Title
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Journal
Proceedings of the Vertebrate Pest Conference, 14(14)

ISSN
0507-6773

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Publication Date
1990

RODENT DAMAGE TO HAWAIIAN SUGARCANE

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ABSTRACT: Rattus norvegicus, R. exulans, and R. rattus cause extensive damage to Hawaiian sugarcane. This paper gives an overview of the problem and briefly summarizes the history of rodent control on Hawaiian sugarcane plantations. Current baiting practices with zinc phosphide may favor the proliferation of R. norvegicus, and more effective control methods are needed for this species. A cooperative research and development program by the Denver Wildlife Research Center and the nonprofit Hawaiian Sugar Planters' Association is described.

Proc. 14th Vertebr. Pest Conf. (L.R. Davis and R.E. Marsh, Eds.)
Published at Univ. of Calif., Davis. 1990.

INTRODUCTION

Sugarcane has been an integral part of Hawaii's economy for more than 150 years. It is the state's leading agricultural industry, with annual revenues exceeding $350 million. More than 20,000 jobs in the state are attributable directly or indirectly to the sugar industry (Hawaiian Sugar Planters' Association 1989).

Although Hawaiian sugarcane yields are among the highest in the world, growers have struggled to stay in business during recent years. Between 1968 and 1988, the number of Hawaiian sugarcane plantations decreased from 25 to 12 through consolidation and closures, with a corresponding decline in acreage from 242,000 to 176,000. Adverse weather and competition from foreign producers and from the corn sweetener and beet sugar industries have affected the Hawaiian sugarcane industry unfavorably. In addition, rodents have had a detrimental effect on production. This paper reviews the history of rodent control in Hawaiian sugarcane and describes current research conducted by the Denver Wildlife Research Center (DWRC) and the Hawaiian Sugar Planters' Association (HSPA).

SUGARCANE-RAT PROBLEMS

Gnawing by rats diminishes sugarcane yields and increases the incidence of secondary infection, which reduces cane quality. The most severe damage is to unirrigated sugarcane on the windward side of the islands of Hawaii and Kauai, where abundant rain and lush vegetation of noncrop lands adjacent to sugarcane fields favor the proliferation and survival of rodents. Crop losses due to rats on one windward plantation on the island of Hawaii average 11% at harvest (J. Cross, Mauna Kea Agribusiness Co., Inc., pers. comm.). Annual statewide losses are estimated conservatively at $6 million.

Three species of rats damage sugarcane in Hawaii. Polynesian rats (Rattus exulans), the smallest of the three, arrived with early human migrants from the central Pacific. Norway rats (R. norvegicus) and black rats (R. rattus) were introduced sometime after the arrival of Captain Cook in 1778. Most of the damage to sugarcane is caused by Polynesian and Norway rats, and to a lesser degree by black rats. The latter is a major pest in macadamia nut orchards.

Hawaii is one of a few areas in the world where sugarcane is grown as a 2-year crop. Most rats living in cane fields either die or migrate to surrounding areas during harvest (Nass et al. 1971), and populations do not build back up until the second half of the crop cycle. During much of the first year, the sugarcane stalks stand erect, the crop canopy is open, and most fields have little ground cover. Some rats forage along the periphery of young sugarcane fields, but few venture into the interior until the cane is between 8 and 12 mo old. At about this time, sugarcane stalks become lodged and dead leaves begin to accumulate. The resulting thatch layer is rich in invertebrate food and provides protective cover where rats establish infield dens. Adjacent cane fields and surrounding noncrop areas are a ready source for reinvasion. Rat damage accumulates slowly at first, but escalates rapidly after the crop is 14 or 15 months old (Hood et al. 1971).

DAMAGE CONTROL

Various methods have been employed to control rat damage in sugarcane. Mongooses (Herpestes auropunctatus) were introduced during the 1880s and are now abundant on all the major islands except Kauai. Although these predators are ubiquitous in and around sugarcane fields and eat many rodents (Baldwin et al. 1952, Kami 1964), rats continue to thrive. Extensive trapping campaigns also are ineffective. Between 1914 and 1922, an average of 141,000 rats were taken per year from sugarcane plantations on the island of Hawaii, with no apparent effect either on rat populations or on sugarcane damage (Pemberton 1925). Other attempts also have met with little success. Fumigating rats in their burrows is impractical because of the porous and rocky nature of most soils in Hawaii (Doty 1945). The use of dogs and the introduction of viral diseases have been attempted but with little success (Doty 1945). Alteration and/or destruction of noncrop habitat to reduce reservoir rat populations is economically unfeasible and environmentally undesirable (Sugihara et al. 1977).

Hawaiian sugarcane growers have used rodenticides extensively since the early 1900s. Formerly used poisons include barium carbonate, strychnine alkaloid, 1080, and thallium sulfate. Flour dough, rolled oats, and whole wheat served as carriers (Pemberton 1925). Although effective initially, all the acute rodenticides mentioned above gradually lost their usefulness owing to the sublethal consumption of bait by rats and their subsequent bait shyness (Doty 1945). Prebaiting with unpoisoned material and rotation of baits formerly were recommended for increasing initial bait consumption and reducing bait shyness (Doty 1938, 1944); these practices rarely are followed today.

During the 1950s, anticoagulants became the toxicant of choice in and around sugarcane fields (Doty 1951, Gross et al. 1951). Formerly warfarin, and later fumarin, pival, and diphacinone, were placed in plastic baggies and tossed into fields and surrounding noncrop areas. Possible nontarget and secondary hazards, especially to humans eating contaminated feral pigs (Engeman and Pank 1984), prompted HSPA in 1981 to recommend against the outdoor use of anticoagulants (Hilton and Pank 1981). Rapid deterioration of bait due to mold was also a problem (Doty and Wismer 1949). Current regulations allow the use of anticoagulants in noncrop areas surrounding sugarcane fields, but require that they be put in tamper-proof bait stations. However, such bait stations need intensive labor to carry into the field and to service (Smythe 1964). Furthermore, they do little to control rats in field interiors (Lindsey et al. 1971), and they do not protect bait from humidity (Teshima 1976, 1977).

In 1970, a joint research effort by DWRC and HSPA led to the registration of zinc phosphide for use in sugarcane fields (Hilton et al. 1972). This was the first full registration of any rodenticide in the United States for agricultural use. Today zinc phosphide is the only toxicant available for infield use in sugarcane. It is most commonly formulated with an oat bait and broadcast from an airplane.

Although probably effective against two of the three species of depredating rats, zinc phosphide baits are not effective against Norway rats (Fellows 1977, Fellows and Garrison 1981). Current baiting practices with this material may actually be causing a shift in the relative abundances of the three species. Norway rats formerly were rare in sugarcane fields (Kami 1966, Tomich 1986), but their numbers have increased substantially since the discontinued use of anticoagulants and the widespread adoption of zinc phosphide baiting (Hirata 1977, Karim 1983). A long crop cycle and reliance on a single toxicant may exacerbate the problem. The use of as many as four applications of zinc phosphide during the final year before harvest may be promoting the development of bait shyness. Additional control materials are needed.

RAT CONTROL RESEARCH

In 1967, DWRC and HSPA joined in a cooperative research and development effort to find effective methods of controlling rat depredations in sugarcane. DWRC operated a research station in Hilo from 1967 until 1983, when government budget constraints forced the closing of the station. In 1988 the U.S. Congress again appropriated funds to conduct rat control research in Hawaii, and DWRC reopened its Hawaii Field Station. Below we describe research currently being done at the station.

To estimate the relative abundances of the three species of rats in sugarcane fields and to determine whether their relative numbers have changed, we conducted an extensive trapping study between 13 February and 26 May 1989. Fourteen fields greater than 12 mo of age were selected at random from each of three plantations on the island of Hawaii and one plantation on Kauai; 50 snap traps were placed at 3-m intervals along a 150-m transect extending from the edge to the interior of each field. Three days after prebaiting with grated coconut, traps were baited with pieces of coconut, set for four consecutive nights, and checked each following morning between sunrise and noon. We used ANOVA to detect differences among plantations and species, and Duncan's multiple range test to make paired comparisons at the 0.05 level of probability.

We captured a total of 1,000 rats during 11,200 trap-nights (Table 1). The number of captures varied among the four plantations ($F = 15.06$; 3, 156 df; $P < 0.0001$), with more rats captured at each of the three plantations on Hawaii than at the one on Kauai. The total number of captures did not vary significantly among the three plantations on the island of Hawaii. Capture success did vary among species ($F = 27.13$; 3, 167 df; $P < 0.0001$). Norway rats were more numerous than either of the other two species, and Polynesian rats were more numerous than black rats. Norway rats were the predominant species in 35 fields, and Polynesian rats predominated in 16 fields. These results indicate that the relative abundance of Norway rats in sugarcane fields has increased during the past decade, and also that Polynesian rats are still a major problem. These data are being analyzed further to determine the effects on rat numbers of various crop characteristics, environmental variables, and past zinc phosphide baiting practices.

Table 1. Number of rats captured on each of four unirrigated sugarcane plantations in Hawaii, February to May 1989.[a]

		Number of captures			
Island	Plantation	Norway rat	Black rat	Polynesian rat	Total
Hawaii	Mauna Kea	186	9	108	303
	Kau	174	82	57	313
	Hamakua	130	45	146	321
Kauai	Lihue	39	6	18	63
	Total	529	142	329	1,000

[a]Fifty snap traps were baited with coconut and set for four consecutive nights in each of 14 randomly selected fields on each plantation.

During 1989, we conducted 3-day, no-choice feeding trials to measure the efficacy of five commercially available zinc phosphide baits. The baits included three different pelleted formulations (ZP Rodent Bait AG[a], Hopkins Zinc Phosphide Bait, and Ridall-Zinc) and two oat formulations (KFE Zinc Phosphide Prepared-Rat Bait and HGP Zinc Phosphide Oats). Untreated oat groats were used as a control. All baits were most effective against Polynesian rats and, with one exception, least effective against Norway rats (Table 2). For each of the three species, the pelleted baits gave better control than the oat baits. Poor moisture resistance has limited the effectiveness of past formulations of pelleted baits under the wet conditions present in Hawaii (Fellows et al. 1982a,b), and the durability of the pelleted baits used in this study should be evaluated before their use is recommended.

[a]Reference to trade names does not imply endorsement by the U.S. Government or HSPA.

Table 2. Effectiveness of five commercial zinc phosphide baits against three species of rats during 3-day, no-choice feeding trials. Five males and five females of each species were tested for each bait.

Bait	Mortality		
	Norway rat	Black rat	Polynesian rat
ZP Rodent Bait AG[a]	2/10	7/10	9/10
Hopkins[a]	7/10	8/10	10/10
Ridall-Zinc[a]	8/10	7/10	10/10
KFE[b]	2/10	6/10	8/10
HGP[b]	0/10	3/10	7/10

[a]Pelleted formulation.
[b]Oat formulation.

Broken grains, chaff, and other debris present in the two commercial oat formulations used in the above tests may have reduced the efficacy of these baits. We conducted additional tests to evaluate bait prepared in our laboratory with better quality oats. Our objectives were 1) to determine whether efficacy would improve with better quality oats, and 2) to evaluate the adhesive commonly used to prepare this bait in Hawaii. During 3-day, no-choice feeding trials, 10 individually caged rats of each of three rat species were offered one of three formulations: 1) plain oat groats, 2) oat groats treated with 2.0% Alcolec-S, or 3) oat groats treated with 2.0% Alcolec-S plus 1.88% zinc phosphide. Mortality with the zinc phosphide formulation was 90% for Polynesian rats, 70% for black rats, and 30% for Norway rats (Table 3). The relative efficacy against the three species of rats was similar to that with the commercial oat baits (Table 2), indicating that the lack of control of Norway rats is due to more than poor oats. Fellows (1977) and Fellows and Garrison (1981) also concluded that this bait is effective against Polynesian rats, but not Norway rats. Consumption during Day 1 varied among test foods ($F = 32.66$; 2, 72 df; $P < 0.0001$) and was significantly greater for the Alcolec-S formulation than for either plain oat groats or the zinc phosphide-treated oats (Table 3). Thus, Alcolec-S appears to be an attractive adhesive for use against Hawaiian populations of Norway, black, and Polynesian rats. Pank (1976) also reported increased bait acceptance and mortality with zinc phosphide-Alcolec-S formulations.

Cholecalciferol (Vitamin D_3) might provide an effective alternative to zinc phosphide. Both laboratory (Marshall 1984) and field (Rennison 1974) studies indicate that this material can control Norway rats. Delayed toxicosis is thought to prevent the development of bait shyness with cholecalciferol (Marshall 1984), and a reported lack of secondary toxicity (Marshall 1984) should facilitate registration in Hawaii, where the endangered Hawaiian hawk is a major predator of rats. In preliminary laboratory tests conducted by HSPA in 1985, 0.075% cholecalciferol on rolled oats gave good control of Polynesian and black rats but only marginal control of Norway rats (Table 4). A limited field test conducted in a recently harvested sugarcane field also resulted in poor control of Norway rats. Cholecalciferol-treated oats were broadcast at the rate of 10 lb/ac in a 20-ft-wide strip along a 50-ft-wide gulch, and pre- and posttreatment trapping success was compared. Trapping success for Polynesian rats declined by 94% after baiting with cholecalciferol but that for Norway rats increased by 42%. Additional laboratory work with this material is in progress.

Table 3. Average consumption and mortality of rats offered one of three baits during 3-day, no-choice feeding trials. Five males and five females of each species were tested for each bait.

Species	Bait[a]	Consumption (g)			Mortality
		Day 1	Day 2	Day 3	
Norway rat	1	0.9	0	0	3/10
	2	12.7	13.5	13.6	0/10
	3	7.4	11.5	13.3	0/10
Black rat	1	0.6	0.2	0	7/10
	2	7.1	7.3	9.0	0/10
	3	5.5	8.2	9.5	0/10
Polynesian rat	1	0.3	0.1	0	9/10
	2	3.4	4.9	5.8	0/10
	3	1.8	3.7	5.4	0/10

[a]1 = oat groats treated with 2.0% Alcolec-S and 1.88% Zn_3P_2; 2 = oat groats treated with 2.0% Alcolec-S; 3 = plain oat groats.

Table 4. Effectiveness of 0.075% cholecalciferol on rolled oats against three species of rats during 3-day, no-choice feeding trials.

Rat species	No. rats tested	Mortality	% Mortality	Mean days to death
Norway	22	11	50	6.3
Black	14	12	86	4.0
Polynesian	7	6	86	5.0

SUMMARY

A prevalence of lush noncrop areas in Hawaii, together with a long crop cycle, favor the proliferation of rats in and around sugarcane fields. Controlling rodent damage to this crop requires reducing not only infield populations of rats, but also reservoir populations in adjacent gulches and noncrop areas. Currently available zinc phosphide baits do not give adequate control, especially of Norway rats, and a more effective rodenticide is needed. DWRC and HSPA are continuing their cooperative efforts in this area.

ACKNOWLEDGMENTS

D. Elias and R. Engeman reviewed an earlier draft of this manuscript. D. Hirata assisted with the trapping study. G. Mikami conducted the cholecalciferol bioassays.

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