to best control this pathogen? At what rate, by what method(s), and at what frequency should fungicides be applied? What environmental factors promote or inhibit the growth of the pathogen? Are there management practices that can prevent ferneries from becoming infected or that can help suppress disease development? These and other questions must be answered for leatherleaf fern anthracnose control to become an economic reality.

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EFFECTS OF ROSE MOSAIC DISEASE ON PERFORMANCE OF HYBRID TEA ROSES IN FLORIDA

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Abstract. **A bed of 'Double Delight' Hybrid Tea rose (*Rosa* hybrid) grafted to 'Dr. Huey' rootstock, was grown in the Florida Southern College rose garden. Some plants were graft-inoculated with a mild strain of prunus necrotic ringspot virus (PNRSV) and others with a severe strain of apple mosaic virus (ApMV), the two major causes of rose mosaic disease. Virus-infected plants produced fewer flowers and shorter stems than did healthy controls, on the spring growth flush. Other growth flushes throughout the season did not show significant differences between treatments and control. No spread of either virus occurred over the 4-year period. During the fourth year, most of the ApMV-infected bushes died.**

Rose mosaic is a disease of cultivated roses caused by prunus necrotic ringspot virus (PNRSV) and/or apple mosaic virus (ApMV), in the United States. Arabis mosaic virus (AMV) is also a possibility in other areas of the world, but it is not believed to exist in US-grown roses. PNRSV and ApMV are naturally occurring diseases of fruit trees such as cherry, peach, and apple, and they are contagious among those species, spreading via pollen. They are not believed to occur naturally in roses; however, the viruses will survive in a rose bush and cause rose mosaic, if a plant is infected by budding or grafting infected wood into it. There have been some lively debates over exactly how mosaic spreads in roses. Aphids, thrips, pruning shears, contaminated soil, root contact and pollen have all been suggested (Cochran, 1988; Davidson, 1988; Horst, 1983; Manners, 1988). Many growers continue to believe that mosaic can be transmitted by one or more of these means. Yet there has never been any proof of such contagion. In extensive research over many years, none of these methods has ever been demonstrated to occur in roses. As far as is known, the American forms of rose mosaic never spread from bush to bush in a garden. The only demonstrated method of infection is in the grafting process, and a healthy budded or grafted bush should remain free of mosaic for life (Harwood, 1991; Manners, 1988).

Another unsubstantiated opinion, often expressed among commercial and hobbyist rosarians, is that rose mosaic does no significant damage to a rose, other than a few mottled leaves from time to time. Since rose mosaic is not deadly, often shows no foliage symptoms, and may not be obviously detrimental, it is easy to see how one might assume that the disease is not doing significant damage. This idea persists despite published reports from England (Thomas, 1981, 1982) that mosaic causes reduced flower production, poorer flower quality, reduced plant survival, reduced cold-hardiness, more difficulty in transplanting, and reduced rates of budding success. Unpublished research in California has also demonstrated reduced flower production and flower quality (George Nyland, personal communication).

Rose cultivars can be freed of the viruses causing rose mosaic by heat-therapy. Florida Southern College's heat-therapy program was previously described in these Proceedings (Manners, 1985).

The research described in this paper was designed to provide data on the effects of rose mosaic on outdoor-grown, Hybrid Tea roses in Florida. We were interested in the effects of mosaic on the growth, productivity, and quality of infected bushes over several seasons. Too, we thought it would be a good opportunity to provide further data on the already heavily studied subject of rose mosaic's lack of contagion in a rose garden.

Materials and Methods

Plant material. 'Double Delight' scions on 'Dr. Huey' rootstock, were used for the study. 'Double Delight' was selected for the following reasons:

1. It is a good, representative Hybrid Tea, relatively easy to grow, relatively popular among rose growers, and not noted for being unusually susceptible or resistant to the effects of viral disease.

2. Florida Southern College's official colors are red and white, so a bed of roses in those colors would be desirable in the campus landscape.

3. We knew from previous experience that red roses suffer from thievery of the flowers, whereas other colors (including red blends) are much less likely to be stolen.

'Dr. Huey' was chosen as the rootstock because it is relatively well adapted to Central Florida's growing conditions and is the most commonly used rose rootstock in the United States. While 'Fortuniana' is recommended as a superior stock for Florida-grown roses, the majority of roses actually sold and grown in Florida are propagated in California, on 'Dr. Huey' roots. We wanted to study a "typical" rose, and this stionic combination seemed quite appropriate. The plants were budded in April 1989, using mosaic-free scions from our heat-therapy program at Florida Southern College, and mosaic-free 'Dr. Huey' supplied by Prof. L. C. Cochran, of Oregon State University.

Virus inoculation. The experiment consisted of two virus-infected treatments and an uninfected control. For the first virus treatment, a strain of ApMV was obtained from the University of California at Davis, originally given to them by Dr. Dan Opgenorth of the California Department of Agriculture. This strain produced strong yellow to white, blotchy mosaic symptoms on most leaves throughout the year (Fig. 1). Since the viruses which cause rose mosaic cannot survive storage outside a living host plant, the ApMV was maintained in 'Dr. Huey' plants until the time of inoculation. To insure that we were working with the desired virus and not a mixed infection of several viruses, it was tested by enzyme-linked immunosorbent assay (ELISA), by Dr. Opgenorth's lab and by Agdia, Inc. of Elkhart, Indiana. In both cases, it tested positive for ApMV and negative for PNRSV. It was also positively indexed at University of California at Davis on 'Shirofugen' cherry for a mosaic-type virus infection (Fleisher et al., 1971). 'Shirofugen' does not differentiate between the types of virus; rather, it gives either a positive or negative test for "mosaic."

The second virus-infected treatment used a strain of PNRSV obtained in a plant from a California mail-order rose nursery. This strain produced only faint watermark symptoms, mostly on the spring flush of growth, and usually on only a few leaves (Fig. 2). It was never very noticeable and most of the year was completely undetectable by leaf observation. It was indexed positive for a mosaic virus on 'Shirofugen' cherry (at U. C. Davis) and on 'Mme. Butterfly' rose (at Florida Southern College). It was tested by ELISA by Dr. G. I. Mink, at Washington State University, and by Agdia, Inc. In both cases, it tested positive for PNRSV and negative for ApMV. This virus was maintained in plants of the Hybrid Perpetual rose 'Arrillaga' until the time of inoculation.

Before inoculation, the 'Double Delight' plants were tested and found negative for infection with the mosaic viruses on 'Shirofugen' cherry, 'Mme. Butterfly' rose, and by ELISA. Ten of these plants were used as the uninfected control. Another ten were inoculated with ApMV by grafting small patches of bark from the infected 'Dr. Huey' plants into the bases of several canes on each 'Double Delight' bush. Another ten bushes were inoculated with PNRSV in the same manner, using bark patches from the infected 'Arrillaga' bushes. Inoculations were performed in August 1990 and again in November 1990, since some of the bark patches did not survive in the August inoculation. All treated plants contained at least three living bark chips, 1 month after the November inoculation.

Planting design. The plants were grown in a single row, running north to south, with the plants spaced 5 feet apart. Every third plant in the row was an uninfected control, with a PNRSV-infected bush on one side and an ApMV-infected bush on the other side, so that every plant was next to a member of each of the other two groups. Extra bushes were planted on the north and south ends of the plot and infected with the appropriate virus to provide a "neighbor" for the northernmost and southernmost test plants. Data were not collected from these border plants.

Figure 1. Typical, severe symptoms of ApMV infection, visible on foliage throughout the year.

Figure 2. Typical faint, "watermark" symptoms of PNRSV infection, usually visible only on the spring growth flush, and then only on a few leaves per bush.

Culture. All bushes were grown in a commercial mixture (Fafard #2; Fafard, Agawam, Mass.) of sphagnum peat, composted pine bark, and polystyrene beads, in 20-gallon plastic pots sunk to their rims in the native soil, in the Florida Southern College rose garden. An automatic microsprinkler system provided 3 to 4 gallons of water per day, to each bush. The plants were fertilized regularly, using common Central Florida fertilizer practices and materials (about 1 cup per bush per month of 12N-2.6P-6.6K). The soil reaction was tested annually and adjusted to approximately pH 6.5 with dolomite as needed. The plants were mulched with pine bark. Fungicidal sprays (triforine - 1 tsp per gallon) were applied year-round every 7 to 10 days. During blackspot weather (warm humid nights; rainy), 1 Tbsp Manzate 200 (zinc ion + maneb complex; Du Pont, Wilmington, Del.) or Dithane M-45 (Rohm & Haas, Philadelphia, Pa.) was added each gallon of the triforine solution. But insecticides and miticides were seldom used. In addition to harvesting stems for data collection, the bushes were heavily pruned each year in early March, to a uniform size, along with the rest of the college's rose gardens. Pruning was done with non-sterilized clippers and the plants were pruned in order, north to south on some occasions, and south to north at other times, to provide the opportunity for contagion, if mechanical spread were possible.

Data collection. Flowers were harvested on twenty occasions, over the period of April 1991 through May 1993. The number of flowers produced by each bush was counted and recorded at each harvest. In late April or early May, each year, cuts were made at the lowest 5-leaflet leaf, so stem length could be measured. Stems were measured from the cut to the base of the flower receptacle. At all other times of the year, the cuts were made at the highest 5-leaflet leaf and no stem-length measurements were made. In April 1993, a count was made of the number of old basal canes on each bush, as well as the number of new basal breaks.

Indexing. All plants were tested for the presence of both viruses by ELISA, before, annually during, and after the experiment, to determine whether either virus was being transmitted from one plant to another. Also, all plants were tested by 'Shirofugen' cherry indexing at the end of the experiment, to complement the ELISA results.

Statistical analysis. An analysis of variance was performed on the data to determine their significance. The performance of each virus-infected treatment was compared to that of the uninfected control.

Results and Discussion

Flower production. Figure 3 shows the average number of flowers produced, per bush, for each of the three spring seasons of the experiment. The uninfected control plants averaged more flowers than either virus-infected treatment, although for the PNRSV treatment, the difference was statistically significant only in 1993. Plants infected with ApMV produced significantly fewer flowers each spring.

The effect of mosaic on flower production was noticed primarily in the spring. At other times of the year, there were slight, but statistically insignificant variations. Neither virus-infected treatment ever produced more flowers than did the uninfected control.

We observed that leaf symptoms of mosaic were always strongest on the spring flush. In the case of the ApMV treatment, it may be reasonable to assume that a reduction in photosynthesis, due to a lack of chlorophyll in the leaf, might be the cause of the reduced flower production. In the case of the PNRSV treatment, even the spring symptoms were so faint, and occurred in so few leaves, that it seems doubtful that reduced photosynthesis could be the complete explanation for the reduction in flowering. Perhaps the same factors that lead to increased production of leaf symptoms in the spring also affect flower production.

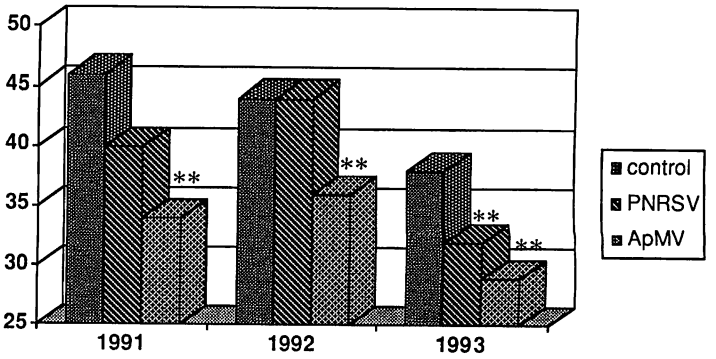

Figure 3. Average number of flowers produced per bush, in the spring growth flush. "**" indicates that the treatment was highly significantly different from the control ($\alpha = .01$).

Stem length. Figure 4 shows the effects of the virus treatments on stem length in the spring growth flush. The average stem length of the control plants was significantly greater than that of either virus infected treatment. Also, we arbitrarily rated lengths of harvested stems in 10 cm intervals. The control plants produced a greater percentage of their flowers with stems in the 40-50 cm range, the 50-60 cm range, and all lengths over 40 cm, than did the virus treatments, although the ApMV lengths were not significantly less than those of the controls (Fig. 5).

Basal break production. No significant difference in the number of old basal canes or new basal breaks was observed for any treatment.

Contagion. The ELISA and 'Shirofugen' tests were entirely in agreement throughout the study—control plants all remained free of both viruses. ApMV-infected plants always tested positive for ApMV but never for PNRSV. PNRSV-infected plants always tested positive for PNRSV but never for ApMV. Observations of the plants for leaf symptoms on the spring growth flush were also in agreement: no contagion occurred at all, in spite of frequent cuts made with unsterilized pruning shears, from one treatment to another, and the fact that we usually made no attempt to control the aphids, thrips, mites,

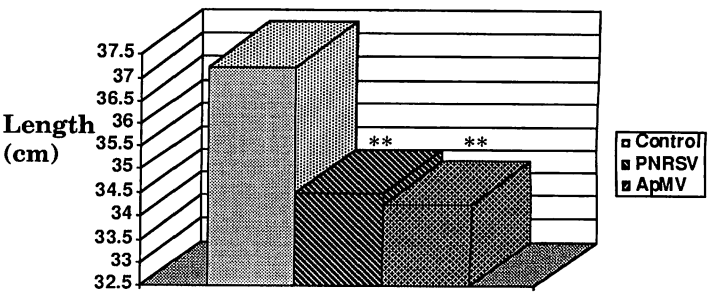

Figure 4. Effects of virus infection on average cut-flower stem length, in the spring growth flush (1992-93 data combined). "**" indicates that the treatment was highly significantly different from the control ($\alpha = .01$).

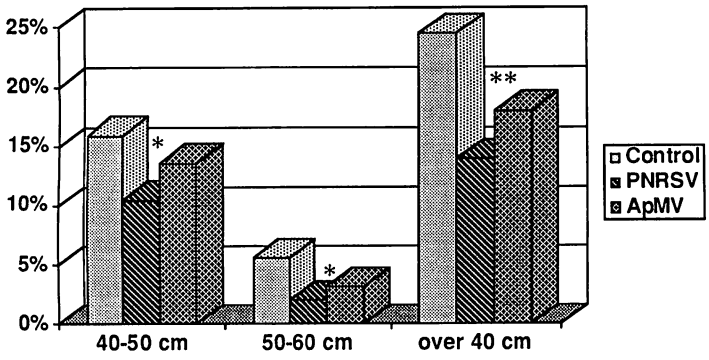

Figure 5. Effect of virus infection on production of long-stem cut flowers in the spring flush (1992-93 data combined). Values are expressed as a percentage of the total harvested crop. "*" and "**" indicate that the treatment was significantly different ($\alpha = .05$) or highly significantly different ($\alpha = .01$) from the control, respectively.

whiteflies or nematodes on the bushes. Plants were sprayed with pesticides only in the case of such extreme populations (mostly of mites) that they were in danger of being defoliated if we didn't spray.

It is important to remember that these results represent the performance of one cultivar ('Double Delight') on one rootstock ('Dr. Huey'), grown in one garden in Central Florida, over a specific three-year period. Results for other varieties, locations or seasons, could vary; but our results do agree with those of previous research in Great Britain and California: Rose mosaic reduced the number of flowers produced and the average stem length of those flowers, for the spring growth flush. The effect was not pronounced in other seasons. Nevertheless, in most areas of the world, it is the spring growth flush that produces the largest number of flowers and often the best flowers of the year. Also, spring is the time most rose shows are held, so the effect of rose mosaic could be quite important to a rosarian, whether or not he or she is an exhibitor, even if its effects only occur in the spring.

Only carefully defined and controlled test conditions, and indexing or ELISA testing for the presence of virus before and after the experiment, can give useful information on contagion. Other researchers have found no evidence from such properly controlled experiments that rose mosaic spreads by any means other than grafting or budding (L. C. Cochran, Oregon State University; Charlene Harwood, Bear Creek Nurseries; George Nyland, University of California; personal communications). Our results completely support that premise: no contagion occurred from pruning shears, insects, or any other means. It seems likely that the unsubstantiated reports of natural or mechanical spread of the disease, which appear from time to time, are due to misinterpreted observations—either the plants which appear to have contracted mosaic were infected all along and have just begun showing symptoms, or perhaps symptoms which are interpreted as being those of mosaic are in fact something else.

In summary, two strains of rose mosaic were shown to reduce the number of flowers produced and the average length of their stems, in the spring growth flush. Contagion did not occur in the garden over the three-year period of the experiment, in spite of constant insect attack and the use of unsterilized pruning equipment.

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