the results of the untransformed data analysis are given. ANOVA results indicated a highly significant treatment x stratum interaction ($P = 0.002$), thus the effect of field-edge versus whole-field treatment depends upon which stratum is considered, edge or center (Table 1). A linear contrast on the mean proportion of rats marked in the centers of edge-treated fields with the means of the other three treatment x stratum combinations yielded a highly significant difference ($P < 0.001$).

Table 1. Number of roof rats marked by consumption of demeclocycline hydrochloride-treated bait/number trapped in whole-field or field-edge baited sugarcane fields, Clewiston, Florida, October 1981.

	Treatment							
	Whole-field baited				Field-edge baited			
Field	1	2	3	4	5	6	7	8
Stratum trapped								
Edge	46/50	24/28	13/14	29/30	39/40	35/36	13/17	34/35
		$\bar{x}$ = 92% marked				$\bar{x}$ = 92% marked		
Center	24/35	17/22	21/21	23/24	10/27	2/25	2/17	4/21
		$\bar{x}$ = 85% marked				$\bar{x}$ = 19% marked		

Phase 2 - Population reduction along edge - Roof rats [360] were captured from the eight test fields post-treatment ($\bar{x}$ = 20.2 from full-field and 69.5 from field-edge treated fields). A mean of 43.0 roof rats were removed from field-edge treated fields during removal trapping, and 26.5 roof rats were captured from these fields in the final snaptrapping.

ANOVA results again indicated a significant treatment x stratum interaction ($P = 0.01$). A linear contrast on the mean proportion of rats marked in the centers of field-edge treated fields with the means of the other three treatment x stratum combinations (Table 2) yielded a highly significant difference ($P < 0.001$).

Table 2. Number of roof rats marked by consumption of demeclocycline hydrochloride-treated bait/ number trapped in whole-field or field-edge baited sugarcane fields, Clewiston, Florida, October 1982. Rats were trapped and removed from the edge strata of field-edge treated fields for six days before the final snaptrapping results were obtained.

	Treatment							
	Whole-field baited				Field-edge baited			
Field	9	10	11	12	13	14	15	16
Stratum trapped								
Edge	13/13	19/21	3/4	14/16	13/20	29/35	7/8	5/9
		$\bar{x}$ = 88% marked				$\bar{x}$ = 73% marked		
Center	7/8	9/10	5/5	3/4	1/11	1/13	1/7	1/3
		$\bar{x}$ = 88% marked				$\bar{x}$ = 16% marked		

Of 122 roof rats eartagged in field centers pretreatment, only two were recaptured in the final snaptrapping . One of these, in a field-edge treated field, moved from the center to the edge stratum.

A total of 72 roof rats were eartagged and released in the edge stratum of whole-field treated fields, during the removal period in edge-treated fields. Of these, seven were recaptured in the final snap-trapping, all in the edge stratum.

DISCUSSION

Field-edge bait applications were less effective than whole-field applications in delivering bait to roof rats living in field centers. The majority of rats inhabiting field centers in edge-treated fields did not move to field edges and consume the marked bait. Even when rats were removed from the edges of edge-treated fields, to simulate bait-induced mortality, there did not appear to be a major shift in rat movements toward field edges during the period that bait was available. However, the mean percentage of rats (18%) from both phases of the study that consumed DMCH-treated bait and were later trapped in field centers was notable. This suggests that some roof rats move far enough in maturing sugarcane fields to encounter bait applied in swaths, particularly if bait were to be applied farther into fields than is currently practiced. When economic constraints are considered as well as optimal population control, a compromise between whole-field and field-edge treatments, such as in-field swath baiting, probably will be the most practical approach. Bait density may have to be higher in swaths than in whole-field applications in order to provide a sufficient quantity of bait for all rats.

The difference between the number of roof rats captured in field centers [61] vs field edges [126] during the final snaptrapping in Phase 2 may simply reflect the unequal trapping effort in these strata (1,536 trap nights in field centers vs 2,688 in field edges). There was less difference between field center [192] and field edge [250] captures in Phase 1, when trapping effort was more equal between strata (1,312 vs 1,504 trap nights).

Eartagging did not provide information on whether or not rats from field centers moved to field edges in response to population reduction at the edges. Recapture success for roof rats was extremely low, as we have found it to be in previous studies (14). Overall there did not appear to be a major shift in roof rat movements toward field edges in response to removal of rats in edge-treated fields. The ratios of roof rat captures between center and edge strata in whole-field treated fields (27:54) and field-edge treated fields (34:72) were similar. If many rats had moved from field centers to edges in field-edge treated fields, a smaller ratio of center to edge captures would be expected. Most of the roof rats captured in the edges of the field-edge treated fields were DMCH-marked (73%), although not quite as many as in whole-field treated fields (88%). If a large number of rats had moved into the edge strata of field-edge treated fields from field centers or surrounding fields, a smaller percentage of marked rats would have been expected. An important consideration in Phase 2 was our ability to remove a significant portion of the populations in the field-edge treated fields. A total of 173 roof rats were removed from the edges of the four field-edge treated fields, more than twice as many as were subsequently captured in edge strata during snaptrapping with approximately the same level of trapping effort (twice as many traps were used in snaptrapping for half as many nights as in removal trapping). While it can be argued that our reduction was not as great as a highly effective rodenticide treatment might have been, we believe that a substantial reduction was achieved in the field-edge treated fields.

Implications for Current Baiting Practices

Further work is needed on registration of effective rodenticides which can be applied in-field in Florida sugarcane. Zinc phosphide is the only toxicant which is currently approved for in-field use in Florida sugarcane because it is the only one for which a tolerance level has been established and residue data obtained in this crop. The only rodenticide currently registered for in-field treatment of Florida sugarcane (ZP® Rodent Bait AG, Bell Laboratories, Inc.) was ineffective in reducing roof rats in a field test (7), and its efficacy on cotton rats is unknown. Anticoagulant baits, which are used by many growers, may be legally applied only to noncrop areas outside of fields. Such applications would be even less likely than a field-edge application to effectively reduce in-field rat populations. No regulations specifically prohibit the use of rodenticide bait stations in field edges, however these require maintenance and are labor intensive if used properly. It is possible that rat mortality over a longer period than was simulated in this study, such as might occur with properly maintained bait stations or repeated aerial applications, might result in greater rat dispersal from field centers than we observed. An effective in-field application would undoubtedly be more cost-effective.

Until they can be legally applied in-field, we do not recommend that Florida growers broadcast anticoagulants, except perhaps in situations where noncrop areas are extensive and support large rodent populations. As effective rodenticides registered for in-field application become available, research on swath intervals and bait density may lead to a bait distributional pattern that greatly improves bait delivery to rats, and is at the same time economically feasible.

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REFERENCES

1. Cochran, W. G. and G. M. Cox. 1957. Experimental Designs: pp. 294-299. John Wiley and Sons, Inc., New York. 611 pp.

2. Crier, J. K. 1970. Tetracycline as a fluorescent marker in bones and teeth of rodents. J. Wildl. Manage. 34:829-834.

3. Hilton, H. W., W. H. Robison, A. H. Teshima, and R. D. Nass. 1972. Zinc phosphide as a rodenticide for rats in Hawaiian sugarcane. Proc. Int. Soc. Sugar Cane Technol. 14:561-570.

4. Holler, N. R., L. W. Lefebvre, and D. G. Decker. 1971. Ecology and control of rats in Florida sugarcane. Proc. 2nd Inter-American Sugar Cane Seminar: 183-188.

5. Holler, N. R., L. W. Lefebvre, D. G. Decker, and N. J. Shafer. Cumulative damage and rodent populations in Florida sugarcane. Unpubl. manusc.

6. Lefebvre, L. W., C. R. Ingram, and M. C. Yang. 1978. Assessment of rat damage to Florida sugarcane in 1975. Proc. Amer. Soc. Sugar Cane Technol. 7:75-80.

7. Lefebvre, L. W., N. R. Holler, and D. G. Decker. 1985. Efficacy of aerial application of a 2% zinc phosphide bait on roof rats in sugarcane. Wildl. Soc. Bull. 13:324-327.

8. Lefebvre, L. W., N. R. Holler, D. G. Decker, and C. D. Hillman. 1982. Pilot study for the use of radio transmitters on roof rats (Rattus rattus). Final report on U. S. Fish and Wildlife Service study performed in cooperation with the Florida Sugar Cane League. 7 pp.

9. Lindsey, G. D., R. D. Nass, and G. A. Hood. 1971. An evaluation of bait stations for controlling rats in sugarcane. J. Wildl. Manage. 35:440-444.

10. Nass, R. D., G. A. Hood, and G. D. Lindsey. 1971. Fate of Polynesian rats in Hawaiian sugarcane fields during harvest. J. Wildl. Manage. 35:353-356.

11. Nass, R. D., G. A. Hood, and G. D. Lindsey. 1971. Influence of gulch-baiting on rats in adjacent sugarcane fields. J. Wildl. Manage. 35:357-360.

12. Teshima, A. H. 1970. Rodent control in the Hawaiian sugar industry. Proc. Vert. Pest Conf. 4:38-40.

13. Tomich, P. Q. 1970. Movement patterns of field rodents in Hawaii. Pacific Sci. 24:195-233.

14. Walsh, L. E., N. R. Holler, D. G. Decker, and C. R. Ingram. 1976. Studies of rodent damage and rodent population dynamics in Florida sugarcane. Proc. Amer. Soc. Sugar Cane Technol. 5:227-230.