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RAT BIOLOGY AND CONTROL IN MACADAMIA ORCHARDS

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Rats damage 5-10% of the developing macadamia crop in Hawaii. Damage can occur at any time during nut development, from the time the kernels are soft, fleshy unprotected fruits to when they are fully developed and surrounded by a hard shell and fibrous husk. To better understand the importance of macadamia nuts in the diet of rats, our laboratory analyzed the stomach contents of 199 rats captured throughout the year at Ka'u Agribusiness' orchard near Pahala. Macadamia nut was the dominant food item throughout the study and was present in all stomachs inspected, with a mean relative frequency of 85%. Insect fragments, primarily lepidopteran larvae, occurred in 66% of the stomachs, with a mean relative frequency of 8%. Rats probably ate the insects as a source of protein to compensate for the limited amounts of amino acids in macadamia nuts, although some insects that were present in macadamia husks and shells may have been ingested incidentally. We found moss in 48% of the stomachs, with a mean relative frequency of 4%. The moss was probably ingested incidentally. The major moss we identified is ubiquitous throughout low areas of Hawaii and was present in the study orchard on tree trunks, branches, and even macadamia husks. Grass seeds, fruit seeds, and non-insect animal material were present in small amounts.

In spite of the apparent impact of rats in orchards, little is known about their behavior. Seasonal variations in the abundance and quality of nuts undoubtedly influence the density, home ranges, and movements of rats in orchards. More knowledge about their daily and seasonal movements could provide the basis for implementing more effective control strategies. For example, knowledge of home ranges would indicate the amount and spatial distribution of traps, rodenticide baits, or other measures necessary to control troublesome populations. An understanding of seasonal variations in rat behavior would indicate the best times to apply control measures. Many growers wait until after the harvest season to apply control measures. However, we do not know whether rats leave orchards at this time to seek food elsewhere. To get a better idea of the movements of rats in and around orchards, we conducted a radio-telemetry study at Mauna Loa's orchard in Keaau. We fitted rats with ratio-transmitters and followed their nightly movements for 3 weeks during each of 3 periods of the crop cycle: peak anthesis, mid-season, and peak harvest.

We conducted the study in a 21-ha block that was situated in the middle of the orchard and was surrounded by windbreaks of Norfolk Island pine trees. We monitored 19 rats during peak anthesis, 18 rats during mid-season, and

17 rats during peak harvest. All rats had restricted home ranges that averaged about 0.5 acres. Except for two rats that lived in the windbreak, only one rat ventured outside of the orchard. This study indicated that rats move limited distances in mature macadamia orchards, and that there was little movement in and out of the orchard. Based on these movement patterns, growers who use traps or apply rodenticides in bait stations should place them throughout their orchards at 2 or more locations per acre.

Rat problems usually increase as orchards mature. We find the most extensive damage in orchards 20 years of age. The canopy in such orchards provides safe nesting sites and interlocking branches that allow rats to move unhindered among trees. This, in large part, is what attracts rats.

Traps can be effective in reducing rat populations in small orchards, but are labor intensive and probably not cost-effective for protecting larger orchards. We routinely trap rats during our studies. Coconut is a very effective bait. Rolled oats and peanut butter would also work. Growers who use traps should cover them to exclude cardinals and other birds.

Rodenticides are the most practical approach for protecting large areas. Two rodenticide products currently are registered for use in macadamia orchards: Hopkins Zinc Phosphide Bait and ZP Rodent Bait AG . Both of them have zinc phosphide as the active ingredient. Our laboratory testing indicates that the former bait is the more effective of the two for killing black rats.

A major problem with both baits is something we call bait shyness. Rats that consume sublethal doses learn very quickly not to eat any more bait. Thus, if the bait did not kill the rat the first time, it will not do any good to put out more bait; the rat will simply ignore it. For the same reason, you should not leave zinc phosphide bait out in your orchard on a continuous basis because you will reinforce rats' aversion to the bait. Unfortunately, in Hawaii we have a mild climate and a prolonged crop season, and thus need to control rat populations over an extended period.

Anticoagulant rodenticides like Eaton's Bait Block, Talon , and Maki might be alternatives, if they were registered for orchard use. Anticoagulants have a different mode of action from that of fast acting poisons like zinc phosphide. Rats usually do not get sick until 3-4 days after eating anticoagulant baits and thus do not associate toxicosis with the bait. Our laboratory plans to investigate the efficacy and safety of anticoagulants for reducing rat populations in orchards.

Inappropriate application methods may reduce the efficacy of some operational baiting programs. Regulations allow for baits to be broadcast on the ground, placed in burrows, or placed in bait stations in trees. Our studies indicate that in many orchards, rats spend very little time on the ground and are unlikely to eat bait placed on the ground. Rats on the ground are vulnerable to predation by cats, mongooses, and other predators, especially in orchards with little ground cover.

We currently are conducting a study to determine where in the orchard rats are most likely to eat bait. We treated non-toxic oats with a biological marker that allowed us to later determine whether rats had eaten the bait. The

marker chelates with calcium in growing bones and teeth and fluoresces under UV light. In different blocks we broadcast the bait on the ground, placed it in trees, or put it in burrows. Seven to 10 days later we trapped rats and determined whether they had eaten the bait.

At the Mauna Loa Orchard in Keaau, 91% of the rats in the block where we placed the bait in trees ate the bait, compared to 70% where we placed it in burrows, and only 38% where we broadcast the bait on the ground ate the bait. This indicated that at least in this orchard, broadcast baiting is not very effective, and that growers should place bait in trees to get maximum acceptance by rats.

These findings may not apply to other orchards that are managed differently. For instance, rats might spend more time on the ground in orchards with more ground vegetation. Thus, we conducted a similar study in a Kapulena orchard along the Hamakua coast. This orchard had more ground vegetation and was interspersed with surrounding non-crop vegetation. We captured rats both in the orchard and in surrounding non-crop areas. More than 80% of the rats in the orchard where we placed the bait in trees ate the bait, versus only 10% of the rats where we placed the bait on the ground. There was limited movement between the orchard and surrounding areas; only 40% of the rats that we captured in the adjacent non-crop areas had consumed bait.

Three species of rats occur in Hawaii: black rats *(Rattus rattus)*, Norway rats *(R. norvegicus)*, and Polynesian rats *(R. exulans)*. Black rats are the main pest in all of the orchards we have studied. This is the only 1 of the 3 species that regularly climbs trees. However, at Kapulena we also captured the other two species. We captured Polynesian rats and Norway rats mainly in the non-crop areas adjacent to the orchard, and very few of either species consumed any marked bait, whether it was placed in trees or on the ground. This confirmed our suspicions that Polynesian rats and Norway rats have only a minor impact in orchards, and that black rats are the major pest species. We plan to duplicate the study in macadamia orchards in Kona and Kau districts.

To summarize, black rats are the major rodent pest of concern in macadamia orchards. This species can subsist year-round on a diet composed largely of macadamia nuts; overall, they probably damage 5-10% of the macadamia crop. If you have a small orchard, you may be able to control populations by setting traps in trees. However, in larger orchards rodenticides probably are more cost-effective. In most orchards, placing baits in bait stations in trees probably will yield the best results. HMNA should consider pursuing registration of alternative rodenticides for in-orchard use.