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TIME-OF-PLANTING TREATMENTS AND THE ROLE OF <u>PRATYLENCHUS PENETRANS</u> IN PEACH DECLINE IN MASSACHUSETTS

A Thesis Presented

By

Susan R. McCouch

Submitted to the Graduate School of the
University of Massachusetts in partial fulfillment
of the requirements for the degree of

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Plant Pathology

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DEDICATION

To my Uruguayan friends,
who inspired this change of course.
And to the many special people encountered along the way.

ACKNOWLEDGEMENTS

Many thanks to Abby Cox for his care of plants and devotion to people, Frank Southwick, Duane Greene, and Howard Bigelow for their help in various stages of this project, and to my advisor, Richard A. Rohde, whose kindness and support were a constant accompaniment throughout this program.

ABSTRACT

Populations of _Pratylenchus penetrans_ were monitored in the peach rhizosphere, and root infection by these parasites was also assessed, in order to evaluate the relationship between nematodes and growth of newly planted peach trees under field conditions. Roots were also evaluated for colonization by a native species of VA mycorrhizal fungus. Soil treatments aimed at suppressing or stimulating _Pratylenchus_ populations were compared on two scion/rootstock combinations of tree.

Soil treatments with nematicides failed to affect growth of either scion/rootstock combination during the trees' first two years in the orchard. Amending the soil with _Pisolithus tinctorius_ spore inoculum stimulated _Pratylenchus_ populations, and also promoted growth of Harbinger/Siberian C trees. Peach trees on Siberian C rootstock were more resistant to injury by _Pratylenchus penetrans_, had a greater percentage of mycorrhizal roots, and grew more vigorously than did trees on Halford stock.

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CHAPTER I

LITERATURE REVIEW

Pratylenchus penetrans on Orchard Trees

The most important factor limiting peach (*Prunus persica*) production in Massachusetts is cold (Childers, 1975; Johnson et al, 1978; Layne, 1974; Layne et al, 1977) but numerous pathogenic factors may also contribute to peach decline in the Northeastern U.S. and in Canada (Yadava and Dowd, 1980). The exact causes of decline have not been clarified but the problem tends to be site-related. Treatment of the soil with a nematicide helps promote tree vigor and increase yields (Bird, 1969; Horton et al, 1981; Koch, 1955; Lownsbery et al, 1968; Mai, 1972), and diminishes tree loss related to winter injury (Edgerton and Parker, 1958; Nesmith and Dowler, 1975; Nyczepir and Lewis, 1980; Wehunt et al, 1980; Zehr et al, 1976). Success of the nematicide treatments have been correlated with a reduction in populations of plant parasitic nematodes.

In the Northeastern U.S., the most damaging nematode on emerging peach roots is the lesion nematode, *Pratylenchus penetrans* (Cobb, 1917), Filipjev and Schuurmans Stekhoven, 1941 (Mai et al, 1977; Mountain and Boyce, 1958). This nematode is widely distributed in Massachusetts agricultural soils and is pathogenic on peach (Mountain and Patrick, 1959).

P. penetrans is an obligate parasite, requiring a host plant in order to reproduce, and it has a wide host range which includes most weeds (Jensen, 1953). It penetrates unsuberized rootlets, burrows into the root cortex where it feeds and the females lay their eggs (endoparasite), and then both larvae and mature nematodes move out into the soil and may re-enter a root many times (migratory nematode). These nematodes penetrate the root epidermis with the aid of digestive enzymes in their saliva and the physical probing of their stylets. This activity harms the root cells, and the feeding and development of large numbers of lesion nematodes in the roots results in extensive damage to the plant (Mai et al, 1977).

Young trees have relatively few feeder roots and these are of vital importance in the development of a vigorous root system. The function of the feeder roots is water and mineral uptake from the soil, as well as hormone production, and if these tissues are damaged, the tree suffers from a lack of water, nutrients, and growth regulating substances, producing the above-ground symptoms of wilting, chlorotic foliage, and generally poor growth and yields which are characteristic of decline. Infection by Pratylenchus penetrans decreases tree vigor and longevity in a variety of orchard fruits, including peach, cherry, plum, and apple (Allen and Marks, 1977; Mai, 1960, 1972; Parker and Mai, 1956).

Edgerton and Parker (1958) have demonstrated a correlation between lesion nematode damage and winter injury on cherries and their work suggests that nematode feeding lowers the cold-hardiness of trees. Nyczepir and Lewis (1980) showed that nematode feeding by Macroposthonia xenoplax altered the physiological rhythm of growth regulators in peach cuttings. This suggests an alteration in the dormancy and cold-hardiness mechanisms of peach trees.

The role of nematodes in the "decline syndrome" of orchard trees is not clear. A complex of factors weaken the trees and some workers feel that although P. penetrans is a pathogen in its own right, that the role it plays in peach decline is primarily as an incitant of root degeneration through formation of extensive infection courts (Mountain and Patrick, 1959). Patrick (1955) postulated that the basic mechanism of lesion formation in peach roots is likely to be the production of phytotoxic substances released when cells are ruptured. Cell damage caused by any lesion- producing agent results in the hydrolysis of amygdalin, a cyanophoric B-glucoside, found in peach root cells. Hydrogen cyanide and benzaldehyde are released in the hydrolysis reaction, and these substances have been shown to inhibit respiration of peach root tips and induce darkening and finally necrosis of meristematic cells (Harris and Gilkeson, 1947; Hildebrand, 1945; Horsley, 1973; Israel et al, 1973; Patrick, 1955; Proebsting and Gilmore, 1941; Rowe and Catlin, 1971; Ward and Durkee, 1956) 1973). Nematode injury to peach roots may thus be compounded by this allelopathic reaction.

Nematode Management in Orchards

Management of nematode populations in peach orchards has been attempted using a variety of approaches. Several chemical nematicides have been evaluated for their effectiveness in reducing both soil and root populations of nematodes and for their effect on growth of young trees. Soil fumigants (Bird, 1969; Horton et al, 1981; Lambert et al, 1979; La Rue et al, 1975; Mai, 1972; Marks and Davidson, 1973; Wehunt et al, 1980; Zehr et al, 1976) and non-fumigant chemicals (Abawi and Mai, 1972; Allen and Marks, 1977; Funt et al, 1979) have been assessed.

Of the fumigants, 1,2 dibromo-3-chloropropane (DBCP) was reported to consistently decrease nematode populations and increase growth of peach trees. Its success as a post-plant as well as pre-plant treatment, and its relatively low cost made it a favorite among orchardists before production was suspended in 1977 (McKenry, 1982).

Fumigation with methyl-bromide was reported to cause stunting of a variety of orchard seedlings (Bird et al, 1974; Lambert et al, 1979; La Rue et al, 1975; Schenck and Tucker, 1974). This was apparently due to an inhibitory effect on mycorrhizal fungi in the soil.

Fumigation with dichloropropene and related hydrocarbons (Telone) (Mai, 1972), methyl isothiocyanate and chlorinated C-3 hydrocarbons (Vorlex) (Marks and Davidson, 1973), and ethylene dibromide (Dowfume) were all reported to control populations of <u>P. penetrans</u> and promote growth of young peach trees.

A number of non-fumigant chemicals have also been tested for their nematicidal activity and ability to promote growth of trees. These include 2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate (Carbofuran-Furadan) , ethyl 4-(methylthio) -m-tolyl isopropylphosphoramidate (Phenamiphos-Nemacur) (Allen and Marks, 1977; Funt et al, 1979), methyl N', N'-dimethyl-N- (methylcarbamoyl)oxy -1-thiooxamimidate (Oxamyl-Vydate) (Abawi and Mai, 1972; Allen and Marks, 1977), 2-methyl-2-(methylthio)propionaldehyde O-(methylcarbamoyl) oxamine (Aldicarb-Temik) (Allen and Marks, 1977).

Limitations of these materials include lack of persistent effect, potential carcinogen, poor chemical movement in the soil, damaging to root systems, and residues in fruit (McKenry, 1981). Researchers are looking for ways to use these chemicals to advantage while minimizing their limitations.

Several workers have investigated the relationship between chemical protection of the plant root system from soil pathogens and cultural practices designed to promote vigor of the trees (Adams et al, 1975; Horton et al, 1981; Mai, 1972; Wehunt et al, 1980). They found that soil pH, water supply, fertilization, and time of pruning are all critical factors in a disease management program. Site-related factors, such as soil characteristics, need also be evaluated. Soils which are favorable for peach tree growth are often the same as those which favor high populations of Pratylenchus species. Both do best in a light, sandy soil with good water drainage (Endo, 1959).

Further, the practice of sod management between orchard rows, which is common in most New England orchards today, provides abundant alternate host roots in which nematode populations can reproduce, even when a chemical nematicide is used in the peach row. As the peach root system expands, it inevitably extends into infected soil.

The choice of a cover crop that is a poor host for *P. penetrans* can help depress potential nematode inoculum in an orchard. Creeping red fescue, perennial rye grass (Marks and Townshend, 1973) and sudan grass (Bird, 1968) have been suggested as suitable crops for this purpose.

Some peach rootstocks are also better hosts for *P. penetrans* than others. Allen and Marks (1977), Bird (1969), and Johnson et al. (1978) have reported that Siberian C rootstock seedlings had significantly higher levels of *P. penetrans* populations in both root tissues and surrounding soil than other seedling rootstocks tested. Siberian C seedlings also suffered more injury than other seedlings in greenhouse experiments, producing the shortest plants when grown in infested soil.

Despite the apparent susceptibility of Siberian C seedlings to lesion nematodes, this rootstock makes a valuable contribution to the peach industry in Canada and the Northeastern U.S. in terms of cold-hardiness (Johnson et al, 1978; Layne, 1974; Layne et al, 1976, 1977). Investigation of other rootstocks well-suited to a northern environment is underway, and although varieties resistant to some nematode species do exist (Sharpe, 1974), no peach rootstock has yet been reported that is resistant to *P. penetrans* (Layne, 1974).

Mycorrhizae

Almost all plants in nature develop "fungus-roots" (mycorrhizae) to varying degrees. In fact, it has been said that "under field conditions, plants do not, strictly speaking, have roots, they have mycorrhizae" (Wilheim, 1966). Of the two commonly distinguished kinds of mycorrhizae, endo-mycorrhizae is the more ubiquitous type of symbiont, and colonizes the roots of almost all plants. As far as is presently known, ecto-mycorrhizae are restricted to several genera of forest trees (Gerdemann, 1968; Kormanik et al, 1977; Marx, 1975; Mosse, 1973; Nicholson, 1967; Smith, 1974).

Mycorrhizal colonization is necessary for successful reproduction of the fungus (Mosse, 1973) and, in some cases, for normal development of the host plant (Bryan and Kormanik, 1977; Kleinschmidt and Gerdemann, 1972; Marx et al, 1971). Little is known, however, about exactly how the fungus affects plant metabolism.

In his review article, Slankis (1974) examines the nature of the symbiotic relationship between plant and fungus. He concludes that although the symbiosis is generally viewed as mutual, it does not necessarily mean that the benefits are in equilibrium. Fox and Spasoff (1972) found that the same fungus may be symbiotic on one cultivar of tobacco and pathogenic on another. Melin (1963) suggests that mycorrhizal fungi are parasites and that their aggression is curbed to mutual symbiosis by the plant's protective measures. According to this theory, the fungus gains entrance only at suboptimal nutritional conditions when it provides essential aid to the host in obtaining soil nutrients. With improved nutritional conditions, the plant host dominates and the virulence of the fungal associate, along with its benefit to the plant, decrease. More information is needed about the physiological and metabolic factors in the plant that control fungal invasion into roots and subsequent mycorrhizal colonization.

Endo-mycorrhizal fungi are usually referred to as "Vesicular-Arbuscular" mycorrhizae. They survive as spores in the soil and upon germination, fungal hyphae grow until they encounter a plant root, or die from lack of nutrients. The hyphae penetrate the cell walls of the epidermis behind the meristematic region and then grow into the cortical cells of the root. These infective hyphae develop specialized absorbing, or nutrient-exchanging, structures called "arbuscules" in the cortical cells. Vesicles are developed later and are regarded as temporary storage organs for the fungus. They appear as hyphal swellings either within or between cells. Fungal mycelium extends out into the soil, increasing the absorption potential of the root system through increased surface area (Kormanik et al, 1977; Sanders et al, 1975).

VA mycorrhizae are formed by certain species of Endogonaceae, a family of fungi in the Mucorales (Gerdemann, 1975), and most commercial fruit and nut trees are colonized by these fungi. Commonly identified species of VA mycorrhizae found in peach roots include: Gigaspora margarita (Hussey and Roncadori, 1982), Glomus etunicatus (Hussey and Roncadori, 1982; McGraw and Schenck, 1981), Glomus fasciculatus (La Rue et al, 1975; McGraw and Schenck, 1981), *Glomus epigaeus* , *G. mosseae* (McGraw and Schenck, 1981), *Endogone mosseae,* and *E. fasciculata* (Gilmore, 1971; Ruele, 1973).

Plant growth is normally stimulated due to colonization by VA mycorrhizae, especially in soils of low fertility (Gerdemann, 1968, 1975; Kormanik et al, 1977; Mosse, 1973), but other organisms in the soil environment may affect this relationship. Where both a mycorrhizal symbiont and a plant pathogen co-exist in the rhizosphere of a host, plant response may vary greatly depending on the organisms involved (Powell, 1974; Schenck and Kinloch, 1974). Disease symptoms caused by pathogenic organisms may be less severe in the presence of mycorrhizae (Baltruschat et al, 1973; Hussey and Roncadori, 1978; Roncadori and Hussey, 1977) or antagonism may occur whereby both the pathogen and the symbiont are adversely affected (Bird et al, 1974; Fox and Spasoff, 1972; Kellam and Schenck, 1980; O'Bannon et al, 1979; O'Bannon and Nemec, 1979), or the mycorrhizae may predispose its host to the effects of a pathogen (Ross, 1972; Schonbeck and Schinzer, 1972).

Mycorrhizae and Nematodes

The combined influence on a plant host of symbiotic mycorrhizal fungi and plant parasitic nematodes has been studied only recently. These studies include work with migratory (Hussey and Roncadori, 1978, 1982; Kunickis, 1977; O'Bannon and Nemec, 1979; O'Bannon et al, 1979; Rich and Schenck, 1981; Ruehle, 1973; Schenck and Kinloch, 1974) and sedentary (Bird et al 1974; Fox and Spasoff, 1972; Hussey and Roncadori, 1982; Kellam and Schenck, 1980; Rich and Bird, 1974; Roncadori and Hussey, 1977; Ruele, 1973; Schenck et al, 1975; Sikora, 1979) nematode parasites. They also include reference to both endo and ecto-mycorrhizal associations.

Hussey and Roncadori (1982) discuss the diversity of interactions between plant parasitic nematodes and VA mycorrhizae in plant roots. Both organisms colonize the same host roots and thus affect one another directly. The most common effect of VA mycorrhizal fungi on nematode-susceptible plants, according to Hussey and Roncadori, is promoting tolerance to nematodes. The mycorrhizal fungi may be important in altering plant stress caused by parasitic nematodes.

The mechanism(s) by which this increased tolerance may be brought about are not clearly understood. Improved nutrition may play a role (Gerdemann, 1975; Mosse, 1973). Gilmore (1971), La Rue et al.(1975), and Strobel et al.(1982) reported that mycorrhizal peach seedlings had significantly higher levels of Zn and Cu than did non-mycorrhizal seedlings. Higher levels of phosphorus are commonly associated with mycorrhizal plants, and reports of increased efficiency of nutrient uptake for several other elements have been reported (Gerdemann, 1975; Kormanik et al, 1977; Mosse, 1973). The effect of VA mycorrhizae in increasing plant tolerance to nematode injury, however, does not appear to be simply nutritional.

Other possible mechanisms of mycorrhizae-stimulated tolerance to nematodes and other parasitic organisms include: (1) an altering of root exudates that would affect rhizosphere-inhabiting microflora and make mycorrhizae less attractive to parasites (Mosse, 1973); (2) an alteration in the balance of microbes near the roots in such a way that non-parasites are favored over parasites (Gerdemann, 1975; Slankis, 1974); and (3) altered plant hormone levels that could significantly influence relative tolerance or susceptibility to pathogen attack, as well as growth and development of the plant itself (Kormanik et al, 1977).

Roots exude numerous and diverse substances and their influence on soil microflora is profound (Rovira, 1969). Certain microbial populations in the rhizosphere may stimulate (Mosse, 1962) or inhibit (Levisjohn, 1957) mycorrhizal formation. Foster and Marks (1967) have found that different types of mycorrhizal fungi, in association with the same host plant, differentially affect the microflora found in the vicinity and on the surface of the mycorrhizae. They suggested that the specific composition of rhizosphere-inhabiting microorganisms depends on two main factors: the root exudates and extracellular metabolites of mycorrhizal fungi.

In the case of VA mycorrhizae, extracellular metabolites may differ not only between different species of fungi, but also between the vesicular-arbuscular part of a fungus and the mycelium extending out into the soil. How nematodes, specifically, are affected by different root and mycorrhizal exudates is not known at the present time.

It appears fairly certain that these fungal symbionts do provide the host plant with growth hormones (Barea and Azcon-Aguilar, 1982; Kormanik et al, 1977). It is not clear whether these fungal hormones are responsible for inducing and maintaining a specific physiological state that allows for continued mycorrhizal development, and if so, how this might affect other host-parasite relationships. More information is also needed about stimulation or inhibition of fungal hormone production by host plant metabolites.

In the case of the sedentary, endoparasitic nematodes, such as the root-knot and cyst nematodes, mycorrhizal colonization tends to actually reduce subsequent infection by these parasites. Kellam and Schenck (1980) reported that soybean roots colonized by _Glomus macrocarpa_ had fewer galls than non-mycorrhizal plants. It was not ascertained whether this was the result of a reduced affinity of the nematode for the mycorrhizal root, or whether the presence of the fungus disrupted the delicate process of giant cell development, thus inhibiting successful completion of the nematode life cycle. In the reverse situation, nematode infection and giant cell formation were likewise found to inhibit colonization by mycorrhizal fungi, and it was concluded that the two organisms were mutually inhibitory.

Baltruschat et al (1973) reported that mycorrhizae formed by _Endogone mosseae_ on tobacco increased the resistance of tobacco to _Meloidogyne incognita._ Fox and Spasoff (1972), working with the cyst nematode, _Heterodera_ (now, _Globodera_) _solanacearum_ and the mycorrhizal fungus, _Endogone gigantea_ on tobacco, described the mutually inhibitory effects that one organism had on the other. They considered this the result of a competition for "living space" within a rootlet, rather than postulating a physiological explanation for the inhibition.

A few cases of specific disease resistance mechanisms related to mycorrhizal infection have been reported. Orchids, in response to a highly specialized mycorrhizal association, produce a phytoalexin which may protect the plant against pathogens (Gaumann et al, 1960). Also certain ecto-mycorrhizal fungi produce antibiotics (Santoro and Casida, 1962). How and under what conditions VA mycorrhizae may affect the susceptibility of plants to disease is a topic that deserves more research.

CHAPTER II

MATERIALS AND METHODS

A block of 144 peach trees was replanted in April of 1980. The new trees included three different scion/rootstock combinations: Harbinger, an early fruiting cultivar on Siberian C rootstock; Garnet Beauty, a mid-season cultivar on Halford stock; and Glohaven, a late fruiting cultivar on Siberian C stock. Siberian C is considered a cold-hardy rootstock while Halford is known as a medium-tender rootstock (Layne et al, 1976, 1977). Forty-eight trees of each cultivar were obtained from Bountiful Ridge Nurseries in Maryland.

One year old whips were planted in a moderately well-drained Scituate, fine, sandy, loam soil at the Horticultural Research Center in Belchertown, Massachusetts. New trees were set in the intersite areas directly following the removal of seven year old peach trees.

All trees were spring fertilized with one pound per tree in April, and another pound per tree in June, of 10-20-20, limed, and mulched. Eight different time-of-planting treatments were applied:

1) Control
2) Oxamyl soil drench (Vydate L)- 4.8 ml. of Vydate L per tree (1.2 g. a.i./4 l. per tree) poured into planting hole 10 days after planting.
3) Phenamiphos soil drench (Nemacur 3)- 420 ml. of Nemacur 3 (2.0 g. a.i./4 l. per tree) sprayed on soil surface in a 2.5 m. diameter circle around each tree 10 days after planting.

4) Carbofuran (Furadan 10% granular)- 40 g. granules (4.0 g. a.i./tree) distributed in a 3 m. diameter circle around each tree 10 days after planting but no granules within .33 M. of each tree.

5) Oxamyl root dip and soil drench (Vydate L)- trees lifted 10 days after planting and roots dipped for 15 minutes in a solution of (1.2 g. a.i./8 l.) Oxamyl. Trees then replanted and soil drenched with 4 l./tree (0.6 g. a.i./4 l.) of Oxamyl solution.

6) <u>Pisolithus</u> <u>tinctorius</u> spore inoculum (obtained from Abbott Laboratories)- trees lifted 10 days after planting, and 3,750 ml. soil mixed with 750 ml. <u>Pisolithus</u> spore inoculum was placed around the root system of each tree as trees replanted.

7) <u>Pisolithus</u> <u>tinctorius</u> spore inoculum (same as treatment 6) and Oxamyl soil drench (same as treatment 2).

8) <u>Pisolithus</u> <u>tinctorius</u> spore inoculum and Upstart (5-15-5 + IBA 0.003%)- trees lifted 10 days after planting, spore inoculum mixed in soil (as in treatment 6), and 3 l./tree of Upstart solution (70.2 ml. Upstart/l. H_2O) placed around roots of each tree as trees replanted. (3 l. of Upstart soln. contains 3,300 mg. of N, 9,900 mg. of of P_2O_5, 3,300 mg. of K_2O, and 2.1 mg. IBA.)

The treatments were distributed in a randomized block design. There were six replicates of each treatment per cultivar/rootstock combination. Due to a shortage of *Pisolithus tinctorius* spore inoculum, the Glohaven trees on Siberian C rootstock did not receive the *Pisolithus* , *Pisolithus* plus Oxamyl, or the *Pisolithus* plus Upstart treatments, and therefore Glohaven/ Siberian C trees were not analyzed in full detail during the experiment.

Rhizosphere soil samples were evaluated for nematodes each month during two consecutive growing seasons. Four subsamples were taken from around the drip line of each tree and mixed. Samples were taken with a core sampler to a depth of 25 cm., and approximately half a liter of soil was taken per tree. Nematodes were extracted from a 50 ml. sub-sample of mixed soil by the Baerman Funnel technique (Southey, 1970).

Comparison of the Baerman Funnel and the Sugar Flotation (Jenkins, 1964) extraction techniques indicated that a representative sample of nematode genera was obtained with the Baerman Funnel and since this technique is considerably less time-consuming, it was employed throughout the course of the experiment. *Pratylenchus* species were identified under the dissecting microscope.

Root infection by both *Pratylenchus* and an endogenous species of VA mycorrhiza was also evaluated. In August of 1981, feeder roots were sampled from Harbinger/Siberian C and Garnet Beauty/Halford trees in five of the treatments including Control, Carbofuran granules, Oxamyl root dip and soil drench, *Pisolithus* spore inoculum, and *Pisolithus* plus Oxamyl soil drench. Glohaven trees were not sampled and three treatments were left unsampled due to time constraints.

Samples were taken from the top 15-20 cm. of soil at two sites around each tree, the uphill and the downhill side. Roots were carefully washed and immediately preserved in Formalin Acetic Acid (FAA). They were then stained in Goodey's formula, a mixture of lactophenol and acid-fuchsin (Goodey, 1973) and allowed to clear in clear lactophenol and ultimately transferred to glycerol. Thirty 1 1/2 cm. root segments per tree were mounted on slides and the percent of rootlets containing one or more lesion nematode and/or mycorrhizal vesicle was evaluated.

Evaluation of tree vigor was done by measuring the circumference of each tree approximately 50 cm. above ground at planting time and once a year during the dormant season. Cross-sectional area was calculated from the trunk circumference (using the formula $A=C^2/4\pi$). This measurement of tree growth is most closely correlated with yield, and is the most sensitive assessment of growth available (Layne et al, 1976).

These data were analyzed using the Analysis of Variance and Duncan's Multiple Range Analysis. Counts of soil populations of nematodes were analyzed using a log (x + 1) transformation as suggested by Proctor and Marks (1974).

CHAPTER III

RESULTS

The cultivar/rootstock differences between peach trees were readily observable in terms of growth in this experiment, being significant at the .01 level. The early blooming Harbinger on cold-hardy Siberian C rootstock was a larger, more vigorous tree than either of the other two scion/rootstock combinations. Glohaven, also on Siberian C rootstock, averaged intermediate in size, with Garnet Beauty on Halford stock being the smallest of the three sets of trees.

Treatment affected growth of Harbinger/Siberian C and Garnet Beauty/Halford trees in different ways. As can be seen in Table 1, _Pisolithus_ and _Pisolithus_ plus Oxamyl treatments promoted growth of Harbinger/Siberian C. Trees treated with _Pisolithus_ were 40% larger and trees treated with _Pisolithus_ plus Oxamyl drench were 47% larger than Controls by the end of the second growing season. In comparison, growth of Garnet Beauty/Halford trees was not influenced by the _Pisolithus_ or the _Pisolithus_ plus Oxamyl drench treatments.

Garnet Beauty/Halford trees treated with _Pisolithus_ plus Upstart were more than 200% bigger than trees receiving _Pisolithus_ alone in August of 1980, after one growing season (Table 1). The effect was no longer significant by the end of the 1981 growing season. _Pisolithus_ plus Upstart produced no growth effects either year on Harbinger/Siberian C trees.

The nematicides did not improve growth of any of the scion/

TABLE 1 Effect of time of planting treatments on growth of Harbinger/Siberian C, Garnet Beauty/Halford, and Glohaven/Siberian C trees.

Treatment	X-Sectional Area Increase (cm^2)		
	1980-81	1981-82	1980-82
Harbinger/Siberian C			
1.) Control	1.98 a*	13.79 a	15.78 a
2.) Oxamyl soil drench	2.59 ab	16.29 abc	18.88 ab
3.) Phenamiphos soil drench	3.18 ab	15.06 ab	18.24 ab
4.) Carbofuran granules	3.49 ab	16.95 abc	20.44 ab
5.) Oxamyl root dip and soil drench	2.66 ab	16.99 abc	19.65 ab
6.) *Pisolithus* spore inoculum	3.79 b	18.77 bc	22.57 b
7.) *Pisolithus* + Oxamyl drench	3.95 b	19.58 c	23.53 b
8.) *Pisolithus* + Upstart	3.34 ab	16.15 abc	19.49 ab
Garnet Beauty/Halford			
1.) Control	2.14 ab	11.91 ab	14.04 ab
2.) Oxamyl soil drench	1.81 ab	10.29 ab	12.09 ab
3.) Phenamiphos soil drench	2.18 ab	13.80 b	15.98 b
4.) Carbofuran granules	2.26 ab	11.40 ab	13.66 ab
5.) Oxamyl root dip and soil drench	2.11 ab	12.02 ab	14.13 ab
6.) *Pisolithus* spore inoculum	1.30 a	9.64 a	10.62 a
7.) *Pisolithus* + Oxamyl drench	1.14 a	10.23 ab	11.36 ab
8.) *Pisolithus* + Upstart	2.62 b	10.91 ab	13.53 ab
Glohaven/Siberian C			
1.) Control	2.19 a	13.62 a	15.81 a
2.) Oxamyl soil drench	1.75 a	12.47 a	14.22 a
3.) Phenamiphos soil drench	1.77 a	11.82 a	13.61 a
4.) Carbofuran granules	3.17 a	13.97 a	17.14 a
5.) Oxamyl root dip and soil drench	2.70 a	14.47 a	17.17 a

* Mean separation within columns and between scion/rootstock combinations by Duncan's Multiple Range test, 5% level.

rootstock combinations (Table 1). The chemicals were all equally ineffective on Harbinger/Siberian C and on Glohaven/Siberian C trees, while there was a tendency toward greater growth of Phenamiphos treated trees on Garnet Beauty/Halford.

Initial rhizosphere populations of Pratylenchus penetrans were measured in June 1980 when the trees were first put in the ground, and were found to be similar on all trees, regardless of treatment or scion/rootstock combination. Populations around the trees were practically zero at this time, due to the preparation of the planting hole which dispersed and crushed existing populations. By August 1980, however, populations had built up and treatment effects were measureable.

Table 2 shows how Pratylenchus penetrans populations were affected by treatment after one growing season. Effects on total populations of nematodes (all genera) are also compared. The Pisolithus treatment increased Pratylenchus populations, as well as Pratylenchus as a percent of total nematodes, on both Harbinger/Siberian C and Garnet Beauty/Halford trees in August 1980. This treatment does not increase populations of all nematodes, but rather affects Pratylenchus species specifically.

The nematicide treatments did not affect Pratylenchus populations compared to Controls, but total nematode populations were reduced when Phenamiphos soil drench or Carbofuran granules were used. Carbofuran was not specifically effective against Pratylenchus penetrans, while both Phenamiphos and Oxamyl soil drench (at the 1.2 g. a.i./4 l. con-

TABLE 2 Effect of treatments on total nematode and *Pratylenchus* populations in the rhizosphere of Harbinger/Siberian C and Garnet Beauty/Halford trees, August 1980.

Treatment	*Pratylenchus*	Total	% *Pratylenchus*
Harbinger/Siberian C			
1.) Control	1.33 ab*	73.16 a	1.82 ab
2.) Oxamyl soil drench	0.83 a	46.83 a	1.77 a
3.) Phenamiphos soil drench	0.33 a	54.49 a	0.61 a
4.) Carbofuran granules	2.00 ab	42.33 a	4.72 abc
5.) Oxamyl root dip and soil drench	3.17 bc	74.67 a	4.25 bcd
6.) *Pisolithus* spore inoculum	5.83 c	61.83 a	9.43 cd
7.) *Pisolithus* + Oxamyl drench	6.83 c	52.83 a	13.09 d
8.) *Pisolithus* + Upstart	4.33 bc	68.83 a	6.29 bcd
Garnet Beauty/Halford			
1.) Control	2.00 ab	146.33 b	1.36 ab
2.) Oxamyl soil drench	0.33 a	86.83 ab	0.38 a
3.) Phenamiphos soil drench	0.50 a	60.50 a	0.82 a
4.) Carbofuran granules	1.17 ab	53.27 a	2.20 ab
5.) Oxamyl root dip and soil drench	2.33 ab	89.66 ab	2.60 ab
6.) *Pisolithus* spore inoculum	11.33 c	98.66 ab	11.48 c
7.) *Pisolithus* + Oxamyl drench	3.50 bc	70.16 a	4.99 bc
8.) *Pisolithus* + Upstart	4.00 bc	67.66 a	5.91 bc

* Mean separation within columns and between scion/rootstock combinations by Duncan's Multiple Range test, 5% level.

centration) showed a tendency toward lowering populations of Pratylenchus. This implies that these materials have some degree of specificity for lesion nematodes.

The effect of treatment on rhizosphere populations was not significant on either set of trees during the second (1981) growing season (Table 3).

A close look at the population dynamics of Pratylenchus over time (sampled August 1980, June, July and August, 1981) shows how scion/rootstock combination affected the rhizosphere environment (Figure 1). On the Harbinger/Siberian C trees, lesion nematode populations in all treatments peaked in July and dropped off sharply by mid-August. On Garnet Beauty/Halford, populations continued to climb throughout the growing season. The difference in nematode populations between July and August of 1981 was significant by variety at the .01 level. Glohaven/Siberian C trees were not monitored.

Growth of Garnet Beauty/Halford trees was inversely correlated with rhizosphere populations of Pratylenchus penetrans at the .05 level. Nematode populations sampled in August 1980 correlated with 1980-82 growth of Garnet Beauty/Halford trees (Figure 2). Pratylenchus populations around Harbinger/Siberian C trees rose as tree size increased.

Root samples of Control trees showed identical levels of Pratylenchus infection for both Harbinger/Siberian C and Garnet Beauty/Halford trees. On both, thirty-five percent of the root segments examined contained at least one lesion nematode (Table 4).

TABLE 3 Population dynamics of *Pratylenchus penetrans* in rhizosphere of Harbinger/Siberian C and Garnet Beauty/Halford over time.

	Pratylenchus per 50 cc soil		
Treatment	8-80	7-81	8-81
Harbinger/Siberian C			
1.) Control	1.33 ab*	14.33 a	4.17 ab
2.) Oxamyl soil drench	0.83 a	---	---
3.) Phenamiphos soil drench	0.33 a	---	1.00 a
4.) Carbofuran granules	2.00 ab	12.17 a	4.50 ab
5.) Oxamyl root dip and soil drench	3.17 bc	10.17 a	4.67 ab
6.) *Pisolithus* spore inoculum	5.83 c	---	7.83 b
7.) *Pisolithus* + Oxamyl drench	6.83 c	13.17 a	4.83 ab
8.) *Pisolithus* + Upstart	4.33 bc	---	---
Garnet Beauty/Halford			
1.) Control	2.00 ab	7.67 a	14.00 ab
2.) Oxamyl soil drench	0.33 a	---	---
3.) Phenamiphos soil drench	0.50 a	---	5.67 a
4.) Carbofuran granules	1.17 ab	5.33 a	9.33 ab
5.) Oxamyl root dip and soil drench	2.33 ab	7.83 a	7.67 ab
6.) *Pisolithus* spore inoculum	11.33 c	---	19.33 b
7.) *Pisolithus* + Oxamyl drench	3.50 bc	12.00 a	10.67 ab
8.) *Pisolithus* + Upstart	4.00 bc	---	---

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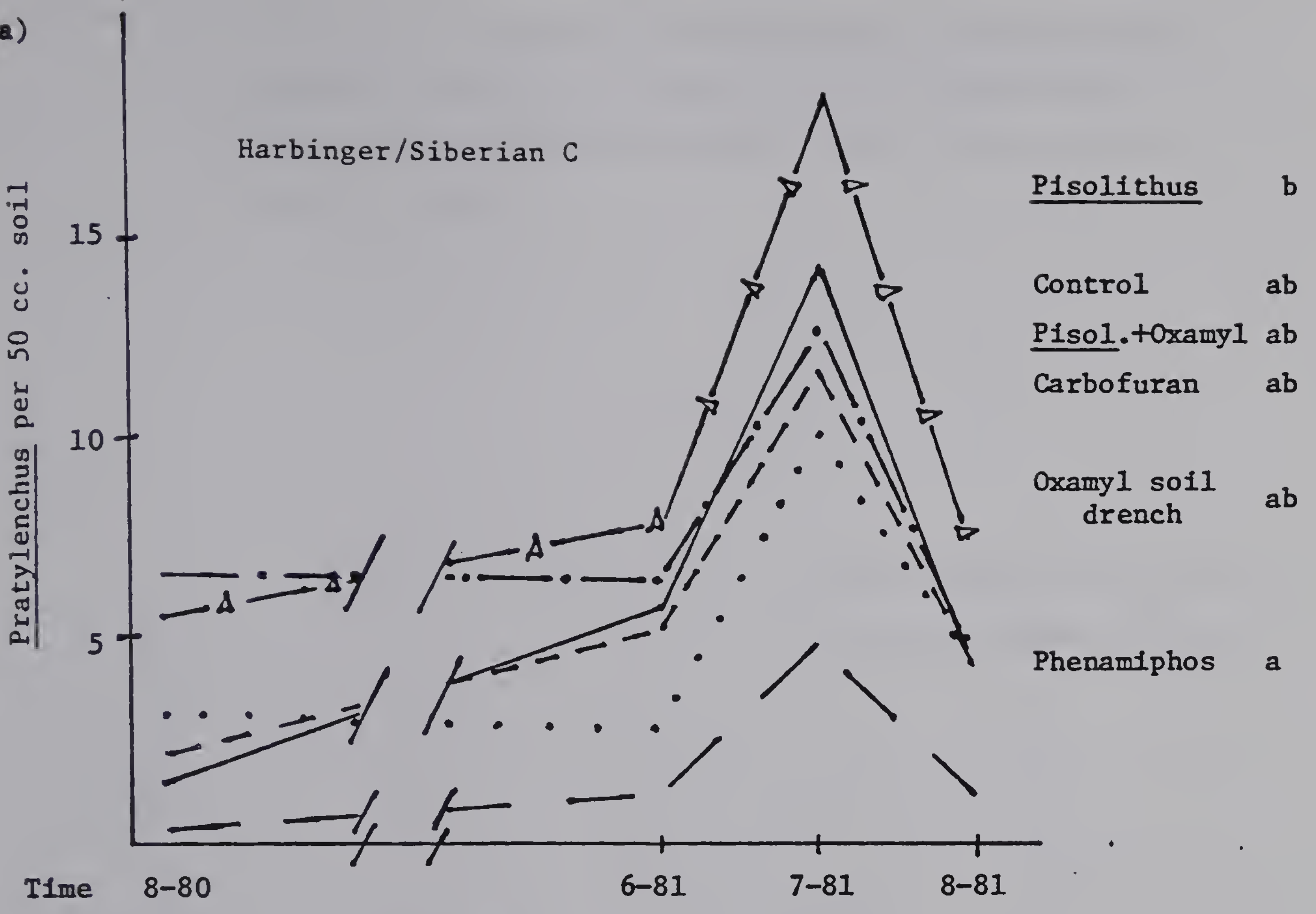
* Mean separation within columns and between scion/rootstock combinations by Duncan's Multiple Range test, 5% level.

Figure 1. Population dynamics of <u>Pratylenchus penetrans</u> in rhizosphere of a) Harbinger/Siberian C and b) Garnet Beauty/ Halford trees over time.

(Note: values for <u>Pisolithus</u> treatment and Phenamiphos treatment, sampled 7-81, are projections where data is missing.)

a)


Harbinger/Siberian C
Pratylenchus per 50 cc. soil
15
10
5
Time
8-80
6-81
7-81
8-81
Pisolithus b
Control ab
Pisol.+Oxamyl ab
Carbofuran ab
Oxamyl soil drench ab
Phenamiphos a

b)

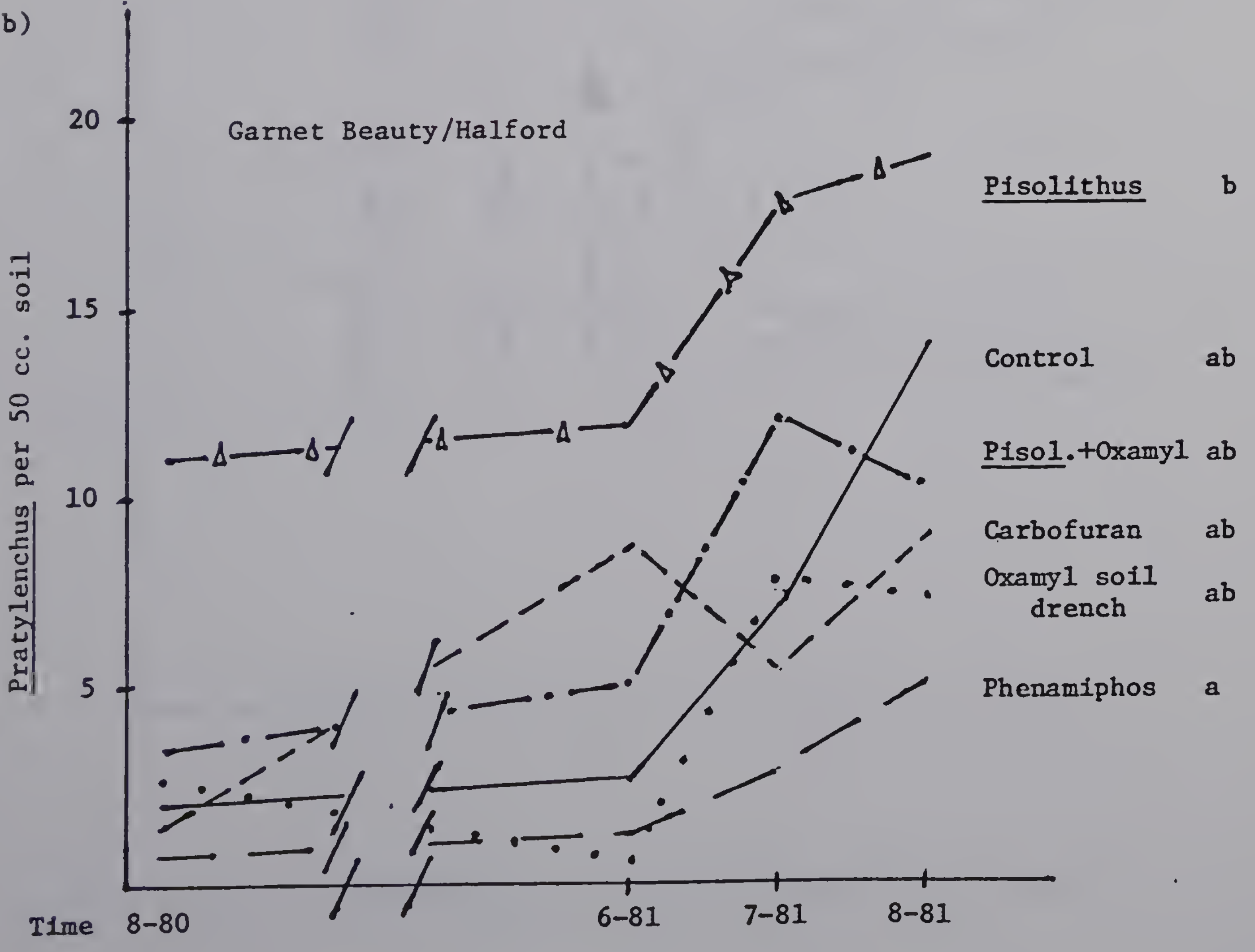

Garnet Beauty/Halford
Pratylenchus per 50 cc. soil
20
15
10
5
Time
8-80
6-81
7-81
8-81
Pisolithus b
Control ab
Pisol.+Oxamyl ab
Carbofuran ab
Oxamyl soil drench ab
Phenamiphos a

Figure 2: Effect of rhizosphere populations of _Pratylenchus penetrans_ sampled in August 1980 on subsequent growth of Harbinger/Siberian C and Garnet Beauty/Halford trees.

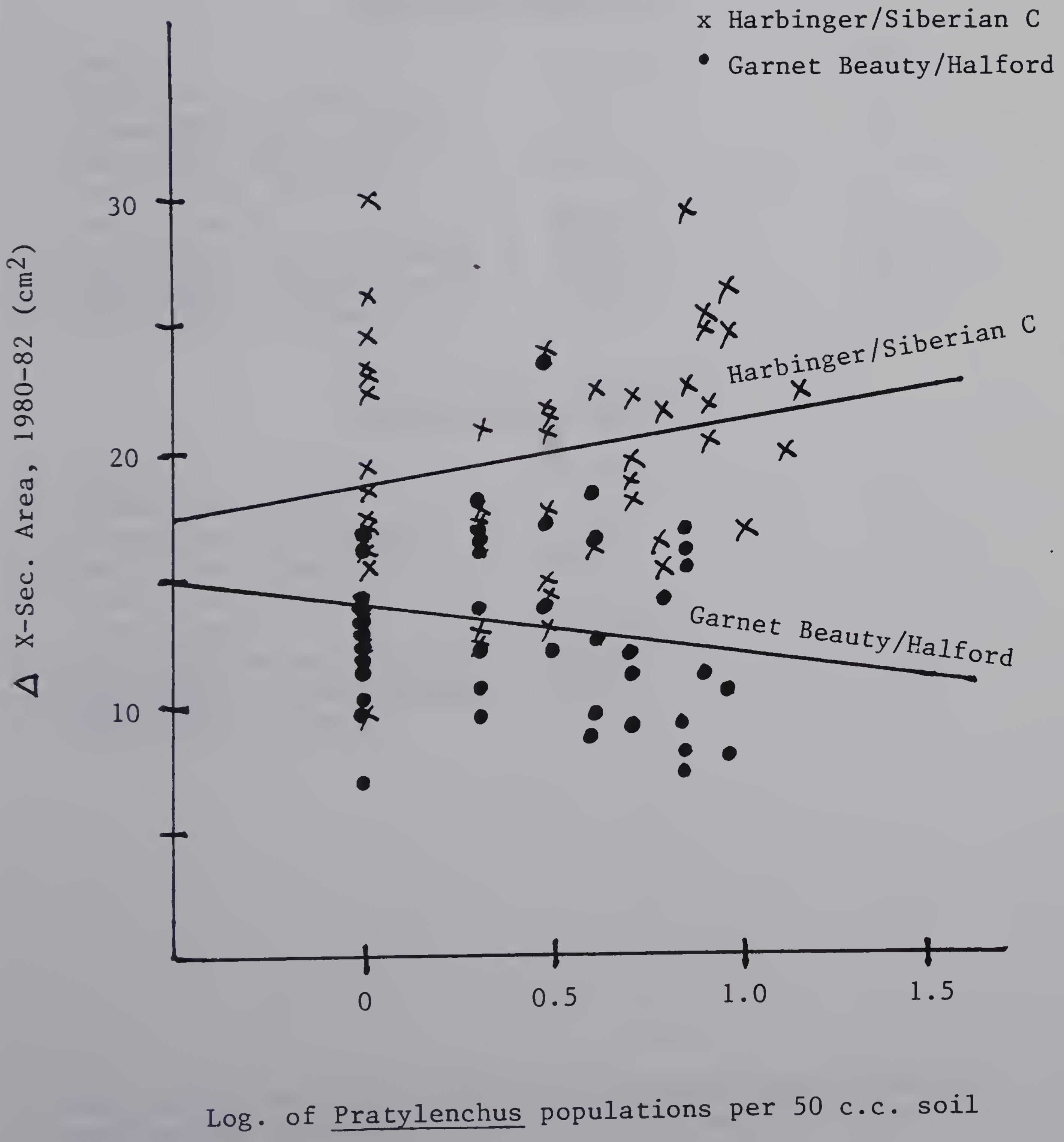


TABLE 4 Percent of roots infected with _Pratylenchus_ and/or VA mycorrhizal fungus on Harbinger/Siberian C and on Garnet Beauty/Halford trees, August 1981.

Treatment	% Roots Infected _Pratylenchus_	Mycorrhizae
	Harbinger/Siberian C	
1.) Control	34.44 a*	36.67 a
2.) Oxamyl soil drench	---	---
3.) Phenamiphos soil drench	---	---
4.) Carbofuran granules	26.83 a	24.67 a
5.) Oxamyl root dip and soil drench	38.33 a	19.45 a
6.) _Pisolithus_ spore inoculum	37.22 a	28.39 a
7.) _Pisolithus_ + Oxàmyl drench	37.28 a	25.33 a
8.) _Pisolithus_ + Upstart	---	---
	Garnet Beauty/Halford	
1.) Control	34.50 a	2.22 a
2.) Oxamyl soil drench	---	---
3.) Phenamiphos soil drench	---	---
4.) Carbofuran granules	16.67 a	7.22 a
5.) Oxamyl root dip and soil drench	37.78 ab	5.00 a
6.) _Pisolithus_ spore inoculum	53.34 b	6.11 a
7.) _Pisolithus_ + Oxamyl drench	46.67 b	1.67 a
8.) _Pisolithus_ + Upstart	---	---

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* Mean separation within columns and between scion/rootstock combinations by Duncan's Multiple Range test, 5% level.

The percent of roots infected with *Pratylenchus* was not affected by any of the treatments tested for Harbinger/Siberian C; infection rates remained around Control levels (35%) for all treatments (Table 4). (The Oxamyl soil drench, Phenamiphos soil drench, and *Pisolithus* plus Upstart treatments were not tested for root infection on either Harbinger/Siberian C or Garnet Beauty/Halford trees.) The percent of roots infected with lesion nematodes rose in response to both the *Psolithus* and the *Pisolithus* plus Oxamyl treatments on Garnet Beauty/Halford trees (Table 4).

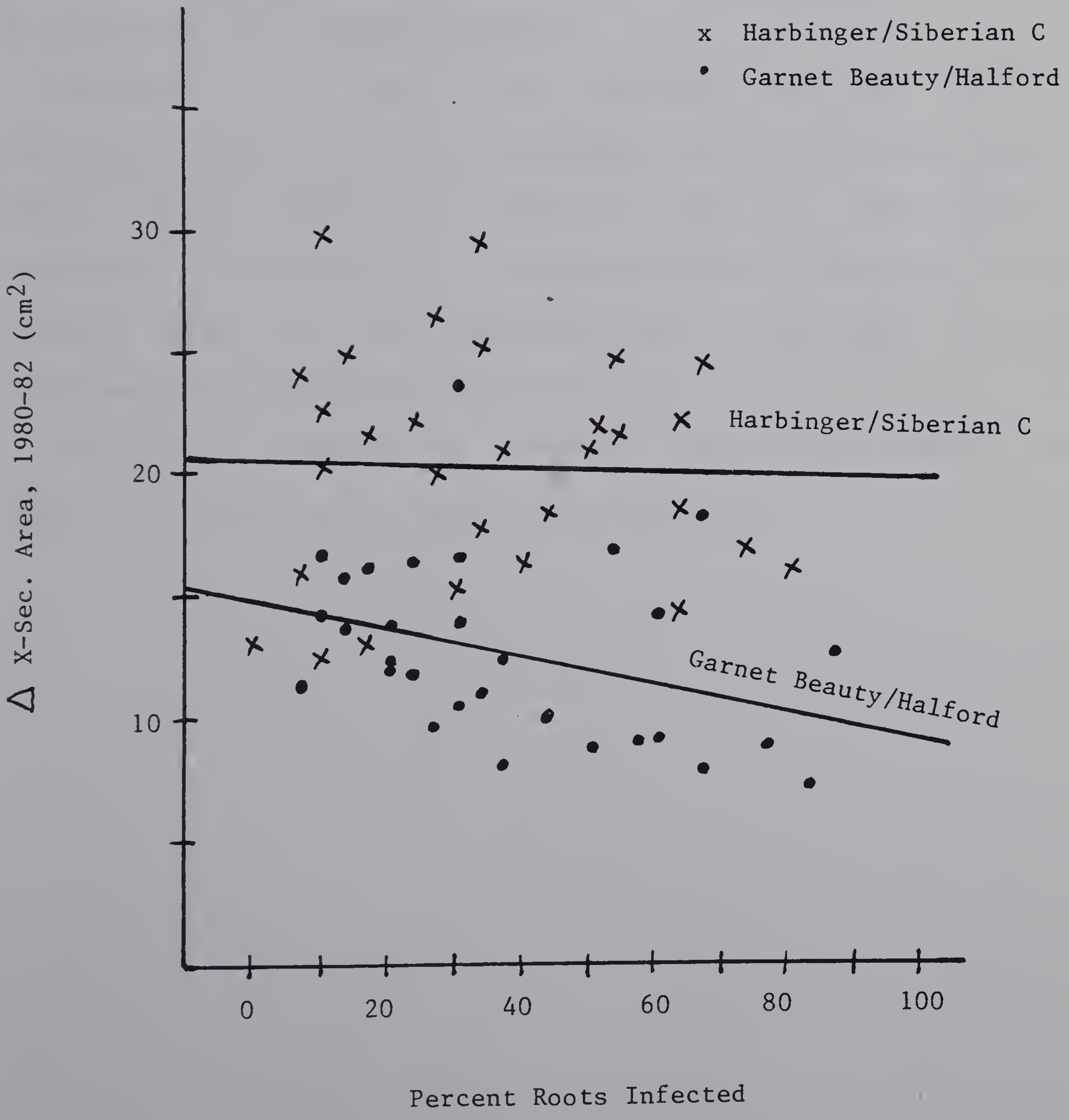
Root infection correlated inversely with growth of Garnet Beauty/Halford trees and was significant at the .05 level (Figure 3). No such correlation was seen for Harbinger/Siberian C trees.

The correlation between percent of roots infected with lesion nematodes and soil (rhizosphere) populations of *Pratylenchus penetrans* was significant at the .01 level for rhizosphere populations sampled in July 1981 and at the .05 level for populations sampled in August 1981 on Harbinger/Siberian C trees. The percent of roots infected did not correlate with rhizosphere populations of *Pratylenchus* on Garnet Beauty/Halford trees.

The greater number of soil samples taken over the course of this experiment provide a wider data base from which to assess nematode disease pressure than do the more limited number of root samples. However, root infection is more directly allied with growth of nematode susceptible trees.

Observations of the roots collected in August of 1981 showed

Figure 3: Relationship between Pratylenchus root infection and growth of Harbinger/Siberian C and Garnet Beauty/Halford trees.



endo-mycorrhizal colonization by an Endogone species of fungus (Gerdemann and Trappe, 1974; personal help of Dr. Howard Bigelow). Vesicles and arbuscules were visible within the cortical cells of the roots (Figure 4). There was no evidence of ecto-mycorrhizal colonization by Pisolithus tinctorius, (used in the Pisolithus , Pisolithus plus Oxamyl drench, and Pisolithus plus Upstart treatments) on any of the root segments examined.

Percent of roots having formed endo-mycorrhizae was greater on Harbinger/Siberian C than on Garnet Beauty/Halford trees (significant at the .01 level, although not shown in Table 4). High levels of mycorrhizal colonization on Harbinger/Siberian C correlated with more vigorous growth of this scion/rootstock combination, and the relationship is significant at the .01 level.

No effect of treatment on levels of mycorrhizal infection were detected for either set of peach trees (Table 4).

Figure 4. a) Peach root showing vesicle formation by an Endogone species of VA mycorrhizal fungus. (10X)

b) Arbuscules of the same fungus within peach root cells and extra-cellular hyphal strand. (45X) a)

b)

CHAPTER IV

DISCUSSION

Scion and/or rootstock response to soil treatment differed in this experiment. Harbinger trees on Siberian C rootstock grew significantly larger than Garnet Beauty trees on Halford stock, whereas Glohaven/Siberian C trees were intermediate in size. Whether this difference in size is primarily a rootstock influence is not known, but since both of the scion cultivars on Siberian C rootstock were larger than trees on Halford stock, and fruit tree understocks commonly exert an influence on size (Layne, 1974), Siberian C is suspected to have imparted vigor.

Cold-hardiness is considered to be characteristic of Siberian C, but vigor can be high or low. Layne et al. (1975), working with peach seedling rootstocks in Canada, reported that Siberian C reduced scion growth during the first two or three years in an orchard, and associated the stunting effect to a precocious fruiting habit. They were comparing Siberian C to several other rootstocks, including Halford. Ultimately, however, their work showed no long-term growth differences between varieties and trees on all rootstocks attained roughly equivalent size.

Site may influence rootstock response. Many site-related factors such as soil moisture, soil type, climate, and soil microflora interact with genotype to influence growth of trees (Yadava and Doud, 1980). The interaction between endogenous microflora and cultivar/rootstock may be the key to understanding site-related growth variation, especially with respect to decline.

Populations of Pratylenchus penetrans were monitored in the peach rhizosphere, and root infection by these parasites was also assessed, in order to evaluate the relationship between nematodes and growth of trees. Control populations of Pratylenchus in the rhizosphere were relatively similar for the two scion/rootstock combinations when averaged over the two years these populations were monitored. The percentage of roots infected by lesion nematodes was also practically identical on Control trees of the two sets of trees. This suggests that the rootstocks are equally good hosts for this nematode.

Treatments were found to have similar composite effects on Pratylenchus populations on the two cultivar/rootstock combinations, despite the fact that these treatments did not provide a totally consistent method for altering nematode populations. Pisolithus spore inoculum tended to stimulate rhizosphere populations over Control levels, while the nematicides generally depressed nematode populations. There was a significant difference between rhizosphere populations of Pratylenchus penetrans on Phenamiphos-treated trees and on Pisolithus -treated trees.

Differences in rhizosphere populations of lesion nematodes represent different inoculum pressures on the trees. A susceptible peach cultivar/rootstock would be expected to demonstrate a pattern of growth response that correlates inversely with nematode inoculum pressure. A tolerant combination would show no such correlation.

Harbinger/Siberian C trees demonstrated no significant correlation between growth and either rhizosphere populations of Pratylenchus _penetrans_ or percent of roots infected with lesion nematodes. Garnet Beauty/Halford trees, on the other hand, demonstrated an inverse correlation between growth and both measures of nematode disease pressure. Contrary to the literature on this subject (Bird, 1969; Allen & Marks, 1977; Johnson, Dirks, & Layne, 1978), these results suggest that in this experiment, the trees on Halford stock are more susceptible to _Pratylenchus_ injury than trees on Siberian C.

Siberian C trees responded to treatment in a predictable way, but the growth response of these trees was almost a mirror image of the growth response of Halford trees to the same treatments. Treatments aimed at simplifying microbial populations in the soil around newly planted trees reflect the belief that young trees will develop a healthier and more vigorous root system in the absence of many organisms commonly found in orchard soil, especially in a replant situation. The problem is that the starting point is not well understood in terms of soil microbes, so that it is very difficult to evaluate the effects that the treatments have on the peach rhizosphere. Techniques for monitoring the dynamics of soil organisms and root systems are not as developed as those for monitoring above-ground systems. Yet, soil treatments must be assessed for both above-ground effects on growth of plants and the more obscure developments underground. Lesion nematode data alone offer no clue as to what the stimulus is that promotes or depresses growth of Harbinger/Siberian C trees, yet growth of Garnet Beauty/Halford trees was negatively correlated with lesion nematode populations.

Chemical nematicides may affect plant growth through an immediate influence on the plant system which can either stimulate or depress growth, and indirectly through effects on soil microbes in the treated area. Indirect effects take longer to be translated into measureable growth responses. If, for example, populations of parasites are kept in check during the first few years of a tree's life in an orchard, growth of a susceptible plant may be primarily in terms of root proliferation, while increased top growth becomes more evident in future years as a result of the more vigorous root system. Nematicides undoubtedly affect many organisms in the soil besides nematodes (Harrison, 1967) and the impact of specific changes in the microbial environment on a plant system will be highly variable, depending on soil conditions, cultivar, or rootstock of the plant (Davey & Danielson, 1968). It may take several years for the full effects of a chemical treatment to become evident on orchard tree growth and yield (Mai, 1972).

Pisolithus spore inoculum produced the most dramatic short-term results of any treatments used in this experiment. Effects on growth of both sets of trees were clearly measureable after the first growing season and were consistent both years (though they were different depending on cultivar/rootstock combination). _Pratylenchus_ populations in the rhizosphere also increased immediately on all trees in response to this soil amendment.

Many other changes in microbial populations may have been encouraged by this treatment. Something in the new environment seems to have stimulated growth of Harbinger/Siberian C trees. This factor was, however, either not conducive to growth of Garnet Beauty/Halford trees, or not present in the rhizosphere of Garnet Beauty/Halford.

Upstart, in combination with Pisolithus inoculum, stimulated growth of Garnet Beauty/Halford trees more than Pisolithus alone. No effect was seen on Harbinger/Siberian C trees. Upstart was originally included in this experiment to stimulate root initiation, thus providing an early growth stimulus to young trees. As a fertilizer, its effect was probably minimal because all trees received a regular fertilization program. IBA has shown strong auxin activity (personal communication with Dr. Duane Greene) and may have been responsible for specific effects on Pisolithus or directly on tree root initiation.

Measurements of root infection were assessed as percent of roots infected, rather than actual numbers of either nematodes or mycorrhizal fungi. This decision was based on two major considerations. A minimal number of root segments were collected from the trees in an effort to disturb the trees as little as possible. With a limited number of rootlets to work with, it was best if the two root-colonizing organisms could be observed together. Since one commonly used technique for evaluating nematode root infection involves incubating the roots in a film of water and counting nematodes as they emerge (Young, 1954), the possibility of observing both nematodes and mycorrhizal fungi would have been lost had this procedure been followed.

On the other hand, the decision to assess root injury on the basis of the presence or absence of nematode parasites, rather than counting numbers of worms in each root segment, was based on the observation that individual Pratylenchus penetrans rarely occur alone in roots. Where one nematode enters a root and tunnels its way into the cortex, others tend to follow, using the same point of entry (Lavalle, 1962). Thus they are usually observed in clusters within the infected root. Eggs are also laid in groups, so that larvae emerge in clusters as well. The damage to the plant can therefore be as well assessed by the presence or absence of nematode clusters in roots at any particular time, as on the basis of numbers of individual inhabitants.

In this work, evaluation of nematode root infection was aimed at understanding whether a given treatment was significantly more or less effective in maintaining roots free of nematodes than another treatment under field conditions. Roots were thus evaluated as either healthy or infected.

In the case of mycorrhizal fungi, these organisms are difficult to define as individuals, and the question then becomes whether it is valuable to quantify infection on the basis of numbers of vesicles or density of arbuscule formation within cells. This could be valuable if the project were designed to evaluate life stages of the fungus or as a taxonomic study. Here, mycorrhizal colonization was evaluated similarly to nematode infection, roots being either mycorrhizal or not.

Levels of mycorrhizal infection may be important to understanding improved growth of trees on Siberian C rootstock. Control trees on the two scion/rootstock combinations differed significantly in terms of percent of roots that were mycorrhizal.

A common interpretation of mycorrhizal specificity rests on an evaluation of how much of an impact the symbiosis has on plant growth.

Another approach is to try and directly quantify root infection levels on different species or cultivars of plant. The relationship between growth stimulation and amount of root infection has not been clarified, though Marx et al. (1971) reported that greater mycorrhizae-related growth stimulation correlated positively with a higher percentage of roots infected on rough lemon compared to sour orange seedlings. These fungi are not considered to be highly host-specific, (Gerdemann, 1975), thus the degree of infection and specifics of fungal growth within cells, as well as the effects of colonization on plant growth, vary considerably. Even on a given plant, VA mycorrhizal infection has been found to be highly dependent on soil type and fertility (Gerdemann, 1975).

In this experiment, similar soil conditions resulted in much higher levels of mycorrhizal infection on Siberian C trees than on Halford trees. There was correspondingly greater growth of cultivars on Siberian C stock, despite reports by other researchers that this rootstock depressed growth of the scion in the early years. There may be site-related differences in the distribution of mycorrhizal propagules, since the scion/rootstock combinations were planted in separate rows. This deserves clarification and if it is not the case, suggests the possibility that some cultivars or cultivar/rootstock combinations within a single species of plant may encourage more mycorrhizal colonization by a given species of fungus than others. Control trees indicate that about thirty-five percent of root segments were mycorrhizal for Siberian C trees while only about two percent were mycorrhizal for Halford trees.

The plants may benefit from the mycorrhizal relationship in several ways. The symbiosis may enable them to exploit the soil environment more efficiently. This would be primarily a nutritional and water-related phenomenon. It may also change plant growth regulator balances. And, it may alter the plant's relationships with other organisms in the soil, perhaps enhancing tolerance to pathogens and thus reducing desease severity (Davey, 1969).

The mycorrhizal condition may be the normal situation under field conditions. The particular VA mycorrhizal fungus observed here is native to soils of this experimental orchard (though it has not been positively identified). Yet, experimentally, root-pathogen associations have rarely been studied taking into consideration the three-way host-symbiont-pathogen interaction, so little is known about how some plants may benefit normally from the mycorrhizal association with respect to disease.

The studies that have been undertaken to investigate the interaction between VA mycorrhizae and nematode parasites on given hosts have produced evidence to suggest that the two root colonizers tend to be mutually exclusive (inhibitory). If this is the case, early infection by VA mycorrhizal fungi might limit the extent of nematode-inflicted injury on a plant root system. The possibility of coordinating particular strains of fungi with specific cultivars of plant holds potential as a disease management strategy.

The two organisms were observed to doubly infect roots, though they do not colonize the same cells. There tends to be a zone of cells free of infection separating clusters of infection by the different organisms. But because both fungus and Pratylenchus can coexist in roots, a comparison of percent of root segments infected with one and those infected with the other did not indicate a straight-forward inhibition phenomenon. More roots would have to be sampled so that the root system as a whole could be examined, and a time study of infection levels by the two organisms could be undertaken to elucidate the phenomenon more clearly.

Rather than directly inhibiting root infection by lesion nematodes, mycorrhizal colonization may in some way alter the stress than nematode feeding imposes on the plant system. In this way, VA mycorrhizae may make nematode-susceptible plants more tolerant to nematode infection, as suggested by Hussey and Roncadori (1982). The implication in this work is that trees on Siberian C rootstock which, under other conditions, have been shown to be very sensitive to nematode damage and to grow less well than trees on Halford stock, not only grew more vigorously in these soils, but were less susceptible to nematode disease pressure.

This tolerance could also enhance their cold-hardiness characteristic, which is of such major importance to the peach industry in the Northeast. The explanation may rest with the mycorrhizal symbiont. Further research will give a more complete picture of this complex of interactions between organisms in the soil.

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APPENDIX

Figure 5. a) Peach trees - July 1980.
b) Peach trees - May 1982.

a)

b)

Figure 6.

Pratylenchus penetrans emerging from peach root.

Table 5. Data File.

Key to Data File

Tr = Treatment

Tr 1 = Control
Tr 2 = Oxamyl soil drench
Tr 3 = Phenamiphos soil drench
Tr 4 = Carbofuran granules
Tr 5 = Oxamyl root dip and soil drench
Tr 6 = *Pisolithus* spore inoculum
Tr 7 = *Pisolithus* + Oxamyl drench
Tr 8 = *Pisolithus* + Upstart

S/R = Scion/Rootstock combination

S/R 1 = Harbinger/Siberian C
S/R 2 = Garnet Beauty/Halford
S/R 3 = Glohaven/Siberian C

Loc = Location

Loc 1 through Loc 6 = randomized block design

Total Nemas = Total nematodes (all genera) sampled Aug. 1980

P.p. 8-80 = Rhizosphere populations of *Pratylenchus penetrans* sampled in Aug. 1980

P.p. 7-81 = Rhizosphere populations of *Pratylenchus penetrans* sampled in July 1981

P.p. 8-81 = Rhizosphere populations of *Pratylenchus penetrans* sampled in Aug. 1981

P.p./Roots = Percent of roots infected with *Pratylenchus penetrans*

Mycor./Roots = Percent of roots colonized by VA mycorrhizae

X-Sec. Area80 = Cross sectional area of trunk (cm^2) measured before trees were planted

X-Sec. Area81 = Cross sectional area of trunk (cm^2) measured after one growing season in the field

X-Sec. Area82 = Cross sectional area of trunk (cm^2) measured after two growing seasons in the field

DATA FILE

Tr	S/R	Loc	Total Nemas	*P.p.* 8-80	*P.p.* 7-81	*P.p.* 8-81	*P.p.*/ Roots	Mycor./ Roots	X-Sec. Area80	X-Sec. Area81	X-Sec. Area82
1	1	1	038	02	19	02	53.33	73.33	1.83	4.97	23.54
1	1	2	096	01	30	04	16.66	50.00	0.92	1.99	13.86
1	1	3	096	02	09	01	63.33	50.00	0.72	3.80	15.15
1	1	4	088	01	10	02	10.00	00.00	0.97	2.07	13.44
1	1	5	081	02	09	01	33.33	26.67	0.87	3.47	18.62
1	1	6	032	00	12	15	30.00	20.00	1.15	2.07	16.50
1	2	1	166	06	07	35	16.67	00.00	0.67	3.57	16.73
1	2	2	108	02	02	04	30.33	00.00	1.03	2.96	14.93
1	2	3	079	04	20	11	33.33	06.67	0.29	1.99	11.27
1	2	4	205	00	00	05	10.00	03.33	1.03	3.47	15.15
1	2	5	055	00	07	23	86.67	03.33	0.82	2.41	13.44
1	2	6	253	00	10	06	30.00	00.00	0.62	2.87	17.19
1	3	1	132	01	09	13	99.99	99.99	1.03	3.57	17.43
1	3	2	043	00	04	01	99.99	99.99	0.82	2.15	17.19
1	3	3	081	00	03	00	99.99	99.99	0.67	3.80	18.62
1	3	4	070	00	02	04	99.99	99.99	0.97	5.35	22.19
1	3	5	206	02	14	11	99.99	99.99	0.77	1.15	12.04
1	3	6	022	00	00	03	99.99	99.99	0.77	2.15	12.43
2	1	1	063	05	99	99	99.99	99.99	0.82	4.60	22.45
2	1	2	054	00	99	99	99.99	99.99	1.40	5.35	23.81
2	1	3	054	00	99	99	99.99	99.99	0.54	2.87	17.90
2	1	4	042	00	99	99	99.99	99.99	0.77	3.90	20.11
2	1	5	049	00	99	99	99.99	99.99	0.82	2.24	16.27
2	1	6	014	00	99	99	99.99	99.99	0.82	1.76	17.90
2	2	1	036	01	99	99	99.99	99.99	1.27	2.87	10.70
2	2	2	083	00	99	99	99.99	99.99	1.21	3.68	14.07
2	2	3	110	01	99	99	99.99	99.99	0.62	1.61	11.27
2	2	4	072	00	99	99	99.99	99.99	0.72	3.57	17.43
2	2	5	153	00	99	99	99.99	99.99	0.67	3.06	16.50
2	2	6	065	00	99	99	99.99	99.99	0.72	1.27	07.80
2	3	1	053	01	99	99	99.99	99.99	0.77	2.77	11.84
2	3	2	123	02	99	99	99.99	99.99	0.97	2.07	17.43
2	3	3	040	05	99	99	99.99	99.99	0.77	1.68	13.65
2	3	4	088	00	99	99	99.99	99.99	1.47	2.68	12.63
2	3	5	148	01	99	99	99.99	99.99	0.97	4.97	21.66
2	3	6	165	00	99	99	99.99	99.99	1.47	2.77	14.50
3	1	1	023	01	99	00	99.99	99.99	1.03	2.87	18.38
3	1	2	045	00	99	00	99.99	99.99	0.54	1.68	10.16
3	1	3	083	00	99	01	99.99	99.99	1.91	6.45	25.21
3	1	4	126	01	99	00	99.99	99.99	1.09	5.75	18.62
3	1	5	021	00	99	02	99.99	99.99	0.92	4.48	24.09
3	1	6	027	00	99	03	99.99	99.99	0.92	4.24	19.36
3	2	1	078	00	99	03	99.99	99.99	1.15	3.16	17.19
3	2	2	028	00	99	01	99.99	99.99	0.67	1.47	12.43

3	2	3	032	00	99	00	99.99	99.99	9.99	9.99	99.99
3	2	4	054	01	99	27	99.99	99.99	0.62	3.90	18.62
3	2	5	046	00	99	03	99.99	99.99	0.46	3.06	17.43
3	2	6	122	02	99	00	99.99	99.99	0.77	2.96	17.90
3	3	1	045	00	99	00	99.99	99.99	0.72	2.15	13.44
3	3	2	106	00	99	00	99.99	99.99	1.03	1.15	09.80
3	3	3	046	00	99	01	99.99	99.99	0.82	5.35	21.40
3	3	4	040	00	99	00	99.99	99.99	0.77	2.07	14.93
3	3	5	078	00	99	00	99.99	99.99	0.92	2.41	12.83
3	3	6	080	00	99	02	99.99	99.99	0.77	0.32	14.28
4	1	1	029	02	04	00	06.66	23.33	0.87	4.24	24.92
4	1	2	044	02	27	04	16.67	13.33	0.92	4.72	22.45
4	1	3	032	00	08	01	43.33	20.00	0.72	4.01	19.11
4	1	4	032	07	31	12	51.00	64.67	0.67	4.24	22.45
4	1	5	037	00	00	00	06.67	26.67	0.72	4.13	16.73
4	1	6	068	01	03	10	36.67	00.00	1.34	4.84	22.19
4	2	1	066	01	01	01	10.00	00.00	0.87	3.68	17.43
4	2	2	078	03	15	15	23.33	10.00	1.09	4.60	17.43
4	2	3	037	00	00	01	26.67	13.33	1.09	2.41	10.89
4	2	4	053	02	06	31	20.00	03.33	0.54	2.15	12.63
4	2	5	045	00	05	02	06.67	03.33	0.82	2.50	12.23
4	2	6	033	01	05	06	13.33	13.33	0.72	3.36	16.50
4	3	1	057	00	01	00	99.99	99.99	0.87	3.47	17.43
4	3	2	023	01	00	00	99.99	99.99	0.77	1.68	15.15
4	3	3	030	02	01	05	99.99	99.99	1.03	1.83	10.34
4	3	4	069	01	12	19	99.99	99.99	0.92	5.09	21.66
4	3	5	097	00	02	01	99.99	99.99	0.92	8.44	26.93
4	3	6	058	00	01	02	99.99	99.99	1.34	4.36	17.19
5	1	1	102	00	03	02	26.67	30.00	0.72	3.80	26.93
5	1	2	017	02	00	00	00.00	20.00	0.72	1.40	13.65
5	1	3	052	07	11	03	33.33	46.67	1.03	5.48	26.35
5	1	4	124	03	19	08	80.00	00.00	0.62	2.32	16.73
5	1	5	057	02	11	03	50.00	00.00	1.21	5.75	22.19
5	1	6	077	05	17	12	40.00	20.00	1.09	2.58	17.43
5	2	1	074	02	01	04	30.00	00.00	0.77	5.75	24.36
5	2	2	128	01	07	01	20.00	03.33	0.67	2.77	14.50
5	2	3	118	06	26	18	83.33	00.00	0.92	1.61	08.12
5	2	4	079	00	02	17	20.00	10.00	0.72	2.07	13.03
5	2	5	047	00	10	04	13.33	13.33	1.03	1.99	14.71
5	2	6	078	05	01	02	60.00	03.33	1.21	3.80	15.37
5	3	1	141	00	02	08	99.99	99.99	0.97	4.24	21.92
5	3	2	046	01	00	05	99.99	99.99	0.79	3.90	18.87
5	3	3	004	00	13	14	99.99	99.99	0.82	2.77	16.27
5	3	4	082	00	08	03	99.99	99.99	0.97	2.07	14.93
5	3	5	043	01	08	09	99.99	99.99	0.82	5.62	22.45
5	3	6	100	02	01	00	99.99	99.99	0.92	2.87	13.86
6	1	1	084	00	99	03	10.00	33.33	1.03	7.03	30.87
6	1	2	066	09	99	08	73.33	30.33	1.03	2.32	17.90
6	1	3	030	07	99	03	10.00	33.33	0.97	5.09	21.40
6	1	4	095	04	99	17	63.33	40.00	1.15	4.48	19.86
6	1	5	038	07	99	11	13.33	20.00	1.21	5.35	26.06
6	1	6	023	08	99	05	53.33	13.33	1.09	4.97	25.78
6	2	1	067	43	99	14	76.67	00.00	0.92	1.47	09.80

6	2	2	095	06	99	23	36.67	06.67	1.91	2.50	09.98
6	2	3	170	00	99	54	43.33	00.00	1.21	2.77	11.27
6	2	4	038	08	99	19	30.00	03.33	0.92	1.99	11.46
6	2	5	087	03	99	03	66.67	26.67	0.62	3.36	18.87
6	2	6	049	08	99	03	66.67	00.00	1.21	0.58	09.11
6	3	1	999	99	99	99	99.99	99.99	9.99	9.99	99.99
6	3	2	999	99	99	99	99.99	99.99	9.99	9.99	99.99
6	3	3	999	99	99	99	99.99	99.99	9.99	9.99	99.99
6	3	4	999	99	99	99	99.99	99.99	9.99	9.99	99.99
6	3	5	999	99	99	99	99.99	99.99	9.99	9.99	99.99
6	3	6	999	99	99	99	99.99	99.99	9.99	9.99	99.99
7	1	1	053	13	15	03	63.33	20.00	1.03	4.97	23.26
7	1	2	047	06	31	00	33.33	20.00	1.34	6.45	30.87
7	1	3	053	04	09	16	23.33	03.33	1.34	4.97	23.54
7	1	4	029	12	09	00	27.00	58.66	1.40	5.22	21.40
7	1	5	024	06	06	04	10.00	40.00	0.92	4.48	23.54
7	1	6	066	00	09	06	66.67	10.00	1.47	5.09	26.06
7	2	1	064	04	29	14	23.33	00.00	1.03	2.96	12.87
7	2	2	114	03	11	11	50.00	03.33	0.72	1.91	09.45
7	2	3	076	03	00	11	36.66	06.66	0.92	1.83	13.44
7	2	4	050	04	13	21	56.66	00.00	0.97	1.91	09.98
7	2	5	055	06	15	01	60.00	00.00	0.62	1.40	09.80
7	2	6	041	01	04	06	53.33	00.00	0.54	1.61	17.43
7	3	1	999	99	99	99	99.99	99.99	9.99	9.99	99.99
7	3	2	999	99	99	99	99.99	99.99	9.99	9.99	99.99
7	3	3	999	99	99	99	99.99	99.99	9.99	9.99	99.99
7	3	4	999	99	99	99	99.99	99.99	9.99	9.99	99.99
7	3	5	999	99	99	99	99.99	99.99	9.99	9.99	99.99
7	3	6	999	99	99	99	99.99	99.99	9.99	9.99	99.99
8	1	1	063	02	99	99	99.99	99.99	1.91	4.72	16.73
8	1	2	054	03	99	99	99.99	99.99	1.40	5.09	23.81
8	1	3	099	05	99	99	99.99	99.99	1.15	3.80	16.50
8	1	4	092	04	99	99	99.99	99.99	0.72	3.06	18.87
8	1	5	013	04	99	99	99.99	99.99	1.21	4.97	20.88
8	1	6	066	08	99	99	99.99	99.99	0.97	5.75	27.52
8	2	1	065	06	99	99	99.99	99.99	0.77	3.90	16.27
8	2	2	054	07	99	99	99.99	99.99	1.15	2.24	12.23
8	2	3	022	03	99	99	99.99	99.99	1.27	2.77	10.89
8	2	4	123	06	99	99	99.99	99.99	1.54	5.75	18.38
8	2	5	074	01	99	99	99.99	99.99	0.50	2.15	12.63
8	2	6	044	01	99	99	99.99	99.99	0.72	4.84	16.73
8	3	1	999	99	99	99	99.99	99.99	9.99	9.99	99.99
8	3	2	999	99	99	99	99.99	99.99	9.99	9.99	99.99
8	3	3	999	99	99	99	99.99	99.99	9.99	9.99	99.99
8	3	4	999	99	99	99	99.99	99.99	9.99	9.99	99.99
8	3	5	999	99	99	99	99.99	99.99	9.99	9.99	99.99
8	3	6	999	99	99	99	99.99	99.99	9.99	9.99	99.99