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ABSTRACT: Heavy losses In Hawaiian sugarcane are caused by Polynesian rats (Rattus exulans), Norway rats (R. norveglcus), and black rats (R. rattus). Relative population levels, movement patterns, damage to sugarcane, and suggested timing of control during five stages of the 2-year crop cycle are described. The progress toward the registering of zinc phosphide for use in crops and the development of other rodenticides are mentioned.

In 1966, a research program was established in Hawaii by the Bureau of Sport Fisheries and Wildlife to develop methods of eliminating crop damage by rodents. The rat problem in Hawaiian sugarcane is severe and losses have been estimated at 4.5 million dollars annually (Doty, 1945; Hilton, 1968; Hood, 1967, 1968a, 1968b; Lindsey, 1969; Pemberton, 1925; Smythe, 1964; Teshima, 1968).

Three species of rats are involved-—Polynesian (Rattus exulans), black (R. rattus), and Norway (R. norvegicus). All three species breed year-round, with the highest populations occurring in late summer and early winter. An average life span of 3 to 5 months, with few animals living as long as a year, indicates rapid population turnover (Tomich and Haas, 1966), In fields, the diets of Polynesian and black rats are primarily sugarcane. In gulches next to cane fields, Polynesian rats subsist mainly on sugarcane, but black rats feed heavily on grass stalks and fruits (Kami, I966).

For discussion purposes, envision a hypothetical but typical sugarcane field located on a plantation near Hilo. The field, 600 to 1,500 ft. wide and about 3,000 ft. long, is bordered on both sides with heavily vegetated gulches, a windbreak on one end. Across the gulches are fields of immature and mature sugarcane. Fifty percent of the sugarcane acreage lies within 200 ft. of noncrop areas. The species composition of rats in the cane and surrounding habitats is shown in Table 1. Grower fields usually contain higher percentages of Norway and black rats than plantation fields. This may reflect the lack of rat control practiced by the growers. Changes in the field during the crop cycle affect the rats and their behavior. The following is a brief outline.

IMMATURE SUGARCANE—1 TO 4 MONTHS OLD

The field of very young sugarcane, 1 to 6 ft. in height, provides very little cover and food for rats. Although rats are numerous in the adjoining gulches, there are few or none in the field. When a rat population is present, it consists entirely of Polynesian rats that live in the gulches and forage out into the field.

No rat damage to sugarcane is evident at this stage of the crop cycle, and control efforts are probably not yet warranted.

IMMATURE SUGARCANE—4 TO 8 MONTHS OLD

Cover has now increased, but since the 6- to 12-ft. cane has not yet lodged (fallen over and started growing laterally), a mat of stalks and dead leaves has not developed on the ground. A moderate to high population of Polynesian rats is usually present in the field, and a few black and Norway rats may be found along the field edges. Telemetry studies indicate that none of the rats are yet living in the field. They forage an average of 300 to a maximum of 1,200 ft. into the field and remain there most of the night. Tracer studies indicate that most, if not all, of the rats in the field are living or feeding in the gulches.

Very little rat damage occurs during this stage of the crop cycle, although milliable stalks are present. Occasionally, damage may start during the latter part of this period.

About this time, rat control should be started in surrounding noncrop areas to reduce the population just before cane damage begins and the rats start living in the field.

MID-TERM SUGARCANE—8 TO \k MONTHS OLD

More cover is present when the cane is this age; some stalks have lodged, producing a mat of stalks and leaves on the ground in addition to a 15-ft. canopy. Many of the rats, primarily Polynesians, now begin living in the field, digging burrows and building nests. Since adequate food sources are available in the field, these rats reduce their average daily movements to about 125 ft. Rats living at mid-field seldom forage into the gulches, but gulch-living rats are still foraging up to 300 ft. into the field.

Damage to sugarcane stalks usually starts during this period. The exact time it begins is probably related to the season and the age of the cane. Rats first attack the internodes of small mature stalks of recumbent cane. The injuries may either kill the stalks or severely reduce sugar production because micro-organisms enter the wounds and cause souring. These losses are of far greater importance than the small amounts of cane the rats actually consume. Other essential but unidentified foods augment their diets, since rats cannot survive only on sugarcane, which is deficient in protein (Garrison and Breidenstein, 1970).

For maximum crop protection, control programs should now be extended from the noncrop areas to the field, since many of the field rats no longer visit the gulches. Aerial baiting is feasible; our tests show that approximately 90 percent of the bait penetrates into the zones of rat activity in the mat and on the ground. Theoretically, if the rats would eat poisoned baits the first night after application as readily as they eat nontoxic oats, 35, 85, 95, and 100 percent mortality could be achieved with rates of 1, 3, 6, and 9 pounds per acre. In practice, however, population reductions exceeding 90 percent have not yet been achieved.

MATURE SUGARCANE—15 MONTHS TO HARVEST AT 22 MONTHS

Mature sugarcane, averaging 130 tons per acre, provides heavy cover and enough food for relatively high populations of rats. The home ranges of field rats become smaller as the cane matures. The average daily movement is now 60 to 100 ft., with only a few moving as far as 200 ft. Rats that live or feed in the gulches are now common only near the edges of the field.

During this period, rat damage is extensive, and up to 5 percent of the stalks are attacked each month. Many stalks are redamaged during successive months. Damage becomes more uniformly distributed as the injury rate increases at mid-field during the last few months before harvest. Rats attack larger stalks, which are usually near the top of the 2- to 3-ft. mat—some injuries may even be found at 4 to 8 ft. At harvest, 20 to 40 percent of the stalks will have been rat-damaged, and 30 percent of the injured stalks will have died. Within practical limits, the amount of damage per month is not correlated with the estimated number of rats. Approximately 60,000 injuries will have been inflicted on 19,000 stalks by a population conservatively estimated at 30 rats per acre.

Because the rats continue to move into and out of the surrounding noncrop areas, control should be continued there as well as in the field.

HARVESTING—SUGARCANE 22 TO 24 MONTHS OLD

Mechanical harvesting is an example of extreme habitat manipulation. It is devastating to the rat population, but the effect occurs too late to protect the crop. Telemetry studies show that none of the rats are killed when the crop is burned to remove dead leaves, but that 75 percent are crushed by heavy machinery or suffocated when their burrows collapse. In addition, the disruption of the habitat exposes the rats to predation by mongooses and raptors, with the result that only 10 percent survive harvesting.

Rat control at harvest for the purpose of protecting adjoining fields or the subsequent cane crop is probably not warranted. The few survivors will not appreciably increase the rat populations in the gulches, which serve as sources of rats invading other fields, and no damage will occur in the subsequent crop for about a year.

The cycle begins again as the next crop is planted or ratooned.

DEVELOPMENT OF CONTROL AGENTS

When chemical control agents appear promising in preliminary tests at the Bureau's Denver Wildlife Research Center, the Hilo station routinely evaluates them on the three rat

species in Hawaii. Those that are sufficiently toxic and acceptable to rats are tested further in the laboratory and the field.

Thus far, the toxicant that has been developed the farthest toward operational use is zinc phosphide. The Hawaiian Sugar Planters' Association, Hawaii State Department of Agriculture, and the Bureau have been cooperating in an attempt to register a zinc phosphide bait for aerial application over sugarcane fields. Results of two field trials of this method indicated that population reductions of 60 to 80 percent could be expected. The final decision on the petition to the USDA and FDA should be coming early in 1970.

Another promising toxicant is Gophacide'. In one test in a noncrop area, a Gophacide bait reduced the rat population 72 percent. We have also started a study to evaluate anticoagulant bait stations which are widely used in Hawaii.

In the future, and until better control methods can be developed, we hope to be able to recommend aerial baiting of cane fields with zinc phosphide, in conjunction with a more effective control agent applied in noncrop areas. This second rodenticide would not have to be registered for application in crops.

TABLE I. Percent species composition in habitats associated with sugarcane production.

	Polynesian	Norway	Black
Gulches	75	15	10
Coastal windbreak	14		80
Grower cane field			
Mature	51	37	15
Plantation cane field			
Mature	60-90	8-40	1-5
Immature	96	4	1

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