When sampling for nematodes in annual field and vegetable row crops, a sampling depth of 18 inches (45 cm) is normally adequate for estimating population numbers. In fields that have had a prolonged dry fallow period, nematodes will tend to be at deeper vertical profiles, where there is greater soil moisture; sampling down to the 3-foot (90 cm) level is desirable under these conditions. For grapevines, sampling within rows to a depth of 2½ feet (75 cm) and, for tree crops, sampling beneath the canopy to a depth of 3 feet (90 cm) are adequate for detecting parasitic nematode populations.

In relation to vertical distribution and sampling strategy, cyst nematodes present a different problem, because eggs in a cyst can remain viable and survive in dried surface soil. Surface soil sampling of the tilled soil after cultivation can provide an accurate quantitative estimate of the cyst nematode population.

At very great soil depths, the increased anaerobic conditions limit the survival of most plant parasitic nematode species; however, examples of nematodes found at great depth include *Xiphinema index*, found 6 feet below surface on grapes, and *Pratylenchus vulnus*, found 10 feet below surface around walnut roots.

Studies on the movement and migration of root knot nematodes in soil have shown that second stage juveniles of *Meloidogyne incognita* can move over a distance of greater than 3 feet (90 cm) in either direction in the vertical plane. Downward movement over this distance could be important in terms of following retreating moisture gradients during drying soil conditions, such as fallow periods, and the upward migration of nematodes over this distance may partly explain the rapid reinfection and infection of plants grown in soil following fumigation treatments.

**Common Nematode-Crop Damage Associations**

The list of nematode-crop damage associations in Table 1 is the result of the effort of a university-industry committee, led by B. F. Lownsbury of the University of California at Davis. The listing provides an indication of the nematodes most likely to be associated with damage of selected California crops.

<table>
<thead>
<tr>
<th>Deciduous fruits</th>
<th>Nuts</th>
</tr>
</thead>
<tbody>
<tr>
<td>apple—<em>Pratylenchus penetrans</em>, <em>P. vulnus</em>, <em>Meloidogyne</em> spp.</td>
<td>almond—<em>Meloidogyne incognita</em>, <em>M. javanica</em> (peach rootstocks resistant to root knot nematodes may be used), <em>Xiphinema americanum</em>, a ringspot virus vector</td>
</tr>
<tr>
<td><em>Xiphinema americanum</em>, a ringspot virus vector</td>
<td>pistachio—<em>Pistacia vera</em> susceptible to <em>Meloidogyne</em> spp.</td>
</tr>
<tr>
<td>apricot—<em>Pratylenchus vulnus</em>, <em>Xiphinema americanum</em>, a virus vector</td>
<td><em>P. atlantica</em>, <em>P. terebinthi</em>, and <em>P. integerrima</em> resistant to all <em>Meloidogyne</em> spp. <em>X. americanum</em> and <em>P. hamatus</em> develop in fields.</td>
</tr>
<tr>
<td>Paratylenchus spp. are also common on cherry. Their effects on cherry have not been studied.</td>
<td>Citrus fruits</td>
</tr>
<tr>
<td>peach and nectarine—<em>Meloidogyne incognita</em>, <em>M. javanica</em> (root knot nematode resistant rootstocks available), <em>Criconemella xenoplax</em>, <em>Pratylenchus vulnus</em>, <em>Xiphinema americanum</em>, a ringspot virus vector. <em>Pratylenchus</em> spp. and <em>Trichodorus</em> or <em>Paratrichodorus</em> spp. are sometimes associated with poor growth of peach, but their effects on peach have not been studied in controlled experiments.</td>
<td>The principal nematode pathogen on all the citrus fruits is <em>Tylenchulus semipenetrans</em>.</td>
</tr>
<tr>
<td>pear—<em>Pratylenchus</em> spp., <em>Helicotylenchus</em> spp., <em>Xiphinema americanum</em>, <em>Pratylenchus vulnus</em> and other <em>Pratylenchus</em> species have been found commonly in surveys of pear orchards. Evidence to date suggests that pears are pretty tolerant of these nematodes.</td>
<td>Subtropical fruits other than citrus</td>
</tr>
<tr>
<td>persimmon—<em>Tylenchus semipenetrans</em></td>
<td>avocado—<em>Pratylenchus vulnus</em></td>
</tr>
<tr>
<td>plum and prune—<em>Pratylenchus vulnus</em>, <em>Paratylenchus neoambylcephalus</em>, <em>Criconemella xenoplax</em>, <em>Xiphinema americanum</em>, a ringspot virus vector</td>
<td>fig—<em>Pratylenchus vulnus</em>, <em>Meloidogyne incognita</em>, and <em>M. javanica</em></td>
</tr>
<tr>
<td><em>Pratylenchus vulnus</em>, <em>Tylenchulus semipenetrans</em>, <em>Meloidogyne incognita</em>, <em>M. javanica</em></td>
<td>olive—<em>Pratylenchus vulnus</em>, <em>Tylenchulus semipenetrans</em>, <em>Meloidogyne incognita</em>, <em>M. javanica</em></td>
</tr>
</tbody>
</table>

Grapes and small fruits

| grapes—*Meloidogyne incognita*, *M. javanica*, *Pratylenchus vulnus*, *Xiphinema index*, *X. americanum* (X. californicum), *Paratrichodorus minor*, *Tylenchulus semipenetrans*, *Criconemella xenoplax* | blackberries and relatives—*Pratylenchus vulnus* |

continued next page
TABLE 1. Continued

Grapes and small fruits, continued
raspberries—Pratylenchus vulnus, Xiphinema americanum
strawberries—Pratylenchus penetrans, P. vulnus, Aphelenchoides fragariae, A. ritzemabosi, Meloidogyne hapla, Xiphinema americanum

Vegetables
artichokes—Merlinius brevidens is found commonly around artichoke. Its effect on artichoke has not been studied.
aparagus—Meloidogyne incognita
carro—Meloidogyne arenaria, M. hapla, M. incognita
lima bean—Meloidogyne incognita, M. javanica
snap beans—Meloidogyne incognita, Pratylenchus scribneri
table beets—Heterodera schachtii, Meloidogyne hapla, M. incognita, M. javanica
 cabbage, brussel sprouts, broccoli, cauliflower—Heterodera schachtii, H. cruciferae, Meloidogyne hapla, M. incognita, M. javanica
cantaloupes, watermelons, other melons—Meloidogyne incognita, M. javanica
celery—Meloidogyne hapla, M. incognita, when growing season extends into warm weather
corn—Paratrichodorus minor, Meloidogyne spp. Helicotylenchus spp., Merlinius brevidens, Pratylenchus minor, and Tylencorythynchus spp. are also associated with corn in California. Their effects on corn in California have not been studied.
blackeye beans—Pratylenchus scribneri, Meloidogyne incognita
cucumbers and pickles—Meloidogyne incognita, M. javanica
eggplant—Meloidogyne incognita, M. javanica
endive and chicory—Meloidogyne incognita, M. javanica, Longidorus africanaus. Merlinius brevidens is found commonly around lettuce. Its effect on lettuce has not been studied.
garlic and onions—Ditylenchus dipacii, Meloidogyne hapla, M. incognita, M. javanica
garden peas—Heterodera trifolii
parsnips—Meloidogyne incognita
peppers—Meloidogyne incognita, M. javanica, Paratrichodorus minor
irish potatoes—Meloidogyne hapla, M. chitwoodi, M. incognita, M. javanica, Paratrichodorus minor (a vector of corky ringspot virus)
sweet potato—Meloidogyne incognita
radish—Heterodera schachtii, Meloidogyne incognita
spinach—Heterodera schachtii, Meloidogyne incognita
squash—Meloidogyne incognita, M. javanica
tomato—Meloidogyne hapla, M. incognita, M. javanica. Some tomato varieties are resistant.
turnips—Heterodera schachtii

Seeds and grain, continued
alfalfa—Ditylenchus dipsaci, Meloidogyne hapla, M. javanica, Tylencorythynchus clarus, Paratrichodorus minor, Merlinius brevidens, Helicotylenchus spp., Xiphinema americanum and Pratylenchus spp. are also associated with alfalfa. Only
M. bapla and D. dipsaci are shown to be pathogenic in central California.
barley—Meloidogyne naasi, M. chitwoodi, and Merlinius brevidens are also associated with barley. Their effect has not been studied.
dried beans (lima, blackeye, kidney, garbanza)—Meloidogyne incognita, M. javanica, Pratylenchus scribneri. Other nematodes associated with dried beans include Tylencorythynchus clarus, Paratrichodorus minor, and Paratrichodorus spp. Their effects on beans have not been studied.
bermudagrass (for seed)—A number of nematode species are associated with bermudagrass, most commonly Helicotylenchus dihystera, Meloidogyne spp. and Tylencorythynchus clarus, but their pathogenicity to bermudagrass has not been proven.
clover (Alsike, Ladino, Red, White)—Heterodera trifolii, Meloidogyne hapla, M. incognita, M. javanica
oats—Meloidogyne naasi, M. chitwoodi, and Merlinius brevidens are also associated with oats in California. Their effect on oats is not known.
rye—Meloidogyne naasi
rice—Hirschmanniella belli occurs on rice in California. It has not been associated with poor growth of rice, however.
sorghum—Pratylenchus minor, P. thornei, and Merlinius brevidens are associated with sorghum in California. Their effects on sorghum are not known.
wheat—Meloidogyne naasi, M. chitwoodi and Merlinius brevidens, Pratylenchus thornei. P. minor is also associated with wheat. Their effects have not been studied.

Fiber and sugar crops

Fiber and sugar crops

cotton—Meloidogyne incognita, Paratrichodorus minor, Pratylenchus brachyurus, Helicotylenchus spp. and Tylencorythynchus clarus commonly associated with cotton. Their effects on cotton have not been studied.
sugarbeet—Heterodera schachtii, Meloidogyne hapla, M. incognita, M. javanica, Ditylenchus dipsaci, Paratrichodorus spp.

Ornamentals

abelia—Meloidogyne hapla
African violet—Aphelenchoides fragariae, A. ritzemabosi
ajuga—Meloidogyne hapla, M. incognita
anthurium—Heliocotylenchus spp., Paratrichodorus spp., Scutellonema spp. In addition, Radopholus similis is sometimes found on anthurium shipped into California.
arrowroot—Meloidogyne incognita, Pratylenchus penetrans. In addition, Radopholus similis is sometimes found on arrowroot shipped into California.
azaleas—Tylencorythynchus claytonii
banana—Meloidogyne incognita, Helicotylenchus spp., Scutellonema brachyurum, Radopholus similis
birds-nest fern—Aphelenchoides fragariae
boxwood—Pratylenchus vulnus, Meloidogyne spp., Rotylenchus buxophilus
cacti—Meloidogyne hapla, M. incognita, M. javanica, Heterodera cacti

continued
TABLE I. Continued

Ornamentals, continued

caladium—Meloidogyne incognita, *M. javanica*
calla—*Meloidogyne* spp.
camellia—Helicotylenchus erythrina, Hemicicornoides sp.,
Trachelobrychus claytoni
canna—Meloidogyne incognita, *M. javanica*, Pratylenchus
penetrans
carnation—Cricohedra curvatum, Meloidogyne hapla,
Pratylenchus dubius, Rotylenchus robustus
chrysanthemum—*Aphelenchoides ritzemabosi*, Pratylenchus
*cookei*, Pratylenchus penetrans
dahlias—Meloidogyne incognita, *Pratylenchus coffeae*,
P. penetrans
dichondra—*Meloidogyne incognita*, *M. javanica*, Helicotylenchus
spp.
dieffenbachia—Meloidogyne incognita
English daisies—Meloidogyne hapla, *M. javanica*
fibrous begonias—*Aphelenchoides ritzemabosi*
gardenia—Meloidogyne incognita
ginger—*Meloidogyne javanica*. Ginger shipped into California
is often infected with *Radopholus similis*
gladiolus—*Meloidogyne incognita*
gloxinia—*Aphelenchoides ritzemabosi*
iris—*Ditylenchus destructor*, Meloidogyne hapla, *M. javanica*,
P. penetrans
lilacs—*Pratylenchus vulnus*, Meloidogyne spp.
Lilies (Easter and other)—*Aphelenchoides fragariae*, Pratylenchus
penetrans, Meloidogyne spp.
narcissus—*Ditylenchus dipsaci*, Pratylenchus penetrans
nephthytis—*Meloidogyne incognita*
orchids—*Pratylenchus scribneri*
palm trees—Helicotylenchus spp., Meloidogyne spp.
peperomia—*Aphelenchoides ritzemabosi*
philodendron—Meloidogyne spp., *Radopholus similis*
phlox—Ditylenchus dipsaci
pinks—Meloidogyne incognita, *Pratylenchus* spp.
true ferns—*Aphelenchoides fragariae*
primula—Ditylenchus dipsaci
rhododendron—*Trachelobrychus claytoni*, Helicotylenchus
*erythrinae*, Pratylenchus minor
rose—*Meloidogyne hapla*, *Pratylenchus vulnus*
rubber plant—Heterodera fisci
sansaviera—Scutellonema brachyurum, *Radopholus similis*,
*Meloidogyne* spp.
Shasta daisies—*Meloidogyne hapla*
strelitzia—*Meloidogyne* spp., *Scutellonema brachyurum*,
*Helicotylenchus* spp.
vincas—*Meloidogyne hapla*, *M. javanica*
yuccas—*Meloidogyne* spp., *Rotylenchulus reniformis*