PREPLANT SITE PREPARATIONS: WHAT WORKS AND WHAT DOESN'T IN NORTHEAST ORCHARDS?

Ian A. Merwin and Rachel Byard
Department of Horticulture, Cornell University, Ithaca, NY

Terence L. Robinson and Steven Carpenter
Department of Horticultural Science, New York State Agricultural Exp. Station, Geneva, NY

Stephen A. Hoying, Kevin A. Iungermann, and Michael Fargione
Cornell Cooperative Extension

Summary

As New York growers renovate old orchards, apple replant disease (ARD) has become a major problem. Past research at Cornell has shown that ARD problems occur at more than half the farms statewide. Chemical soil fumigation sometimes controls ARD, but fumigation responses have been variable and may be linked with environmental problems. Other possible control tactics for ARD include preplant cover crops of marigolds, Brassicas (mustards) and certain Sudan grass varieties, correction of soil compaction, nutrient and pH problems, and disease resistant rootstocks. Six years ago, we began a project to test and develop comprehensive strategies for diagnosing and controlling orchard replant problems. With funding support from NY apple growers, we have been testing methods for predicting the severity of ARD, and biological or chemical strategies for controlling ARD, at selected commercial apple orchards in the state's major fruit-growing regions. Soils from 17 orchards were sampled during 1996 to 1998 for nematode populations and nutrient status, and growth of apple seedlings or grafted rootstocks was compared in fumigated, pasteurized, and untreated field soil. At the same time, six or seven preplant soil treatments were evaluated at each orchard: 1) No treatment (Control); 2) Brassica/Sudan grass cover crops (B/S); 3) Lime and fertilizer amendments (L/F); 4) Lime and fertilizer plus Brassica/Sudan grass (LFB/S); 5) Lime and fertilizer plus Vapam fumigation (LFV); 6) Vapam soil drench; and 7) Telone C-17 soil fumigation. The following year, apple trees were planted into each preplant treatment, and since then we have measured tree growth, fruit yields, and nutrient uptake each year. The preplant bioassays indicated ARD problems at two-thirds of these orchards—seedlings or grafted trees grew much better in pasteurized or fumigated soil. Nematode populations were below damage thresholds at most sites. In subsequent years, tree responses to the preplant treatments have been inconsistent from farm to farm. Fruit yields varied up to five-fold among the orchards. At a few sites, trees responded positively to fumigation, while at others the best growth and yields occurred in fertilizer/cover crop treatments, or there was no significant response to any preplant treatment. The initial diagnostic bioassays over-predicted substantially the subsequent tree growth responses to soil fumigation in most orchards. As we finish tree growth and fruit yield measurements at these sites, the results indicate that preplant soil fumigation, fertilizer amendments, and pest-suppressive cover crops will not guarantee good growth and early yields of apple trees unless growers can also manage successfully all the other factors that sometimes limit replant establishment and success.

Introduction

When fruit growers renovate and replant apple orchards, the new trees often grow poorly and fail to meet expectations for early yields or profitability. This problem is sometimes called apple replant disease (ARD) and has been the subject of extensive research in New York, Washington and Europe (Mai et al, 1994). Abiotic problems such as soil nutrient depletion, compaction or acidification, and phytotoxic residues of arsenic or old roots have been associated with ARD. Biotic problems such as parasitic nematodes or fungal and bacterial pathogens of tree roots have also been implicated. European fruit growers consider ARD a major threat, and have relied upon a greenhouse bioassay comparing seedling growth in untreated vs. steam-pasteurized or fumigated soil, to diagnose ARD problems. In this bioassay a 50% increase in seedling growth in treated soils is considered the action threshold for recommending soil fumigation before replanting (Gilles and Bal, 1988; Scotto La Massese et al, 1988). In the past decade we have tested soils from 50 orchards in the Lake Ontario, Lake Champlain, Hudson Valley, and Long Island regions with this diagnostic bioassay, and about two-thirds appeared to have serious ARD problems (Merwin, 1995).

Broad-spectrum preplant soil fumigants such as methyl bromide, 1,3-dichloropropene plus chloropicrin (Telone^{TM} C-17), or metam sodium (Vapam^{TM}) provide temporary suppression of soilborne pathogens and weeds, and have dramatically increased growth and yields of replant trees in many regions (Mai et al, 1994; Smith, 1993, 1994). With fewer options and increasing costs for chemical controls, there is renewed interest in using preplant cover crops as biocontrols to suppress nematodes and/or other ARD pathogens. In previous studies of NY orchards, cover crops of marigolds (*Tagetes patula*), Sudan grass (*Sorghum sudanense*), and 'Saia' oats (*Avena sativa*) reduced ARD, but results varied greatly from one site to another (Merwin, 1995). In Europe, growers have used oilseed mustards (*Brassica nigra* and *B. juncea*) as cover crops to suppress soilborne pathogens and improve tree growth. Recent research by Dr. Rosemary Loria and others in the Dept. of Plant Pathology at Cornell University identified two mustard cultivars—'Forge' and 'Cutlass'—with high concentrations of allylisothiocyanates that could suppress fungi or nematodes when grown as a cover crop and incorporated into the soil.

Past research by Dr. Warren Stiles suggested that depletion of essential soil mineral nutrients, and soil acidification from long-term sulfur or nitrogen applications, could also limit the growth of replanted apple trees. There is not much information available on the interactions between previous groundcovers or cropping history, soilborne plant pathogens, and nutritional deficiencies in NY orchards. We therefore included fertilizer treatments with the other factors tested in this project.

The economic impacts of ARD have not been studied much in NY, but we do know that when poor tree establishment delays and reduces yields in high-density plantings, substantial economic losses can result. Economic studies demonstrate that orchards with serious ARD problems are likely to be unprofitable (Geldart, 1994; White and DeMarree, 1992). Considering all these factors, replant problems definitely pose a serious threat to sustainable and profitable apple production. Developing and validating a comprehensive system of ARD diagnosis and control is therefore a priority for the NY fruit industry. Hence, our main objectives in this project were to:

1) Assess the extent and severity of ARD in NY State with bioassays using apple seedlings and grafted rootstocks to test the potential benefits of soil pasteurization and/or fumigation.
2) Evaluate growth and yield of apple trees planted following Vapam or Telone C-17 soil fumigation,

Mustard/Sudan grass cover crops, and soil pH and fertility amendments.

3) Compare the field performance of apple trees in fumigated orchard plots with the results of preplant diagnostic bioassays, to determine the reliability of these bioassays for NY orchards.
4) Develop extension recommendations for preplant soil treatments and adjustment of orchard tree spacing, based on validated soil bioassays and on-farm economic responses to ARD controls.
5) Conduct extension programs including orchard field tours, winter meetings and workshops. Upon completion of the research, write a comprehensive bulletin explaining the causes and extent of replant problems, and appropriate diagnostic and control strategies for NY state.

Research Methods

Each year, five to seven orchards were selected within the state's major fruit growing regions. Soil was sampled extensively at each orchard and analyzed for parasitic nematodes, essential plant nutrients, and physical/chemical properties. Experimental objectives and designs were discussed with participating growers and regional extension specialists. The following preplant treatments were selected: 1) No preplant soil treatments (Control); 2) Soil amendments with lime and fertilizers according to Cornell recommendations as determined for each site by Dr. Warren Stiles (LF);
3) Soil-drench with Vapam at 100 gallons per treated acre, or shank injection of Telone C-17 at 35 gallons per treated acre; 4) Preplant cover crops of Brassica (*B. juncea* cv. Forge) seeded in June, then tilled under and reseeded with Sudan grass (cv. Trudan-8) in late July, which was then tilled down in September (B/S); 5) Lime/fertilizer amendments plus treatment with Vapam (LFV); 6) Lime and fertilizers plus the Brassica/Sudan grass cover crops (LFB/S).

After obtaining 500 kg of composite soil samples throughout each test orchard, plots were blocked out and the first treatments applied in May when the Brassica cover crop was planted. In mid-July, the Brassica was chopped, tilled down, and Sudan grass was seeded. In September, the Sudan grass was chopped and incorporated, the macro/micronutrient fertilizers and lime were applied and worked into the soil, and the Vapam and Telone C-17 were applied. After preplant treatments were completed, the sites were fallowed during winter, and four to six trees were planted into each treatment replicate by growers in April of the following year.

Concurrently with establishing the preplant treatments at each orchard, we also conducted a series of apple seedling and grafted rootstock ARD diagnostic bioassays at a greenhouse and outdoor nursery in Ithaca, NY, using the soil sampled from each site. Nematode identification and counts were performed in the initial soil samples, and again on a second set of samples taken from the Brassica/Sudan grass and untreated control plots in early October. Dormant bare-root 'Gala' or 'Jonagold' trees were obtained from commercial nurseries on M.9 and M.26 rootstocks, using the varieties and rootstocks that each participating grower intended to plant. Grafted trees were grown in ten 20-liter pots of soil from each farm, in an outdoor nursery. There were five pots of pasteurized or Vapam treated soil, and five pots of untreated field soil from each orchard. At planting, trees were headed to 1-m height, lateral branches were removed, and drip irrigation was provided with granular N-P-K fertilizer applications every two weeks. In late October, we measured and weighed all new lateral and central leader growth of each potted tree.

When trees were planted at each test orchard the year after preplant treatments (i.e. in April or May, 1997—1999), we measured tree caliper 40 cm above the graft union. As trees subsequently grew and came into production, we measured trunk caliper, and counted and weighed fruit samples from the center two trees in every plot annually at each orchard—with timely assistance from the growers and local Cooperative Extension specialists.

Results & Discussion

Preplant diagnostic bioassays. For most of the tested soils, there was a substantial increase in grafted tree growth after soil pasteurization or fumigation (Figure1; Photo. 1). However, a few soils each year showed negligible tree-growth responses, or even negative responses, to bioassay soil treatments (for example, orchard ON-5 in Fig. 1). In the seedling greenhouse bioassay tests for these same soils, somewhat different results were obtained (Fig. 2). In some bioassays we included both steam pasteurization and Vapam treatments, and observed that soil pasteurization was often more effective than Vapam treatment for improving seedling growth, but the structure of several soils (usually sandy loams) was damaged by steam pasteurization. In gravelly loam soils of Washington, Vapam has been effective in controlling ARD (Smith, 1993); it may be less effective in NY soil types, or higher than labeled rates may be required for Vapam to control ARD in our soils.

Averaged for all 17 soils tested in three years of bioassays, the growth responses of seedlings and grafted trees to pasteurization or fumigation treatments were remarkably similar. Apple seedling biomass ratios in pasteurized vs. untreated field soil in greenhouse tests averaged 1.48 (range of 0.6 to 3.2); the ratios for seedlings in Vapam vs. untreated soil averaged 1.43 (range of 0.7 to 3.3); and the ratios for grafted trees grown outdoors in 5-gallon pots of pasteurized vs. untreated soil averaged 1.46 (range of 0.5 to 3.5). In other words, despite the different soil types and site histories, growth of apple seedlings and grafted trees in preplant bioassays was increased an average of 43 to 48% by steam pasteurization or Vapam treatments.

Preplant soil treatments at test orchards. Soil types at the 17 farms included sandy loams, gravelly loams, silt loams, and clay loams. Weather conditions during preplant treatments and the first 2 to 4 years of replant tree establishment were also variable—including droughts, floods and hailstorms. Across this range of growing conditions, the cover crops of Brassica and Sudan grass established reasonably well (Photo. 2), providing sufficient biomass for soil improvement and pathogen suppression at most sites. Persistent residues of simazine and other herbicides prevented good cover crop establishment at a few orchards. Also, it was difficult to incorporate cover crop residues thoroughly into the root-zone at farms where large rocks and/or drought-hardened soils prevented rototillers from penetrating deeply into the topsoil. Nematode populations were low at the outset in most orchards, and were not suppressed further by either cover crop treatment. In fact, lesion nematode (*Pratylenchus* spp.) populations actually increased on the Brassica cover crop.

Replant tree growth in test orchards. In contrast with the generally positive growth responses to soil fumigation or pasteurization in our preplant bioassays (Figs.1-2), tree growth after replanting each orchard was highly variable and did not respond consistently to soil treatments (Figs. 3A-C). There were few significant differences among treatments at each site, but the differences in growth among the 17 orchrds were impressive. Trees in the Champlain Valley grew less on average in all treatments, compared with other regions of the state with longer growing seasons (regional site designations in the accompanying figures are: CV=Champlain Valley, HV=Hudson Valley, ON=Ontario shore region, and LI=Long Island). The best overall growth and the most positive response to preplant fumigation and fertilizers were observed in one Long Island orchard. At four sites (HV-1, HV-2, CV-2 and LI-1) tree growth was increased by Vapam treatments with or without fertilizers. A combination of Brassica/Sudan grass cover crops and fertilizers promoted better tree growth at two Ontario region orchards (ON-1 and ON-6). Where Vapam and Telone C-17 could be compared directly (Fig. 3-C for the 1998 sites), neither was very effective in comparison with untreated control plots. In general, the responses to preplant soil treatments were not significant and would not have justified the expenses of fumigation or fertilizer applications at most of the test orchards.

Yield responses to preplant treatments. At five orchards (LI-1, HV-2, HV-3 and ON-2 and ON-5), trees cropped in the second or third leaf, with relatively good production in all treatments and a positive response to the Vapam, LFV or LFB/S relative to Control treatments (Figs. 4A-C). At orchard CV-3, on a sandy loam soal, the yield response to Telone-C17 was greater than to Vapam (Fig. 4-C). At the best yielding of the 1998 sites (HV-5) there was no significant response to any preplant treatment. In five of the best yielding orchards (LI-1, HV-1, HV-2, HV-5 and ON-2), the growers obtained well feathered, large caliper trees and were able to irrigate when necessary. Comparing preplant treatment responses over different soil types and years (Figs. 5A-B), the trends were also mixed, suggesting that preplant cover crop, fertilizer or fumigation responses were not consistently affected by soil texture, organic matter or water holding capacity.

There were many factors beyond the scope of our experimental treatments that probably limited growth and yield of replanted trees at test sites, and might have negated the potential benefits from preplant treatments. For example, weed control in the new plantings was often inadequate. Potato leafhopper infestations caused trees at several orchards to stop growth in mid-summer. There were severe drought periods in some non-irrigated plantings, and one orchard was flooded repeatedly during the first year. Many of the trees at one site had suffered winter injury at the nursery and had to be replaced after their first growing season. Trees obtained for planting at some orchards were low-grade and unfeathered. Meadow voles and fireblight severely damaged or killed trees at two orchards. The lower trunks of trees at one site were completely girdled by plastic baling twine used to tie-down branches. Any one of these problems would be serious enough to counteract the potential gains from preplant soil treatments for ARD.

The preplant diagnostic bioassays appeared not to predict reliably the subsequent replant tree responses to soil fumigation at most of these 17 orchards. However, it is also possible that the 45% average increase in bioassay tree or seedling growth observed following soil fumigation or pasteurization under optimal nursery and greenhouse conditions in the diagnostic bioassays was a valid indication of the potential benefits of controlling soil-borne pathogens when all other growing conditions were optimal for newly planted apple trees. Similarly, the excellent tree growth and impressive yields in the second or third leaf at 5 of the 17 test sites represents a realistic goal that should also be attainable for other New York apple growers under ideal conditions.

These are difficult times for the world apple industry, and growers everywhere are working hard to cut costs and survive in the fruit business. Under such circumstances, it is easy to understand how replanting orchards and meticulous care for non-bearing orchards may not be top priorities for fruit growers. Our research demonstrates that preplant soil treatments are not "cure-alls" for apple replant problems. Without close attention to all the essential details of orchard replant management, it appears that soil fumigation, fertilizer amendments, and disease-suppressive cover crops will not guarantee successful renovation of old apple orchards.

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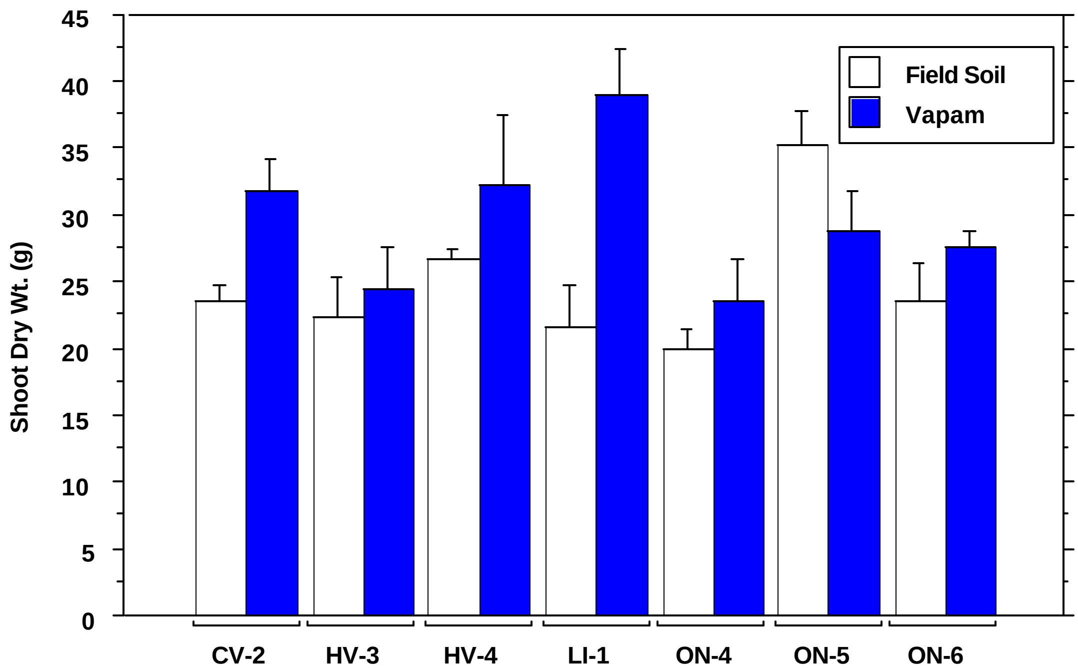


Figure 1. Relative total new shoot biomass for 'Gala' apple on M.9 rootstocks after 6 months growth in 20-liter pots of Vapam treated and untreated Field soil from seven NY orchards tested in 1997. Trends were similar in the 1996 and 1998 diagnostic bioassays. Site designations are: CV=Champlain Valley, HV=Hudson Valley, ON=Ontario lake region, and LI=Long Island region.

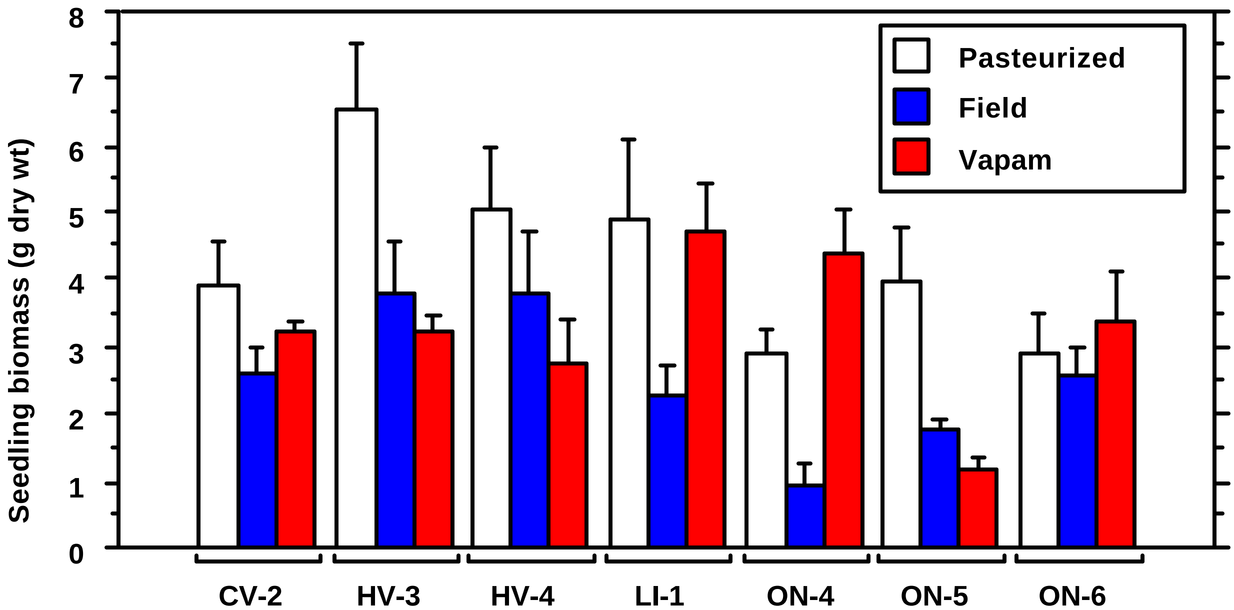
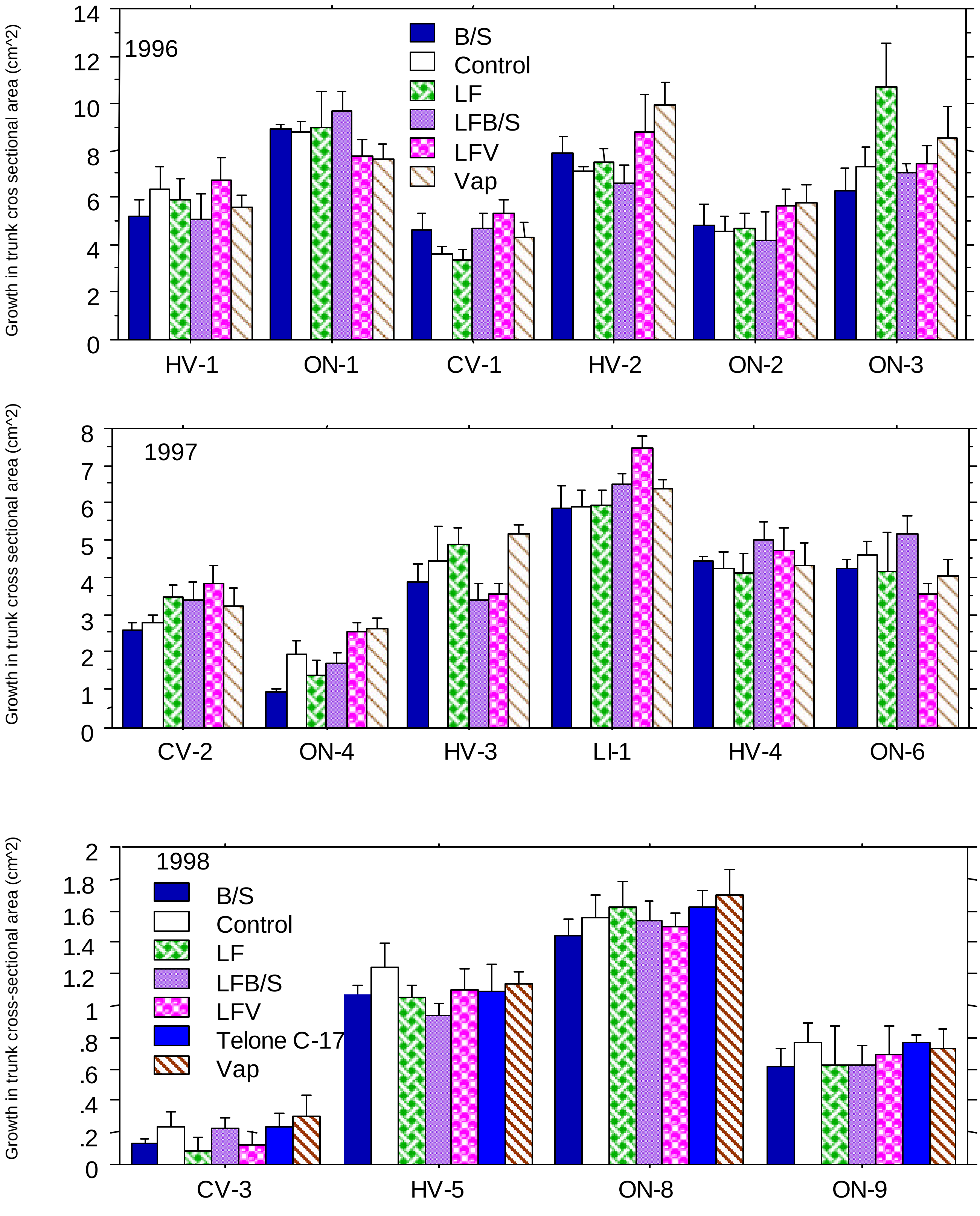
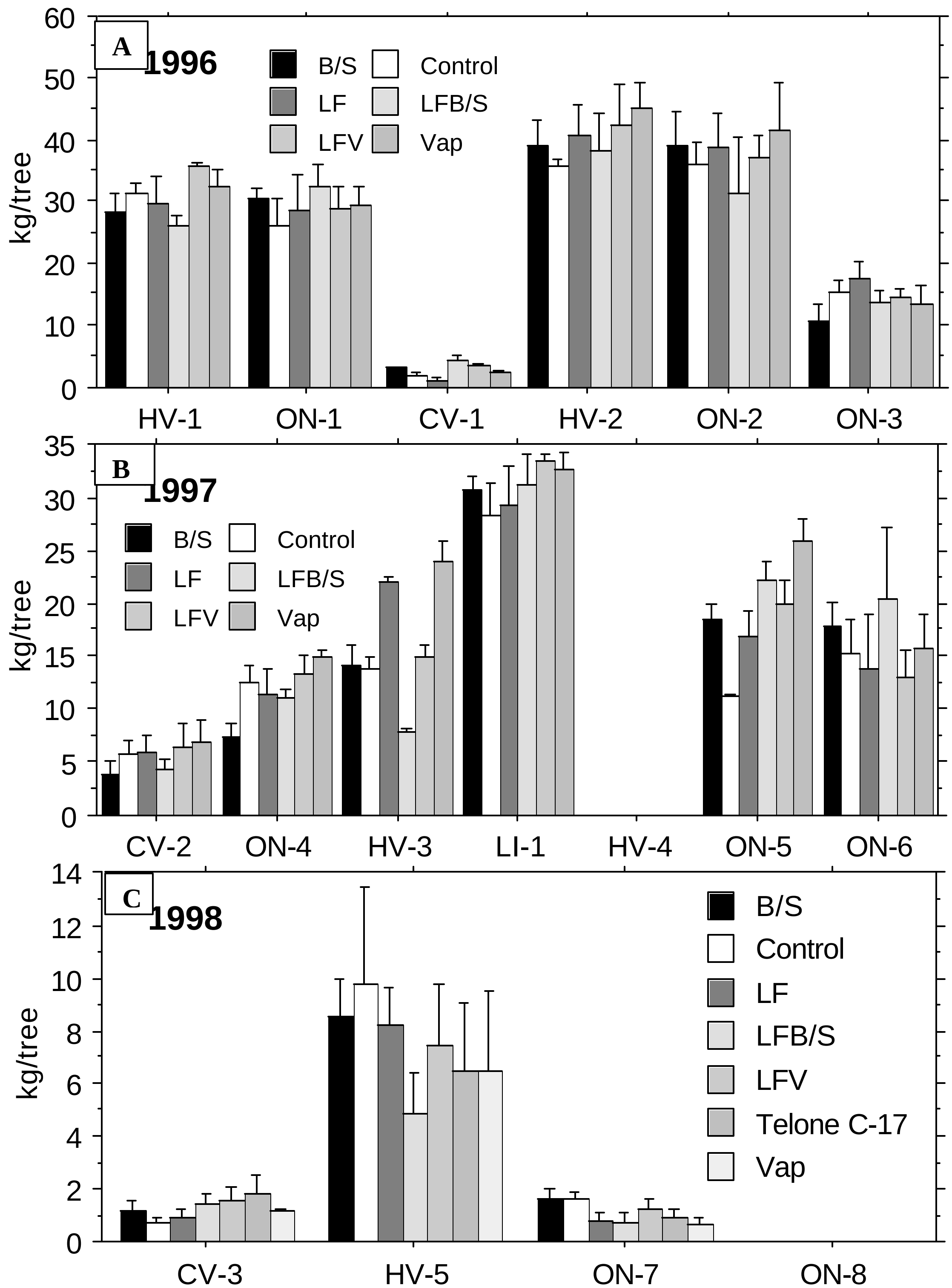


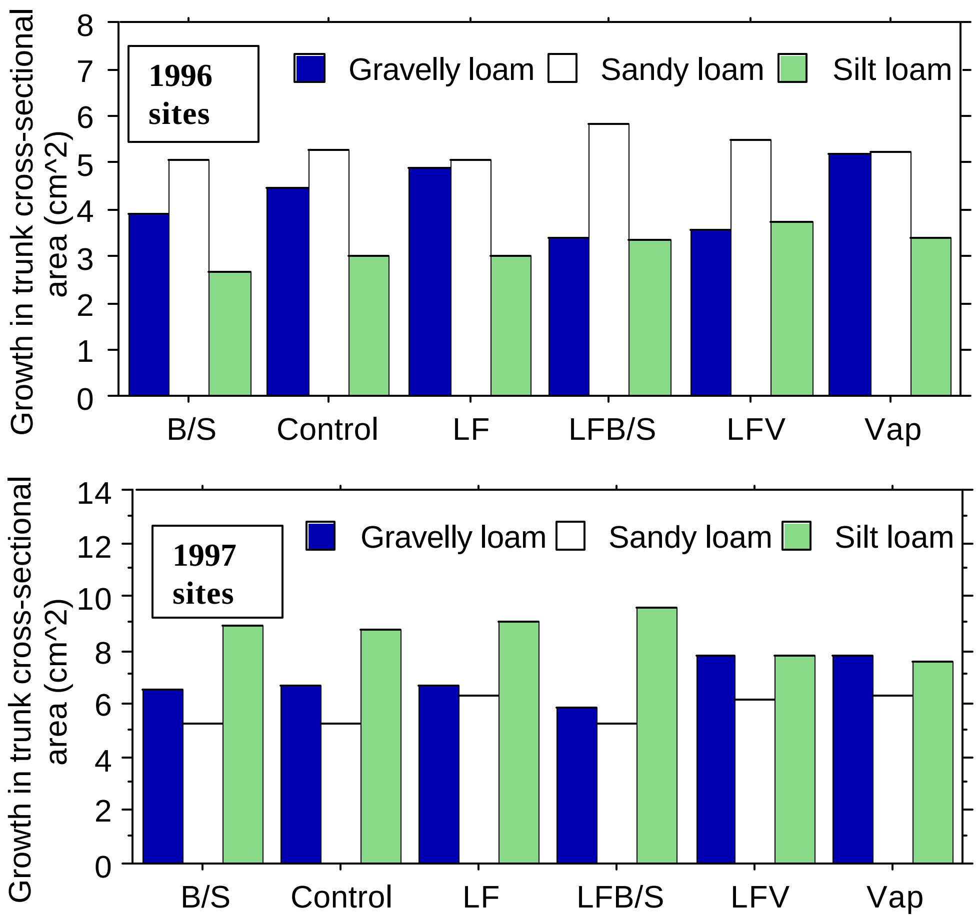
Figure 2. Comparison of 'Northern Spy' seedling apple growth (total grams dry weight) after 80 days in a greenhouse, growing in 2-liter pots of Pasteurized, Vapam treated, and untreated Field soil collected from seven New York orchards in 1997.



Figures 3A-C. Cumulative tree growth in trunk cross-sectional area as of Fall 2000 for 17 NY orchards after different preplant soil treatments in 1996, 1997, 1998.



Figures 4 A-C. Cumulative fruit yields (kg harvested per tree) as of Fall 2001 at 17 New York orchards where different preplant treatments were applied 1996-1998, for control of apple replant disease. Harvest data were not obtained in 2001 for CV-1, ON-8, HV-4, and LI-1.



Figures 5A-B. Apple tree growth (cm^2 of trunk cross-sectional area) following different preplant treatments in 1996 and 1997, grouped by orchard soil type.

Photo 1. A typical tree growth response of 'Gala' on M.9, grown outdoors for 6 months in a 20-liter pot of steam-pasteurized soil (tree on left) vs. untreated field soil (tree on right) from one of test orchards.

Photo 2. Treatment stands and randomization of preplant mustard (*Brassica juncea* cv. Forge) cover crop in a test orchard just before mowing and soil mixing cover crop residues in July.