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Allen H. Teshima
Hawaiian Sugar Planters' Association, Hilo, Hawaii

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ALLEN H. TESHIMA, Assistant Scientist, Hawaiian Sugar Planters' Association, Hilo, Hawaii

ABSTRACT: Past and present concepts of rodent control at the 24 sugar plantations of Hawaii are reviewed with particular attention being given to the research efforts of the Experiment Station of the Hawaiian Sugar Planters' Association in improving operational rodent control in sugarcane. Hawaii offers a unique set of conditions: a 2-year crop cycle, a production of over 100 tons of sugarcane per acre, countless numbers of gulches and wasteland bordering crop fields, and a year-long growing season, all having an effect on rat population and habitat.

The Hawaiian sugar industry -- twenty-four individual sugar companies -- is the ranking agricultural concern of the State of Hawaii, utilizing 68% of the agricultural land (excluding grazing) and accounting for 60% of the agricultural income. The companies work together through a non-profit agricultural organization called the Hawaiian Sugar Planters' Association (H.S.P.A.). One of the major efforts of the Association is the support of the H.S.P.A. Experiment Station, the research arm for Hawaii's sugar plantations. The growing and processing of sugarcane to raw sugar and molasses takes place in Hawaii; refining to various forms of white, brown, and colored crystals is done at C and H in Crockett, California.

Sugarcane is grown commercially on four of Hawaii's seven Inhabited islands -- Hawaii, Maui, Oahu, and Kauai. The Experiment Station, in Honolulu, maintains substations on these four islands and a quarantine station for imported canes on a fifth island -- Molokai. The Islands are volcanic in origin with sugarcane grown in weathered clay or rocky soil on alluvial plains or mountain slopes to 3000-ft. elevation. Rainfall, in sugarcane areas, ranges from 10 inches per year on the leeward slopes to over 200 inches to windward of the prevailing northeast trades, cutting the old lava flows with series of rugged gulches from the mountains to the sea.

Although limited in land area to about 240,000 acres, sugarcane fields dot the island chain for a distance of 360 miles north to south. Hawaii's sugarcane crop is unique: average cane yields of over 100 tons per acre and sugar over 11 tons are the highest in the world. It is grown from stem cuttings for 2 years before the first harvest, then cut at ground level and "ratooned" for about two more crops of 2 years each before replanting. There is no crop rotation and no fallowing, and cane is planted at any season since temperatures vary only slightly.

Unfortunately, the wild jungle habitat of the gulches, the densely-covered crop fields, and the subtropical climate all contribute to a flourishing rat population that becomes established in the fields from the gulches when the canopy and leaf-trash cover get fairly dense -- at about 6-8 months of age -- and through the remainder of the 2-year cycle. Sugarcane is a decumbent grass; stalks may get 40 ft. long -- and number 40,000 to the acre -- but only the top 15 ft. is erect; the remainder lodges in a tangled mat of stalks and dead leaves that may reach over 3 feet in height.

All three species of rats in Hawaii inhabit fields and chew on sugarcane even up to considerable heights off the ground. The Polynesian rat (*Rattus exulans*), once thought to be a rare species, is most abundant. The Norway rat (*R. norvegicus*) and the Black rat (*R. rattus*) also damage cane. Damage by the house mouse (*Mus musculus*) has not been demonstrated although it is commonly found in fields. The mongoose (*Herpestes auropunctatus*) is also common as the only major mammalian predator; while field rodents represent a significant portion of its diet, it is doubtful that the mongoose controls rodent populations to any degree (Tomich, 1969). To many in Hawaii, the mongoose is considered a pest.

Historically the industry has been plagued with damage from rats since at least 1900, and by a limited knowledge about them although some research was started as early as the 1920's. Damage has varied considerably with changes in varieties and cultural practices, and with rat population fluctuations, but it is estimated that dollar losses amount to about 4.5 million per year. Control measures have been carried on since the 1920's and at one time or another have employed barium carbonate, strychnine, thallium sulfate, zinc phosphide, and anticoagulants. Applications have been made by hand at or near field edges because no other means was available. During one period sling-shots were used to fling torpedo baits into the field edges. Frequency of stalk damage varies with climate, being greater in the high rainfall areas where 30% of all stalks may be chewed in two. Damage approaching 90% of

all stalks has been known to occur (Doty, 1945) and still may occur in small patches. Control programs today cost about \$400,000 a year and are of unknown and doubtful value since only the field edges are treated.

Rats injure cane by gnawing through the hard outer rind of the joints between the nodes and chewing out the soft fibrous center. Damage may occur only to one internode of a stalk or may be found on as many as 15-20 out of a total of 30 internodes. While the rats are responsible for the primary injury, sugar loss is partially dependent on secondary infestation from bacterial and fungal diseases, insects, and decrease in continued growth of the stalk.

Because some sugar can still be extracted from a damaged stalk, estimation of sugar loss cannot be made merely by tallying damaged stalks. We must make laboratory analyses for recoverable sugar contained in sound, undamaged stalks and compare this with the sugar in the damaged portions. In this way we get estimates of the quantity and quality of the sugar juice in the plant -- and juice quality relates directly to the amount of recoverable sugar. Such analyses are expensive and time-consuming. However, by having an adequate number of samplings, it is possible to relate the percentage of the total number of stalks damaged in a field with the expected sugar loss. Plots of these two parameters are constructed by the IBM 1130 computer, which also calculates the correlation coefficient for damage counts with sugar loss. The regression curve so obtained can then be used to estimate sugar losses merely by taking field damage census, eliminating the need for the more complicated laboratory analysis. Certain factors such as rainfall, elevation (temperature), and crop variety influence the rate of deterioration of damaged cane, and a preliminary study has been made of these factors.

Samples taken to date reveal losses of about 0.2 ton sugar per acre for each 10% increment in the number of stalks chewed. Several plantations will average between 20-30% stalk damage. Losses are greater, for the same percentage of stalks damaged, under high rainfall conditions where secondary souring appears to be faster.

Plantation rat-control programs rely heavily on anticoagulants and, to a lesser extent, on thallium sulfate. Bait is placed by hand in plastic-coated paper bait stations at intervals of 50-75 ft. along field roads, irrigation ditches, drains, and field edges (especially those bordering waste areas and gulches). Treatments are costly -- 90% of the total cost is labor, only 10% is for bait -- because the bait stations must be refilled as often as 2-week intervals and because trails must be cut along the gulches for access. It has been obvious for some years that rats were not being well controlled, especially in the interior of the fields, and that the programs have to be changed or abandoned because of spiraling labor costs and serious labor shortages. Mechanization and field access can only be brought about by the use of aircraft or, in some areas, of the ground-driven mechanical blower.

Although aerial bait application was first tested as early as 1955, it has been considered seriously only since 1964 when Lowery conducted some experimental aerial applications (Lowery, 1967). His guidelines are still valid, in that a single-grain bait -- such as oat groats or corn -- is thinly distributed over the crop fields so that rats do not need to move far to find bait kernels. The bait should not be protected from weathering and must be effective only in the first few nights of feeding. And the toxicant must be acceptable to the U.S. Department of Agriculture and the Food and Drug Administration for registration and use in a food crop.

In 1967, the U.S. Department of Interior approved the establishment of a Wildlife Damage Research Station in Hilo, Hawaii. This facility, under the local direction of Mr. Glenn Hood, is a branch of the Denver group, and has been experimenting, as part of its research work, with evaluation of the aerial application of zinc phosphide on oat groats. This work and residue analysis by Denver and H.S.P.A. has resulted in preparation and submission of an application for registration of zinc phosphide to be used on oat groats as a rodenticide for sugarcane fields. Cooperative work is also being carried on for suitable rodenticide programs for non-crop gulch edges and waste areas adjacent to the fields. Application here might be aerial or, where aircraft use is restricted, by mechanical blower operated from the ground. This unit was first suggested to us by Maynard Cummings and two such blowers have been built and operated successfully.

There will always be a need for the safer anticoagulant baits near habitation and for other restricted areas. In addition to warfarin, pival, and fumarin now being used, diphacinone is being tested with promising results so far. It may be effective with a shorter feeding period than the present anticoagulants.

In addition to the operational programs, the Experiment Station is engaged in a number of research activities. One area of study deals with the use of tracer materials as a means of detecting bait within the animal. Radioactive phosphorus on oat groats is being considered for control led field tests. Activity in test animals may be measured for a 3-week period during which activity slowly decreases. Radioactive phosphorus has quantitative as well as qualitative possibilities. Activity is recorded with a scintillation counter and samples may come from the blood or internal organs of the rat, or from the whole rat itself after it has been ashed. Field application of the tracer should be made only in controlled areas. When recovery of dead animals is not possible, unpoisoned bait must be used followed by trapping to determine the number of active animals within the population.

Additional research has been initiated in the study of the cane plant and its role as a food source for rats. Incidence of heavy rat damage to cane receiving high rates of nitrogen fertilizer have been noted in the field but the same results could not be duplicated in the laboratory with caged rats. Cane variety selectivity exhibited by rats has been frequently observed in variety plots and partially duplicated in cage studies (Teshima, 1968). A detailed study is being pursued to answer some of these mysteries.

Although cane damage is extensive, rats have not been able to survive on a sugarcane diet when tested in the laboratory, and after two weeks the animals lost up to 25% of their body weight (Teshima, 1968).

Research on the field rats of Hawaii is reaching a plateau. With the presence of the U.S. Department of Interior's Wildlife Damage Research Station in Hilo and the possible registration of zinc phosphide, prospects are brighter for a more effective control program. In the last few years, the knowledge gained from research and the attention focused on rat problems has increased many-fold - but the present plateau is merely a stepping stone to more problems that will arise as rats learn to adapt.

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