Developing An Integrated Program for Diagnosis and Control of Replant Problems In New York Apple Orchards

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This work supported by the New York Apple Research and Development Program.

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. Our research indicates that there is no single "cure-all" treatment for apple replant problems! Without close attention to *all* the essential details of orchard management, we cannot assume that soil fumigation, fertilizers, or preplant cover crops will guarantee successful renovation of old apple orchards

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 percent 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™ C-17), or metam sodium (Vapam™) 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 in New York 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 department 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 New York 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 New York, 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 New York fruit industry. Hence, our main objectives in this project were to:

1. Assess the extent and severity of ARD throughout NY State with bioassays using apple seedlings and grafted rootstocks to test the benefits of soil pasteurization 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 economic responses to ARD controls.
5. Conduct extension programs including orchard field tours, winter meetings and workshops; then upon completion of the research, write a comprehensive bulletin explaining the causes and extent of replant problems, and appropriate diagnostic and control strategies.

Research Methods

Five years ago, we began a project to test and develop comprehensive strategies for diagnosing and controlling orchard replant problems. With funding support from New York 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.

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 4 to 6 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 10 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 and Discussion

Preplant diagnostic bioassays. For most soils, there was a substantial increase in grafted tree growth after soil pasteurization or fumigation (Fig.1; Photo 1). However, a few soils each year showed negligible tree-growth response, or even negative responses, to bioassay soil treatments (for example, soil from 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 impaired by steam pasteurization. In the gravelly loam soils of central Washington, Vapam has been effective in controlling ARD (Smith, 1993); it may be less effective in New York 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 3 years of bioassays, the growth responses of seedlings and grafted trees to both soil treatments were remarkably similar. 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 pasteurized vs. untreated soil averaged 1.46 (range of 0.5 to 3.5). Despite these different soils and site histories, the growth of seedlings and grafted trees was increased an average of 43 to 48 percent by pasteurization or Vapam treatments in preplant bioassays.

Preplant soil treatments at test orchards. Soil types were diverse at the 17 farms, including sandy loams, gravelly loams, silt loams, and clay loams. Weather conditions during preplant treatments and replant tree establishment were also vari-

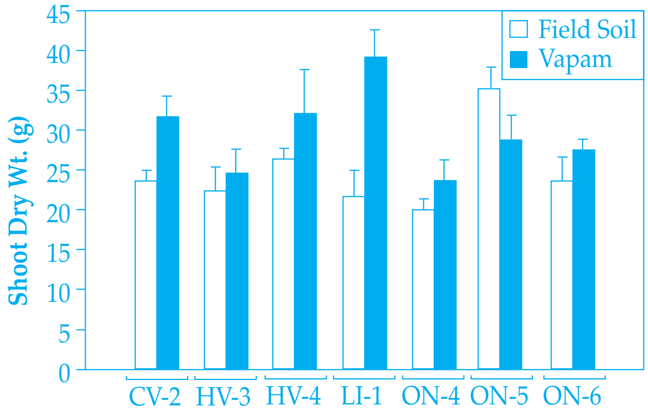

Figure 1. Total new shoot biomass for 'Gala' apple on M.9 rootstocks after six months growth in 20-liter pots of Vapam treated and untreated Field soil from seven New York orchards tested in 1997. Trends were similar in the 1996 and 1998 diagnostic bioassays. Site designations are: CV=Champlain Valley,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

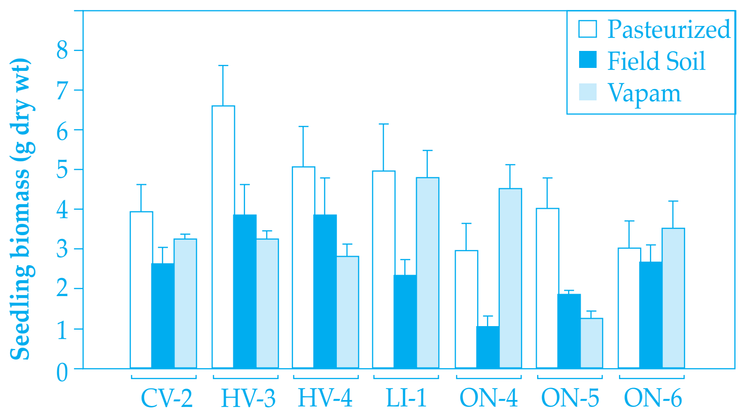

Figure 2. Comparison of 'Northern Spy' seedling apple tree growth (total grams dry weight) after 80 days in a greenhouse, growing in 2-liter pots of Pasteurized, Vapam treated, and untreated Field soil collected from seven New York orchards in 1997.

able, 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 mix cover crop residues thoroughly into the root-zone at farms where large rocks and/or drought-hardened soils prevented rototillers from penetrating down through 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 at each orchard was highly variable (Figs. 3A-C). There were few statistical differences among treatments at each site, but the differences in growth among different sites were dramatic. Trees in the Champlain Valley grew less on average in all treatments, compared with other regions of the state with longer growing seasons (site designations in Figures are CV=Champlain Valley, HV=Hudson Valley, ON=Ontario shore region, and LI=Long Island). Conversely, the best overall growth and the clearest positive response to preplant fumigation and fertilizers were observed in a Long Island orchard. In four sites (HV-1, HV-2, CV-2 and LI-1), the best tree growth was observed in 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), they were both

Photo 1. A typical tree growth response of 'Gala' on M.9, grown outdoors for six 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 plots and randomization of preplant mustard *(Brassica juncea* cv. Forge) cover crop in a test orchard just before chopping and soil incorporation of cover crop residues in July.

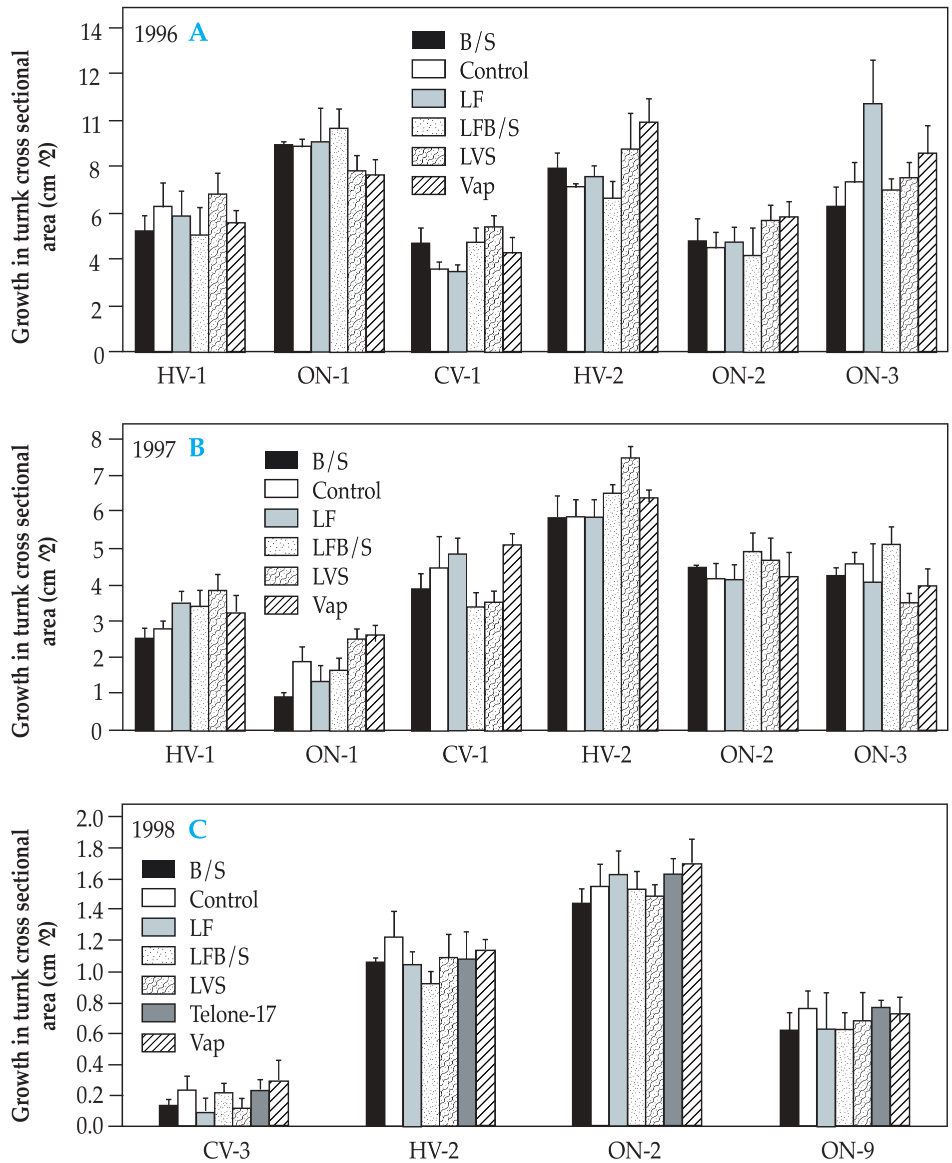

Figure 3A-C. Cumulative increase in trunk cross-sectional area through the Fall 2000 for 17 NY orchards after different preplant soil treatments in 1996, 1997, and 1998.

ineffective compared with untreated control plots. In general, the response to preplant soil treatments was not significant and would not have justified the expenses of fumigation or fertilizer applications at most of these orchards.

Yield Responses to Preplant Treatments

At 3 orchards (LI-1, HV-2 and ON-2), trees cropped in the second leaf, with good production in all treatments and a positive response to the LFV or LFB/S treatments (Figs. 4A-B). In four of the five best yielding orchards (LI-1, HV-1, HV-2, and ON-2), the growers had obtained well feathered, large caliper trees and were able to irrigate whenever necessary. Comparing treatment responses over different soil types and years (Figs. 5A-B), the trends were also mixed, indicating that cover crop, fertilizer, or fumigation responses were not consistently affected by soil texture, permeability, organic matter, or water holding capacity.

There were many factors beyond the scope of our experimental treatments that limited the growth and yield of replanted trees at test sites, and could have negated the potential benefits from preplant treatments. 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.

Our preplant diagnostic bioassays may have overestimated the responses to soil fumigation at most of these orchards. However, it is also possible that the 45 percent average increase in tree or seedling growth that we observed with soil fumigation or pasteurization under nursery and greenhouse conditions in the diagnostic bioassays *was* a valid indication of the potential benefits of controlling soilborne 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 some of these 17 test sites represents a realistic and attainable goal for other growers in New York.

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. With our present research, 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.

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. Resesarch from our research indicates that there is no single "cure-all" treatment for apple replant problems! Without close attention to *all* the essential details of orchard management, we cannot assume that soil fumigation, fertilizers, or preplant cover crops will guarantee successful renovation of old apple 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.

Our results to date suggest 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 all the other factors that can limit replant establishment and success.

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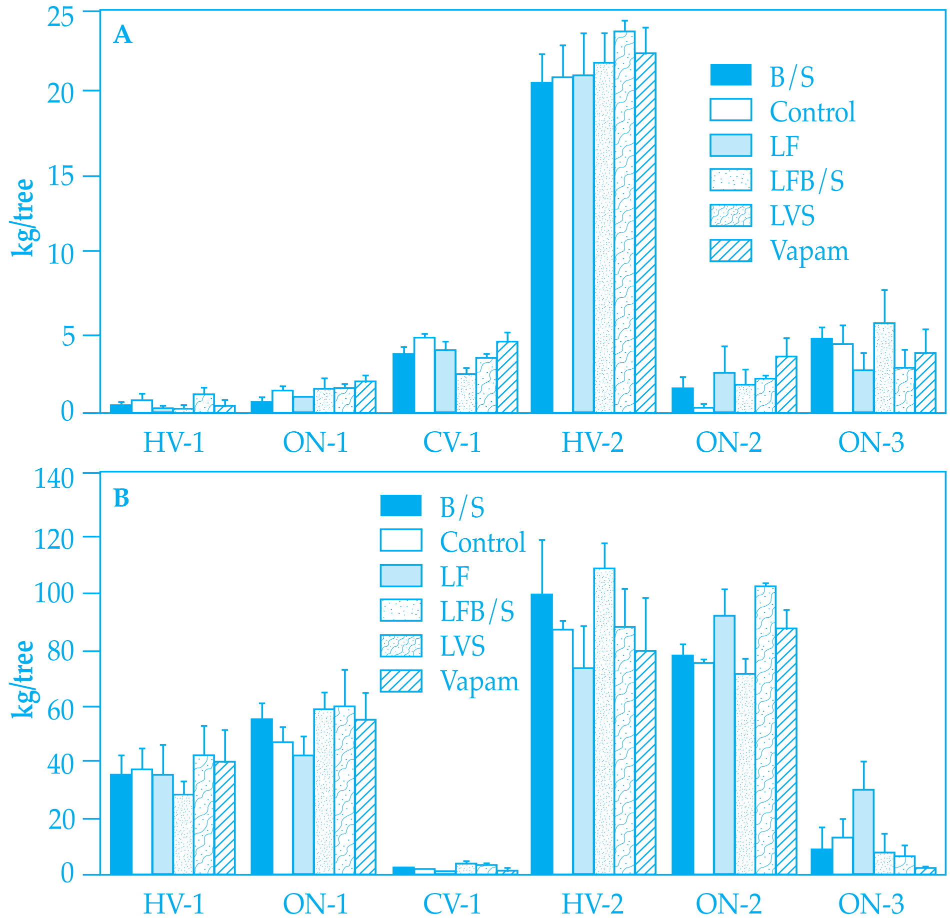

Figure 4A-B. Cumulative yield (kg/tree) harvested as of Fall 2000 in 12 NY orchards following six different preplant soil treatments in 1996 (lower graph) and 1997 (upper graph).

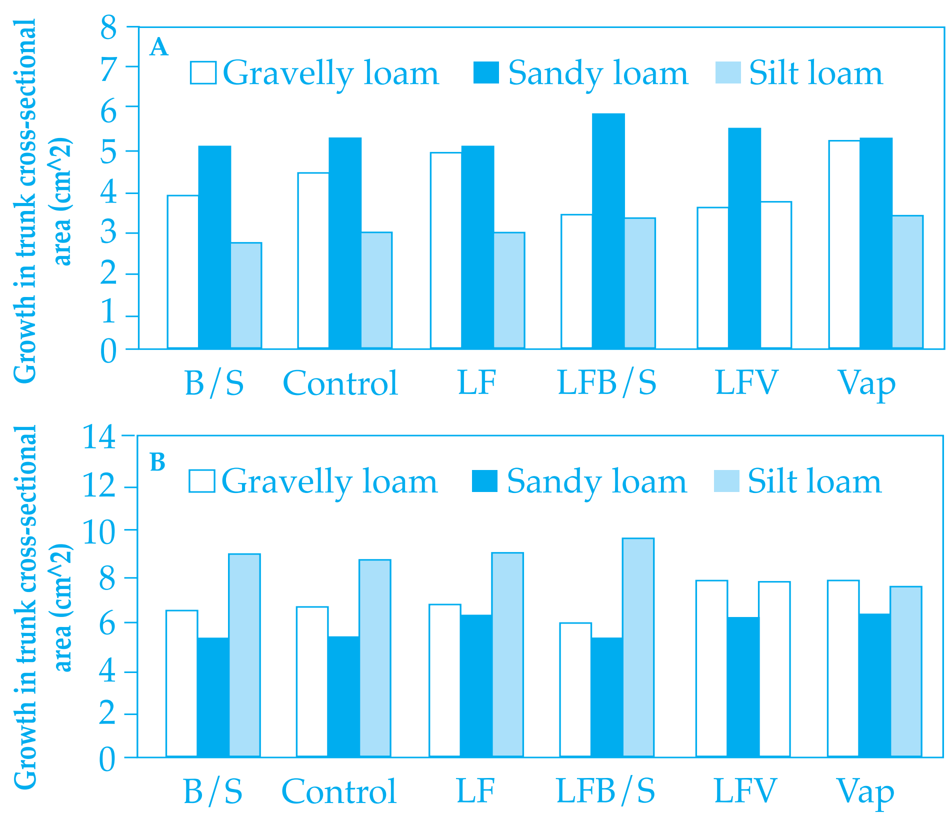

Figure 5A-B. Apple tree growth (cm² of trunk cross-sectional area) following different preplant treatments in 1996 and 1997, grouped by orchard soil type.

ERRATA: Merwin article, New York Fruit Quarterly, Volume 9, Number 1(SPRING 2001 Issue)

Corrections for the previous article by Merwin et al. on “Integrated Diagnosis and Control of Apple Replant Problems”: The farm identification abbreviations in Figures 3-B, 3-C and 4-A were mistakenly altered in printing, and should have been as follows:

Figure 3-B: (from left to right) CV-2, ON-4, HV-3, LI-1, HV-4, and ON-6.

Figure 3-C: (left to right) CV-3, HV-5, ON-8, and ON-9.

Figure 4-A: (left to right) CV-2, ON-4, HV-3, LI-1, ON-5, and ON-6.

We regret any confusion this may have caused our readers.