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Best On-Farm Food Safety Practices: Reducing Risks Associated with Rat Lungworm Infection and Human Eosinophilic Meningitis

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Recent cases of eosinophilic meningitis have drawn attention to a foodborne parasitic infection that occurs in Hawai'i, the Pacific Islands, southern and eastern Asia, and elsewhere. In late 2008, the Hawai'i Department of Health reported that four people on the island of Hawai'i were diagnosed with eosinophilic meningitis, secondary to rat lungworm infection. They may have been infected after eating fresh produce grown in the region that was contaminated with snails or slugs infected with the parasite *Angiostrongylus cantonensis*. Hawai'i also experienced a cluster of five infections by this pathogen from November 2004 to January 2005 (Hochberg et al. 2007). According to the Hawai'i Department of Health, reports of severe infections are uncommon. However, anecdotal evidence from a group of workshop attendees in the Puna district on Hawai'i in January 2009 put the incidence rate much higher. Although reporting appears to lag behind actual disease incidence rate, the threat to residents and visitors is low. Due to the possible severity of the symptoms, it is important to practice preventive measures in your home garden or commercial farm, as well as in your kitchen.

Despite the recent cases reported in Hawai'i, the worldwide incidence of rat lungworm infection (angiostrongyliasis) and the associated clinical illness (eosinophilic meningitis) is relatively low. Since 1945, there have been fewer than 3000 documented cases worldwide, with most of them occurring in Thailand and China (Wang et al. 2008). Usually, the infection is self-limiting, and the patient's clinical signs resolve without treatment. Depending on the person, the amount of time it takes to fully recover varies. Under normal circumstances, people recover from eosinophilic meningitis without

This information is primarily for commercial growers so that they can reduce the risk factors for rat lungworm contamination of their produce. The medical information presented is based on current medical knowledge and science-based literature, and it is not intended to be a substitute for a medical evaluation by a licensed professional. This publication may be updated as new knowledge is made available. For current medical findings, please consult the Centers for Disease Control and Prevention website, www.cdc.gov.

Disease Summary

Disease agent: *Angiostrogylus cantonensis*

Common name: rat lungworm disease

Medical name: human eosinophilic meningitis

Definitive hosts: rats

Intermediate hosts: slugs and snails

Accidental hosts: humans and other mammals

Paratenic hosts: frogs, prawns and other freshwater crustaceans, lizards, and planarian worms

Incubation time: usually 1–3 weeks, but may range from one day to more than 6 weeks.

Clinical signs of eosinophilic meningitis: headache, stiff neck, numbness, tingling or pain of the skin (paraesthesia), fever, nausea and vomiting, blurred vision (diplopia), weakness, joint pain, and neurologic abnormalities. More severe signs can include hyporeflexia or paralysis of the legs, bowel and bladder dysfunction, seizures, coma, and (rarely) death. It is also possible to be asymptomatic.

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medical intervention, making an accurate determination of disease incidence very difficult.

Growers of produce, particularly professional growers, need to be aware of this danger and take the precautions necessary to reduce risks of transferring the pathogen to consumers. Under certain circumstances, it may take only a single exposure to the infective stage of the parasite, as in the case in Jamaica in May 2000, when nine tourists in a group of 23 required hospitalization after eating the same contaminated salad at a local restaurant; in that instance, fortunately, there were no deaths (Slom et al. 2002).

Where does this food-borne parasitic infection come from?

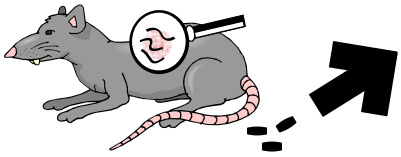
Angiostrongyliasis results from ingestion of the infective stage of the rat lungworm, *Angiostrongylus cantonensis*. This worm, a nematode, has a complex life cycle, involving developmental stages in rats and in slugs or snails. The nematode eggs hatch in the lungs of rats, and the first-stage juveniles move to the digestive tract where they are passed out into the environment in rat feces. At this stage, the nematodes are microscopic and are only infectious to snails and slugs, not humans or other mammals.

Slugs and snails become infected by *A. cantonensis* in two ways. Most commonly, the slug or snail will eat contaminated rat feces. Alternatively, it is possible for the nematode to burrow into the slug or snail through the body wall, or to enter it through the respiratory pore, when the slug or snail comes into close contact with the contaminated rat feces (Cheng and Alicata 1965, Chao et al. 1987). Once inside the slug or snail, the nematode grows until it reaches the third developmental stage; it is still very small, about 400 μm (Lindo et al. 2002, Ash 1970), about the size of the period at the end of this sentence. This is the stage that can infect mammals such as rats or people.

At this point, if a rat eats the snail or slug, the nematode migrates through the rat's body until it reaches the rat's brain, where it develops to the fifth juvenile stage.

How rat lungworm infection gets transferred to people

1. **A rat infected with *A. cantonensis* passes stage-1 juvenile worms in its droppings.**



2. **Snails and slugs acquire the parasite by eating rat droppings. Prawns, lizards, frogs, and flatworms can acquire the parasite from slugs and snails.**

2. **Snails and slugs may contaminate produce by hiding in the leaves or near the stem.**

3. **People may get the disease by eating infected items that are insufficiently cooked.**

3. **People may get the disease by accidentally eating a slug or snail, or pieces of these mollusks, or even their slime left on produce.**

How to prevent the spread of rat lungworm

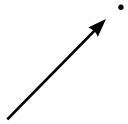
Eliminate rats on your farm by following a rat control program with monitoring schedules for bait stations and traps.

Stop snails and slugs from contaminating your farm or garden by removing snail hiding places, using bait traps, and hand-picking slugs and snails (wear gloves).

Cook all snails, slugs, prawns and other potential hosts to an internal temperature of 165°F before eating.

Rinse and rub all produce to remove slugs and slime. Sanitize food-contact surfaces to prevent cross-contamination.

Actual size of a third-stage nematode that can infect humans if consumed. The infective-stage nematode is very small (~400 micrometers), and that makes it extremely difficult to see if it is on produce.



Finally, it moves from the brain to the rat's lungs, where it completes its development and lays eggs, and the cycle repeats. Other hosts that biologists call paratenic hosts, such as frogs, prawns, lizards, and planarians (free-living flatworms) can also become infected with the nematode, which helps to sustain the parasite cycle in nature. Frogs, prawns, and lizards can become infected by eating infected snails. Flatworms can become infected by coming in contact with infected rat feces. The nematode cannot develop in the paratenic hosts; however, if these animals become contaminated by snails or slugs containing the infective stage of the worm (e.g., by predation) then these paratenic hosts can be potential vehicles for angiostrongyliasis.

Of course, in the United States, eating a snail or slug is usually unintentional, but because immature slugs or snails are small and difficult to see if they are concealed within fresh produce, a slug, snail, or paratenic host might not be detected during food preparation. It is also possible for the slime or mucus of slugs and snails to contain a small number of nematodes, so it is best to avoid eating fresh produce contaminated by their slime or mucus.

Snails and slugs do not pass this parasite to their offspring. Each slug or snail must acquire it anew by eating or coming into contact with rat feces. Unfortunately, we do not have information on infection rates in rats that might be used to identify high-risk areas. In 2007, studies on semi-slugs (*Parmarion* cf. *martensi*) collected at survey sites in Puna found three-quarters of them to be infected, and a quarter of the Cuban slugs (*Veronicella cubenis*) tested were infected with the nematode (Hollingsworth et al. 2007).

As mentioned previously, other possible sources of human infection are the paratenic hosts, such as frogs, freshwater shrimp (prawns), land crabs, monitor lizards, and flatworms (Wang et al. 2008). These animals do not show obvious signs when infected with the rat lungworm. Anyone consuming an animal that could be a potential

Microscopic view of the third-state infective stage worm, *Angiostrongylus cantonensis*.

[photo: Henry S. Bishop, courtesy of Alexandre J. da Silva (CDC)]

A case for vigilance

The Puna district of Hawai'i has experienced an increase in cases attributed to rat lungworm infection (angiostrongyliasis) in recent years. As there is no definitive diagnostic test available to doctors working in the Puna district, a positive diagnosis is generally based on a combination of symptoms and circumstantial evidence.

For most of the suspected cases of angiostrongyliasis reported in Puna, diagnoses have not been confirmed by the Hawai'i Department of Health or the U.S. Centers for Disease Control and Prevention. In addition, symptoms and conditions in these recent cases do not strictly fit the disease profile. Instead, much more severe symptoms, including coma, have been associated with the disease present in Puna.

Current medical literature indicates that cases of angiostrongyliasis are frequently self-limiting, meaning that symptoms will go away without medical intervention. Unfortunately, this is not always the case, as some sufferers report symptoms that are long-lasting and possibly permanent, and two recent sufferers in Puna went into comas for up to three months. *The Honolulu Advertiser* quoted Dr. Francis Pien, an infectious disease specialist, stating that he has "treated at least 20 cases of rat lungworm disease in 35 years of practice. None of the victims in the past went into comas or died. Everybody else got well." (Leone 2009a, b). As of June 2009, both patients had emerged from their comas, but recovery is expected to take many months, or even years due to brain damage. Thus, some of the Puna cases of apparent angiostrongyliasis are much more severe than commonly observed for this disease, and further investigation and research are necessary to identify the special circumstances that have led to this increase in cases.

host of the nematode should cook the item thoroughly. Anyone handling one of these potential hosts should thoroughly wash their hands and sanitize food- preparation equipment and food-contact surfaces with soap and water (Saulo 2009).

The spread of the nematode via slug or snail mucus secretions (slime) has been investigated. A study of the slime of semi-slugs collected in Hawai'i indicated that 12 percent (3 of 25 samples) of them shed nematodes in mucus secretions induced by prodding. However, it is not clear whether or not the concentration of nematodes shed was enough to cause the disease in humans (Qvarnstrom et al. 2007). Earlier studies found that rats fed mucus-contaminated lettuce had acquired small numbers of parasites (Heyneman and Lim 1967). This rapid acquisition of infection may be unique to rats or unique to the specific species of slug that was used in the study. At this time, there are no scientific studies showing that a person can contract angiostrongyliasis by eating produce having snail or slug slime on it, but there are some personal testimonies in support of this possibility. As a preventative measure and an essential part of farm food safety, all produce should be rinsed thoroughly in potable (drinkable) water before it is consumed.

Symptoms of eosinophilic meningitis caused by rat lungworm infection

In adults, the most common symptoms are headache, neck stiffness, paraesthesia (prickling or tingling sensations), vomiting, fever, nausea, and double vision (diplopia). Other symptoms reported are body pain, muscle pain, fatigue, muscle twitching and convulsion, muscle rigidity or neck pain, somnolence (sleepiness), abdominal pain, hyperaesthesia, muscle weakness, and weakness of extremities. In children, the most common symptoms are headache, fever, nausea, blurred vision, somnolence, abdominal pain, and weakness of extremities. It is also possible to be asymptomatic.

Onset of symptoms usually occurs one to three weeks after ingestion of the pathogen, but it can be as soon as one day afterward, or it may take more than six weeks (Hochberg et al. 2007, Wang et al. 2008).

How to avoid risk of infection

Whether purchased or homegrown, fruits and vegetables should be treated with caution. The best way to manage the risk of becoming infected by rat lungworm is to thoroughly rinse all fresh produce in potable water before it is eaten or cooked. Semi-slugs have been shown to have high levels of *A. cantonensis* infection, most snails and slugs are potential carriers, and all of these should be treated with caution and controlled or managed to the best extent possible.

If a fruit has broken skin, it cannot be properly cleaned. Keep your family safe by discarding it. In Hawai'i, semi-slugs have been found, so far, on lettuce, fennel, sweetpotato, banana, passionfruit, lemongrass, and fallen fruits including avocado, guava, citrus, papaya, and mango; semi-slugs have been found on ripe papayas that are still on the plant (Hollingsworth 2007).

Wear gloves if you are going to be working outside with plants or materials commonly infested with slugs or snails. In Hawai'i, snails can be found on land, on trees, and in water (such as in a taro patch). Slugs live only on land and prefer to live under plant materials, wood, rocks, and man-made materials.

Mitigating risks on a commercial farm or in a home garden

Due to the historically low incidence of infections in humans, research focusing on limiting rat lungworm infections has not been extensive. On the other hand, managing rats, slugs, and snails has been an important agricultural endeavor for some time. The authors' recommendation is to follow the techniques below to limit your exposure to rats, slugs, and snails. The following information on best management practices is not specific to avoiding rat lungworm contamination, and you are encouraged to do your own investigations on what works best, within legal limits, on your farm.

Among the many ways to lower the chances that your commercial or home garden produce becomes contaminated with rat lungworm, the best way is to keep rats and slugs away from produce. Eliminating rats, the original source of the parasite, and the slugs and snails that carry it, is the key. Here are some steps to follow:

Controlling rats

Keep your farm or garden as rat-free as possible by removing food sources and living places. Establish and follow a comprehensive rat control program with monitoring procedures and turnover times for bait stations and traps. See Hollyer et al. (2009) for details.

Controlling slugs and snails

Slugs and snails may be responsible for transmitting the

nematode to produce, and they may be harmful if accidentally eaten. For every slug you see, there might be up to 20 you did not see, so slug and snail management needs to be part of a regular, overall pest management program. The specific strategy you follow will depend on whether you are a commercial farmer or a home gardener, and a conventional grower or an organic grower. Nevertheless, the strategy for controlling slugs and snails must contain a strong prevention component and may be paired with a lethal elimination step.

Prevention is your key to success

Preventing snails and slugs from reaching your production areas or your home garden takes a multi-pronged approach.

Slugs and snails are mainly active at night. The main reason is that they quickly become dehydrated if they come out during the day. This is especially true for slugs. The best way to reduce your slug and snail population is to limit the number of moist places the slugs and snails can hide in during the day. This means removing unnec-

Rat lungworm intermediate and paratenic hosts—create a management plan to eliminate them

Semi-slug
[photo: Ken Hayes]

Juvenile semi-slug
[photo: Chris Jacobson]

Giant African snails, and damage from their feeding
[These are small ones—they can be about twice this size; photo: Scot Nelson]

An apple snail, photographed under water
[about actual size; photo: Ken Hayes]

The Cuban slug comes in many colors.
[about actual size; photo: Robert Cowie]

essary groundcovers, cutting back vegetation, removing rocks and fallen wood, and removing unnecessary items that are stored in contact with the ground. Any time you store something in direct contact with the ground, you create a hiding place for slugs. So, place storage sheds on blocks and other items, instead of in direct contact with the ground.

While you should remove any hiding places within your production area, you might actually want to provide hiding places along the perimeter in order to lure and trap the slugs or snails that congregate there. Lures may be as simple as boards or pieces of plywood placed on the surface of the soil. Other lures include overturned flowerpots, overturned melon rinds, or orange peels. These lures need to be checked daily and the slugs and snails should be collected (wear gloves or use a tool, such as chopsticks or tweezers) and disposed.

To further reduce the likelihood of slugs and snails continuing past the lures at the perimeter of your field, you may consider including a bait trap. Slug and snail baits (discussed below) can be placed underneath the lure. This represents a very efficient use of the bait, because the bait will be protected from the direct effects of rain or sun, which contribute to rapid breakdown of the product. Commercial bait traps are available, but you can make your own. A quick Internet search reveals a variety of bait traps. Something as simple as a shallow bowl filled with liquid can lure and capture the slug or snail. The best lures for the liquid bait traps are beer, sugar-water, or a mixture of yeast and water. The snail or slug will drown in the liquid. Thus, bait traps also need to be checked daily, the dead slugs removed, and the liquid bait refreshed. Protect yourself from exposure when performing these tasks: wear gloves when handling the baits, wash your hands, and sanitize equipment used with soap and water.

If you are growing potted plants on benches, or if you have fruit trees you wish to protect, physical barriers may be the most effective method of keeping your crop safe. Copper in various forms is repellent to slugs and snails, and these animals will generally avoid crossing a band that is 3–4 inches wide or greater. Copper foil can be placed around bench supports. Alternatively, bench supports or the trunks of trees can be treated with a sprayable formulation of copper such as Bordeaux mixture. The incorporation of latex paint into the mix will greatly increase the length of time that the material will stay repellent. Additional information on barriers and instructions for Bordeaux mixtures are available at the University of California Pest Notes: www.ipm.ucdavis.edu. Suggested readings are listed in References (p. 8).

Various slug and snail baits [photo: R. Hollingsworth]

Elimination steps

Growers who produce leafy green vegetables may find that the prevention measures already discussed are not sufficient to completely exclude slugs and snails from these crops, which are the favorite food of these pests. In these situations, the careful use of chemical pesticides may also be required. Always consult the product's label for authorized uses, and remember that products labeled for home garden use may not be authorized for use on commercial farms.

Pesticides lethal to slugs and snails, called molluscicides, should be part of an overall control and prevention program. In Hawai'i, the most common types of chemicals used to control slugs and snails in commercial settings are food bait pellets containing either metaldehyde or iron phosphate as the active ingredient. Many different brands of these chemicals are available. Molluscicides are reasonably priced and can cover a large area for a relatively small cost, but using molluscicides as a stand-alone control measure seldom produces adequate results. A bait application might kill only half of the slugs or snails that are present in the treated area. Significant numbers will survive the treatment because either they were buried or hidden at the time of treatment, or they were not attracted to the bait, or they did not eat enough to die. For these reasons, it is essential to use an integrated combination of measures for slug and snail control in your cropping and production areas.

Metaldehyde-containing products come in three forms: food-bait pellets, granules, and liquids. Food-bait pellets attract snails and slugs, but they may also attract domestic pets. Be aware that if consumed, metaldehyde products are very toxic to dogs, cats, and other

animals, and poisoning incidents are common. For this reason, metaldehyde is also available without the food attractants. Granules are smaller than pellets and lack a food attractant. Liquids are used as a foliar spray or pot drench, but they are not allowed on edible crops. Under moist conditions, slugs and snails sometimes recover from metaldehyde poisoning, so these products will be most effective in dry weather or if watering of the crop is delayed after their application.

Alternatively, food baits containing 1% iron phosphate as the active ingredient can be used to avoid situations where animals might accidentally be poisoned. Unlike metaldehyde baits, baits containing iron phosphate are considered safe to use around animals, including dogs. Slugs or snails that feed on iron phosphate baits will stop feeding immediately but may not die for several days. For this reason, the degree of control obtained will not be immediately apparent. Iron phosphate baits can be just as effective as metaldehyde baits, but effectiveness will depend on the pest species involved. All lethal elimination measures should be paired with prevention and control measures.

Note: Liquid formulations of metaldehyde are not allowed on edible crops. There are also legal restrictions on the use of bait formulations around edible crops. For your safety and for the safety of others, always read and follow the directions on the pesticide label. Federal law requires that pesticides be used in accordance with the directions on the product label.

Bringing produce from the field: How to keep it as safe as possible

To keep your produce as free as possible from contamination with any of the pathogens typically found on a farm, including the rat lungworm, make the following guidelines part of your general field operations, and frequently remind workers about the importance of following good food safety practices:

- Provide clean toilets and proper hand-washing facilities for workers (potable water, pump soap, single-use towels).
- Before each use, clean, sanitize, and dry plastic or wooden bins, totes, and baskets used to harvest and transport produce.
- Do not cross-contaminate. Do not grow both snails for food and produce for food in a place where handling the snails could affect the safety of the produce. Wash your hands after handling slugs and snails and before returning to your produce production areas.
- Do not smash snails or slugs near fresh produce. The pathogens are still active in the dead slug or snail and can easily be transferred by hands, tools, or via water to the fresh produce.
- Never harvest produce that has come in contact with the ground or has touched the ground on low-hanging branches (e.g., mangoes, macadamia nuts, avocados), as it could have been exposed to the rat lungworm or other pathogens (e.g., *E. coli*, *Salmonella*, etc.) from other animal sources.
- When you harvest, choose pest-free produce; look out for plants that might be contaminated, and don't include them with clean produce. A little field soil can be washed away, but signs of snail or slug slime, fecal material, bird droppings, or other contaminants are a good reason to leave that produce in the field. Do not try to wash off contamination. Avoid a foodborne illness for yourself or your customers.
- Do not sell snail- or slug-damaged produce for processing. Food processing may not kill the pathogens.
- Visually inspect all produce before packing. Look for specks on the produce; they could be immature snails. If found, do not sell or eat that piece of produce, and dispose of it in a trashcan. Do not throw out this produce where a rat could eat it and restart the infection cycle.
- Rinse and gently rub all produce in potable (drinkable) water. In addition, growers should use an FDA-approved food-grade water sanitizer when washing commercial produce. Food-grade water sanitizers are usually available from restaurant supply houses, agricultural chemical suppliers, and from companies via the Internet. Organic farmers can find food-grade water sanitizers by calling their organic certifier, or checking the Organic Materials Review Institute (OMRI) website. Items on that website meet the national regulations for organic certification and the NOP guidelines (NOP 205.270 and 205.605). From the OMRI website (www.omri.org), follow the link to "Products List" for "Processing and Handling Products." Follow the manufacturer's label for the proper use of each sanitizing agent. If you cannot rinse the harvested produce, as in the case of basil, for instance, then rub or shake the produce to dislodge any undesired materials before packaging and selling it.
- Finally, advise all buyers in writing (such as on your bag, plastic container, or box) to "wash before eating." Produce labeled "wash before eating" should be thoroughly inspected (separate the leaves), and rinsed

in potable water before using. Rinsing and rubbing produce is a best food handling practice at any time.

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Summary points

Problem

***Angiostrongylus cantonensis* can cause harm to humans, and growers need to take precautions to limit the chance of their produce being contaminated with this pathogen.**

Pest management

Remove rodent, slug and snail hiding places.

Trap and kill rodents and slugs and snails in your production fields.

Postharvest treatment of produce

Do not harvest produce with slugs or snails or their feces or slime on it.

Discard any produce that has been harvested with evidence of slugs and snails.

If you suspect that slugs and snails have been on your produce, consider rinsing the produce in water containing a sanitizer that has been approved for food contact.