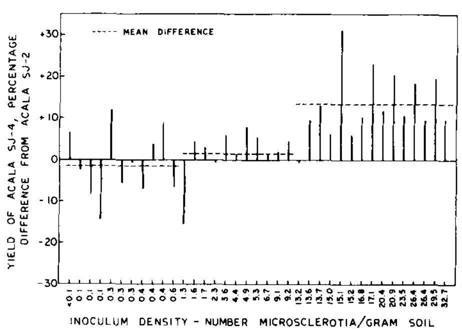

Fig. 2. Comparative yields of Acala SJ-2 and SJ-4 cotton in 37 commercial plantings as affected by natural infestations of wilt fungus microsclerotia.

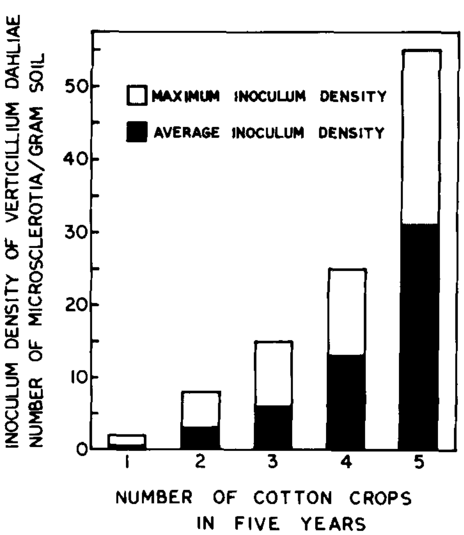

Fig.3. Influence of cotton cropping on buildup of wilt fungus inoculum in soil.

cotton, called 70-110, with moderately tolerant Acala SJ-2 and with even more tolerant varieties Acala SJ-4 and SJ-5 in soil with different inoculum levels. In 1976, yields of 70-110 and Acala SJ-2 decreased with each increase in inoculum density between 1.7 and 20.9 MS/g soil, but yields of the more tolerant varieties, Acala SJ-4 and SJ-5, were unaffected even at the greatest inoculum density (table 1). The variety 70-110 yielded as well as the others at 1.7 and 3.6 MS/g soil but only as well as Acala SJ-2 at 15.2 MS/g soil.

Although Acala SJ-2 yielded as well as Acala SJ-4 at 15.2 MS/g soil in this test, results of 37 comparisons made of the two varieties in commercial fields showed that SJ-4 out-yielded SJ-2 by an average of 13 percent at inoculum densities greater than 9 to 13 MS/g soil. On the other hand, yield of Acala SJ-4 was only about 3 percent greater at inoculum densities below 9 to 13 MS/g soil (fig. 2). Because Acala SJ-4 and Acala SJ-5 are, respectively, fourth and fifth generation descendents of the same parents, the differences between SJ-2 and SJ-4 should be applicable to SJ-2 and SJ-5, which completely replaced SJ-4 as the wilt-tolerant variety in 1979.

The overall average amount of inoculum in San Joaquin Valley cotton soils appears to be relatively stable. For instance, the average inoculum density of 40 fields assayed in 1971 was 7.4 MS/g soil; the maximum inoculum density was 47 MS/g soil, but about 75 percent of fields had fewer than 6 MS/g soil. Similar results were obtained in assays of 120 fields in 1977; the average inoculum density was 5.3 MS/g soil, and about 75 percent of fields had fewer than 6 MS/g soil. These observations probably explain why Acala SJ-2, only moderately tolerant of Verticillium wilt, occupies about 80 percent of San Joaquin Valley acreage: it commonly outyields more tolerant varieties in mild wilt situations.

The importance of cotton in increasing inoculum levels was shown when inoculum densities of 52 fields in 1979 were related to the number of cotton crops grown in the previous five years. The average amount of inoculum approximately doubled with each cotton crop grown in addition to one in five years (fig. 3). Thus, monoculture or near monoculture cropping of cotton (fields 1 to 4, table 2), resulted in unacceptably high levels of inoculum except for highly tolerant cotton varieties.

Cotton culture results in the greatest increase of new inoculum, because microsclerotia form only in moist, dead, infected tissue during cool weather. On the other hand, inoculum buildup is not favored in tissue of susceptible crops such as potato, tomato, melons, and safflower harvested in hot weather. In the San Joaquin Valley, decrease of inoculum when these crops are grown is similar to that when fields are fallowed. Therefore, the rotations for fields 5 to 8 in table 2 kept inoculum levels low enough so that a cotton variety such as Acala SJ-2 could be grown successfully.

None of these rotations can be considered as consistent recipes for success, however, because inoculum buildup following a cotton crop varies from field to field and year to year. Major differences may occur between average and maximum inoculum densities (fig. 3). Therefore, inoculum levels in each field must be determined.

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Combination recommended

Don A. Edwards

Leaf curl was related to vigorous shoot growth rather than rootstock and did not affect yield or fruit characteristics.

# of pear rootstocks for new Bartlett plantings

William H. Griggs □ James A. Beutel
William O. Reil □ Ben T. Iwakiri


Don A. Edwards

Normal Bartlett shoot. Most trees in plot developed leaf curl each fall.

When the 'Bartlett' pear rootstock plot was established at the Deciduous Fruit Station at San Jose, California, in 1964, the relationship between type of rootstock and susceptibility to pear decline, a disease transmitted by the pear psylla *(Psylla pyricola* Foerster), was well established. Since Bartlett trees that had become scion rooted (developed large roots above their bud unions) showed resistance to decline, a possible alternative to using rootstocks was to grow own-rooted Bartlett trees developed from cuttings.

The San Jose plot was set up to determine the influence of apparently decline-tolerant rootstocks on growth, bloom, yield, disease resistance, survival, and various fruit characteristics of the Bartlett scion, and to compare these factors with those of own-rooted Bartlett trees. The plot consisted of a replicated planting of 200 Bartlett trees, 20 with each of nine different kinds of rootstocks, and 20 own-rooted Bartlett trees for controls. The trees were set 10 feet apart in rows 10 feet apart.

The 100 seedling trees and 20 of the own-rooted 'Old Home' trees were top-grafted 1 foot above the ground with Bartlett scions from a single clone during March 1964. The remaining 20 own-rooted Old Home trees were headed at 30 inches above the ground and allowed to develop scaffold branches during the 1964 growing season. During February 1965, four to five scaffold branches on each of these trees were grafted 3 to 5 feet above the ground with Bartlett scions, producing a Bartlett tree with fire blight (*Erwinia amylovora* Burrill, Winslow *et al.*) resistant trunk and scaffold branches. Bartlett is very susceptible to fire blight, and Old Home is highly resistant.

Trees that died were replaced, but replants were not used in the experiment. Yields and other measurements presented in the tables are averages for the survivors of the original 20 trees of each type.

Trunk and shoot growth

The trees were relatively uniform in trunk circumference at planting. By December 1966 and for the next 10 years, the trees with the largest trunk circumferences were Bartlett on Old Home roots and trunks, Bartletts on Old Home roots, trunks, and scaffolds, and Bartletts on *Pyrus betulaefolia* Bunge seedlings. During this period, own-rooted Bartletts declined to sixth place in trunk circumference.

Trees with the greatest increases in trunk circumference also grew longer shoots. However, correlation coefficients revealed that the relationship was not consistent with all types of trees.

In years of normal production, trunk size and shoot growth were correlated with yield: the most vigorous trees generally gave the highest yields.

Bloom

No appreciable differences in bloom periods were noted under the usual range of chilling conditions, but after mild winters Bartlett on Old Home rootstocks bloomed about four or five days earlier than those on other rootstocks or own-rooted Bartlett. Trees with Old Home rootstocks were also more uniform in their stage of bloom than were the other trees.

Apparently, the Old Home roots and not the trunks were responsible for the influence on the chilling requirement of the Bartlett buds, because there were no appreciable differences in stage of bloom between Bartlett trees developed by top-grafting Old Home 1 foot above ground and those developed by top-grafting Old Home 3 to 5 feet above ground. Also, there was no comparable stimulation of bloom on the Bartlett trees with Provence quince roots and Old Home interstocks.

Yield and fruit characteristics

Own-rooted Bartlett trees were the most precocious, producing 20.2 pounds of pears per tree their fifth year in the orchard. Bartletts high-grafted on Old Home ranked second in early production. These trees were not top-grafted at planting, and evidently this gave them an early advantage. By 1970, however, there were no significant differences in the yields of these two types of trees and those of Bartletts low-grafted on Old Home or those of Bartletts with *P. betulaefolia* or 'Winter Nelis' seedling rootstocks.

The trees attained maximum production

in their ninth year (1973), relatively early for a Bartlett orchard. That year, the highest producing trees, Bartlett with *P. betulaefolia* rootstocks and own-rooted Bartletts, gave 112.3 and 92.5 pounds, respectively, per surviving tree. At the 10- by 10-foot planting distance, 435 trees per acre, these yields were equivalent to 24.4 and 20.1 tons per acre and were excellent for trees of this age. The average yield per acre for commercial Bartlett orchards in the state was 8.9 tons in 1973 and 10.1 tons for 1976.

The six-year average yields revealed that Bartletts with *P. betulaefolia* seedling rootstocks gave the best production. Following in order of yields are own-rooted Bartletts, Bartletts high-grafted on Old Home, Bartletts low-grafted on Old Home, and Bartletts with Winter Nelis seedling rootstocks.

The largest pears, by weight, were produced by own-rooted Bartlett trees and Bartletts with Winter Nelis, Kirschensaller, or *Pyrus calleryana* Decne. seedling rootstocks.

There was no significant correlation between individual fruit weight means and yield means for the different types of trees, except in the large crop of 1973.

Fruits from the 10 types of trees differed significantly in both length and width, but length varied more than width. Average fruit width, but not length, was significantly correlated with the average fruit weight.

The different rootstocks had striking effects on fruit shape. The most desirably shaped pears, especially for fresh fruit markets, have a length ranging from 1.2 to 1.5 times their width. Pears with length/width ratios below 1.2 tend to be apple-shaped and are less desirable than the longer ones. Pears from Bartlett trees with Old Home rootstocks or with Provence quince rootstocks and an Old Home interstock had significantly greater length/width ratios than pears from trees with *P. calleryana*, *P. betulaefolia*, Kirschensaller, or Angers quince rootstocks. Pears from trees with *P. calleryana* rootstocks were conspicuously short. Fruits from own-rooted Bartlett trees and Bartletts with Winter Nelis or Bartlett seedling rootstocks had intermediate length/width ratios.

Previous studies in California Bartlett orchards comparing fruit shape and seed content have been inconsistent. We found no significant correlation between the two characteristics.

Firmness and soluble solids content of pears indicate harvest maturity and quality. At harvest, the juice of Bartlett pears should have at least 10 percent soluble solids for the ripe fruits to be of acceptable dessert quality, and much better quality may be expected if the juice contains between 12 and 13 percent soluble solids. Pears with 11 percent soluble solids are considered ready to harvest at 20.5 pounds firmness.

Rootstocks apparently influenced the soluble solids content. Fruits from most trees averaged 12 percent or higher soluble solids, but fruits from trees with *P. betulaefolia* rootstocks were consistently lowest in soluble solids during each of the four years, averaging 11.6 percent. This would suggest a negative relationship between yield and soluble solids, but this theory was not supported by the data.

Evidently, the differences in fruit firmness at harvest were influenced by the type of root system or rootstock, since there was no significant correlation between average fruit firmness and yield of the different types of trees or between firmness and weight of their individual fruits.

At harvest, there were no significant differences in the color of Bartlett fruits from the different types of trees, but there were detectable differences in the amount of yellowing after the fruits were held three to four weeks at 32° F followed by five to six days at 68° F. Yellowing was delayed in fruits from trees with *P. calleryana*, *P. betulaefolia*, and Bartlett seedling rootstocks. The delay may be partly related to low soluble solids content or high fruit firmness, but when measurements of pears from all types of trees were included, there were no significant correlations between fruit color and fruit weight, firmness, or percentage of soluble solids.

Leaf curl

Trees in the plot showed severe symptoms of curl for the first time in October 1966. Over 90 percent of the trees had curl, and on most trees more than 25 percent of the leaves were affected. Curl symptoms were present in similar amounts each fall throughout the experiment. There were significant differences in the proportion of foliage affected with curl on the different types of trees in 7 of 11 years (1966-1976), but the relative amount of curl for a given type of scion-root system was not consistent from year to year.

There was a significant correlation between the six-year average curl ratings and the six-year average shoot lengths. It appears that vigorous shoot growth favors expression of curl symptoms, and that any apparent relationship between type of rootstock and the amount of foliage affected with curl may be explained by the influence of rootstock on tree vigor.

There was no significant correlation between the average curl ratings of the trees and their average yields or individual fruit characteristics at harvest.

Summary and conclusions

Trees with *P. betulaefolia* seedling rootstocks were the most vigorous and gave significantly higher average yields than the other types of trees. Their fruits, however, were only medium in size, were relatively short, and were lowest in soluble solids. Two trees were lost to severe fire blight infections in their eighth year in the plot.

Own-rooted Bartlett trees developed from cuttings yielded consistently large crops from a moderate amount of trunk and shoot growth. Their fruits were large, well-shaped, relatively firm at harvest, and among the highest in soluble solids. The Bartlett-rooted cutting produces an excellent tree with a well-anchored root system. One tree succumbed to fire blight infection in its eighth year in the plot.

Trees developed by top grafting own-rooted Old Home trees with Bartlett scions either 1 or 3 to 5 feet above the ground gave the highest rate (100 percent) of survival, apparently because of their vigor, resistance to pear decline, protection by the Old Home wood against severe blight infection, and resistance of the Old Home roots to oak root fungus. The Old Home-rooted cutting gives rise to a vigorous, well-anchored root system. The trees were productive, and their fruits, although medium in size, had excellent shape and contained high percentages of soluble solids. The Old Home rootstocks apparently reduced the chilling requirement of Bartlett buds and may be valuable in areas where production of Bartlett pears is limited by insufficient winter chilling.

Trees with Winter Nelis seedling rootstocks were moderately vigorous and productive, but had a poor survival record. Their fruits were large, well shaped, and high in soluble solids. Three trees were lost in their third year and another in its fifth year in the plot; pear decline and oak root fungus were at least partly responsible. A fifth tree succumbed to fire blight in its seventh year.

Trees with *P. calleryana* seedling rootstocks were vigorous and moderately productive but had a poor survival record. Four young trees were lost to pear decline and/or oak root fungus, and two older ones succumbed to fire blight. Fruits from these trees were large in weight and width but had the smallest length-to-width ratios. These stocks may have delayed fruit maturity somewhat, because the pears were relatively firm at harvest and below average in percentage of soluble solids.

Bartlett trees with Kirschensaller seedling rootstocks were vigorous, but production

TABLE 1. Effect of Rootstock on Yield of Bartlett Pear Trees Planted at San Jose, California, in 1964. (Trees set 10 feet by 10 feet)

Tree constitution	Yield per surviving tree of pears 2 3/8 inches in diameter or larger* 1968	1969	1970	1971	1972	1973	1974	1975	1976	6-year average yield 1971-'76	Equivalent yield per acre (435 trees per acre, 1971-'76 average)
	lb	*lb*	*lb*	*lb*	*lb*	*lb*	*lb*	*lb*	*lb*	*lb*	*tons*
BARTLETT SCION GRAFTED ON ROOTSTOCK:											
Pyrus betulaefolia Bunge seedlings	9.2 bc	7.8 bc	18.9 a	45.0 a	49.8 a	112.3 a	100.4 a	65.8 a	102.6 a	79.3 a	17.2
Old Home† (grafted 3 to 5 ft above ground)	14.1 ab	11.4 b	18.2 a	43.0 a	50.3 a	77.6 bc	75.3 bc	38.7 bc	77.7 b	60.4 bc	13.1
Old Home† (grafted 1 ft above ground)	7.7 c	6.9 c	17.9 ab	33.0 ab	58.4 a	78.9 bc	73.8 bc	30.0 c	67.7 b	57.0 bcd	12.4
Winter Nelis‡ seedlings	6.5 c	6.0 c	14.2 ab	18.4 bc	35.7 bc	64.0 cd	69.5 bcd	39.2 bc	67.2 b	49.0 bcde	10.7
Pyrus calleryana Decne. seedlings	7.2 c	8.9 bc	10.5 bc	16.1 c	34.2 bc	60.1 cde	54.6 cde	44.7 bc	61.0 bc	45.1 cde	9.8
Kirschensaller§ seedlings	4.1 d	2.4 d	7.5 cd	18.2 bc	32.0 bc	56.1 cde	60.8 bcd	35.2 c	63.6 b	44.3 de	9.6
Bartlett‡ seedlings	6.7 c	6.8 c	9.3 c	18.7 bc	22.8 cd	51.2 de	50.8 de	31.5 c	41.4 cd	36.1 ef	8.0
Provence quince** with Old Home interstock	5.4 cd	4.2 cd	7.8 cd	12.2 c	24.1 cd	36.8 e	37.8 e	11.0 d	29.0 de	25.1 fg	5.5
Angers quince** with Hardy‡ interstock	8.9 bc	1.5 d	5.6 d	16.5 c	11.7 d	13.9 f	12.3 f	8.6 d	12.2 e	12.5 g	2.7
CONTROL: Own-rooted Bartlett trees developed from cuttings	20.2 a	21.3 a	19.8 a	31.9 ab	45.9 ab	92.5 ab	78.2 b	56.7 ab	78.4 b	63.9 b	13.9

*Means followed by the same letter are not significantly different, Duncan's Multiple Range Test, 0.05 level.
†Own-rooted stocks developed from cuttings of *Pyrus communis* L. 'Old Home'.
‡Cultivar of *Pyrus communis*.
§'Kirschensaller Mostbirne', a strain of *Pyrus communis*.
**Cultivar of *Cydonia oblonga* Mill.

TABLE 2. Effect of Rootstock on Characteristics of Bartlett Pears Harvested at San Jose, California.

Tree constitution	Fruit measurements (1971-1974 averages)* Weight	Length	Width	Length/width ratio	Number of seeds per fruit	Soluble solids† At harvest	Soluble solids† After ripening	Firmness‡ At harvest	Firmness‡ After ripening	Color§ after ripening
	g	*mm*	*mm*			%	%	*lb*	*lb*	
BARTLETT SCION GRAFTED ON ROOTSTOCK:										
Pyrus betulaefolia Bunge seedlings	165.5 bc	76.6 d	66.5 ab	1.15 e	0.6 bc	11.6 e	12.3 d	19.6 bc	2.5 a	3.5 cd
Old Home** (grafted 3 to 5 ft above ground)	161.1 c	80.7 ab	64.6 c	1.25 a	1.2 a	12.2 bcd	12.9 bc	19.0 d	2.6 a	3.7 ab
Old Home** (grafted 1 ft above ground)	162.9 bc	81.4 a	64.8 c	1.26 a	0.7 abc	12.4 abc	13.0 bc	19.4 c	2.6 a	3.6 bcd
Winter Nelis†† seedlings	170.7 ab	80.2 b	66.2 ab	1.21 b	0.6 bc	12.4 abc	13.1 abc	19.5 c	2.4 a	3.6 bcd
Pyrus calleryana Decne. seedlings	168.3 abc	74.9 e	67.2 a	1.12 f	0.3 c	12.0 d	12.8 c	20.0 ab	2.6 a	3.4 d
Kirschensaller‡‡ seedlings	169.7 ab	78.8 c	66.5 ab	1.19 c	0.9 abc	12.0 d	12.7 c	19.8 abc	2.6 a	3.8 a
Bartlett†† seedlings	164.0 bc	78.4 c	65.4 bc	1.20 bc	1.0 ab	12.4 abc	13.2 ab	19.6 bc	2.5 a	3.5 cd
Provence quince§§ with Old Home interstock	165.8 bc	81.0 ab	65.0 c	1.25 a	0.9 abc	12.6 a	13.5 a	19.9 abc	2.5 a	3.8 a
Angers quince§§ with Hardy†† interstock	151.8 d	75.1 e	64.4 c	1.17 d	1.2 a	12.1 cd	13.4 a	20.0 ab	2.6 a	3.7 ab
CONTROL: Own-rooted Bartlett trees developed from cuttings	173.6 a	80.5 ab	66.4 ab	1.21 b	0.3 c	12.5 ab	13.3 ab	20.2 a	2.8 a	3.6 bcd

*Means followed by the same letter are not significantly different, Duncan's Multiple Range Test, 0.05 level.
†Determined with a hand refractometer on juice from slices positioned on opposite sides of the fruit.
‡Measured with a Magness and Taylor-type pressure tester having a 5/16-inch plunger head.
§Fruit color rating: 1 = green; 2 = light green; 3 = yellowish-green; 4 = yellow.
**Own-rooted stocks developed from cuttings of *Pyrus communis* L. 'Old Home'.
††Cultivar of *Pyrus communis*.
‡‡'Kirschensaller Mostbirne', a strain of *Pyrus communis*.
§§Cultivar of *Cydonia oblonga* Mill.

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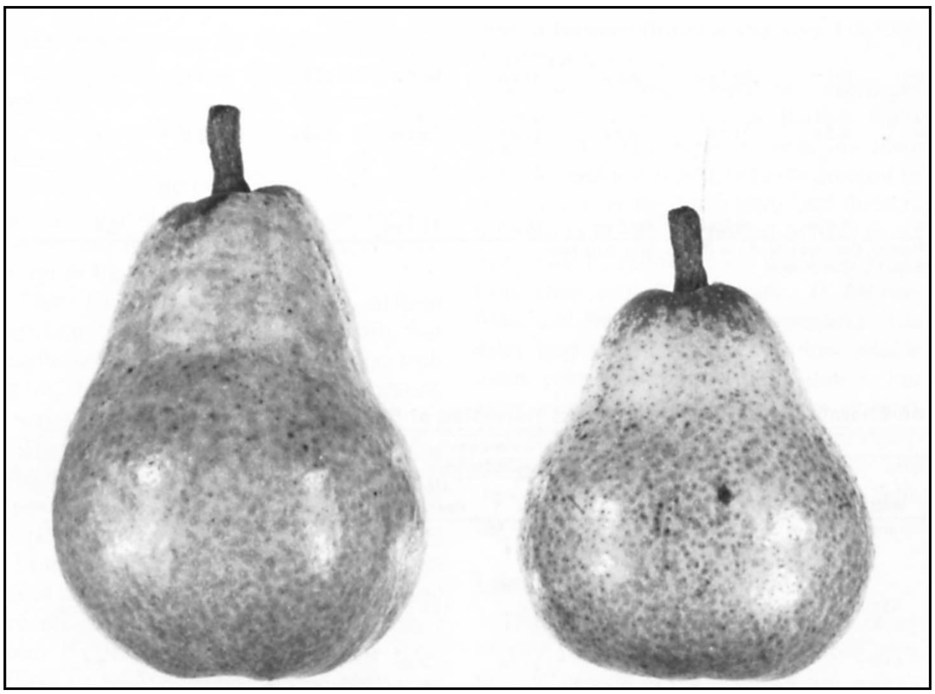

Don A. Edwards

Rootstock had striking effect on shape. Bartlett pear on left is from tree with Old Home rootstock, and on right from tree with *Pyrus calleryana* seedling rootstock. The longer pear is more desirable for the fresh fruit market.

was retarded and their average yields were significantly lower than those of trees with *P. betulaefolia* seedling rootstocks, own-rooted Bartletts, or trees with Old Home rootstocks. The fruits were large, fairly well shaped, and contained adequate, but relatively low, percentages of soluble solids. One tree succumbed to fire blight infection in its eighth year.

Trees with Bartlett seedling rootstocks were moderately vigorous, but their yields were significantly lower than those of own-rooted Bartlett trees or of trees with *P. betulaefolia* seedling or Old Home rootstocks. Their fruits were medium in size, fairly well shaped, and high in soluble solids. One tree died in its fifth year, apparently of pear decline, and three were lost to fire blight in their eighth year.

Trees with Provence quince roots and Old Home interstocks were somewhat dwarfed and made less shoot growth than any of the experimental trees except those with Angers quince roots. They were less precocious and gave significantly lower yields than the more vigorous trees. Fruits were medium in size, well shaped, and high in soluble solids. All of the trees were healthy until their seventh year, when three were severely infected with fire blight.

Trees with Angers quince roots and Hardy interstocks had a poor survival record, made the least trunk and shoot growth, and gave the lowest yields. Six trees were lost—two in their fifth year, two in their sixth year, and two in their twelfth year in the plot. All had symptoms of pear decline and one was infected with oak root fungus. Fruits were relatively small, short, firm and low in soluble solids at harvest. Ripe fruits were relatively high in soluble solids.

Most of the trees in the plot developed leaf curl symptoms in varying degrees of severity each fall. The study indicated that vigorous shoot growth favors the expression of curl symptoms, and any apparent relationship between type of rootstock and amount of foliage affected may be explained by the influence of rootstock on tree vigor. There was no significant correlation between average curl ratings and average yields or weight, firmness, and percentage of soluble solids of fruits.

Data on trunk and shoot growth, leaf curl, and tree survival are available from the senior author.

Since no one type of tree constitution proved to be highly superior to the others in all of the factors considered, we suggest that growers include a combination of the following for their new Bartlett plantings: own-rooted Bartlett trees, Bartletts with *P. betulaefolia* seedling rootstocks, Bartletts top-grafted on own-rooted Old Home trees, and Bartletts with Winter Nelis seedling rootstocks.

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