# Growth of Grapevine Rootlings in Soil from a Field Nursery Naturally Infested with *Meloidogyne incognita* and *Rhizoctonia solani*

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**Grapevine rootlings (*V. vinifera* cv. Colombard and *V. champini* cv. Ramsey) were grown in pots containing soil from a field nursery naturally infested with *Meloidogyne incognita* and *Rhizoctonia solani*. Vine growth in untreated soil with or without dilution using clean sand was compared with growth in soil subjected to a range of treatments including: disinfestation either by aerated steaming or by fumigation with methyl bromide, amendment with 1% (w/w) corn-meal, or treatment with fungicides and/or fenamiphos. Vines grown in infested soil suffered root rot caused by *R. soiani* and galling caused by *M. incognita*. Both disinfestation treatments effectively prevented root rotting and galling, and increased the growth of Colombard but not Ramsey. Fenamiphos increased the growth of the nematode-susceptible Colombard but not Ramsey at a low initial population density of three juveniles per 200 g of soil. Nematode reproduction on Ramsey in the shadehouse and in the field nursery on other rootstocks regarded as being highly resistant to root-knot nematode was higher than previously reported with other South Australian *Meloidogyne* spp. populations. Soil dilution increased Colombard growth and amendment with corn-meal reduced nematode reproduction on both cultivars. *Rhizoctonia solani* caused root rot in both cultivars but quintozene and tolclofos-methyl increased root growth only of Ramsey. These fungicides and pencycuron reduced the severity of root rot; tolclofos-methyl was particularly effective in reducing the frequency of isolation of *R. solani* from roots. Potassium phosphite did not reduce root rot or increase root growth. Quintozene, tolclofos-methyl and pencycuron also inhibited nematode reproduction but these effects were not consistently observed in both cultivars. Most isolates of *R. solani* from grapevine roots belonged to anastomosis group 4. Field observations suggested that galled roots were more prone to infection by *R. solani* than ungalled roots.**

Although several species of root-knot nematode (*Meloidogyne* spp.) occur on grapevines (*Vitis* spp.), *M. javanica* predominates in many viticultural regions of Australia (Sauer, 1962; Meagher, 1969; Stirling, 1976) and South Africa (Loubser, 1988). While this species predominates in the hotter inland regions of Australia along the River Murray, *M. incognita* was almost as common as *M. javanica* in the Orange and Vaal River regions of South Africa (Loubser, 1988). Stirling & Cirami (1984) found that a grapevine population containing *M. incognita* and *M. arenaria* was more virulent than other South Australian populations containing *M. javanica* and *M. hapla*. Loubser (1988) reported that South African populations of *M. incognita* and *M. javanica* were significantly more pathogenic to grapevines than *M. arenaria* and *M. hapla*. At 33°C the *M. incognita* population was more pathogenic than *M. javanica*. Cain *et al.* (1984) reported on a pathotype of *M. incognita* which severely galled grapevine rootstocks regarded as being highly resistant to *M. incognita*. They urged that greater effort be expended on determining the frequency, incidence and distribution of such pathotypes and on incorporating them in breeding programmes for grapevine rootstocks.

This study reports the results of pot experiments, with an aggressive pathotype of *M. incognita* in soil from a South Australian field nursery, on both susceptible and resistant grapevine cultivars. Isolation of *Rhizoctonia solani* from the same soil, causing root rot of grapevine rootlings, and results of shadehouse experiments with soil-applied fungicides are also reported.

## MATERIALS AND METHODS

**Preliminary investigations:** Patches of two-year-old vine rootlings (various cultivars) in a Riverland field nursery exhibiting stunting, shoot dieback and death, and unthrifty growth occurred across the entire nursery. Grapevine rootlings had been grown at the site for two years following four years of grassy fallow and extensive cereal cropping.

Vines from severely stunted patches were examined for root galling and rotting, and 15 mm lengths of necrotic roots were incubated at 25°C for 4 days on potato-dextrose agar (PDA) amended with streptomycin sulphate (200 mg/L). *Rhizoctonia solani* isolates were identified by their characteristic mycelium (Parmeter, Sherwood & Platt, 1969) and representative isolates were sent to Dr S. Neate (CSIRO Division of Soils, Adelaide) for identification of anastomosis groups by comparing extracellular pectic enzyme patterns on polyacrylamide gel electrophoresis (Sweetingham, Cruickshank & Wong, 1986) with those from isolates of known anastomosis groups. Abundance of *Meloidogyne* spp. was investigated by extracting eggs from 30-35 g samples of washed roots taken from unthrifty blocks of vines grafted to three different rootstocks – Schwarzmann (*V. riparia* x *V. rupestris*), K51-32 (*V. champini* x *V. riparia*) and K51-40 (*V. champini* x *V. riparia*) – using 1% sodium hypochlorite (Hussey & Barker, 1973). Counts were expressed as number of eggs and juveniles per g fresh mass of roots and suspensions were re-examined after 72 h to enable most eggs to hatch and confirm their identity as *Meloidogyne* juveniles.

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**Pot experiments:** Soil (sandy loam) from the field nursery was collected during winter from the root zone of unthrifty rootlings. After mixing, it was stored in sealed 20-litre buckets at ambient temperature until use, 4 months later in spring. Before use soil was re-mixed and duplicate 200 g sub-samples were extracted by decanting and sieving followed by 24 h on modified Baermann funnels to determine the initial levels of plant parasitic nematodes. Soil was used either undiluted, or to ensure adequate drainage in pots, after dilution (2 parts field soil to 1 part coarse, washed river sand – v/v). To determine the effects of soil disinfestation on vine growth, a third of the soil was either fumigated with methyl bromide (600 g/m$^3$) or subjected to aerated steaming at 60°C for 30 minutes three weeks before use. Disinfested soil was either used as is or mixed with coarse sand as for infested soil. To provide organic matter and an external nutrient source for proliferation of *R. solani,* half of the diluted soil, whether infested or disinfested, was mixed thoroughly with ground corn-meal (1% w/w) immediately before use.

Grapevine rootlings (*V. vinifera* cv. Colombard and *V. champini* cv. Ramsey) were propagated over winter by striking cuttings on a heated sand bed before transfer to test soils 14 weeks later in November, 1991.

*Experiment 1:* The effects of disinfestation treatments, soil dilution and addition of corn-meal on the growth of grapevine rootlings were evaluated by growing rootlings in the following soils in 600 cm$^3$ pots (approximately 700 g of soil per pot): undiluted field soil +/– disinfestation treatments; diluted field soil +/– disinfestation treatments; diluted field soil with corn-meal +/– disinfestation treatments; uninfested potting mix (pinebark, fine sand, coarse sand and peat moss at 2:1:1:0.35 parts v/v and Osmocote (R) slow-release fertiliser [N:P:K – 18:4.8:8.3] at 4kg/m$^3$).

*Experiment 2:* The effects of the nematicide fenamiphos at 16 mg/pot (200 kg/ha Nemacur 100 G(R), Bayer) and the fungicides pencycuron at 24 mg/pot (120 L/ha Monceren 250 FS(R), Bayer), tolclofos-methyl at 50 mg/pot (127 kg/ha Rizolex 500 WP(R), Shell) quintozene at 41 mg/pot (70 kg/ha Terraclor 750 WP(R), Incitec) and potassium phosphite at 200 mg/pot (1 273 L/ha Foli-R-Fos 200(R), UIM Australia) on the growth of grapevine rootlings were evaluated in diluted field soil in 600 m pots. Nemacur granules were applied to the surface of pots immediately after planting and were watered in. Fungicides were applied as drenches (100 mL/pt) one week after potting to allow soil-borne fungi to infect vine roots. Pots not receiving fungicides (including untreated control pots) were drenched with 100 mL of water. To investigate possible interactions between *M. incognita* and *R. solani* on growth of grapevines, one treatment group was treated with fenamiphos after potting and drenched with quintozene one week later.

In Experiment 1 there were 15-20 replicate pots per treatment (due to insufficient soil); there were 20 pots per treatment in Experiment 2, and both experiments were arranged in randomised block designs in a shadehouse. Mean daily minimum and maximum temperatures over the period of growth (22 weeks) were 12,6°C and 28,3°C respectively. Pots were watered every one to two days as required and were fertilised weekly with a complete soluble fertiliser.

Green shoots were harvested and weighed after 11 and 22 weeks' growth and total production was determined by adding together the fresh weights from each harvest. After 22 weeks' growth roots were washed and blotted dry with paper towels, weighed and examined under a dissecting microscope. Root galling index was scored as 0 (no roots galled), 1 (1-25% of roots galled), 2 (26-50% of roots galled), 3 (51-75% of roots galled), 4 (76-100% of roots galled). Root rot index (proportion of roots browned or rotted) was scored on a similar 0-4 scale (where 4 = 76-100% of roots rotted). However, where *Rhizoctonia*-type runner hyphae were observed on roots (wide, brown hyphae with dolipore septa and wide angles of branching), the score was increased by a value of one, giving a maximum score of 5. The identity of runner hyphae was confirmed by plating representative root segments on PDA (half-strength) amended with streptomycin sulphate 200 mg/L and by examining the resultant fungal colonies. Twenty randomly selected 1 cm-lengths of rotted roots from each treatment group were also plated on this medium, except in the case of vines grown in disinfested soil or potting mix in which case representative root specimens only were plated. Results were expressed as the number of root lengths out of 20 from which *R. solani* was isolated after 72 h incubation at 23°C.

Nematodes were extracted from 2,5 g subsamples of roots per plant by incubating 1-2 cm lengths in plastic bags with 10 mL of 3% hydrogen peroxide for 72 h at 23°C (Tarjan, 1972). The suspension collected after rinsing and vigorously shaking roots twice in water was passed through nested 150-$\mu$m and 38-$\mu$m mesh sieves. Nematode counts were expressed as number per g fresh mass of roots.

Shoot mass, root mass and nematode number (+1) per g of root were analysed using the analysis of variance test ($p<0.05$) with a log transformation where departures from normality occurred. In the cases of root gall and root rot indices, treatments were compared by analysing the number of plants in each index category by contingency table analysis ($p<0.05$).

Root-knot nematodes were identified by examination of perineal patterns from 7 and 10 adult females randomly dissected from Colombard and Ramsey roots respectively. Confirmation was provided by using the differential host test, particularly using the key differentials (tobacco cv. NC95 and cotton cv. Deltapine 16) for *M. incognita* (Taylor & Sassex, 1978).

Representative *R. solani* isolates from roots of both cultivars from the pot experiments were sent to Dr S. Neate for identification of anastomosis groups (AG).

## RESULTS AND DISCUSSION

**Preliminary investigations at field site:** Roots were severely rotted, particularly heavily galled roots, and *R. solani*-like hyphae were abundant on the surface of rotted roots. *Rhizoctonia solani* was isolated from 86% of heavily galled, necrotic roots and from 22% of ungalled, necrotic roots. Other, possibly pathogenic, fungi isolated at lower frequencies from both galled and ungalled roots included *Fusarium* spp., *Cylindrocarpon* sp. and *Macrophomina* sp. Numbers of *M. incognita* eggs and juveniles extracted from Schwarzmann, K51-32 and K51-40 roots were 28, 4 339 and 4 402 per g of root respectively.

TABLE 1
Effects of soil treatments (dilution of field soil with coarse sand, addition of corn-meal or disinfestation by methyl bromide or by aerated steaming) on the abundance of *Meloidogyne incognita* and on the growth and root health of grapevine rootlings cv. Colombard.

| Soil | Treatment | Shoot mass (g) | Root mass (g) | Root rot index (0-5)[1] | Root gall index (0-4)[1] | *M. incognita* juveniles/g root |
|---|---|---|---|---|---|---|
| Field | Nil | 17,34 (2,84 d)[3] | 19,05 e[2] | 4,5 a | 2,8 a | 1351,0 (7,11 a)[3] |
| | Dilution | 20,89 (3,00 c) | 21,66 de | 4,2 a | 1,9 a | 1136,0 (6,96 a) |
| | Dilution + corn | 20,49 (2,99 c) | 24,64 bcd | 4,3 a | 0,7 a | 225,6 (4,87 b) |
| | MBr | 26,54 (3,26 b) | 26,89 b | 0,5 b | 0 c | 0 (0 c) |
| | MBr + dilution | 22,70 (3,10 c) | 22,96 cd | 0,6 b | 0 c | 0 (0 c) |
| | MBr + dilution + corn | 21,42 (3,06 c) | 26,27 bc | 0,7 b | 0 c | 0 (0 c) |
| | Steam | 22,08 (3,07 c) | 26,28 bc | 0,6 b | 0 c | 0 (0 c) |
| | Steam + dilution | 21,83 (3,07 c) | 25,41 bc | 0,7 b | 0 c | 0 (0 c) |
| | Steam + dilution + corn | 21,94 (3,08 c) | 23,46 bcd | 0,5 b | 0 c | 0 (0 c) |
| Potting mix | Nil | 50,58 (3,91 a) | 36,17 a | 0,1 c | 0 c | 0 (0 c) |
| LSD (p = 0,05) | | (0,12) | 3.58 | – | – | (0,59) |

[1] The number of plants in each root rot or gall index category (see text) was compared using contingency table analysis.
[2] Within-column means followed by the same letter are not significantly different ($p<0,05$).
[3] Values in parentheses refer in transformed data: $\log_e$ (shoot mass) or $\log_e$, (number of juveniles + 1).
Corn = amended with corn-meal (1% w/w). MBr = disinfested with methyl bromide. Steam = disinfested by aerated steaming.

TABLE 2
Effects of soil treatments (dilution of field soil with coarse sand, addition of corn-meal or disinfestation by methyl bromide or by aerated steaming) on the abundance of *Meloidogyne incognita* and on the growth and root health of grapevine rootlings cv. Ramsey.

| Soil | Treatment | Shoot mass (g) | Root mass (g) | Root rot index (0-5)[1] | Root gall index (0-4)[1] | *M. incognita* juveniles/g root |
|---|---|---|---|---|---|---|
| Field | Nil | 16,46 cde[2] | 13,02 a | 4,3 a | 0,5 a | 208,2 (4,67 a)[3] |
| | Dilution | 17,27 bcd | 9,06 cdef | 4,6 a | 0,3 b | 85,5 (4,22 a) |
| | Dilution + corn | 14,25 e | 7,72 f | 4,5 a | 0,1 b | 14,4 (2,14 b) |
| | MBr | 18,58 bc | 10,90 b | 0,6 b | 0 c | 0 (0 c) |
| | MBr + dilution | 17,32 bcd | 8,43 ef | 0,8 b | 0 c | 0 (0 c) |
| | MBr + dilution + corn | 16,59 cd | 10,07 bcde | 0,8 b | 0 c | 0 (0 c) |
| | Steam | 15,90 de | 10,23 bcd | 0,7 b | 0 c | 0 (0 c) |
| | Steam + dilution | 19,49 b | 10,60 bc | 0,9 b | 0 c | 0 (0 c) |
| | Steam + dilution + corn | 16,43 cde | 8,77 def | 0,8 b | 0 c | 0 (0 c) |
| Potting mix | Nil | 35,28 a | 13,85 a | 0,2 c | 0 c | 0 (0 c) |
| LSD (p = 0,05) | | 2,24 | 1,76 | – | – | (0,84) |

[1] The number of plants in each root rot or gall index category (see text) was compared using contingency table analysis.
[2] Within-column means followed by the same letter are not significantly different ($p<0,05$).
[3] Values in parentheses refer to $\log_e (x + 1)$-transformed data.
Corn = amended with corn-meal (1% w/w). MBr = disinfested with methyl bromide. Steam = disinfested by aerated steaming.

*M. incognita* eggs and juveniles were more abundant than expected on roots of K51-32 and K51-40 rootstocks, and to a lesser extent on Schwarzmann rootstock in the field nursery. These rootstocks are regarded as being highly resistant to *Meloiodogyne* spp. (Hardie & Cirami, 1988). Numbers found on their roots were 47 to 8 680 X greater than those reported by Stirling & Cirami (1984) from Riverland field plantings, using a different extraction technique (incubation).

**Pot experiments:** Mean population of *M. incognita* juveniles per 200 g of soil at the start of the pot experiments in undiluted and diluted field soil was 4,0 and 2,7 respectively. Species identity was determined from perineal patterns of adult females dissected from roots of both *V. vinifera* cv. Colombard and *V. champini* cv. Ramsey vines from pot experiments. Patterns were consistently those of *M. incognita.* Also, the nematode did not produce galls or egg masses on either tobacco cv. NC95 or cotton cv. Deltapine 16, suggesting that it belonged to *M. incognita* race 1 (Taylor & Sasser, 1978).

*Experiment 1:* Vine growth was greatest in potting mix (Tables 1 & 2), probably because of superior aeration, water-holding capacity and nutritional characteristics of the mix in addition to its freedom from pathogens. Disinfestation of undiluted field soil by either fumigation or steaming increased the growth of *V. vinifera* cv. Colombard (Table 1), adding validity to field observations implicating soil-borne pathogens in the poor growth and dieback of rootlings in the nursery. Growth stimulation following soil disinfestation was less reliable in field soil diluted with clean sand. Also, dilution of infested soil increased Colombard shoot growth, suggesting that the adverse effects of these soil-borne pathogens were directly related to inoculum density. In both field- and shade-house-grown vines the main root pathogens were *M. incognita* and *R. solani.* All soil disinfestation treatments were effective against these pathogens and virtually eliminated root rotting and galling. Root galling did not occur in vines grown in potting mix or disinfested soil, nor were *M. incognita* juveniles or *R. solani* isolated from their roots.

Growth of *V. champini* cv. Ramsey in either undiluted or diluted field soil was not increased by any of the soil disinfestation treatments (Table 2). Ramsey is highly resistant to *Meloidogyne* spp. (Lider, 1954; Hardie & Cirami, 1988), but is susceptible to *R. solani* (Marais, 1979; Walker, 1992) and root rot indices for Ramsey in infested soil were equivalent to those for Colombard. Although regarded as a vigorous rootstock, Ramsey is difficult to propagate and establish in the field due to poor root development caused by unfavourable levels of plant growth regulators (Alley, 1979; Goussard & Orffer, 1979). Root development of Ramsey both before potting and at harvest was much poorer than that of Colombard, and this strong growth inhibition may have masked any slight stimulatory effect of soil disinfestation and elimination of *R. solani.* The observed reduction in root mass of Ramsey grown in disinfested, undiluted soil (Table 2) may also suggest that side-effects of disinfestation treatments such as increased levels of ammonium or manganese (Williamson, 1953; Sonneveld, 1979) had had adverse effects on the growth of this cultivar but not of Colombard. Soil dilution had an adverse effect on root growth of Ramsey. Vines are less vigorous and *Meloidogyne* spp. populations reach higher levels in coarser soils (Ferris & McKenry, 1975); however, Ramsey is regarded as being well suited to coarse soils of low fertility (Hardie & Cirami, 1988). Poor root growth of Ramsey observed in the coarse, diluted soil may be related to zinc deficiency to which it is susceptible (Hardie & Cirami, 1988). Goussard & Orffer (1979) in discussing propagation of Ramsey pointed to the benefits of zinc applications to root development, the prevalence of zinc deficiency in poor, sandy soils and the essential role of zinc in the biosynthesis of auxins. The poor root growth may also be related to increased severity of disease caused by *R. solani* in sandy soils as is known to be the case in wheat (Samuel & Garrett, 1932).

TABLE 3
Frequency of isolation (%) of *R. solani* from grapevine roots.

| Experiment/Soil type or treatment | Grapevine cultivar | |
|---|---|---|
| | Colombard | Ramsey |
| Experiment 1 | | |
| Field soil | 60 | 85 |
| Diluted field soil | 60 | 55 |
| Diluted field soil with corn-meal | 40 | 50 |
| Mean | 53 | 63 |
| Experiment 2 | | |
| No chemical | 70 | 60 |
| Pencycuron | 50 | 50 |
| Tolclofos-methyl | 0 | 0 |
| Quintozene | 20 | 65 |
| Phosphite | 55 | 60 |
| Fenamiphos | 75 | 90 |
| Fenamiphos + quintozene | 20 | 55 |
| Mean | 41 | 54 |

Root galling was more pronounced in the susceptible cultivar Colombard than in Ramsey and was reduced (although not significantly so in the case of Colombard) by dilution of infested soil (Tables 1 and 2). Similarly, higher populations of *M. incognita* juveniles were extracted from Colombard than from Ramsey roots, and populations were lower (but not significantly different) in diluted soil compared with undiluted soil.

Addition of corn-meal to diluted soil could be expected to have increased saprophytic growth and initial inoculum density of *R. solani* (Papavizas & Davey, 1961; Benson & Baker, 1974). However, no further increases in root rot index or frequency of isolation of *R. solani* were seen in either cultivar (Tables 1-3); the inoculum density of unamended soil was evidently sufficient to ensure disease. In both cultivars soil amendment with corn-meal reduced the abundance of *M. incognita* juveniles extracted from roots (Tables 1 & 2), possibly due to changes induced in the soil microflora, particularly antagonistic micro-organisms, or to the effects of nematicidal breakdown products (Kerry, 1987).

*Experiment 2:* Fenamiphos was effective in reducing the root galling index and the number of *Meloidogyne* juveniles extracted from roots of both cultivars (Tables 4 and 5). Fenamiphos increased shoot growth of the susceptible cultivar Colombard in the diluted soil with an initial population level of only 2,7 *M. incognita* juveniles per 200 g of soil (Table 4). Much larger populations have typically been involved in other studies (including both pot and field

TABLE 4
Effects of soil-applied fungicides and the nematicide fenamiphos on the abundance of *Meloidogyne incognita* and on the growth and root health of grapevine rootlings cv. Colombard in field soil diluted with coarse sand.

| Chemical | Rate (mg a.i./pot) | Shoot mass (g) | Root mass (g) | Root rot index (0-5)[1] | Root gall index (0-5)[1] | *M. incognita* juveniles/g root |
|---|---|---|---|---|---|---|
| Nil | – | 18,60 b[2] | 18,77 | 4,1 a | 1,8 a | 628,0 (6,35 a)[3] |
| Pencycuron | 24 | 17,44 bc | 19,38 | 3,6 b | 1,5 a | 580,0 (6,33 a) |
| Tolclofos-methyl | 50 | 17,12 bc | 17,85 | 3,5 ab | 1,0 a | 132,2 (4,67 b) |
| Quintozene | 41 | 16,85 bc | 18,69 | 3,4 b | 1,2 a | 377,0 (5,79 a) |
| Phosphite | 200 | 18,43 b | 18,69 | 4,0 a | 1,3 a | 373,4 (5,83 a) |
| Fenamiphos | 16 | 21,27 a | 21,88 | 3,7 a | 0 b | 0,6 (0,37 c) |
| Fenamiphos + quintozene | 16 41 | 15,56 c | 17,94 | 3,0 b | 0,1 b | 0,9 (0,46 c) |
| LSD (p = 0,05) | | 2,26 | N.S. | – | – | (0,72) |

[1] The number of plants in each root rot or gall index category (see text) was compared using contingency table analysis.
[2] Within-column means followed by the same letter are not significantly different ($p<0,05$).
[3] Values in parentheses refer to $\log_e (x + 1)$-transformed data.
N.S. = Not significant.

TABLE 5
Effects of soil-applied fungicides and the nematicide fenamiphos on the abundance of *Meloidogyne incognita* and on the growth and root health of grapevine rootlings cv. Ramsey in field soil diluted with coarse sand.

| Chemical | Rate (mg a.i./pot | Shoot mass (g) | Root mass (g) | Root rot index (0-5)[1] | Root gall index (0-5)[1] | *M. incognita* juveniles/g root |
|---|---|---|---|---|---|---|
| Nil | – | 16,83 ab[2] | 9,75 cd | 4,4 a | 0,5 a | 75,6 (4,24 a)[3] |
| Pencycuron | 24 | 17,95 a | 10,36 bc | 3,5 b | 0,3 a | 29,4 (2,74 b) |
| Tolclofos-methyl | 50 | 18,12 a | 12,09 ab | 3,1 b | 0,2 a | 42,6 (3,50 ab) |
| Quintozene | 41 | 13,90 c | 12,96 a | 3,2 b | 0,3 a | 41,4 (2,92 b) |
| Phosphite | 200 | 16,50 ab | 8,35 d | 4,6 a | 0,4 a | 63,0 (3,83 ab) |
| Fenamiphos | 16 | 15,40 bc | 7,95 d | 4,5 a | 0 b | 0 (0 c) |
| Fenamiphos + quintozene | 16 41 | 13,67 c | 11,06 abc | 3,6 b | 0 b | 0,3 (0,18 c) |
| LSD (p = 0,05) | | 1,82 | 1,98 | – | – | (1,27) |

[1] The number of plants in each root rot or gall index category (see text) was compared using contingency table analysis.
[2] Within-column means followed by the same letter are not significantly different ($p<0,05$).
[3] Values in parentheses refer to $\log_e (x + 1)$-transformed data.

experiments) where deleterious effects of *Meloidogyne* spp. on the growth and/or yields of grapevines have been reported (e.g. Stirling & Cirami, 1984; Loubser & Meyer, 1987; Loubser, 1988; Edwards, 1991). Comparisons between these studies (particularly where artificial inoculation was used instead of naturally infested soil) and the present one are difficult because of the varying conditions used. However, the results do suggest that the population used in this study was highly virulent. Ferris & McKenry (1975) found little correlation between *Meloidogyne* population and vine performance in the field and suggested that spring populations (which ranged from 0,8 to 31,0 juveniles/500 mL of soil) at many of the field sites they studied were below economic threshold levels. Numbers of juveniles/g of root from vines grown in undiluted soil reached levels 27 to 103 X and 46 X higher on *V. vinifera* and Ramsey respectively in this study than in those reported by Stirling & Cirami (1984). However, the latter artifi-

cially inoculated vines using a mixed population including *M. incognita,* an initial population density 210 X higher, and a six-month growth period after inoculation. Loubser (1988) did not observe reproduction of a South African population of *M. incognita* on Ramsey in a pot experiment but egg production (86/g of root) was observed by Loubser & Meyer (1987) in the field.

Walker (1992) found that root masses of Ramsey, but not *V. vinifera* cv. Sultana, were reduced following inoculation with *R. solani.* In this study root masses of Ramsey, but not Colombard, were increased when quintozene and tolclofos-methyl were applied to *R. solani*-infested soil (Tables 4 & 5). These results suggest that Ramsey is more susceptible to root rot caused by *R. solani* than *V. vinifera* cultivars. Marais (1979) commonly isolated *R. solani* from Ramsey rootstocks of declining vines in South Africa and also found that isolates reduced root masses of this cultivar. Ramsey has been widely used in Australian viticulture in recent years and *R. solani* may become increasingly important as a cause of vine decline. Quintozene and tolclofos-methy appeared to be the most useful potential fungicides for control of *R. solani* in vines, being the only ones to increase Ramsey root masses; however, quintozene tended to inhibit shoot growth of Ramsey (Table 5). It also inhibited shoot growth of Colombard when applied in combination with fenamiphos (Table 4). Quintozene, tolclofos-methyl and pencycuron had beneficial effects in reducing root rot in one or more cultivars (Tables 4 & 5), and tolclofos-methyl was particularly effective in reducing the incidence of *R. solani* on roots (Table 3), an effect also reported by Walker (1992). Quintozene also appeared to have reduced the frequency of isolation of *R. solani* but only in the case of Colombard (Table 3). The activity of quintozene against plant parasitic nematodes is well known (Wright, 1981) but in this study tolclofos-methyl and pencycuron also demonstrated activity against *M. incognita* (Tables 4 & 5).

**Identity of R. solani isolates:** Five out of six representatives isolates of *R. solani* isolated from roots of both cultivars from the pot experiments were identified as belonging to AG 4. The other isolate belonged to an unknown group. Similarly six out of eight isolates from grapevine roots from the field nursery were identified as belonging to AG 4, one to AG 2-1 and the other to an unknown group. Both AG 4 and AG 2-1 are known from South Australian soils (Neate & Warcup, 1985). AG 2-1 has been most commonly associated with the Cruciferae and AG 4 with the Chenopodiaceae, Leguminosae and Solanaceae (Ogoshi, 1987).

Although *R. solani* AG 8 is the primary cause of cereal bare-patch disease in Australia (Neate & Warcup, 1985) and the site had a cropping history of cereals and grasses, no isolates belonging to this group were detected on grapevine roots. Kataria, Hugelshofer & Gisi (1991) found that activity of pencycuron against different AGs and isolates of *R. solani* was highly variable, and that it was the least effective fungicide tested against an AG 4 isolate causing damping-off of rape seedlings. However, they found that tolclofos-methyl had good *in vitro* and *in vivo* activity against AG 4 and AG 2-1 isolates.

Pot experiments using quintozene with and without fenamiphos (Tables 4 & 5) did not provide evidence of an interaction between *M. incognita* and *R. solani* such as has been observed on tobacco (Batten & Powell, 1970) and tomato (Golden & Van Gundy, 1975). However, quintozene treatment did not equate to an absence of *R. solani* and combined treatment with fenamiphos and quintozene did not reduced root rot ratings to those of vines grown in soil disinfested by fumigation or steam. Observations made at the field site suggested that galled roots suffered higher rates of infection by *R. solani* and increased rotting than ungalled roots.

Although *Meloidogyne* spp. are already widespread in South Australian vineyards (Stirling, 1976), spread of aggressive pathotypes in infested nursery stocks needs to be avoided as does the spread of grapevine strains of *R. solani.*

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