The Impact of Root Lesion Nematodes on Woody Plants[1]

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Abstract

Lesion or meadow nematodes are not as well known to the plantsmen as common root-knot species, yet they do cause injury to fruit trees, woody landscape plants, and to some extent, forest (nursery) trees. Studies by numerous researchers have demonstrated that *Pratylenchus* species cause wilting, off-color foliage, fruit reduction, less root growth and general growth suppression. Research highlights of the past several decades are discussed in terms of the general effects these soil-inhabiting species have on plants and points are raised concerning the future research needed to better assess the impact of lesion nematodes on plants.

Index words: Lesion nematodes, *Pratylenchus spp.*, landscape plants, fruit crops

Introduction

Steiner (61) wrote in 1945 "While the root-knot nematode has received considerable attention as a disease factor, the meadow nematodes—*Pratylenchus* Filipjev—have been completely ignored. This is unfortunate. The pratylenchs are doubtless one of the most important factors in root destruction among cultivated and uncultivated plants. The overall damage caused by these pests in the United States is probably greater than that which is attributable to the root-knot nematode."

The genus *Pratylenchus* is in the Order Tylenchida (Golden), in the family Pratylenchidae (14). The type species is *Pratylenchus pratensis* (de Man, 1880) Filipjev, 1936. The cytogenetic relationship among the 40-plus described species is complex (55); the haploid chromosome number for amphimitic (sexually reproductive) species *P. penetrans, P. vulnus,* and *P. coffeae* is 5 or 6, 6 and 7, respectively (64, 65). Other species reproduce by meiotic or mitotic parthenogenesis. All species are characterized by strong stout stylets, blunt heads, and bluntly rounded tails (2). All are migratory endoparasites with life cycles that vary from 45 to 65 days.

Little is known about the biochemistry of these nematodes. Research, however, has shown they respond to CO_2, contain cholinesterase, cytochrome c oxidase, 27% lipids (dry wt.) and at least 8 amino acids (9, 29, 39). The morphology of the body wall, stylets, and esophageal glands are known at the ultrastructure level.

This paper is a review of the literature relative to the impact members of this genus have on fruit trees, forest trees and woody plants. A bulletin (30) published by the Technical Committee of the Northeastern Regional Research Project NE-64 is a valuable reference for the state of knowledge on one of these species, *P. penetrans.* [An excellent article on the genus *Pratylenchus* appeared after this review was completed (70).]

The invasion of roots by nematode larvae or adults occurs in a radial direction, but soon thereafter the nematode is aligned parallel to the root's axis. Intracellular penetration is accomplished rapidly after invasion, mostly by the destructive force of the probing stylet, but also probably by enzymes released by the nematodes (39). Plant cell walls weaken and may, or may not, turn brown due to accumulation of phenols, the formation of HCN (51), or enzymes (38), depending on the host. Most feeding continues in the cortical parenchyma of the root, with little or no invasion of the endodermis or stem tissues. As the female nematodes continue to move throughout the root cortex, egg laying occurs. As a result of feeding, roots soon exhibit darkened sunken areas for which the descriptive name of root-lesion nematode is very appropriate. Rarely do lesion nematodes continue upward migration into stem tissue! Why they don't generally invade endodermis or stem tissue is unknown.

As a consequence of the nematode's destructive physical and biochemical activity on the host plant root system, the above-ground parts of the plant are soon affected because absorption of nutrients and water apparently is impaired. Generally, terms such as off-color, stunting, and decline describe the disease symptoms.

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Impact on Fruit Trees

In the relationship of *Pratylenchus* species to woody plants, perhaps more research effort has been devoted to their effect on fruit trees than on any other group of plants. *P. penetrans, P. vulnus* or *P. brachyurus* are involved with replant problems in the major apple, cherry, peach and citrus growing areas of the world. Replant problems have been described for New York, California, Florida, Georgia, and South Carolina in the U.S., as well as Canada, Netherlands, Australia, England and Germany (32, 35, 49). Articles describing "specific" and "nonspecific" replant diseases are available (1, 4, 18, 33, 42, 59, 69).

P. penetrans is one of the dominant nematodes in orchards of New York State (31). Its pathogenicity to peach has been demonstrated conclusively (3, 38). Growth response of trees and decline of nematode populations occurred repeatedly following preplant or post-plant fumigation with nematicides during the 1960's and 70's.

Age of the fruit tree at time of the nematode attack has significant influence on subsequent growth. For example, Jaffee and Mai (24) proved the younger the apple tree when infected, the less shoot weight produced.

Researchers frequently note that the number of nematodes in roots, or soil is not always positively correlated with growth responses such as decreases in top growth, although in many experiments there is a positive correlation (45). There is some agreement that nematodes are not the only causes of replant problems—particularly those which are considered to be *nonspecific* replant diseases as in apple, pear and cherry orchards of New York State (33).

Injury to sweet and sour cherry can be attributed mainly to *P. penetrans* in the Eastern United States and to *P. vulnus* in the West (35, 36). Symptoms on cherry include: wilting of leaves, off-color foliage, lack of feeder roots, and less growth compared to noninoculated trees. Cold hardiness of rootstocks can be adversely affected by nematodes (12). Mazzard and Mahaleb rootstocks are severely damaged, although some roots have few nematodes because of outward migration due to adverse conditions in the root created by secondary microorganisms (31).

The possibility of finding satisfactory fruit rootstocks with resistance to lesion nematodes is not encouraging. Barker and Clayton (4) found *P. penetrans* and *P. vulnus* reproduced well on 21 different peach rootstocks and there were no significant differences in nematode numbers/gram of root. It may only require 1 nematode/gram of soil to damage peach (7). Ritchie and Clayton (54) recently reemphasized that a major step toward solving the peach tree short life problem in the Southeastern United States would be to have a root-knot and ring nematode resistant rootstock that produces a vigorous, productive, long-lived healthy tree. Perhaps one resistant or tolerant to *P. penetrans* or *P. vulnus* would be helpful too!

P. brachyurus, P. coffeae, P. vulnus are the 3 main species that damage citrus (11). Citrus is considered a poor host for *P. brachyurus* (52). Other conditions in combination with this nematode probably cause more damage than this nematode alone (40). *P. coffeae* caused 80% growth reduction on rough lemon and sour orange 4 years after infection (42). The number of fruit/tree was significantly less on rough and sour lemon infected trees than on noninfected trees. There was as much root reduction with *P. coffeae* as with *Radopholus similis* (43), the citrus nematode. To complicate matters, all *R. similis* resistant citrus cultivars are susceptible to *P. coffeae* (41).

Height, trunk diameters, dry top and root weights of sour orange were suppressed by *P. vulnus* (19). Cells adjacent to infected areas were noted to have coagulated protoplasm.

P. vulnus is destructive to small fruits in California. At levels of 1,000 nematodes/plant, *P. vulnus* retarded grape vine and root growth, and diminished leaf area (35, 50). This nematode is a strong competitor, gradually replacing populations of dagger nematodes. *P. penetrans* also causes a growth reduction of small fruits; as much as 66% the first year after planting according to McElroy (36).

Pre- and post-plant fumigation for nematode control, particularly during the early life of orchards, has helped answer questions regarding the what and how of nematode damage. As these chemicals become less accessible, and if no new ones become available, what are our alternative control strategies? Are we developing other methods to reduce losses to our fruit trees? And from the grower's standpoint, what can be recommended for control where nematode densities are sufficiently great to constitute an economic threat to newly-set trees? Hoestra and Oostenbrink (18) pointed out the influence of cover crops [or weeds] under orchard trees have on nematode populations around tree roots. Can we develop workable systems whereby we can manage nematode populations with multiple cropping or rotational schemes of cover crops? Oostenbrink (44) suggests that rotational schemes are precarious because of the polyphagous (multi or many eating) character of Pratylenchus. He probably is right but it may be worth trying.

Impact on Woody Landscape Plants

Concerning losses to woody landscape plants, if we use the roughly estimated 1971 figures published by the Society of Nematologists (8) on *losses in ornamental crops* due to all nematodes, today's dollar values would be almost 100 million. A dollar loss attributable to *Pratylenchus* species alone is unavailable. While it may be appropriate to establish loss figures for specific nematode species, perhaps it is more meaningful to establish losses for mixed nematode populations and nematode-disease complexes on a given host. Although loss figures are soon outdated, they do provide certain perspectives.

The 1977 Host Index of Plant Parasitic Nematodes in North Carolina (5) listed 20 genera of woody plants as hosts of or association with *Pratylenchus* species. Goodey and Franklin (15) reported at least 86 woody plants as host of *P. penetrans* alone. These lists include such popular landscape plants as *Abies, Acuba, Buxus, Camellia, Cornus, Forsythia, Gardenia, Hydrangea, Ilex, Juniper,* etc.—members of widely diverse plant families.

Two decades ago Jenkins and colleagues (16, 47, 48) demonstrated that growth retardation and changes in nutrient composition of woody ornamentals occurred as a result of *P. vulnus* and *P. penetrans* feeding. Other researchers also found general growth reduction caused by nematodes (34, 46). High populations of *P. vulnus* reduced the fresh weight of one rose rootstock, *Rosa noisettiana,* by 65% (58). Another rootstock, *R. fortuneana,* also is susceptible (37). Benson et al. (6) demonstrated that as few as 160 *P. vulnus* specimens/500 cm^3 soil can suppress the growth of American boxwood by 81%. Over one-half of the boxwood samples received in the North Carolina Plant Disease Clinic over an 8-year period contained lesion nematodes. In the southeast, *P. vulnus* is found on azalea and boxwood in the Piedmont, whereas *P. penetrans* and *P. zeae* are common in the sandier Coastal Plain areas.

Microplot studies are in progress at North Carolina State University and at many other locations. These contained systems, under "natural" conditions, utilize a variety of woody ornamentals and nematode species, individually and in combination. Evaluations are made not only from the standpoint of how much growth retardation occurs at specific *Pratylenchus* nematode populations, but also, are certain plant species sustaining nematodes populations without appreciable injury. Information on mixed populations, including interactions of root-knot, stunt, ring, and lesion on different woody ornamentals, should provide economic threshold data which investigators indicate is necessary for proper management decisions (13).

Impact on Forest Trees and Nurseries

In natural forest stands, lesion nematodes may be of little consequence. Recent surveys of diseases in softwood and hardwood forests failed to cite nematodes (20, 21) as causing any losses, but the situation is quite different in forest nurseries. Reviews by Ruehle (56, 57) and numerous other authors (17, 28, 60, 62) establish that *Pratylenchus* is often associated with tree species.

Generally, pines are less affected by *Pratylenchus* than are hardwoods. However, numerous pine species are known hosts for *P. brachyurus* (56). *P. vulnus* and *P. penetrans* were shown to be more injurious to ponderosa pine than *P. brachyurus* (68). More studies of this nature are needed to aid forest management teams select productive nursery sites.

Having observed the tragic destruction of shade trees in urban centers, due primarily from construction damage to root systems, soil compaction, or the misapplication of herbicides, I submit that the injury to full-grown shade trees due to all nematodes must be relatively insignificant.

Are root-lesion nematodes a stress factor?

Considerable emphasis is now given to the effect of stress on plants. Reviews, books, and journal articles on this topic appear regularly (27, 53, 63, 67). We have conducted studies using containerized woody ornamentals exposed to moisture stress to determine if *P. penetrans* affects the plant water relations. The Scholander pressure bomb method was chosen to measure the xylem water potential (66). In repeated trials we observed xylem water potential to generally decrease as expected following cessation of watering in noninfected Japanese holly, Korean boxwood or azalea (Walker, unpublished). The results with Japanese holly previously infected with 500, 2000, 4000, or 10,000 lesion nematodes per container were the opposite; increases in the xylem water potential were measured in woody stems at least during the initial or early stages of water stress.

Using other instrumentation, some researchers have shown that nematodes cause an increase in water tension (22, 25, 26). Water stress reduces transpiration, photosynthesis, and stomatal conductance, although recently Canadian horticulturists could not demonstrate such effects when watering only 25% of the plant's root system (63). In our experiments when different amounts of azalea and holly root systems were mechanically severed, the removal had significant effect on the xylem water potential in only one of three experiments. The pressures in nondamaged azalea roots were often greater (indicating more dryness) than in damaged roots, suggesting that rapid shifts in a plant's water potential occurs under drying conditions.

Dropkin (10) suggested that the extensive top growth reduction observed with some nematode infections was probably due to changes in growth regulators indirectly related to nematodes. The concomitant interaction of other pathogens with nematodes has been demonstrated in several cases (23), but more information on the role these microorganisms play in combination with endoparasites such as *Pratylenchus* should provide a better understanding of the impact nematodes *per se* have on our woody plants.

Significance to the Nursery Industry

Plant parasitic nematodes are only one of numerous pathogens which may impose stresses on green plants. Considerable research in the past several decades has been directed at control measures for these microorganisms, but basic information gathered from additional research has led to a better understanding of what their impact is on general plant growth. Additional investigations are needed on the biological relationships between the nematode and its host in order to provide a better assessment of the injury which plants sustain from nematode attack, especially under environmental stresses.

Literature Cited

1. Abawi, G.S. and W.F. Mai. 1971. Root diseases of fruit trees in New York State. III. Control of *Pratylenchus penetrans* in roots of apple, peach, pear and cherry by foliar sprays with a nematicide-insecticide. Plant Disease Reptr. 55:617-620.

2. Agrios, G.N. 1978. Plant Pathology. 2nd ed. Academic Press. N.Y. 703 pp.

3. Ark, P.A. and H.E. Thomas. 1936. *Anguillulina pratensis* in relation to root injury of apple and other fruit trees. Phytopathology 26:1128-1134.

4. Barker, K.R. and C.N. Clayton. 1973. Nematodes attacking cultivars of peach in North Carolina. J. Nematology 5:265-271.

5. Barker, K.R. 1977. Host index of plant parasitic nematodes in North Carolina. *In* North Carolina Plant Disease Index, N.C. Agric. Expt. Station Tech. Bull. 240.

6. Benson, D.M., K.R. Barker and R. Aycock. 1976. Effects of density of *Helicotylenchus dihystera* and *Pratylenchus vulnus* on American boxwood growing in microplots. J. Nematology 8:322-326.

7. Bird, G.W. 1969. Effect of *Pratylenchus penetrans* and sequential nematicide application on growth of peach rootstock cultivars. Plant Disease Reptr. 53:760-763.

8. Committee on Crop Losses. 1971. Estimated crop losses due to plant parasitic nematodes in the United States. Special Publication No. 1 Soc. Nematologists, 7 p.

9. Croll, Neil O. 1971. The Behavior of Nematodes. St. Martin's Press. 117 p.

10. Dropkin, V.H. 1969. Cellular responses of plants to nematode infections. Ann. Rev. Phytopathology 7:101-122.

11. Du Charme, E.P. 1969. Nematode problems of citrus. *In* Peachey, J.E. [ed.]. Nematodes of tropical crops. Tech. Commun. Commonw. Bur. Helminth. No. 40

12. Edgerton, L.J. and K.G. Parker. 1958. Effects of nematode infestation and rootstock on cold hardiness of Montmorency cherry trees. Proc. Amer. Soc. Hort. Sci. 72:134-138.

13. Ferris, H. 1978. Nematode economic thresholds; derivation, requirements, and theoretical considerations. J. Nematology 10:341-350.

14. Golden, A.M. 1971. Classification of the genera and higher categories of the order Tylenchida (Nematodes). *In* Plant Parasitic Nematodes. Vol. 1. [Eds. Zuckerman, Mai, and Rohde], Academic Press. 345 pp.

15. Goodey, J.B. and M.T. Franklin. 1965. The nematode parasites of plants catalogued under their hosts. Commonwealth Agric. Bureaux, Bucks, England. 214 pp.

16. Heald, C.M. and W.R. Jenkins. 1964. Aspects of the host-parasite relationship of nematodes associated with woody ornamentals. Phytopathology 54:718-722.

17. Hepting, G.H. 1971. Diseases of forest and shade trees of the United States. U.S. Department of Agriculture. Forest Service. Agriculture Handbook No. 386. 658 p.

18. Hoestra, H. and M. Oostenbrink. 1962. Nematodes in relation to plant growth. IV. *Pratylenchus penetrans* (Cobb) on orchard trees. Neth. J. Agric. Sci. 10:286-296.

19. Inserra, R.N. and N. Vovlas. 1977. Effects of *Pratylenchus vulnus* on growth of sour orange. J. Nematology 9:154-157.

20. Jacobi, W.R., E.B. Cowling, N.D. Cost and J.P. McClure. 1980. Disease losses in North Carolina forests: I. Losses in softwoods, 1973-74. Plant Disease 64:573-576.

21. Jacobi, W.R., E.B. Cowling, N.D. Cost and J.P. McClure. 1980. Disease losses in North Carolina forests: II. Losses in hardwoods, 1973-74. Plant Disease 64:576-578.

22. Jaffee, B.A. and W.F. Mai. 1979. Effect of soil water potential on growth of apple trees infected with *Pratylenchus penetrans*. J. Nematology 11:165-168.

23. Jaffee, B.A., G.S. Abawi and W.F. Mai. 1982. Role of soil microflora and *Pratylenchus penetrans* in an apple replant disease. Phytopathology 72:247-251.

24. Jaffee, B.A. and W.F. Mai. 1979. Growth reduction of apple seedlings by *Pratylenchus penetrans* as influenced by seedling age at inoculation. J. Nematology 11:161-165.

25. Kaplan, D.T., R.A. Rohde and T.A. Tattar. 1976. Leaf diffusive resistance of sunflower infected by *Pratylenchus penetrans*. Phytopathology 66:967-969.

26. Kaplan, D.T., T.A. Tattar and R.A. Rohde. 1976. Reduction of electrical resistance in sunflower roots infected with lesion nematodes. Phytopathology 66:1262-1264.

27. Kaufmann, M.R. 1981. Development of water stress in plants. HortScience 16:12-14.

28. Kir' yanova, E.S. and E.L. Krall. 1980. Plant-parasitic nematodes and their control. Vol. II. ARS/USDA and NSF Washington, D.C. 748 pp.

29. Krusberg, L.R. 1971. Chemical composition of nematodes. *In* Plant Parasitic Nematodes Vol. II [Eds. Zuckerman, Mai, and Rohde] Academic Press. 347 pp.

30. Mai, W.F., J.R. Bloom and T.A. Chen, Eds. 1977. Biology and ecology of the plant-parasitic nematode, *Pratylenchus penetrans*. Pennsylvania State University, Agricultural Experiment Station, Bull. 815. University Park, PA.

31. Mai, W.F. and K.G. Parker. 1967. Root diseases of fruit trees in New York State. I. Populations of *Pratylenchus penetrans* and growth of cherry in response to soil treatment with nematicides. Plant Disease Reptr. 51:398-401.

32. Mai, W.F. and K.G. Parker. 1972. Root diseases of fruit trees in New York State. IV. Influence of preplant treatment with a nematicide, charcoal from burned brush and complete mineral nutrition on growth the yields of sour cherry trees and numbers of *Pratylenchus penetrans*. Plant Disease Reptr. 56:141-145.

33. Mai, W.F. and G.S. Abawi. 1978. Determining the cause and extent of apple, cherry, and pear replant diseases under controlled conditions. Phytopathology 68:1540-1544.

34. Mamiya, Y. 1970. Parasitism and damage of *Pratylenchus penetrans* to *Cryptomeria* seedlings. J. Japan Forestry Soc. 52:41-50.

35. McElroy, F.D. 1972. Nematodes of tree fruits and small fruits. *In* Economic Nematology. J.M. Webster [ed.] pp. 335-376. Academic Press. N.Y.

36. McElroy, F.D. 1976. Effects of *Pratylenchus penetrans* and *Xiphinema bakeri* on establishment, growth and yield of raspberry. [Abstr.] J. Nematology 8:295.

37. McFadden, S.E., Jr. and A.A. DiEdwardo. 1961. Control of the root-lesion nematodes, *Pratylenchus penetrans*, on *Rosa fortuneana* stock. Proc. Florida State Hort. Soc. 94:388-392.

38. Mountain, W.B. and Z.A. Patrick, 1959. The peach replant problem in Ontario. VII. The pathogenicity of *Pratylenchus penetrans* (Cobb, 1917) Filip & Stek. 1941. Can. J. Bot. 37:459-470.

39. Myers, R.F. and L.R. Krusberg. 1965. Organic substances discharged by plant parasitic nematodes. Phytopathology 55:429-437.

40. O'Bannon, J.H., A.C. Tarjan and F.W. Bistline. 1973. Control of *Pratylenchus brachyurus* on citrus and tree response to chemical treatment. Proc. Soil Crop Sci. Soc. Florida 33:65-67.

41. O'Bannon, J.H. and A.T. Tomerlin. 1971. Susceptibility of *Radopholus similis*—resistant citrus species to *Pratylenchus coffeae* and *Tylenchulus semipenetrans*. [Abstr.] J. Nematology 3:321-322.

42. O'Bannon, J.H. and A.T. Tomerlin. 1973. Citrus tree decline caused by *Pratylenchus coffeae*. J. Nematology 5:311-316.

43. O'Bannon, J.H., J.D. Radewald, A.T. Tomerlin and R.N. Inserra. 1976. Comparative influence of *Radopholus similis* and *Pratylenchus coffeae* on citrus. J. Nematology 8:58-63.

44. Oostenbrink, M. 1956. The influence of different crops on the reproduction of and damage by *Pratylenchus pratensis* and *Pratylenchus penetrans* (Vermes, Nematoda), with a record of an unidentified sickness in woody perennials. T. Pl. ziektan 62:189-203.

45. Oostenbrink, M. 1961. Nematodes in relation to plant growth. III. *Pratylenchus penetrans* (Cobb) in tree crops, potatoes and red clover. Netherlands J. Agric. Sci. 9:188-209.

46. Oostenbrink, M. and H. Hoestra. 1961. Nematode damage and "specific sickness" in Rosa, Malus and Laburnum. T. Pl. ziekten 67:264-272.

47. Osborne, W.W. and W.R. Jenkins. 1962. Pathogenicity of *Pratylenchus vulnus* on boxwood, *Buxus sempervirens* var. *arborescens*. Plant Disease Reptr. 46:712-714.

48. Osborne, W.W. and W.R. Jenkins. 1963. Host-parasite relationships of *Meloidogyne hapla, M. incognita acrita,* and *Pratylenchus vulnus* on *Forsythia intermedia*. Plant Disease Reptr. 47:354-358.

49. Parker, K.G. and W.F. Mai. 1956. Damage to tree fruits in New York by root lesion nematodes. Plant Disease Reptr. 40:694-699.

50. Pinochet, J. and D.J. Raski. 1977. Observations on the host-parasite relationship of *Pratylenchus vulnus* on grapevine, *Vitis vinifera*. J. Nematology 9:87-88.

51. Pitcher, R.S., Z.A. Patrick and W.B. Mountain. 1960. Studies on the host-parasite relationships of *Pratylenchus penetrans* (Cobb) to apple seedlings. I. Pathogenicity under sterile conditions. Nematologica 5:309-314.

52. Radewald, J.D., J.H. O'Bannon and A.T. Tomerlin. 1971. Temperature effects on reproduction and pathogenicity of *Pratylenchus coffeae* and *P. brachyurus* and survival of *P. coffeae* in roots of *Citrus jambhiri*. J. Nematology 3:390-394.

53. Ritchie, J.T. 1981. Water dynamics in the soil-plant-atmosphere system. Plant and Soil 58:81-96.

54. Ritchie, D.F. and C.N. Clayton. 1981. Peach tree short life: a complex of interacting factors. Plant Disease 65:462-469.

55. Roman, J. and H. Herschmann. 1969. Morphology and morphometrics of six species of Pratylenchus. J. Nematology 1:363-386.

56. Ruehle, J.L. 1968. Plant parasitic nematodes associated with Southern hardwood and coniferous forest trees. Plant Disease Reptr. 52:837-839.

57. Ruehle, J.L. 1973. Nematodes and forest trees—types of damage to tree roots. Ann. Rev. Phytopathology 11:99-118.

58. Santo, G.S. and B. Lear. 1976. Influence of *Pratylenchus vulnus* and *Meloidogyne hapla* on the growth of rootstocks of rose. J. Nematology 8:18-23.

59. Savory, B.M. 1966. Specific replant diseases. Research Review No. 1. Commonwealth Bureau of Horticulture and Plantation Crops, East Malling, Maidstone, Kent.

60. Smith, W. 1970. Tree Pathology. Academic Press, N.Y. 309 pp.

61. Steiner, G. 1945. Meadow nematodes as the cause of root destruction. Phytopathology 35:935-937.

62. Sutherland, J.R. 1967. Host range and reproduction of the nematodes *Paratylenchus projectus, Pratylenchus penetrans,* and *Tylenchus emarginatus* on some forest nursery seedlings. Plant Disease Reptr. 51:91-93.

63. Tan, C.S., A. Cornelisse and B.R. Buttery. 1981. Transpiration, stomatal conductance, and photosynthesis of tomato plants with various proportions of root system supplied with water. J. Amer. Soc. Hort. Sci. 106:147-151.

64. Triantaphyllou, A.C. 1971. Genetics and cytology. *In* Plant Parasitic Nematodes Vol. II. [Eds. Zuckerman, Mai, and Rohde] Academic Press. 347 pp.

65. Triantaphyllou, A.C. and H. Hirschmann. 1980. Cytogenetics and morphology in relation to evolution and speciation of plant parasitic nematodes. Ann. Rev. Phytopathology 18:333-359.

66. Turner, N.C. 1981. Techniques and experimental approaches for the measurement of plant water status. Plant and Soil 58:339-366.

67. Turner, N.C., and J.E. Begg. 1981. Plant-water relations and adaptation to stress. Plant and Soil 58:97-131.

68. Viglierchio, D.R. 1979. Response of *Pinus ponderosa* seedlings to stylet bearing nematodes. J. Nematology 11:377-386.

69. Zehr, E.I. 1981. Nematodes and the replant problem in fruits. Proc. of Symposia, IX International Congress of Plant Protection, Vol. II. pp. 603-605.

70. Thames, W.H. 1982. The genus Pratylenchus. *In* Nematology in the Southern Region of the United States. Eds. Riggs, R.D. and Editorial Committee SRRC S-76 and S-154. Southern Cooperative Series Bulletin 276.

Effects of Pruning and Staking on Landscape Trees[1]

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Abstract

Pruning and staking can be effectively used to develop structurally stable trees. The growth of young trees can be directed by pruning branches that are in unwanted permanent positions. Staking should be used primarily to protect and anchor young trees; support staking should be used only when plants are not able to stand upright without support.

Index words: Pruning, staking

Introduction

Young landscape trees are pruned and usually staked during training to be structurally strong and to perform their intended landscape functions. This paper focuses on some pruning and staking considerations in training young trees and cities research results and observations that provide the basis for evaluating these practices.

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Pruning

Two seemingly opposite effects occur when young plants and those that do not have a heavy flower and fruit load are pruned. *Invigoration* of individual shoots is the universal response, but *dwarfing* of the remaining branch and the entire plant results by the end of the growing season (1, 2). Because of these responses the growth of plants can be directed by pruning.

Pruning is the most common practice in training young trees and in maintaining mature ones. Branches that are to become the main scaffolds should be spaced vertically along and radially around the trunk. Other branches should be removed or pruned back so as not to compete with those selected.