then the mat to mushroom soil treated at 212°F/30 min.

The hope is to develop a suppressive nursery mix so that the transplants will carry the suppressive microflora to the field. This must be combined with use of cover crops to supply abundant organic matter, and maintenance of high Ca and NH_4 nitrogen in the field.

LITERATURE CITED

1. Baker, K.F., and R.J. Cook. 1974. Biological Control of Plant Pathogens. W.H. Freeman and Co., San Francisco. 433 pp.
2. Broadbent, P., K.F. Baker, and Y. Waterworth. 1971. Bacteria and actinomycetes antagonistic to fungal root pathogens in Australian soils. *Austral. Jour. Biol. Sci.* 24:925-944.
3. Broadbent, P., and K.F. Baker. 1974. Behaviour of *Phytophthora cinnamomi* in soils suppressive and conducive to root rot. *Austral. Jour. Agr. Res.* 25:121-137.
4. Broadbent, P., and K.F. Baker. 1974. Association of bacteria with sporangium formation and breakdown of sporangia of *Phytophthora* spp. *Austral. Jour. Agr. Res.* 25: 139-145.
5. Malajczuk, N., A.J. McComb, and C.A. Parker. 1977. Infection by *Phytophthora cinnamomi* Rands on roots of *Eucalpytus calophylla* R. Br. and *Eucalyptus marginata* Donn. ex Sm. *Austral. Jour. Bot.* 25:483-500.
6. Malajczuk, N., and A.J. McComb. 1977. Root exudates from *Eucalyptus marginata* Donn. ex Sm. and *Eucalyptus calophylla* R. Br. and their effects on *Phytophthora cinnamomi* Rands. *Austral. Journ. Bot.* 25:501-514.
7. Pegg, K.G. 1977. Biological control of *Phytophthora cinnamomi* root rot of avocado and pineapple in Queensland. *Austral. Nurs. Assoc. Ann. Conf. Seminar Papers* pp. 7-12. 38 pp.
8. Shea, S.R., and N. Malajczuk. 1977. Potential for control of eucalypt dieback in Western Australia. *Austral. Nurs. Assoc. Ann. Conf. Seminar Papers* pp. 13-19. 38 pp.

ROOT WEEVILS: FROM CUTTINGS TO LANDSCAPE

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I want to stress the importance of knowing *which* root weevil is causing problems, because the steps to take to alleviate the situation vary, depending on the species of weevil involved and the stage of development of the plant. Many nurserymen and some trade journal articles discuss the "strawberry root weevil" *Otiorynchus ovatus* as if that were *the* problem. In fact, I have never seen it seriously injuring, or even commonly associated with, woody plants.

There are many, perhaps a hundred, "root weevils", larvae

of the family Curculionidae, which feed on roots of plants. Some have very few hosts; others are nearly omnivourous. Some root weevils are widespread and some have a limited range. Nationally, the one of greatest concern to those who produce or maintain woody plants is *Otiorynchus sulcatus*, the black vine weevil (BVW).

Cutting Bench. I have seen cutting benches with yew, juniper, arborvitae, *et al.* cuttings stuck into wet, coarse sand or perlite with hundreds of BVW larvae causing nearly 100% mortality of the cuttings. With high populations of the weevil all new roots are consumed, the callus tissue is eaten away, and the bark girdled up to the medium surface. Almost always, the cases I have seen are in old wooden greenhouses that aren't as tight as they used to be, so it is easy to understand how a few adults could have gotten in. Since BVW adults are all female and lay an average of 6 eggs per day, with some laying 10 per day and since they can live for 2 years in a protected environment, one can understand both how the high number of larvae get to the plants and how one can prevent that from happening.

Sanitation and exclusion are the only tools we have in this case. There are no registered or recommended insecticides in the U.S. that can be used to eradicate the grubs; cuttings are often so severely injured before the problem is discovered that they cannot be saved. Checking the progress of rooting by periodically pulling a few cuttings at random will usually be sufficient to indicate problems in time to allow for resticking viable ones into a new clean bench if necessary.

Liners. Once out of the cutting bench, and either lined out or containerized, the plants face increased chances of root weevil damage. If stock is planted into an infested field or is subjected to heavy oviposition before there is a chance for good root establishment, grubs of BVW can again cause problems. Nurseries with sandy soil are much more likely to be prone to this than are those with clay soils. And the nurseryman should be aware of sources of likely adult migration in the proximity of new plantings. Established field stock is not so often badly damaged by grubs, although I have seen severe problems with some kinds of rhododendrons, hemlock, and especially yew, when such plants are grown in sandy soils. Again the best solution is sanitation and exclusion. There are no pesticides registered for elimination of an established grub population. Nielsen in Ohio has worked out a procedure for control of adult BVW which he has detailed in Ornamentals Northwest (1) and American Nurseryman (2). This is a procedure to try if there are recurring BVW problems in field-planted nursery stock. The adult BVW is not often very destructive, but reduction in their num-

bers reduces oviposition and subsequent grub problems. They are generally present and laying eggs for about 4 months out-of-doors.

The adult BVW feeds on above-ground plant tissue, generally leaves, and does little damage. Sometimes when leaf tissue is scarce they will destroy buds and this can be very serious. This usually occurs in spring before leaf break or, occasionally, in the autumn after leaf drop.

Containers. Plants in containers are a bigger problem than those in the field. BVW larvae can be very destructive to many kinds of plants in wood, metal, or plastic containers, much more so than in field-planted stock. I guess that this is so because of two factors. First of all, the larvae have a restricted area to search for new roots. In the field, through chance, many are probably lost or move to a different plant when they seek a new feeding site. In a container they don't have far to go before they encounter an impervious barrier and are turned back toward the root area. Also, vigorous, new, susceptible roots are often along the wall of the container making them even more readily found by the grubs. Secondly, the grubs have much more protection from natural enemies in containers than they do in the field. Predatory ground beetle larvae cannot leave the soil and climb into a container, for example. The container mix may not be so easily colonized by pathogenic fungi as is field soil, and fungus is a major killer of BVW in the U.S. Pacific Northwest. A third *possible* factor is vigor of plant growth in container stock versus field stock. Damage to foliage or buds of container-grown stock by adult weevils is not usual and is easily detected.

We need a good material for control of weevil larvae in container-grown nursery stock, ideally one which, once applied, will last long enough to provide season-long protection and one effective enough to eradicate established populations. Unfortunately there are no good candidates. None of the currently marketed insecticides, nor any now under development, have that potential. The best hope for the forseeable future is exclusion and, perhaps, use of the Ohio adulticide program.

Landscape. In established public or private landscape plantings root weevil larvae are sometime involved with decline of yew and some rhododendrons, such as 'Olive', but are not usually a problem. Apparently, older plants have enough roots that they can stand the loss of a few; in addition fungi and other natural enemies become established and keep the weevil numbers down. At any rate, we seldom see established landscape plants damaged by root weevil grubs and treatments with insecticides are seldom warranted.

The adult BVW is not a serious threat to foliage or buds in

established landscapes either. However, there are some other kinds of root weevil adults which are very serious as destroyers of the esthetic value of landscape plants and which, if not controlled, can reduce leaf tissue to the point where the hardiness and health of the plant is endangered. In the U.S. mid-Atlantic states the pretty little weevil *Pseudocneorhinus bifasciatus* feeds heavily on California privet, azalea, weigela, and a dozen other ornamentals, creating havoc with the homeowners' carefully manicured landscaping. The grubs, however, seem to be inconsequential. Also in this area are the Asiatic oak weevil and Pales weevil. California has the cribrate weevil. All of these are more injurious as adults than as larvae.

On the west side of the Cascade Mountains of Oregon and Washington, up into British Columbia and down into California we have the most serious problem with adult root weevils. A dozen different species, notably the obscure root weevil (*Sciopithes obscurus*), the woods weevil (*Nemocestes incomptus*), *Otiorynchus singularis*, and three species of *Dyslobus* cause unacceptable damage to the foliage of rhododendrons, viburnums, roses, ivy, currant, fuschia, clematis, primrose, azalea, salal, and many more. These, *especially* the obscure root weevil and the woods weevil, tend to remain active in much cooler weather than BVW and cause considerable early spring and late autumn havoc. My best collecting ever was in a red raspberry field in early May from 10 PM to midnight when the temperature was 33°F where two of us collected several hundreds of weevils from the canes for use in lab studies. They were feeding on the buds and newly-expanding leaves.

Table 1. Effect of various chemical treatments as a deterrent to leaf damage to rhododendron caused by adult root weevils, 1976.

Treatment (lb. a.i./100 gal.)		Treatment interval, weeks	Mean feeding per leaf, sq. cm.	Percent reduction from check
Untreated check		—	1.10	—
Orthene 75 S	(1)	4	.02	98
Orthene 1.3 EC	(0.75)	4	.03	97
Orthene 75 S	(0.75)	4	.03	97
Imidan 50 WP	(1)	4	.05	95
Orthene 75 S	(0.5)	4	.06	95
TH-6041 25 WP	(0.25)	4	.10	91
Orthene 75 S	(1)	6	.16	85
Malathion 5E	(1)	2	.24	78
Sumithion 8 EC	(1)	4	.58	47

For these foliage-destroying "root" weevils, none of which is usually serious in the grub stage, we have determined that the systemic organophosphate insecticide acephate (marketed as Orthene® by Chevron Chemical Company) is the best foliage

protectant (Table 1) and there is a 24c (local need) label for that use in Washington and Oregon.

Our current research effort is in the study of the reasons for different susceptibility of various *Rhododendron* species and hybrids to feeding by adult root weevils, in the hope that we may be able to exploit any differences we find for protection of existing plants and/or development of resistant new hybrids.

LITERATURE CITED

1. Nielsen, D.G., M.J. Dunlap, and J.F. Boggs. 1978. Controlling black vine weevils. *American Nurseryman* 147(7):12-13, 89-92.
2. Nielsen, D.G., M.J. Dunlap, and J.F. Boggs. 1978. Progress report on research in black vine weevil control. *Ornamentals Northwest* 2(4):12-13.

CHEMICAL CONTROL OF ROOT WEEVILS

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Root weevils, the black vine and strawberry, continue to be a serious problem of nursery stock in British Columbia. Since the loss of pesticides such as chlordane and aldrin from our market, weevils have been increasing in population. Weevils infest almost every species and cultivar of plant from rhododendrons to maple and arborvitae.

Leaf notching caused by adult feeding is unsightly and renders an infested plant unsaleable. The larvae feed on roots of both established plants and liners, restricting uptake of nutrients and water. High mortality in liners results from girdling at the crown by larvae.

There is *usually* only one generation of weevils per year. The adults emerge from pupae in late May to early June and begin laying eggs in 2 to 3 weeks. Eggs are laid throughout July, August and September. The insect overwinters as a larvae and pupates in May.

We are now finding that with container growing, the use of heated propagating benches and polyethylene covered houses, more than one generation of weevils may occur in one year. Therefore populations, in these circumstances, increase very rapidly.

Adults, pupae, and young adults, as well as larvae, have been found simultaneously in polyethylene-covered houses in early spring.