Management of Nitrogen and Calcium in Pear Trees for Enhancement of Fruit Resistance to Postharvest Decay

David Sugar[1],
Timothy L. Righetti[2],
Enrique E. Sanchez[3], and
Habib Khemira[2]

Additional index words. Pyrus communis, blue mold, side rot, *Penicillium expansum, Phialophora malorum*

Summary. Management of pear (*Pyrus communis* L.) trees for low N and high Ca content in the fruit reduced the severity of postharvest fungal decay. Application of N fertilizer 3 weeks before harvest supplied N for tree reserves and for flowers the following spring without increasing fruit N. Calcium chloride sprays during the growing season increased fruit Ca content. Nitrogen and Ca management appear to be additive factors in decay reduction. Fruit density and position in the tree canopy influenced their response to N fertilization. Nitrogen : Ca ratios were lower in fruit from the east quadrant and bottom third of trees and from the distal portion of branches. High fruit density was associated with low N : Ca ratios. Nutritional manipulations appear to be compatible with other methods of postharvest decay control.

[1]Southern Oregon Experiment Station, Oregon State University, 569 Hanley Road, Medford, OR 97502.

[2]Department of Horticulture, Oregon State University, Corvallis, OR 97331.

[3]INTA Alto Valle, Casilla de Correo 782, 8332 General Roca, Rio Negro, Argentina.

Postharvest decay in pear and other fruit crops is a major source of financial loss for producers. Postharvest fungicide application is common, but chemical options have been reduced in recent years by the withdrawal of certain fungicides for postharvest use and exclusion of fungicide-treated produce from certain markets (Willett and Kupferman, 1991). Furthermore, fungicide resistance has been encountered in target pathogens (Bertrand and Saulie-Carter, 1978), and some postharvest diseases (e.g., mucor rot, side rot) are not controlled by any currently registered fungicide (Jones and Aldwinkle, 1990). To control postharvest decay of pome fruits satisfactorily, a control strategy must be developed in which diverse cultural, biological, and chemical practices are integrated. We have been studying how management of the N and Ca contents of pear fruit can alter their susceptibility to postharvest fungal decay.

Nitrogen and Ca nutrition influence the quality of pome fruits in several ways. Many physiological disorders in pears and apples are related to both their N and Ca status. Pears with excessive N and insufficient Ca (high N: Ca ratio) are prone to cork spot (Curtis et al., 1990; Raese, 1986; Shear, 1974) and alfalfa greening (Raese, 1986). High fruit N has been associated with increased susceptibility to fungal decay in apple (Sharples, 1980; Wallace, 1953). Severity of blue mold decay of apples is reduced by postharvest infiltration with $CaCl_2$ solutions (Conway, 1982; Conway and Sams, 1983).

Although traditional application of N either before or soon after bloom is effective in promoting tree growth, environmental concerns about nitrate pollution and water quality may necessitate changes in current fertilizer practices. If alternative N management strategies can both lessen environmental impact and improve postharvest fruit quality, growers will have an economic incentive to use them. Relatively high N levels in pear flower buds may be valuable in promoting fruit set (Khemira, 1991; Williams, 1965), but high N available for vegetative growth may promote physiological disorders (Bramlage and Drake, 1980; Raese, 1986) and increase susceptibility to fire blight (van der Zwet and Keil, 1979). High-N pear fruit generally are more prone to storage disorders and, as found in our study, may be more susceptible to postharvest decay.

Strategies for the enhancement of fruit Ca have been developed for reducing disorders and improving decay resistance (Conway and Sams, 1983; Raese, 1986; Sugar et al., 1991a). It is important to determine how both the N and Ca status of fruit influence decay severity as either independent or combined factors in a management scheme.

Variability in fruit mineral concentration among individual pear fruit from a given orchard may be high (Curtis et al., 1990). Several-fold differences in fruit mineral concentrations also are found among fruit within individual pear (Sanchez et al., 1991b) and apple trees (Wilkinson and Perring, 1961). Since decay usually affects only a small percentage of the total fruit, the amount of fruit that is low or high in either N or Ca is more important than the mean N and Ca concentrations for an orchard. There is some evidence that mean concentrations do not predict clearly the actual number of fruit with either high or low mineral concentrations (Curtis et al., 1990). Understanding the nature and causes of fruit N and Ca variability could assist the development of management techniques to limit the number of high-N–low-Ca fruit and of sampling procedures to accurately quantify the incidence of high-risk fruit.

There are vast differences in the mineral content of fruit depending on their location within the canopy of an individual tree (Jackson et al., 1971; Sanchez et al., 1991a). Specific subgroups of the overall population of fruit on a given tree may respond differently to orchard management than other subgroups. It may be important to develop strategies that address certain categories of fruit within a tree canopy and understand that not all fruit respond similarly. Fruit N and Ca status and the pattern of fruit distribution within tree canopies are manipulable. Different rates and timings of N fertilizers can be used, Ca sprays can be applied, and training or thinning procedures can alter fruit distribution.

Alternate N strategies

It has been demonstrated with labeled N fertilizer that some tree parts depend more on newly acquired N than others (Fig. 1). Fruit, leaves, and
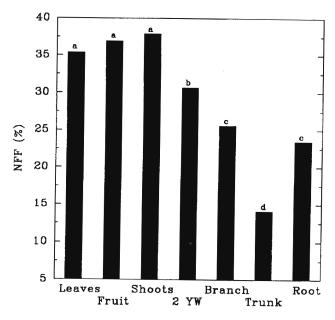
Fig. 1. *Percentage of total N from the labeled fertilizer (NFF) in different components of Comice' pear trees at the end of the growing season. Fertilizer N was applied 1 month after full bloom. 2 YW = 2-year-old wood. Adapted from Sanchez et al. (1991b).*
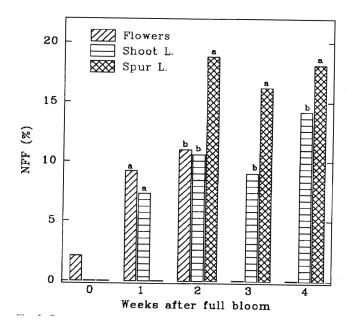

Fig. 2. *Percentage of total N from the labeled fertilizer (NFF) in flowers and spur and shoot leaves of 'Comice' pear trees. Fertilizer N was applied 1 month before bloom. Different letters denote significant differences at P < 0.05. From Sanchez et al. (1990b).*

1-year-old wood contained large amounts of labeled N following traditional spring application. Other tree parts contained substantially less labeled N. Even though pears require only small amounts of exogenous N during the growing season (Sanchez et al., 1991b), an adequate N supply during the first period of growth is essential. Although exceptions may occur on sandy soils under warm spring conditions (Sanchez et al., 1990b), it appears that spring-applied N does not reach flower buds until well after full bloom (Fig. 2). Flower development and early growth of vegetative tissues depend almost entirely on stored N.

Beneficial effects of late-spring N fertilizer applications on yield are likely due to a buildup of tree reserves that provide N for flower buds the following spring. To achieve relatively low N levels during the period of rapid shoot growth and fruit enlargement, N management strategies must consider the role of tree reserves. Reserves can be enhanced without the deleterious consequences of large, early spring N applications. Considering the ease with which tree N levels may be increased, there is probably a greater risk of physiological disorders and lowered productivity due to excess N fertilization than to N deficiency.

In an experiment using 'Bosc' pear trees grafted on 'Old Home × Farmingdale 333' rootstock, N was applied to the soil either 1 month before harvest or at harvest (Fig. 3). The percentage of N from preharvest fertilizer applications found in leaves and fruit was drastically less than that found following spring applications (Fig. 1). At the same time, the percentage of N from the fertilizer in flower buds was similar to spring applications (Sanchez et al., 1990b). 'Cornice' pear trees on quince rootstock respond similarly (Sanchez et al., 1992). Harvest and postharvest applications result in more N being partitioned to roots and less N available to developing flower buds. For applied N to reach the flower buds in early spring of the following year, N must be applied at least 3 weeks before harvest.

Postharvest foliar urea sprays may provide another tool to build reserves while avoiding excessive vegetative growth and high N fruit. A single postharvest spray of 5% or 10% urea increases the N concentration in 1-year-old wood, flower buds, and flowers in the spring following treatment (Sanchez et al., 1990a). It may be possible to reduce or eliminate spring-applied N and still build reserves with a combination of relatively small late-season, soil-applied N and postharvest foliar urea applications.

The above procedures could serve to 1) increase N reserves in the roots and above-ground structures of the tree, 2) provide adequate N to flower buds for strong fruit set, 3) avoid high-N fruit, 4) prevent excessive shoot growth, and 5) allow more efficient use of applied N. Spring N applications are most appropriate in situations where vigor is insufficient.

Nitrogen management and decay

To evaluate the effects of the timing of N application on postharvest fruit decay, mature fruit were collected from 'Comice' pear trees that had been fertilized with ammonium nitrate at various times of the year. Fruit from each treatment were surface-sterilized, wounded with a sterile finishing nail, and dipped in a suspension of *Penicillium expansum* spores (10^4 spores/ml). The fruit were stored in air at −1C. After 2 months the fruit were removed from storage and the diameter of each lesion was measured. Lesion diameter is an indicator of disease severity and reflects the relative resistance of the fruit cortical tissues to fungal decay.

In each of 3 years of testing, blue mold was more severe in fruit from trees receiving soil-applied N 3 weeks pre- or postbloom than in fruit from trees fertilized later in the season or from unfertilized trees (Table 1). Application of ammonium nitrate 6 weeks before harvest resulted in an average reduction in decay severity of 26.2%
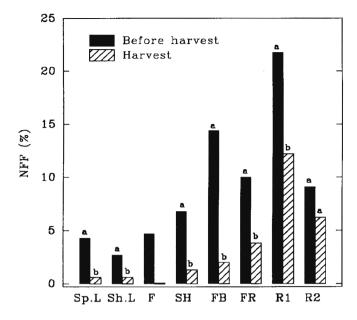
Fig. 3. *Percentage of total N from the labeled fertilizer (NFF) in different components of 'Bosc' pear trees when applied 1 month before harvest or at harvest. Sp.L = spur leaves; Sh.L = shoot leaves; F = fruit; SH = 1-year-old shoots; FB = flower buds; FR = frame; R1 = roots <1 cm in diameter; R2 = roots >1 cm in diameter. Different letters denote significant differences at P < 0.05. From Sanchez et al. (1992).*
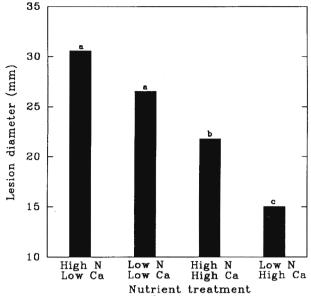

Fig. 4. *Effects of nutrient management in 'Bosc' pear on susceptibility of fruit to postharvest decay by Penicillium expansum. High N = fertilized annually 3 weeks postbloom; low N = 2 years without N, then fertilized 1 month preharvest; high Ca = three sprays of $CaCl_2$ (6 g Ca/liter) during the growing season; low Ca = no supplemental Ca.*

compared to prebloom application, over the three years of testing. Since N contents of fruit peel and cortex are correlated (Curtis et al., 1990; Sanchez et al., 1991a), mineral analyses were performed only on peels. The peel N content was higher in fruit from pre- or postbloom-fertilized trees than in fruit from trees fertilized later in the season (Table 1).

Calcium sprays and decay

The benefits of spray applications of $CaCl_2$ to 'Bosc' pear trees for reduction of postharvest fungal decay have been evaluated over several years (Sugar et al., 1991a). Incidence of side rot from natural infection by *Phialophora malorum* was reduced by three midsummer sprays of 1.2, 3.6, or 6.0 g Ca/liter applied by handgun to run-off. Leaf tip and margin burn, ranging from mild to moderate, resulted from the spray treatments, but the fruit surface was not affected by the treatments. The naturally russeted surface of 'Bosc' pear allows use of relatively high rates of $CaCl_2$ that might cause undesirable russet on green-skinned pear cultivars. Analyses of fruit peel mineral contents indicated that Ca contents were significantly increased by $CaCl_2$ sprays containing at least 1.2 g Ca/liter (Table 2).

Side rot severity was measured in fruit from pear trees sprayed with $CaCl_2$

during the growing season. Fruit were wound-inoculated postharvest with spores of *Phialophora malorum* (10^5 spores/ml) and stored for 4 months at 0C. The mean side rot lesion diameter was reduced 22.1% and 27.7% by spray treatments at 3.6 and 6.0 g Ca/liter, respectively, compared to nonsprayed controls (Table 2).

Integration of N management and Ca sprays

Based on the understanding of the distribution of fertilizer N in the pear tree presented above (Sanchez et al., 1991b, 1992), a plot was established at the Southern Oregon Experiment Station in which replicate blocks of 'Bosc' pear trees were managed for high or low fruit N. High fruit N blocks were fertilized annually 3 weeks postbloom, while low fruit N blocks

were not fertilized for 2 years, then received a N fertilizer application ≈ 1 month before harvest in the third year. Within each replicate of each N management block, a subgroup of trees received three summer sprays of $CaCl_2$ at 6.0 g Ca/liter, while the remaining trees received no $CaCl_2$. After harvest, fruit from each treatment were wound-inoculated with *Penicillium expansum* (10^4 spores/ml). Lesion diameters were measured after 2 months of storage at 0C.

Disease severity was reduced by ≈ 50% in fruit from low-N blocks with summer $CaCl_2$ sprays compared to fruit from high-N blocks without $CaCl_2$ sprays (Fig. 4). Nitrogen management and Ca enrichment appear to be additive factors in reducing blue mold severity in 'Bosc' pears (Sugar et al., 1991b).

Table 1. *Effect of timing of soil application of ammonium nitrate on 'Comice' pear fruit N concentration and severity of postharvest fruit decay by Penicillium expansum.*

Timing of	Fruit N (%)	Lesion diam (mm)[z]		
N application	1989	1989	1990	1991
Prebloom	0.49 a	40 a	19 a	20 a
Postbloom	0.54 a	39 a	18 a	19 a
6 Weeks preharvest	0.43 b	33 b	11 b	17 b
3 Weeks preharvest	0.42 b	33 b	12 b	17 b
No N	0.42 b	33 b	12 b	18 b

[z]*Values in the same column followed by the same letter are not significantly different by Duncan's new multiple range test (P = 0.05).*

Table 2. *Effect of three sprays of CaCl$_2$ during the growing season on severity of side rot in 'Bosc' pears.*[z]

Spray concn (g Ca/liter)	Peel Ca concn (ppm dry wt)	Lesion diam[y] (mm)
0	1540 a	151 a
1.2	1950 b	131 a
3.6	2040 b	92 b
6.0	2450 c	80 b

[z]*Adapted from Sugar et al. (1991a).*
[y]*Values in the same column followed by the same letter are not significantly different by Duncan's new multiple range test (P = 0.05).*

Compatibility of nutritional decay prevention with other decay control methods

A valuable aspect of nutritional management of postharvest fungal decay of fruit is that nutritional techniques appear to be compatible with other methods of decay control. Calcium chloride sprays on apples during the growing season do not affect the efficacy of biocontrol of *Botrytis cinerea* by the yeast *Cryptococcus laurentii* (Roberts and Raese, 1990). Nitrogen and Ca management are additive factors in the control of *Penicillium expansum* and *Phialophora malorum* rots of pears by C. *laurentii* (Sugar et al., 1991b). The postharvest application of fungicides for control of decay fungi should be compatible with nutritional management in the orchard. Techniques for producing low-N–high-Ca fruit have been combined successfully with management of fruit maturity at harvest, postharvest yeast treatment, and controlled-atmosphere storage in an integrated decay control program (D. Sugar, unpublished data).

Nutritional aspects of fruit distribution within tree canopies

In 'Comice' pear trees managed for high or low fruit N, data were collected on individual fruit with respect to their location in the tree canopies (Sanchez et al., 1991a). All fruit from two low- and two high-N trees were harvested and the position in the canopy of each individual fruit was recorded. The level of the branch bearing each fruit was placed into one of three categories: bottom, middle, or top third of the main trunk. The fruit position on each branch also was placed into one of three categories:

proximal, middle, or distal third. The distance to the nearest adjacent fruit on the same branch and whether more than one fruit was borne on the same spur were recorded. This procedure was carried out in each of four quadrants (north, south, east, and west) of each tree. All fruit were weighed and analyzed for N and Ca concentration in the peel. For simplicity, only comparisons where fruit density differed greatly (proximal vs. distal, top vs. bottom, and west vs. east) are represented here.

Average leaf and fruit N concentrations and fruit weights were similar for the four trees. There were no significant differences in fruit weight or N or Ca concentrations between single- and double-fruited spurs. Although significant, correlations between fruit weight and Ca concentration were low ($r^2 < 0.16$). The N concentrations of individual fruit were not related to fruit size. However, N and Ca concentrations and fruit size were larger in the high-N treatment (Table 3). Fruit N increased more than fruit Ca in high-N trees, thus the N : Ca ratio was higher.

Differences in mineral content due to canopy location were also apparent (Table 3). Nitrogen concentration and N : Ca ratio were significantly different for position, level, and orientation categories. Calcium concentration was significantly different for west and east orientations. If fruit in all categories are assigned into high-density (>40% of fruit in category) or low-density (<25% of fruit in category) groups, fruit weight, Ca concentration, and N

: Ca ratio are significantly different. In all cases, the category with the lowest fruit density had larger fruit, less Ca, and more N.

Nitrogen and Ca behave differently in pear trees. In areas of dense fruiting, N concentrations are diluted. For example, although there was three times more fruit in distal than in proximal positions and the collective N concentration of all fruit in distal positions was much higher, individual fruit concentrations were less. In contrast, individual fruit from denser areas had more Ca than those from less-dense areas. The relationship of Ca concentration to crop density is consistent with the concept that a smaller leaf : fruit ratio leads to more fruit Ca (Schumacher et al., 1978; Shear, 1980)..

Location vs. N treatment interactions (Fig. 5) indicated that treatment effects were not evenly distributed in the tree canopy. Although proximal and distal fruit responded similarly to N treatment, this was not the case with fruit from different levels or orientations. In top and bottom or west and east categories, treatment effects were much less apparent in the more densely fruited category (bottom and east). The N : Ca ratios of fruit in the east quadrant or in the bottom third of the trees were relatively unaffected by N treatment. These data may have practical implications. In canopy regions where fruit are sparse, individual fruit N concentrations are likely to be relatively high and Ca concentrations low. Those regions consequently are the most susceptible to the undesirable

Table 3. *Effects of fruit location within a tree canopy (orientation, level, and position) and tree N status on fruit weight, peel Ca, and peel N in 'Comice' pears.*

Location/ N status	Fruit wt (g)	Fruit in category (%)	Peel Ca (ppm)	Peel N (%)	N : Ca
Orientation					
West	235 a[z]	18 a	990 a	0.53 a	5.3 a
East	226 a	40 b	1060 b	0.48 b	4.5 b
Level					
Top	244 a	23 a	990 a	0.52 a	5.3 a
Bottom	227 a	48 b	1000 a	0.49 b	4.9 b
Position					
Proximal	250 a	14 a	1020 a	0.54 a	5.3 a
Distal	225 a	43 b	1050 a	0.50 b	4.8 a
N status					
High	242 a		1100 a	0.58 a	5.3 a
Low	221 a		950 b	0.44 b	4.6 b

[z]*Values followed by the same letter for the two orientation, level, position, or N status categories are not significantly different (P < 0.05).*
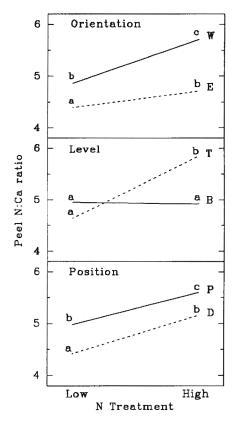
Fig. 5. *Effects of fruit location within a tree canopy on peel N : Ca ratio for low- and high-N 'Comice' pear trees. Values followed by the same letter for orientation, level, or position category are not significantly different (P < 0.05). W = west quadrant; E = east quadrant; T = top third of tree; B = bottom third of tree; P = proximal third of branch; D = distal third of branch. Adapted from Sanchez et al. (1991a).*

effects of excessive N in the tree. There may be advantages to cultural practices that equalize fruit distribution throughout the tree and avoid sparsely fruited canopy regions.

Although N management effects may differ for canopy locations with varying fruit density, it is unclear whether Ca sprays have uneven effectiveness. Since Ca concentrations in fruit are extremely variable, it is difficult to distinguish if spray treatments uniformly increase Ca concentrations. Preliminary data on Ca : Sr ratios of fruit in trees sprayed with a mixture of Ca and Sr salts indicate that fruit Ca enhancement is relatively uniform throughout the canopy (T.L.R., unpublished data).

Conclusions

Alternate N fertilization strategies for pear include late-season ground application and supplementary foliar urea sprays, partially or entirely replacing spring application. These practices

likely can build tree reserves, produce high-N buds in the spring, minimize groundwater pollution, avoid excessive vigor, and produce fruit with lower N concentrations. If these evolving N management strategies can reduce postharvest decay consistently (as shown here), growers will have an economic incentive and environmental motives to use them. Fruit that are distributed differently throughout the tree respond differently to N fertilization, thus canopy management practices also may be important in decay prevention. Calcium sprays reduce postharvest decay, and these effects are additive when combined with fertilizer management for low fruit N. These nutritional decay prevention techniques also appear compatible with other decay control methods. Although any individual component of a comprehensive decay management strategy may not provide satisfactory disease control, the cumulative effects from diverse practices should contribute to the stability and dependability of control.

The specific N and Ca manipulations described as beneficial in this paper may not be advantageous for all tree fruit types or cultivars. Phytotoxic responses to $CaCl_2$ sprays vary widely, and some fruit types (e.g., apples) are able to take up significant amounts of Ca from briefpostharvest dips (Conway and Sams, 1983). Peaches sprayed with $CaCl_2$ during the growing season have increased fruit Ca but are not more resistant to postharvest infection by *Monilinia Fructicola* (brown rot) than nonsprayed fruit (Conway et al., 1987). Furthermore, trees in various conditions do not respond uniformly to variations in timing of N application. For example, vigorous, large 'Anjou' pear trees with substantial N reserves growing on fertile soil in central Washington have not produced low-N fruit when fertilized preharvest as compared to spring-fertilized trees (T. Smith, Washington State Univ., personal communication). We hypothesize that large trees with substantial N reserves may be difficult to manipulate by altering the timing of fertilizer application.

Literature Cited

Bramlage, W.J. and K. Drake. 1980. Influence of mineral nutrition on the quality and storage performance of pome fruits grown in North America, p. 29-39. In: D. Atkinson, J.E. Jackson, R.O. Sharples, and W.M. Waller (eds.). Mineral nutrition of fruit trees. Butterworths, London.

Bertrand, P.F. and I. Saulie-Carter. 1978. The occurrence of benamyl-tolerant *strains of Penicillium expansum and Botrytis cinera* in the Mid-Columbia Region of Oregon and Washington. Plant Dis. Rptr. 62:302-305.

Conway, W.S. 1982. Effect of postharvest calcium treatment on decay of Delicious apples. Plant Dis. 66:402-403.

Conway, W.S. and C.E. Sams. 1983. Calcium infiltration of Golden Delicious apples and its effect on decay. Phytopathology 73: 1068-1071.

Conway, W.S., G.M. Greene, and K.D. Hickey. 1987. Effect of preharvest and postharvest calcium treatments of peaches on decay caused by *Monilinia fructicola.* Plant Dis. 71:1084-1086.

Curtis, D., T.L. Righetti, E. Mielke, and T. Facteau. 1990. Postharvest mineral analysis of corkspotted and extra fancy 'Anjou' pears. J. Amer. Soc. Hort. Sci. 116:969-974.

Jackson, J.E., R.O. Sharples, and J. W. Palmer. 1971. The influence of shade and within-tree position on apple fruit size, colour, and storage quality. J. Hort. Sci. 46:277-287.

Jones, A.L. and H.S. Aldwinkle (eds.). 1990. Compendium of apple and pear diseases. APS Press, St. Paul.

Khemira, H. 1991. Influence of canopy orientation on fruiting of 'Anjou' pears and postharvest urea spray on ovule longevity and fruit set of 'Cornice' pears. MS Thesis, Oregon State Univ., Corvallis.

Raese, J T. 1986. Nitrogen and calcium important in determining yield, fruit quality, and disorders of 'Anjou' pears, p. 156-168. In: Pear production in the Pacific Northwest. Washington State Univ. Shortcourse Proc.

Roberts, R. G. and J. T. Raese. 1990. Effect of apple fruit tissue calcium on postharvest biocontrol efficacy of *Cryptococcus laurentii* against *Botrytis cinerea.* Phytopathology 80:1050. (Abstr.)

Sanchez, E.E., T.L. Righetti, D. Sugar, and P.B. Lombard. 1990a. Response of 'Comice' pear trees to postharvest urea spray. J. Hort. Sci. 65:541-546.

Sanchez, E.E., T.L. Righetti, D. Sugar, and P.B. Lombard. 1990b. Seasonal differences and soil texture alter uptake of newly absorbed nitrogen in field-grown pear trees. J. Hort. Sci. 65:395-400.

Sanchez, E.E., T.L. Righetti, D. Sugar, and P.B. Lombard. 1991a. Nitrogen variability among 'Cornice' pear fruits from trees having high and low nitrogen status. J. Hort. Sci. 66:43-50.

Sanchez, E.E., T.L. Righetti, D. Sugar, and P.B. Lombard. 1991b. Recycling ofnitrogen in field-grown 'Cornice' pears. J. Hort. Sci. 66:479-486.

Sanchez, E.E., T.L. Righetti, D. Sugar, and P.B. Lombard. 1992. Effects of timing of nitrogen application on nitrogen partitioning between vegetative, reproductive, and structural components of mature 'Cornice' pears. J. Hort. Sci. 67:51-58.

Schumacher, R., F. Fankhauser, and W. Stadler. 1978. Mineralstoffgehalte und Stippeanfalligkeit von Apfeln in Abhangigkeit von ihrer Ansatzstelle in der Baumkrone. (Mineral nutrient contents and susceptibility of apples depending on their position in the canopy.) Schweiz. Z. Obst-u. Weinb. 113:295-303.

Sharples, R.O. 1980. The influence of orchard nutrition on the storage quality of apples and pears grown in the United Kingdom, p. 17-28. In: D. Atkinson, J.E. Jackson, R.O. Sharples, and W.M. Waller (eds.). Mineral nutrition of fruit trees. Butterworths, London.

Shear, C.B. 1974. Interaction ofcalcium and nitrogen and time of calcium availability in relation to the development of apple disorders. Proc. 7th Intl. Colloq. Plant Analysis Fertil. Problems, Hanover, German Soc. Plant Nutr. p. 427-436.

Shear, C.B. 1980. Interaction of nutrition and environment on mineral composition of fruits, p. 40-50. In: D. Atkinson, J.E. Jackson, R.O. Sharples, and W.M. Waller (eds.). Mineral nutrition of fruit trees. Butterworths, London.

Sugar, D., K.A. Powers, and R.J. Hilton. 1991a. Enhanced resistance to side rot in pears treated with calcium chloride during the growing season. Plant Dis. 75:212-214.

Sugar, D., R.G. Roberts, R.J. Hilton, E.E. Sanchez, and T.L. Righetti. 1991b. Effects of fruit nutrient management and postharvest yeast application on fungal decay in pear. Phytopathology 81:1163. (Abstr.)

van der Zwet, T. and H.L. Keil. 1979. Fire blight, a bacterial disease of rosaceous plants. U.S. Dept. Agr. Sci. & Educ. Admin. Agr. Hdbk. 510.

Wallace, T. 1953. Some effects of orchard factors on the quality and storage properties of apples, p. 140-161. In: Science and fruit. Univ. of Bristol, U.K.

Wilkinson, B.G. and M.A. Perring. 1961. Variation in mineral composition of Cox's Orange Pippin apples. J. Sci. Food Agr. 12:74-80.

Willett, M.J. and E.A. Kupferman. 1991. Management of postharvest diseases and disorders. Tree Fruit Postharvest J. 2(2):14.

Williams, R.R. 1965. The effect of summer nitrogen applications on the quality of apple blossoms. J. Hort. Sci. 40:31-41.