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Survival and growth of peach trees and pest populations in orchard plots managed with experimental ground covers

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ABSTRACT

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Field experiments conducted in North and South Carolina (USA) demonstrated that survival and growth of peach trees (*Prunus persica* (L.) Batsch) as well as the severity of orchard pest populations (arthropods and nematodes) are profoundly affected by the plant species selected for orchard ground cover. Cover crops of brome (*Bromus mollis* L.), hard fescue (*Festuca longifolia* Thuill.) and rattail fescue (*Vulpia myuros* (L.) C. Gmelin) caused high mortality in young peach trees. Bahia-grass (*Paspalum notatum* var. *sauri* Parodi) stunted tree growth, and Korean lespedeza (*Lespedeza stipulacea* Maxim.) supported unacceptably large populations of arthropod pests.

Nimblewill (*Muhlenbergia schreberi* J.F. Gmelin) emerged from these experiments as the most promising candidate for ground cover in commercial peach orchards. This short-statured perennial grass tolerated drought, grew well in partial shade, did not harbor two-spotted spider mites (*Tetranychus urticae* Koch) or catfacing insects (Hemiptera), inhibited populations of ring nematodes (*Criconemella xenoplax* (Raski) Luc and Raski), and survived winter weather with little injury. Nimblewill successfully crowded out most weed species, but it did not appear to be highly competitive with peach trees for water and nutrients even when growing directly under the tree canopy.

INTRODUCTION

The make-up and management of ground cover has far-reaching ecological consequences in commercial peach orchards. Weeds may compete for water and nutrients, serve as shelter or host plants for vertebrate or invertebrate

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pests, regulate temperature in the microclimate, harbor parasites and natural enemies, prevent soil compaction, increase soil permeability to rainfall, preserve roadability, and retard erosion. These advantages and disadvantages have been widely debated, but there is no consensus for an optimal management strategy (Lord and Vlach, 1973; Skroch and Shribbs, 1986). Many growers eschew ground cover in the belief that passive radiation from bare, well-packed soil can provide several degrees (Fahrenheit) of night-time frost protection (Hamer, 1975; Jordan and Jordan, 1984). Others maintain a solid sod of bermuda grass, orchard grass or natural sward to maximize retention of rainfall and prevent erosion in hillside orchards (Lanyard, 1937; Welker and Glenn, 1985). Still other growers compromise by keeping bare soil beneath their trees and planting a cover crop only in the alley-ways between tree rows (Johnson, 1980; Butler, 1986).

Not all plant species are equally desirable (or undesirable) in an orchard ecosystem. Grass sods and broad-leaf weeds are generally regarded as strong competitors with peach trees for water and nutrients (Lord and Vlach, 1973; Arnold and Aldrich, 1980). Legumes, such as vetch (*Vicia* spp.) and clover (*Trifolium* spp.), and winter annuals, such as henbit (*Lamium* spp.), chickweed (*Stellaria* spp.), or pepperweed (*Lepidium* spp.) attract stink bugs (Pentatomidae) and tarnished plant bugs (*Lygus lineolaris*) whose feeding injury causes scarring and deformity (known as 'catfacing') in developing fruit (Meyer, 1984; Killian and Meyer, 1984). During early spring, spider mite (*Tetranychus* spp.) populations may develop explosively in ground cover plants (especially vetch, henbit, *Geranium* spp., and other winter annuals) and then migrate to peach trees in midsummer when the ground cover begins to senesce (Meagher and Meyer, 1990b). Numerous weed species, including dandelion (*Taraxacum* spp.), geranium, purslane (*Portulaca* spp.), and many legumes have been implicated as alternate hosts for the ring nematode, *Criconemella xenoplax* (Raski) Luc and Raski (Zehr et al., 1986, 1990). This nematode feeds on the young roots of peach trees thereby increasing the tree's susceptibility to cold injury and bacterial canker (Lownsbery et al., 1973; Nyczepir et al., 1983). This syndrome, often called peach-tree-short-life, is a major limiting factor for peach production in sandy soils of the southeastern US and elsewhere.

Eliminating undesirable plant species from orchard ground cover has greatly reduced catfacing injury at harvest (Killian and Meyer, 1984; Meagher and Meyer, 1990a) and mite populations during midsummer (Meagher and Meyer, 1990b). Zehr et al. (1990) suggested that similar cultural controls might also suppress growth of ring nematode populations in commercial peach orchards. Research in North and South Carolina has focused on a search for potential ground cover species that are not hosts for ring nematodes, spider mites, and catfacing insects; grow well in sandy soils; tolerate drought and partial shade; have a low growth habit; do not compete excessively with peach trees for water and nutrients; and will not be crowded out by other weeds on the orchard floor.

MATERIALS AND METHODS

Peach trees were interplanted with experimental ground covers in North and South Carolina in an effort to identify plant species that would be desirable as cover crops in commercial peach orchards. Each experimental species had previously been reported as a 'non-host' for *C. xenoplax* (Zehr et al., 1986, 1990) and was chosen on the basis of its growth habit and ease of management.

Four ground cover species were evaluated in South Carolina, including two annuals, Florida pusley (*Richardia scabra* L.) and bracted plantain (*Plantago aristata* Michaux), and two perennial grasses, nimblewill (*Muhlenbergia schreberi* J.F. Gmelin) and hard fescue (*Festuca longifolia* Thuill. cultivar 'Durar'). Nimblewill was also evaluated in North Carolina along with two other perennial grasses, centipede-grass (*Eremochloa ophiuroides* (Munro) Hackel) and bahia-grass (*Paspalum notatum* var. *saurae* Parodi); three annual grasses, brome (*Bromus mollis* L.), rattail (annual) fescue (*Vulpia myuros* (L.) C. Gmelin cultivar 'Zorro'), and green foxtail (*Setaria viridis* (L.) Beauvois); a perennial broad-leaf, dichondra (*Dichondra carolinensis* Michaux); an annual legume, Korean lespedeza (*Lespedeza stipulacea* Maxim.). Green foxtail seed was purchased from Valley Seed Service (Fresno, CA); nimblewill seed was provided by Dr. W.A. Skroch (Horticulture Dept., NC State University). Seeds for all other species were obtained from USDA-SCS Plant Materials Centers (Americus, GA and Lockeford, CA).

Nematode suppression

In South Carolina, peach seedlings (cultivar 'Nemaguard') were planted in pots containing Lakeland sand (89% sand, 5% silt, 6% clay) and inoculated with 500 *C. xenoplax* per plant 10 days later. After 5 weeks in a greenhouse, seedlings were transplanted into field microplots (about 1 m diameter) where they grew without weed competition for 4 years. By this time, *C. xenoplax* was well established in all plots ($\bar{x}=765$ nematodes cc^{-1} of soil; $n=33$ samples; SE 126.8).

During May 1987, seeds of nimblewill, Florida pusley, hard fescue, and bracted plantain were germinated and raised in the greenhouse until seedlings were well-established. On 23 June 1987, seedlings were transplanted by hand into field microplots arranged in a completely random design with seven replications of five treatments (four ground covers and one bare ground control).

Supplementary water was provided by drip irrigation (one emitter per plot) during dry weather. Soil samples, four subsamples per plot, were collected with a sampling cone for nematode assay prior to transplanting and once monthly thereafter through March 1989. Nematodes were extracted from soil samples by elutriation (Byrd et al., 1976) followed by centrifugal flotation (Jenkins, 1964) and counted under 30× magnification. Student's *t*-statistic was used to compare monthly counts from each ground cover treatment with the bare ground control.

Field plots and arthropod suppression

In North Carolina, a block of fallow land (Candor sand and Eunola sandy loam) was strip-fumigated with methyl bromide under plastic during October–November 1987. In March 1988, randomized complete blocks of ten ground cover treatments replicated three times were seeded into 9.1 × 10.7 m plots inside the fumigated area. Each treatment was separated from all others by a 2 m alley-way. Treatments included a weedy control, a bare ground control, and eight species of ground cover: brome (87.3 g per plot), rattail fescue (87.3 g per plot), centipede-grass (227 g per plot), nimblewill (66 g per plot), dichondra (227 g per plot), bahia-grass (2268 g per plot), green foxtail (328 g per plot), and Korean lespedeza (328 g per plot). In April 1988, cultivar 'Biscoe' peach trees (budded in June, 1987 to cultivar 'Lovell' rootstock) were planted into each ground cover plot (four trees per plot at approximately 3 m apart). Overhead irrigation was used only in 1988 to ensure establishment of the ground cover plots.

At planting, the trunk circumference of each tree was measured with a cloth tape. A horizontal white line painted on each tree marked the height at which circumference measurements were repeated annually during the dormant season. These measurements were statistically evaluated using a repeated-measures analysis of variance in a randomized complete block experimental design (Freund and Littell, 1981). The Waller–Duncan *k*-ratio *t*-test was used to determine significant differences among annual treatment means (Waller and Duncan, 1969).

Preliminary soil samples were taken in March 1988 for nematode analysis and subsequent soil samples were collected each fall through 1990. Nematode assays were conducted at Clemson University as described above. During 1989 and 1990, plots were sampled biweekly for arthropods using sweepnet and modified Tullgren funnel sampling techniques (Farrier et al., 1980; Meagher and Meyer, 1990b). Samples of ground cover foliage were examined for mite eggs and feeding injury under 20× magnification. Percentage of cover and stand purity were monitored each spring and summer using a square meter grid technique (Conn et al., 1982; Killian and Meyer, 1984). Percentage of cover included all surface area occupied by any plant species; stand purity was the percentage of treatment species among all plants in the plot.

All fruit buds were removed from 2- and 3-year-old peach trees in the field plots. Freezing temperatures during April 1990 prevented fruit set in any of these trees during the fourth growing season.

RESULTS

Climatological conditions

In 1987, moisture was generally adequate during the summer months and only occasional irrigation was needed to maintain the microplots in South Carolina. Rainfall was sparse during the spring and summer of 1988 and irrigation was necessary in both locations. Above-average rainfall was recorded in most months during 1989, but conditions were hot and dry from June through September of 1990. No irrigation was applied to the ground cover plots in North Carolina during the drought of 1990.

Ground cover suitability

In the South Carolina plots, Florida pusley established quickly in 1987 but seed germination was low in 1988. Bracted plantain and hard fescue were slower to become established. They survived well under the drip emitters during 1988, but died in drier parts of the microplots. Nimblewill was slow to establish in North Carolina where it was sown as seed, but it grew quickly in South Carolina where it was transplanted as seedlings. Nimblewill persisted well in both North Carolina and South Carolina once it became established; its vigorous habit of growth choked out most other vegetation.

Plots of brome, bahia-grass, and centipede-grass became established quickly in North Carolina and persisted well through the summer of 1990. Rattail fescue, dichondra, Korean lespedeza and green foxtail germinated and grew well during the spring and summer of 1988. Green foxtail re-seeded poorly for 1989; rattail fescue and Korean lespedeza re-seeded poorly for 1990. Dichondra survived well until the drought of 1990; by August these plants were under obvious water stress and many failed to recover in the autumn. Table 1 gives the annual values for stand purity and percentage cover in the North Carolina plots.

Pest populations

No significant differences were found among ring nematode populations sampled from South Carolina's control microplots and bracted plantain, hard fescue, and Florida pusley treatments ($P>0.05$). However, ring nematode populations were consistently lower in the nimblewill plots than in the bare ground controls; this difference was statistically significant ($P<0.05$) in October 1987, November 1987, and April 1988 (Fig. 1).

TABLE 1

Stand characteristics (percentage cover and stand purity) and population densities of tarnished plant bugs, two-spotted spider mites, and ring nematodes in North Carolina field plots of ground cover interplanted with peach trees

	Ground cover treatments[1]									
	BGrd	Weed	Brom	Cent	Dich	Baha	Nmwl	RtFs	KoLe	GrFx
Percentage cover										
Summer 1988	<1	96	84	84	80	84	88	96	88	88
Spring 1989	<1	92	84	72	84	88	88	–[2]	–[2]	–[2]
Summer 1989	<1	96	88	84	84	92	92	88	80	48
Spring 1990	<1	88	92	88	84	96	92	—	—	—
Summer 1990	<1	96	92	84	56	96	96	64	84	80
Percentage stand purity										
Summer 1988	—	—	88	84	88	92	60	92	88	92
Spring 1989	—	—	88	84	88	92	72	—	—	—
Summer 1989	—	—	92	92	92	92	80	92	80	60
Spring 1990	—	—	92	92	92	92	84	—	—	—
Summer 1990	—	—	96	92	80	92	88	72	64	36
Tarnished plant bugs[3]										
1989	0	22	0	0	0	0	0	0	12	0
1990	0	9	0	0	0	0	0	0	11	0
Two-spotted spider mites[4]										
1989	0	127	5	0	0	12	0	1	211	0
1990	0	345	0	0	0	4	0	0	562	0
Ring nematodes[5]										
Spring 1988	0	1	0	0	2	0	0	1	0	0
Fall 1988	0	0	2	0	4	0	2	0	0	0
Fall 1989	1	1	10	5	15	2	5	0	0	2
Fall 1990	4	0	0	29	6	10	3	8	0	1

[1]BGrd, bare ground; Weed, weedy; Brom, brome; Cent, centipede-grass; Dich, dichondra; Baha, bahiagrass; Nmwl, nimblewill; RtFs, rattail fescue; KoLe, Korean lespedeza; GrFx, green foxtail.
[2]Rattail fescue, Korean lespedeza, and green foxtail were dormant during spring sampling.
[3]Total number of adults and nymphs collected in six biweekly sweepnet samples (20 sweeps per sample) beginning 1 April.
[4]Total number of motile stages collected from six biweekly Tullgren foliage extractions (50 g wet weight per sample) beginning 1 April.
[5]Nematodes per 100 cc soil; 20 cores per plot.

Soil fumigation in the North Carolina plots reduced initial populations of *C. xenoplax* below the detection threshold in most treatments. These populations remained low in most treatments thoughout the duration of the experiment. Significant increases were detected only in dichondra (1989) and centipede-grass (1990) (Table 1).

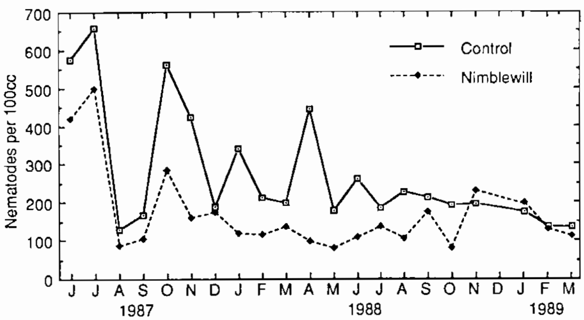

Fig. 1. Population densities of ring nematode recovered in monthly soil samples from bare ground (control) and nimblewill microplots interplanted with peach trees (South Carolina).

TABLE 2

Frequency of cold injury (1988–1989) to 'Nemaguard' peach trees growing in South Carolina microplots. Soil was infected with ring nematodes and trees were interplanted with selected ground covers[1]

Interplanted cover crop	Number of dead trees	Number injured by cold[2]	Total damaged	Percentage damaged
Bare ground control	1	3	4	57
Hard fescue	4	2	6	86
Bracted plantain	1	2	3	43
Florida pusley	1	0	1	14
Nimblewill	0	1	1	14

[1]Each interplanting treatment was replicated seven times.
[2]Injury sufficient to impair growth of trees.

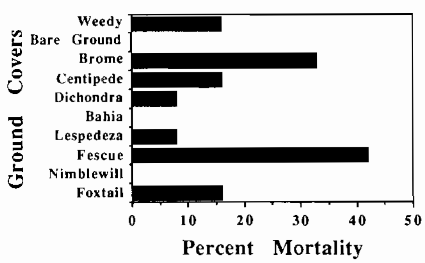

Fig. 2. Percentage mortality of peach trees (1988–1990) in North Carolina ground cover plots ($n=12$ trees per treatment).

No stink bugs were collected in any of the sweepnet samples, but tarnished plant bugs were found in the Korean lespedeza and weedy plots (Table 1). Motile stages of two-spotted spider mites were recovered from samples of Korean lespedeza, rattail fescue, bahia-grass, brome, and weedy plots, but eggs

TABLE 3

Annual treatment means of trunk circumference (standard error) for North Carolina peach trees growing in different ground cover plots (1988–1990). In each column, means followed by the same letter are not significantly different ($P > 0.05$) based on the Waller–Duncan *k*-ratio *t*-test (Waller and Duncan, 1969)

Ground cover treatments	Trunk circumference (standard error) in millimeters[1]			
	Initial	1988	1989	1990
Bare ground	18.0 (1.0) abc	68.3 (3.4) a	168.2 (6.3) a	230.7 (8.4) a
Nimblewill	20.1 (0.9) a	54.7 (1.7) b	149.5 (8.7) ab	220.3 (12.8) a
Fescue	17.4 (0.6) abc	44.9 (3.6) c	138.4 (15.9) b	203.4 (18.0) ab
Brome	15.4 (0.9) c	42.3 (3.5) c	128.4 (6.7) bc	199.0 (14.2) ab
Foxtail	19.1 (1.0) ab	61.4 (4.9) ab	148.5 (15.4) ab	184.9 (22.6) b
Dichondra	16.6 (0.6) bc	40.4 (2.1) cd	98.9 (6.1) d	149.3 (7.3) c
Centipede	18.8 (1.0) ab	41.1 (2.4) c	106.7 (5.0) cd	145.6 (8.0) c
Lespedeza	16.7 (1.0) bc	32.8 (2.0) d	100.3 (7.6) d	137.6 (9.9) cd
Weedy	19.9 (0.8) abc	42.5 (2.4) c	74.1 (6.8) e	108.0 (17.0) de
Bahia	18.8 (0.6) ab	38.1 (1.8) cd	69.8 (1.9) e	80.6 (2.1) e

[1] $n=12$ except: fescue ($n=7$, 1989–1990); brome ($n=6$, 1988; $n=5$, 1989–1990); foxtail ($n=10$, 1988–1990); dichondra ($n=11$, 1989–1990); centipede ($n=11$, 1988–1990); lespedeza ($n=$ 1989–1990); weedy ($n=11$, 1989–1990).

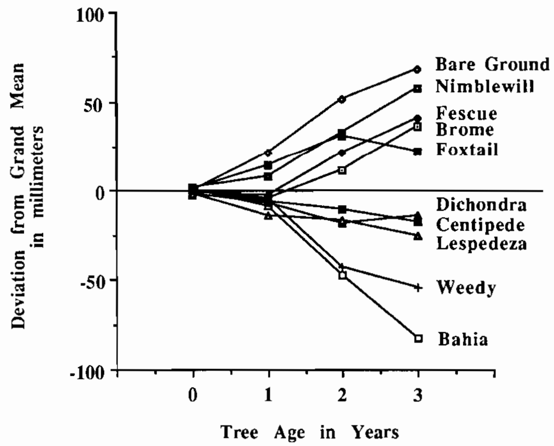

Fig. 3. Growth in trunk circumference of peach trees interplanted with different ground covers (North Carolina 1988–1990). The ordinate (y-axis) represents the mathematical difference (in millimeters) between the mean trunk circumference of all surviving trees (grand mean) and the mean trunk circumference of trees in each of ten ground cover treatments. All points lying above the horizontal line (zero value) represent better-than-average tree growth.

and feeding damage were found only in Korean lespedeza plots and on vetch, henbit, chickweed, and geranium in the weedy plots. Some of these mites may have immigrated from a large population in an adjacent peach orchard.

Peach tree survival and growth

In 1988, when trees in the South Carolina microplots were 5 years old, three trees died with cold injury symptoms usually associated with peach tree short life. Additional injury and death were observed in 1989 (Table 2). Tree mortality was highest in the hard fescue plots and lowest in the Florida pusley and nimblewill plots, but χ-square comparisons with the bare ground control were not statistically significant ($P>0.05$).

After 4 years of growth in North Carolina, trees in the brome and rattail fescue plots had suffered significant mortality (33% and 42%, respectively). No trees died in the bare ground, nimblewill, or bahia-grass plots, and only one or two trees died in foxtail, dichondra, centipede-grass, Korean lespedeza, and weedy plots (Fig. 2). As ring nematode populations were low in all plots, mortality was probably the result of competition or mechanical injury.

Trees growing in bare ground and nimblewill plots were taller, fuller, and had significantly larger trunk circumference than trees in any other ground cover plot. Growth was poorest in the weedy and bahia-grass plots where annual increase in mean trunk circumference was only one-third that of trees in the bare ground plots (Table 3). Effects were cumulative, resulting in greater than eight-fold differences in trunk cross-sectional area over three growing seasons (Fig. 3). Analysis of variance was highly significant ($P<0.01$) for blocks, treatments, years, and for the interaction between treatments and years ($F=74.6$; df$=41,392$; $r^2=0.88$).

DISCUSSION AND CONCLUSIONS

Interest in ground cover management in peach orchards as a tool for integrated pest management arose following the discovery of an ecological relationship between catfacing insects and selected weed species in orchard ground cover (Killian and Meyer, 1984). Subsequent research implicated many of these same weeds as hosts for two-spotted spider mites (Meagher and Meyer, 1990b) and ring nematodes (Zehr et al., 1986, 1990). Using selective herbicides to remove only certain weed species from the ground cover and allowing regrowth of perennial grasses and summer annuals, Meagher and Meyer (1990a) reduced pest populations and injury to fruit without causing economically significant losses to yield or tree growth. In some respects, this research parallels that conducted in apples (Rock and Apple, 1983; Skroch, 1984), but the plant community associated with peaches in the southeastern

US is quite different from that of apples because of differences in local climate and soil type.

Although survival and tree growth is optimal in bare ground, there are distinct horticultural and ecological advantages in maintaining a cover crop in peach orchards (Skroch and Shribbs, 1986; Glenn and Welker, 1989). The ground cover species tested in North and South Carolina have shown dramatic differences in their effects on tree mortality and tree growth: brome and both types of fescue caused unacceptably high mortality, and Korean lespedeza, centipede-grass, dichondra, and bahia-grass impeded tree growth. Dichondra, hard fescue, and bracted plantain did not survive well under drought conditions, and uncertainty of re-seeding eliminated Florida pusley, Korean lespedeza, and green foxtail from further consideration.

Nimblewill, a perennial grass, has emerged from these experiments as the most promising candidate for ground cover in peach orchards. Nimblewill shows good tolerance of drought. It crowds out most weed species, but is not highly competitive with peach trees for water and nutrients even when growing directly under the tree canopy. Nimblewill does not harbor spider mites or catfacing insects. It grows well in partial shade and it survives winter conditions with little injury. Nimblewill is not a host for ring nematodes and may even provide some allelopathic suppression. These characteristics are especially desirable in peach orchards of the southeastern US where productivity may be limited by the peach-tree-short-life syndrome.

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REFERENCES

Arnold, C.E. and Aldrich, J.H., 1980. Herbicidal effects on peach seedling growth and weed control. HortScience, 15: 293–294.

Butler, J.D., 1986. Grass interplanting in horticulture cropping systems. HortScience, 21: 394–396.

Byrd, Jr., D.W., Barker, K.R., Ferris, H., Nussbaum, C.J., Griffin, W.E., Small, R.H. and Stone, C.A., 1976. Two semiautomatic elutriators for extracting nematodes and certain fungi from soil. J. Nematol., 8: 206–212.

Conn, J., Proctor, C.H. and Skroch, W.A., 1982. Selection of sampling methods to determine weed abundance in apple orchards. Weed Sci., 30: 35–40.

Farrier, M.H., Rock, G.C. and Yeargan, R., 1980. Mite species in North Carolina apple orchards with notes on their abundance and distribution. Environ. Entomol., 9: 425–429.

Freund, R.J. and Littell, R.C., 1981. Statistical Analysis Systems for linear models. A guide to the ANOVA and GLM procedures. SAS Institute Inc., Cary, NC, 231 pp.

Glenn, D.M. and Welker, W.V., 1989. Orchard soil management systems influence rainfall infiltration. J. Am. Soc. Hortic. Sci., 114: 10–14.

Hamer, P.J.C., 1975. Physics of frosts. In: H.C. Pereira (Editor), Climate and the Orchard. Common. Agric. Bur. Res. Rev., East Malling, UK, pp. 66–72.

Jenkins, W.R., 1964. A rapid centrifugal-flotation technique for separating nematodes from soil. Plant Dis. Rep., 48: 692.

Johnson, P.A., 1980. The effect of herbicide strips and nitrogen on fruit tree nutrition. J. Sci. Food Agric., 31: 844–845.

Jordan, L.S. and Jordan, J.L., 1984. Tillage reduction in orchards with covercrops and herbicides. In: A.F. Wiese (Editor) Weed Control in Limited Tillage Systems. Weed Sci. Soc. Am. Monogr. Ser. No. 2, pp. 127–140.

Killian, J.C. and Meyer, J.R., 1984. Effect of weed management on catfacing damage to peaches in North Carolina. J. Econ. Entomol., 77: 1596–1600.

Lanyard, L.R., 1937. Effect of sod, cultivation, and straw mulch upon orchard soil moisture content. Proc. Am. Soc. Hortic. Sci., 35: 313–314.

Lord, W.J. and Vlach, E., 1973. Responses of peach trees to herbicides, mulch, mowing, and cultivation. Weed Sci., 21: 227–229.

Lownsbery, B.F., English, H., Moody, E.H. and Schick, F.J., 1973. *Criconemoides xenoplax* experimentally associated with a disease of peach. Phytopathology, 63: 994–997.

Meagher, Jr., R.L. and Meyer, J.R., 1990a. Effects of ground cover management on certain abiotic and biotic interactions in peach orchard ecosystems. Crop Prot., 9: 65–72.

Meagher, Jr., R.L. and Meyer, J.R., 1990b. Influence of ground cover and herbicide treatments on *Tetranychus urticae* populations in peach orchards. Exp. Appl. Acarol., 9: 149–158.

Meyer, J.R., 1984. Catfacing in peaches: effects of ground cover and surrounding vegetation. Proc. Joint Nat. Peach Council and Southeast. Peach Conv., pp. 5–11.

Nyczepir, A.P., Zehr, E.I., Lewis, S.A. and Harshman, D.C., 1983. Short life of peach trees induced by *Criconemella xenoplax*. Plant Dis., 67: 507–508.

Rock, G.C. and Apple, J.L., 1983. Integrated pest and orchard management systems for apples in North Carolina. North Carolina Agric. Res. Tech. Bull. No. 276.

Skroch, W.A., 1984. Orchard floor management for apples. North Carolina Agric. Ext. Bull. No. 308.

Skroch, W.A. and Shribbs, J.M., 1986. Orchard floor management: an overview. HortScience, 21: 390–394.

Waller, R.A. and Duncan, D.B., 1969. A Bayes rule for the symmetric multiple comparison problem. J. Am. Stat. Assoc., 64: 1484–1499.

Welker, W.V. and Glenn, D.M., 1985. The relationship of sod proximity to the growth and nutrient composition of newly planted peach trees. HortScience, 20: 417–418.

Zehr, E.I., Lewis, S.A. and Bonner, M.J., 1986. Some herbaceous hosts of the ring nematode (*Criconemella xenoplax*). Plant Dis., 70: 1066–1069.

Zehr, E.I., Aitken, J.B., Scott, J.M. and Meyer, J.R., 1990. Additional hosts for the ring nematode, *Criconemella xenoplax*. J. Nematol., 22: 86–89.