“My chestnuts are wormy!” is a common complaint from producers and consumers. The "worm" causing the problem is the larva of either the small chestnut weevil (*Curculio sayi Gyllenhal*) or the large chestnut weevil (*Curculio caryatrypes Boheman*). Both species are native to North America where they commonly infested American chestnuts before the chestnut blight epidemic. When the blight wiped out the American chestnut trees it also wiped out the chestnut weevils - almost. Now that chestnuts, mostly Chinese, have been widely planted the chestnut weevils have made a comeback. Many chestnut plantings in eastern North America are now plagued with these pests. The good news is that acceptable control is possible. The bad news is that without control, they can render the entire crop unmarketable.

Weevil grubs emerge from chestnuts shortly after harvest, but the problem begins before the chestnuts ripen. Adult weevils lay tiny eggs inside the shell, while the nuts are still on the tree. After hatching, the grubs eat tunnels through the nut kernel. Sometime after nut drop, they eat their way out through the shell, leaving pencil lead-sized exit holes in the shell. The squirming, cream-colored grubs, about 7-14 mm (1/4- to 1/2 in) long, are repulsive but harmless.

Adult chestnut weevils are hard-shelled beetles which vary in color from mottled light tan to dark brown, almost black. A prominent snout (proboscis) is as long as or longer than the body. The small chestnut weevil female is 5-11 mm (1/6 to 1/3 in) long; the large chestnut weevil female is 7-14 mm (1/4- to 1/2 in) long. Females have a much longer snout than males. Other than the difference in size, both the large and small weevils look similar.

The small chestnut weevil is more common than the large, but both species are reportedly distributed wherever chestnuts occur. When both species are found together, the large chestnut weevil seems to predominate. But new weevil infestations are almost always the small species. Apparently, small chestnut weevils can fly several miles or more to find previously uninfested trees. In our orchards, thus far, we have found only the small chestnut weevil.

Life Cycles of the Insects:
Small Chestnut Weevils
Small chestnut weevils (*C. sayi)* emerge from the ground as adults during May and June. After emergence they remain on the ground for several days before flying. They can be found in chestnut trees during flowering, apparently feeding on catkins. After flowering they disappear and it is not known where they harbor for the two to three months between their emergence and their appearance in the trees at egg-laying time. Mating and then egg laying begin about three weeks before nut ripening, i.e., from mid-August to the beginning of September. Egg laying occurs throughout the nut ripening period. Adult females deposit eggs into the nut, usually on the round side through tiny holes that look like pin-pricks. Three to five pear-shaped eggs are laid in each nut. Each adult female lays up to 50 eggs. Eggs hatch in about 8 days and the larvae tunnel through the kernel. Larval development is usually complete in two to three weeks, but development time is very temperature dependent. Warm temperatures promote fast development while cold temperatures may delay emergence for two months or more. Larvae generally exit after the nut has fallen to the ground.

Full-grown larvae enter the soil, burrowing 5-20 cm (2 to 8 in) below the surface to hibernate inside earthen cells that they construct. They pass the first winter as larvae and most pupate and become adults by the next autumn. Then they pass the second winter as adults in the soil, and emerge the following May or June. Some larvae pupate the second autumn and pass the third winter as adults. In

summary, small chestnut weevils usually have a two-year life cycle, but a few individuals delay to a three-year life cycle. This tactic ensures survival, and complicates control.

The extent of crop damage depends on weevil population and crop size. Weevil infestation can range from 0 to 100% of the crop. While the main damage is caused by feeding larvae, the adults also feed on nuts, and this provides a point of entry for fungus and yeast organisms. This damage is often not noticeable until after storage.

Large Chestnut Weevils
Large chestnut weevils (*C. caryatrypes*) have a life cycle and habits similar to the small species except for the following differences. Adults emerge from the soil in late July to early September, just before egg-laying. Mating and egg laying begin when the kernel begins to form, from mid to late August, which is a week or two before the small chestnut weevil. Females usually lay no more than three eggs per kernel. Because of their earlier egg laying, a few larvae complete development and exit the shells before the chestnuts fall off the tree. Large chestnut weevils usually have a one-year life cycle, with a few individuals delaying until two years.

Control
Three control methods can reduce weevil infestation: sanitation, hot water treatment, and insecticide applications. Sanitation and hot water treatment target larvae, insecticide application targets adults.

Sanitation: Sanitation involves collecting fallen nuts before the grubs emerge. If the fallen chest - nuts have exit holes, the grubs have already emerged and it's too late for sanitation to work well. Collected nuts should be stored in containers from which emerging larvae cannot reach the soil, e.g., plastic buckets. Be careful; weevils can chew through plastic or paper bags. Make sure the weevils are destroyed - don't throw them outside! If sanitation is practiced consistently, it will prevent weevil populations from increasing. It is most effective when weevil populations are relatively low, (less than 5% infestation), and the orchard is isolated from other chestnut trees. For sanitation to work, the chestnuts should be picked up within three days after they drop. Sanitation won't work if a significant part of the crop is taken by chipmunks, squirrels, or other varmints that cache their food, since the cached chestnuts will allow weevil larvae to escape to the ground. After weevils have emerged, leaving obvious exit holes, the infested nuts can be destroyed. (Don't just throw them outside, some grubs may have not yet emerged!) Uninfested nuts can be eaten.

Hot water: Rather than waiting for them to emerge, larvae or eggs can be killed inside the kernels by soaking the chestnuts in water at exactly 49° C (120° F) for about 20 minutes. The temperature is critical, the time of soaking less so. *(See below for directions on creating a hot-water bath treatment.)* After soaking, the chestnuts should be allowed to cool and surface-dry before storage. This treatment kills the larvae but does not damage the kernel. If the chestnuts are promptly harvested and hot-water treated, many of the infested chestnuts will contain only unhatched eggs or very small larvae. These small infestations are not noticeable and can be eaten. On the other hand, if exit holes are present in the chestnut shells at treatment time, the weevils have already emerged. All chestnuts which have any chance of being infested should be hot water treated before being sold. Buyers have zero tolerance for living grubs crawling out of the chestnuts they bought, but seem to tolerate dead grubs in a few nuts. If one chestnut in a thousand is infested, this means that every 25 lb lot of chestnuts probably harbors several grubs; this is unacceptable. But most people don't mind discarding one in a thousand bad nuts.

Insecticides: When 10% or more of the crop becomes infested, insecticide sprays are necessary to produce marketable chestnuts. Insecticides have proven effective only when applied to adults during the mating and early egg-laying period. For small chestnut weevils this is mid-August to early September. Presently, the only insecticide labeled for chestnut weevil control is carbaryl (Sevin). Follow label instructions for application rates. Spraying should begin when adult weevils begin arriving in the tree crowns. Weevils tend to seek out early-ripening trees first. So, it is best to look for weevils on early trees, and spray whenever they are present. Spreading a large sheet on the ground and shaking branches is a good way to monitor weevil presence. (Weevils have a habit of dropping to the ground whenever they are disturbed.) Spraying should be done when the weevils are active, i.e., on warm, calm days. The interval between spray applications should range from three to seven days depending on weather and the presence of weevils. Two to four spray applications per season should be sufficient to provide adequate control.

Greg Miller, owner/operator, Empire Chestnut Company, Ohio

Greg Miller, owner and operator of Empire Chestnut Company, Ohio, offers his step-by-step procedure for killing chestnut weevil larvae and eggs via a hot water bath. He stresses that all chestnuts which have any chance of being infested should be hot water treated (for about 20 minutes in water at exactly 49 degrees C/120 degrees F) before being sold. After soaking, chestnuts should be allowed to cool and surface dry before storage. The treatment kills the larvae but does not damage the kernel.

Here is the list of main components you'll need for the treatment:

100 gallon plastic stock (cattle watering) tank: Rubbermaid's comes with plumbing fitting near bottom, used for outlet. This is an adequate size for a 40 gallon water heater (below). If you want to process more than 150 lbs. in a batch, you'll need a bigger stock tank and a bigger water heater, but all other components can remain the same.

Perforated stainless steel cover for outlet: To keep nuts and other large objects from getting sucked into outlet.

Circulation pump: I use a laundry tray pump from Grainger (1P795, $185). It works fine, but the pump is made of cast aluminum and disintegrates after eight years or so from exposure to Clorox. Perhaps a better alternative would be a spa pump (Grainger 4RJ85, $198.50). It is a bigger (more powerful) pump and made of plastic.

Strainer: I have a homemade one made of PVC pipe and a stainless steel screen; perhaps the Grainger swimming pool strainer (1P999, $50.45) would work if it can tolerate the temp. The strainer catches fuzz and styles from chestnuts; without a strainer, the injection pump gets plugged – disastrous.

Injection pump: Smaller than circulation pump; I'd suggest Grainger 3WY86 ($89.25).

Water heater: I use a 40 gallon propane water heater, 38,000 BTU/hr. The water heater BTU output is what ultimately limits the capacity of the treatment system. With my heater, I can treat 120-150 lbs. of

nuts at a time, changing nuts every 20 minutes. The temp of the nuts going in affects capacity: 120 lbs. per load when it's cold, 150 lbs. when it's warm. When I go to upsize my system, I will put another water heater in series or get a water heater with a bigger burner.

Temperature controller: This is the "brains" of the whole system. Don't skimp on this one. Go to www.omega.com and order CN9210A (3-wire RTD input & relay output, $199). You'll also need the RTD probe (PR-10-2-100-1/4-6-E, $63). The Omega site also has tons of engineering information about process control; I learned most of what I know from Omega catalogs and technical bulletins (before Internet).

Plumbing fittings, pipe, hoses: I used 2-inch PVC for the main circulation (but 1.5 inch will work) and 3/4 heater hose for the hot water injection circuit. It's nice to use (at least a short section) of clear hose from the water heater just so you can see at a glance whether or not water is flowing through it.

Electrical connections: Wire, outlet, switches, etc.

To assemble these components, refer to diagram, provided by Miller. The diagram is schematic, not to scale and the components will not be literally placed as pictured. Basically you have two circulation circuits: one circulates water in and out of the stock tank (20 gallon/min. or more); and one circulates water in and out of the water heater (4 gallon/min). To distinguish these two I call one the "circulation" loop and the other the "injection" loop since it injects heat into the system. Both the circulation pump and the injection pump must be positioned below the water level of the stock tank; otherwise they suffer priming problems. On the other hand, the strainer must be positioned above the water level of the stock tank and the water heater so that the strainer screen can be cleaned (pumps turned off) without getting water all over the place.

I put the RTD probe in a "T" close to the outlet from the stock tank; you'll need some bushings and a tubing adapter to seal the probe. Also, I ran the lead wires of the probe through a ¼ in. rubber tube to protect them. The lead wires go to the temperature controller which switches the injection pump on and off to maintain temperature in the stock tank.

As you can see in the diagram, the injection loop has an inlet and outlet into and out of the circulation loop. It is important that the inlet and outlet be placed very close to each other. If the inlet and outlet are too far apart there will be a slight pressure difference between them in the circulation loop. If there is even a slight difference in pressure, it will cause water to circulate through the water heater even when the injection pump is not running. This will cause the temperature in the stock tank to drift upward, uncontrolled, above the limit (I found this out the hard way).

Place the inlet to the stock tank just over the top edge and pointed parallel to the edge of the tank so that the water swirls around in the stock tank like a flushing toilet bowl. Keep the inlet as close to the edge as possible because it will get bumped by nuts going in and out of the tank.

The temperature controller is an electronic device that is as complicated as a digital camera and has all sorts of settings and options. You want simple on-off control and your choice of C or F, choose 0.1 degree precision. Target temperature is 49 degrees C or 120 F. Mount the controller in some easily visible place but out of the splash zone. It gives a constant, real-time, digital readout of the water temperature. You need to watch the temperature like a hawk until you are confident everything is working as it should. In operation, the water heater thermostat should be set as hot as possible. This will result in fast recovery and maximum throughput. Don't try to control the stock tank temperature by adjusting the water heater thermostat. Stock tank temperature is regulated by the temperature controller and injection pump. Depending on ambient temperature, it takes at least two hours for system to get up to operating temperature from a cold start; it's quicker if the water heater remains on.

You should have an on-off switch that controls both pumps but I like to have power to the temperature controller all the time. Most electronic devices last longer and perform better if they run all the time. Mine has been running continuously for more than 15 years. During the "off season" I do dial the set point down so that the relay remains "off." The relay is the part that will eventually fail.

The nice thing about PVC pipe is that it is relatively cheap and easy to cut and re-glue. You may have to re-do the plumbing a few times to get it working as you like.