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ABOUT A QUARTER of a century before virus diseases as such began to be recognized, evidence of graft transmission of a chlorosis of the rose was recorded in France (12).⁴ However, mosaic as a disease of importance in rose culture did not attract attention until about 1928 (14). Mosaic then for several years excited an unusual amount of comment and controversy (7, 8, 18) which has been only partially justified by more extensive observations and experiments (7, 13, 17). It is now apparent, at any rate, that the rose may be affected by virus diseases of some importance and may serve as a potential source of virus for other plants (10).

The material presented in this paper relates to the mosaic type of disease only. The necrotic diseases reported from the eastern United States (2) and abroad (4, 5) have not been found in California.

SYMPTOMS

As early as 1933, evidence began to appear in this work indicating that not one mosaic disease occurs among the cultivated roses but several. Since some of these were not recognized as distinct until recently, it will not be possible to treat them separately throughout this paper. For convenience these will be designated as "rose mosaic 1," "rose mosaic 2," and "rose mosaic 3," and the corresponding viruses distinguished by their respective numbers.

In roses grown out of doors, lime-induced chlorosis without malformation is rather common, notably in the Santa Clara Valley. In such cases the leaf blade becomes uniformly yellow rather than mottled. This may obscure or inhibit development of symptoms of the mosaic diseases and may in some cases be confused with them. Diagnosis in the field is also complicated very frequently by insect injury (7), particularly that produced by leafhoppers.

Types of variegation are encountered occasionally, which appear to be entirely genetic in origin. Scions of one such rose (fig. 3, A) were grafted on *Rosa odorata* and kept under observation for several years.

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⁴ Italic numbers in parentheses refer to "Literature Cited" at the end of this paper.

No evidence of transmission to the stock nor of change in symptoms toward those of the infectious mosaics was ever noted.

Rose Mosaic 1.—This disease on such cultivated varieties as Hollywood, Pilgrim, and Premier Supreme (fig. 1) produces small chlorotic spots somewhat angular or fringed in appearance due to the clearing of small veins and veinlets adjacent to the spot proper. The chlorotic areas

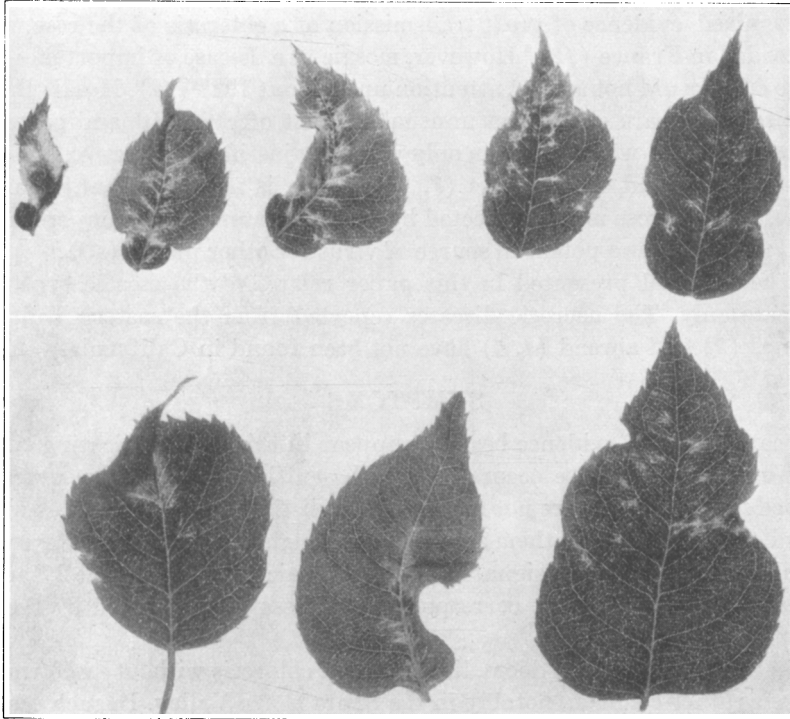


Fig. 1.—Rose mosaic 1 in leaves of the Hollywood variety.

are more numerous at or near the midvein and often appear in greater numbers near the base of the leaflet. The leaf blade around the spot is often more or less distorted. Occasionally pale bands or lines appear on leaves of affected plants, more often out of doors, but it is not known whether these are symptoms of mosaic 1. There may be no reduction in vigor or the plant may be slightly to severely dwarfed, according to the variety and, no doubt to some extent, to the growing conditions. On the four common stocks *Rosa chinensis* var. *Manetti*, *R. multiflora*, *R. odorata*, and Gloire des Rosomanes (better known in California as "Ragged Robin," which term will be used hereafter in this paper), the symptoms

are mild, seldom exceeding in severity the small chlorotic flecks shown in figure 2. Blossoms of the top varieties may be normal or nearly so in appearance or severely dwarfed and pale in color. Usually a part of the

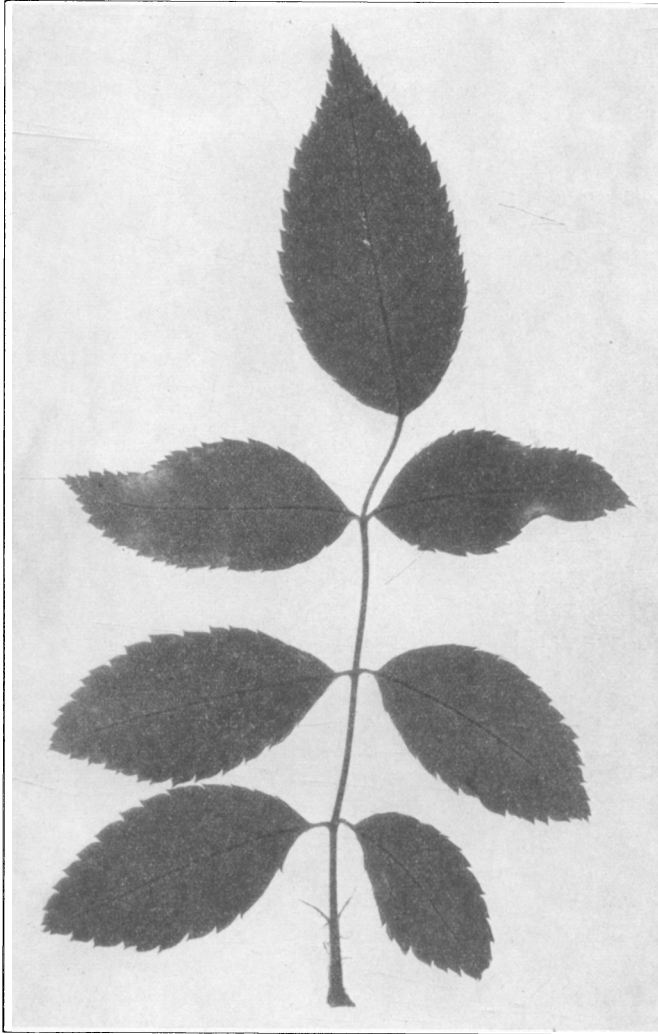


Fig. 2.—Rose mosaic 1 in *Rosa multiflora*. Only a few small chlorotic spots are present.

corolla is attenuated, leaving the flower unsymmetrical and of little commercial value. Rose mosaic 1 seems to be the principal mosaic disease of roses grown under glass, whereas mosaics 2 and 3 are more fre-

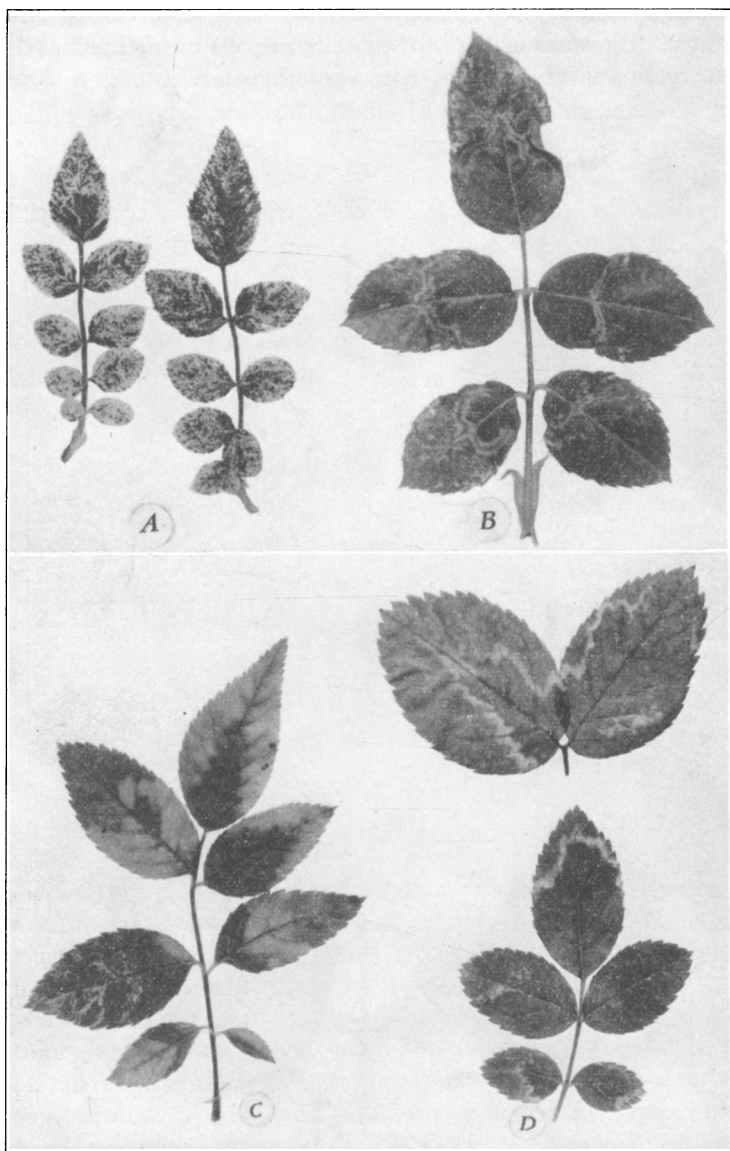


Fig. 3.—*A*, Two small rose leaves representing a noninfectious variegation; *B*, rose mosaic 2 in Belle of Portugal; *C*, rose mosaic 2 in *Rosa odorata*; *D*, rose mosaic 3 on *R. chinensis* var. *Manetti*. Note the oak-leaf pattern on leaves in *B* and *D*.

quently noticed in plants grown in parks and gardens. Mosaic 1 has been seen in gardens and nurseries, however, and may be more generally prevalent out of doors than is indicated by the observations to date. Only a very detailed survey early in the season could determine this point with certainty.

Rose Mosaic 2.—The disease designated as “rose mosaic 2” was first observed in the variety Cecile Brunner in a city park at San Jose. Al-

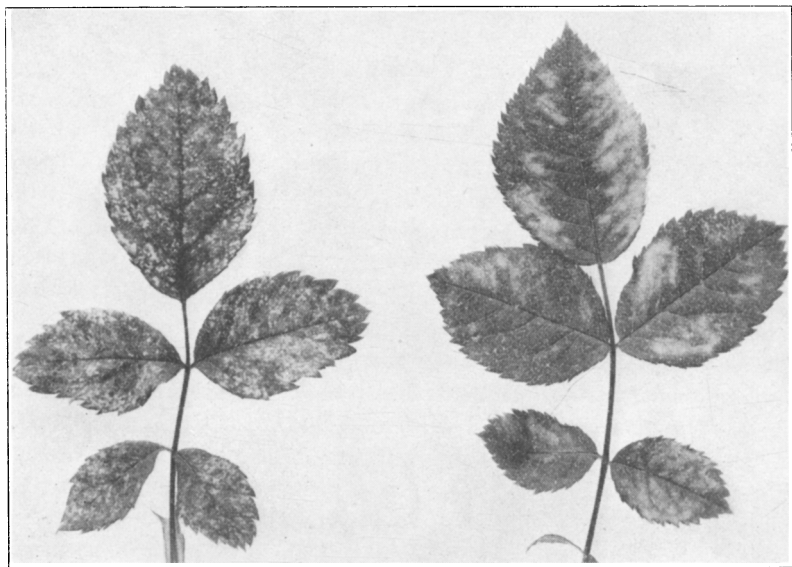


Fig. 4.—Rose mosaic 3 in Ragged Robin.

though somewhat variable in symptom expression even on the same plant, it is typically characterized in such varieties as Belle of Portugal, Cecile Brunner, Hollywood, and Independence Day by chlorotic lines, bands, and broad blotches in the leaf blade with or without distortion (figs. 3, *B*, *C*, and 5, *A*). The symptoms, on the whole, are distinctly more conspicuous than those of mosaic 1 on both top varieties and stocks. In some cases the disease seems to dwarf the plants somewhat; in others little or no dwarfing is apparent. No specific symptoms of blossoms have been noted for this disease.

Rose Mosaic 3.—Specimens of diseased plants designated as “rose mosaic 3” were obtained in the variety Souvenir de Claudius Pernet from a garden in Sacramento through the courtesy of D. G. Milbrath. Mosaic 3 produces symptoms on the four common stocks which are similar to those of mosaic 2 but on the whole are more severe, in some cases

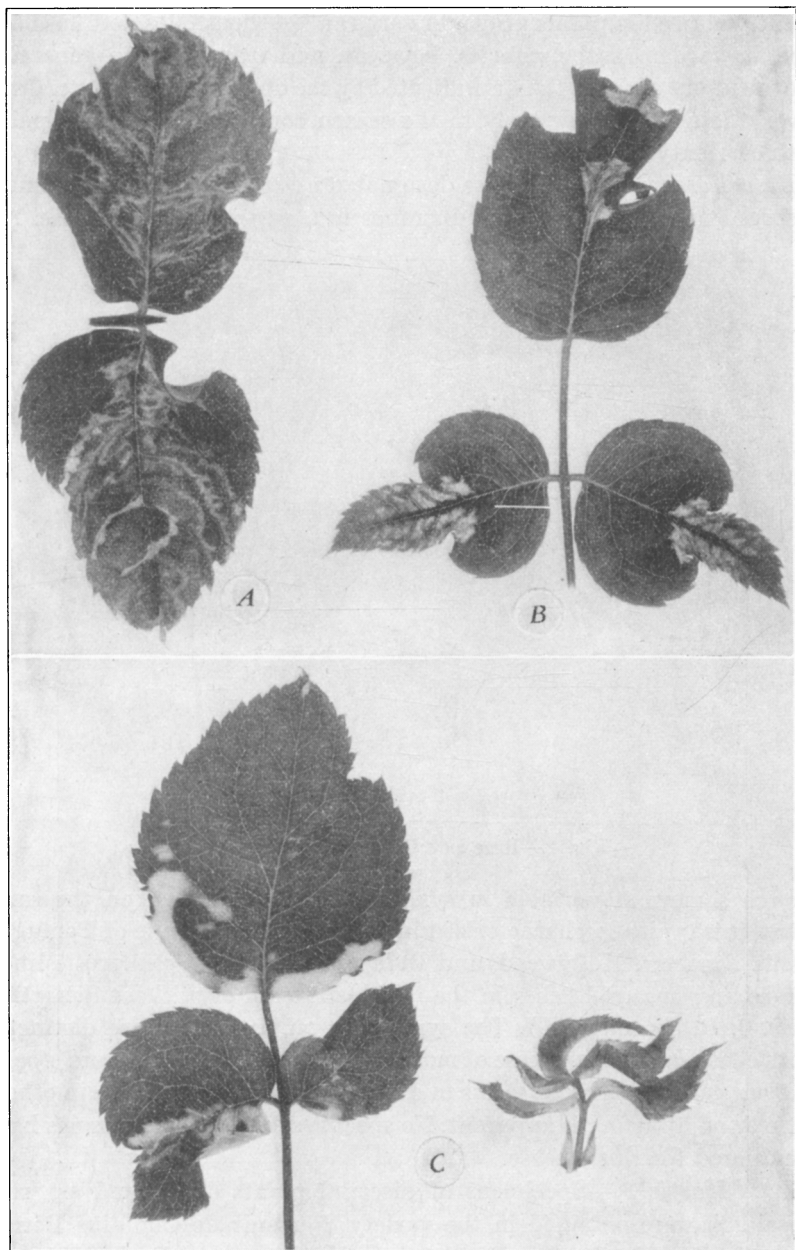


Fig. 5.—*A*, Rose mosaic 2 in Hollywood variety (pair of leaflets); *B*, apple mosaic in same variety; *C*, rose mosaic 3 in same variety, showing mottling and severe distortion.

causing distinct dwarfing. There is also more tendency toward broad chlorotic blotches in the leaf blade and few lines and rings (figs. 3, *D*, 4, and 5, *C*). Occasionally a conspicuous oak-leaf pattern (fig. 3, *D*) is produced, and not infrequently part or all of a leaf may exhibit a pronounced clearing of the veins while other leaves on the same plant bear the more common symptoms.

Other Mosaic Diseases Transmissible to Roses.—In addition to the three rose mosaics described above, the common apple mosaic is transmissible to rose (10) producing symptoms on Belle of Portugal similar to those of mosaic 2 but with the tendency, much more pronounced in Hollywood and Independence Day, toward marked constriction and chlorosis in a fairly definite broad band across and near the middle of the leaflet blade (fig. 5, *B*). Flowers of the Hollywood variety affected by the apple mosaic are reduced in size, and the color is lighter than normal.

Also may be mentioned here the symptoms on the rose of a peach mosaic collected at Winters, California. This mosaic is similar to but distinct from the mosaic of peach reported from Texas, Southern California, and elsewhere (11). The Winters peach mosaic inoculated to rose by inarching has produced marked chlorosis in leaves of Ragged Robin, sometimes rather general (fig. 6, *A*), but often limited to shorter or longer cleared areas along the larger veins. On *Rosa odorata* a few pale-green lines and rings were produced a few weeks after inoculation but these faded and did not reappear on new leaves up to more than a year from the time of inoculation. Symptoms of this disease on the Hollywood variety are similar to those on Ragged Robin, but less severe.

Several cases have come to notice which suggest the presence of still other diseases, but the relation of these to the diseases designated above has not been sufficiently tested to permit any conclusions. Among these is a specimen of Independence Day growing in a garden in Oakland, with vein clearing as the only symptom. This was grafted on *Rosa chinensis* var. *Manetti* and kept at Berkeley for more than a year alternately in the greenhouse and out of doors but remained free, or virtually so, of any other symptom and produced no symptoms on the *R. chinensis* var. *Manetti* stock.

PLANTS AFFECTED

The symptoms of rose mosaic 1 have been seen by us or illustrated by earlier workers (7, 16) on the following rose varieties: American Beauty, Angele Pernet, Autumn, Better Times, Briarecliff, Feu Joseph Looymans, Gruss an Coburg, Hollywood, Hortulanus Budde, Madame Butterfly, Matchless, Mrs. F. R. Pierson, Pilgrim, Premier, Premier Supreme, Radiance, Rapture, Red Radiance, Rose Hill, Southport, and

Ulrich Brunner. The symptoms on Ulrich Brunner were seen out of doors and consisted of numerous small chlorotic spots with little tendency to be aggregated near the midvein or to produce distortion of the leaflet. These symptoms persisted on this variety in the greenhouse, but when such material was used to inoculate Hollywood, the latter developed symptoms which seemed typical of mosaic 1. A considerable number of other varieties have been listed by earlier workers as subject to rose mosaic and some of them are no doubt affected by the disease here delimited as rose mosaic 1.

No attempt is made at present to classify the above varieties or those to follow according to the severity of the disease. It is apparent, however (17), that differences in susceptibility do exist among varieties. For example, the variety Mrs. Charles E. Russell was inoculated with each of the viruses 1, 2, and 3. Only mild symptoms, at most, were produced by any one of these. Mosaic 1 in Independence Day produced no symptoms at all, although the virus was shown to be present.

Among the stocks, Ragged Robin seems to be more affected than *Rosa chinensis* var. *Manetti*, with *R. Multiflora* and *R. odorata* intermediate between them.

Potted plants of the native species *Rosa californica*, *R. gymnocarpa* and *R. nutkana* were inoculated in the greenhouse by inarching on affected plants of cultivated varieties. No symptoms have been seen on the inoculated plants up to 12 months from the time of inoculation. Attempts to recover the virus from these have not been completed. A similar result was obtained with seedling of *R. Soulieana*.

Because of the similarity of symptoms of the other two mosaics, the probability of considerable variation in symptoms of each of them in different varieties, and the fact that most of the field observations were made before the distinction between rose mosaics 2 and 3 became apparent, all of the rose varieties which were noted as exhibiting chlorotic lines, bands, and broad blotches in the leaf blade are here grouped together. They are: Belle of Portugal, Briarecliff, Cecile Brunner, Dazla, Dorothy Perkins, Duchess of Wellington, Duchess of York, Etoile de Hollande, General MacArthur, Golden Dawn, Golden Ophelia, F. J. Grootendorst, Hadley, Hollywood, Independence Day, Irish Elegance, Irish Fireflame, Kaiserin Auguste Viktoria, Lady Margaret Stewart, Los Angeles, Louise Catherine Breslau, Mme. Edouard Herriot, Mme. la Générale Ardouin, Mrs. Aaron Ward, Mrs. E. P. Thom, Mrs. Henry Bowles, J. Otto Thilow, Paul's Scarlet Climber, Pink Cherokee Rose, Queen Alexandra, Souvenir de Claudius Pernet, Sparkler, Sunkist, Talisman, Ville de Paris, and William F. Dreer. It is entirely possible

that some of the varieties listed here were affected by diseases other than mosaics 2 and 3 and not yet differentiated from them.

The four common stocks are readily infected by rose-mosaic viruses 2 and 3. The symptoms of both diseases are somewhat less conspicuous on *Rosa chinensis* var. *Manetti* than on *R. odorata* and Ragged Robin. One strain of *R. multiflora* produced mild symptoms with mosaic 3 and somewhat stronger mottling with mosaic 2. A variety received under the name *R. multiflora Grifferae* developed strong symptoms with mosaic 3.

Plants of the native species *Rosa californica* and *R. nutkana* inoculated with rose mosaics 2 and 3 by inarching have not shown any symptoms up to 18 months after inoculation.

The apple mosaic has been seen by us only on the rose varieties Belle of Portugal, Hollywood, and Independence Day inoculated in the greenhouse. The susceptibility of *Cotoneaster Harroviana*, *Eriobotrya japonica*, *Photinia arbutifolia*, and *Sorbus pallescens* to apple mosaic after inoculation by grafting has been pointed out in an earlier paper (10). Since that time striking symptoms have been obtained by inoculation on *Pyrus spectabilis*, and mild symptoms on a *Sorbus* purchased under the name *S. sitchensis* but in appearance suggesting *S. aucuparia*.

The Winters-peach-mosaic virus appears from inoculation tests to have a rather extensive range of susceptible plants including apricot, almond, and peach, as well as the roses that have been infected by inoculation. No symptoms have been found on a number of rose varieties growing in a garden adjoining a peach orchard in which this disease has been present since 1936 or earlier. Attempts to transmit this disease from peach to *Rosa californica*, *R. multiflora*, and *R. nutkana* have not produced visible symptoms.

Small-scale attempts were made to transmit viruses 1, 2, and 3 to peach seedlings by inarching (8 plants all told). Symptoms on the peaches were doubtful at most, and attempts to recover the viruses have failed.

Seedling apple trees were likewise inoculated with viruses 2 and 3. No evidence of infection with rose mosaic 2 was apparent up to 14 months from the time of inoculation. Of ten plants inoculated with virus 3, only one developed marked mosaic symptoms the following spring, similar in some respects to the common apple mosaic but lacking the pronounced vein clearing of that disease and tending more toward the production of chlorotic lines and rings (fig. 6, B). The apple variety Golden Delicious, which is highly susceptible to the apple mosaic, did not develop any clear symptoms during 15 months after inoculation with virus 3 by inarching with the affected apple seedling.

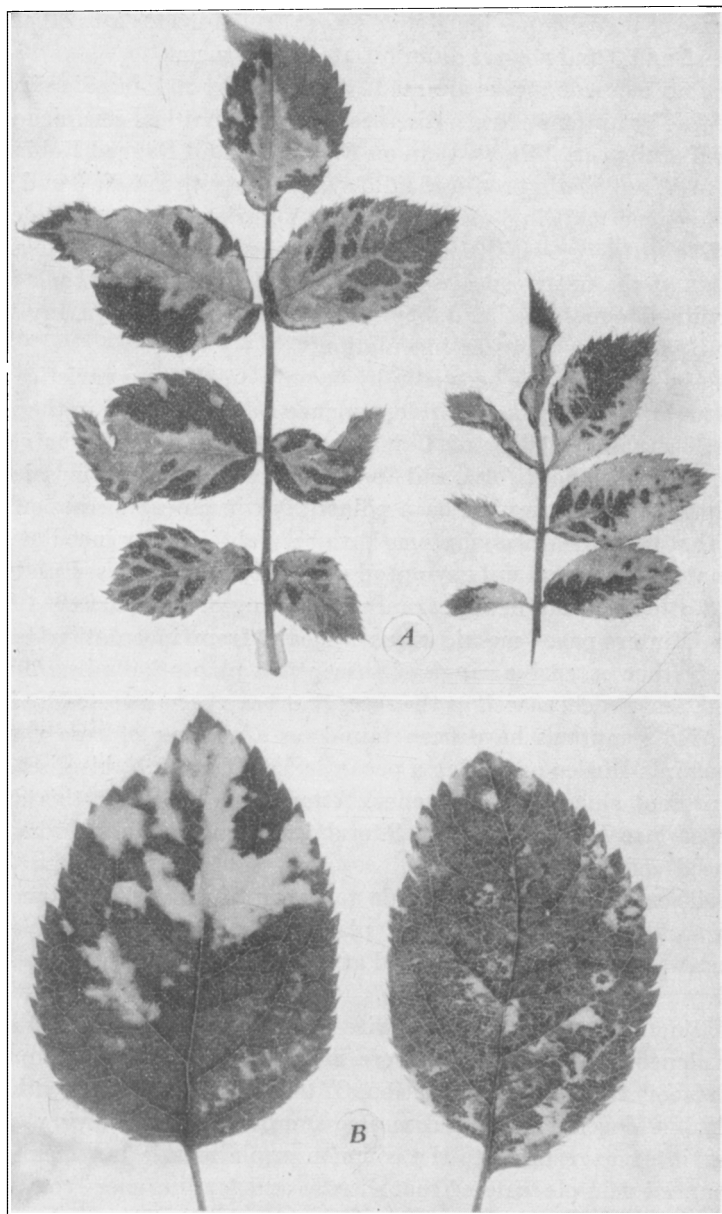


Fig. 6.—*A*, Symptoms of Winters peach mosaic in Ragged Robin rose produced by inoculation in greenhouse; *B*, rose mosaic 3 in seedling apple leaves.

BASIS FOR THE SEPARATION OF DISTINCT MOSAIC DISEASES IN THE ROSE

The tendency has been in the past to group all the mosaic symptoms of the rose together as representing a single disease, although several workers have apparently suspected the existence of more than one disease (3, 16). It is desirable, therefore, to present more specific evidence in support of the above designation of separate diseases.

Rose mosaic 1 is readily separable from the other diseases considered here by symptoms alone, as well as by the results of inoculations of key varieties and species. Evidence of the latter kind was obtained by grafting scions affected by this disease on healthy plants of Cecile Brunner and Independence Day. Such combinations have been grown for as long as four years without the development of any definite symptoms on these two varieties. On the other hand the same varieties develop strong symptoms when inoculated with virus 2.

The separation of mosaics 2 and 3 is more difficult. Both these diseases and the mosaics of apple and peach may at times produce symptoms on roses which are very similar. On the variety Hollywood, rose mosaics 2 and 3 may be distinguished fairly readily by symptoms alone when compared side by side under similar environment (figs. 5 *A, C*). The reaction of Belle of Portugal is also of assistance. With the onset of disease in this variety, rose mosaic 3 produces short necrotic lines or bands along and including the mid-vein and larger lateral veins of younger leaves and later considerable distortion of the leaf blade. The disease then becomes systemic and produces largely chlorotic symptoms. This reaction has not been noted with mosaic 2 nor with the apple mosaic in this variety. Also the Souvenir de Claudius Pernet variety, which is one of the most susceptible to mosaic 3 of those tested, has failed to show any symptoms of mosaic 2 up to 18 months from the time of inoculation.

The apple mosaic is separable from the others by the extremely slow rate of development in the rose, requiring 20 to 27 months to produce symptoms 6 inches below the point of inoculation. The symptoms of this disease are also distinctive in certain respects, notably in the varieties Hollywood and Independence Day (fig. 5, *B*), in which the chlorosis and constriction in a localized area across the leaflet is frequently seen.

The Winters peach mosaic may be separated from rose mosaics 2 and 3 by the apparent failure of viruses 2 and 3 to infect peach, the absence of lines and rings when the peach virus is in Hollywood and Ragged Robin, the presence of discontinuous chlorotic bands along the veins, and the marked tendency of chlorotic areas to become green with age.

RELATION OF STOCKS TO DISEASE IN SCION VARIETY

In a preliminary trial, scions of Pilgrim and Premier Supreme affected by rose mosaic 1 were grafted on the stocks of *Rosa chinensis* var. *Manetti*, *R. multiflora*, *R. odorata*, and Ragged Robin. Although some of these plants were kept under observation for several years, there was no indication that the stock influenced the severity of the disease in the scion variety.

That such a case may be found, however, is indicated by the fact that Belle of Portugal, affected by mosaic 2 and grown on its own roots, has shown less severe symptoms than the same variety with the same disease grown on *Rosa chinensis* var. *Manetti* and Ragged Robin rootstocks.

SYMPTOMLESS CARRIERS

As is the case with many mosaic diseases, all of those under consideration here may fail to exhibit symptoms in some or all of the leaves of an affected plant at any given time. With all except rose mosaic 1, symptoms seem to be favored by relatively low temperatures and tend to be masked at higher temperatures. No controlled experiments have been made on this point, however. Mosaic 1 is often masked for considerable periods in the common rootstocks. A few instances have been noted in which top varieties (Cecile Brunner, Independence Day, Mrs. Charles E. Russell, Souvenir de Claudius Pernet) have been exposed by grafting to virus 1 and kept so for many months (as much as four years) without exhibiting symptoms at any time. In one such case, the virus was recovered from a plant of Independence Day by grafting a healthy Hollywood scion on the side opposite the point of inoculation. The Hollywood scion promptly developed symptoms showing that the virus is at least able to pass through the Independence Day.

DISSEMINATION

Beyond budding and grafting, the method of spread of the mosaic viruses in the fields and greenhouses is not known. Particular emphasis has been placed by several workers on the shipment of rootstocks as a means of dissemination. This is no doubt of some importance, particularly with virus 1 which, at the most, produces relatively inconspicuous symptoms on the common rootstocks. Surveys in the field are not likely to be of much assistance in determining the prevalence of rose mosaic 1 in the stocks unless these are already budded to the more susceptible top varieties. In the course of this work, 3 lots of *Rosa chinensis* var. *Manetti* and 1 each of *R. odorata*, *R. multiflora*, *R. Multiflora Grifferaie*, and

Ragged Robin have been used in various experiments, including grafting to healthy top varieties, without any evidence that any of them had previously been infected by mosaic 1.

Some observations indicate, on the other hand, that the budwood of the top variety has not received sufficient attention as a source of virus (13, 15). For example, in a nursery where the plants were budded in place in the nursery row, rose mosaic (2 or 3) occurred in groups of 3 to 5 consecutive plants in the row, each group representing about the number that would result from a single bud stick. Also may be cited the case of a grower of roses in greenhouses who made a particular effort about five years ago to secure mosaic-free rootstocks. This was apparently done, since these stocks have been grown at Berkeley for several years both with and without grafting to healthy top varieties and have never produced any mosaic symptoms. Nevertheless, mosaic 1 continues to be more or less prevalent in some of the varieties raised by this grower.

One grower pointed out a fact which has probably led to the selection of diseased plants, in some cases, as sources of budwood. An experienced rose grower is able to detect at an early stage the defective buds that appear on affected plants (mosaic 1). Whether or not he is aware of mosaic, these buds are removed in the hope that the plant will produce other normal buds before the cutting season is past. In a variety that is not greatly reduced in vigor by the disease, this practice leaves the affected plants at the end of the harvest season larger and more vigorous in gross appearance than adjacent healthy plants which have been heavily cut for the flowers, and leads in some cases to the singling out of these diseased plants as a source of buds for propagation.

HEAT TREATMENTS OF AFFECTED CUTTINGS

Although exposure to high temperatures has been used successfully in only a few cases (6) in inactivating virus in vegetative plant parts, this remains the only method of any particular promise. One test with negative results has been reported for rose mosaic (9). The results obtained at the California Agricultural Experiment Station with roses are negative thus far and will be treated as briefly as is feasible.

Virus 1 survived the following three treatments when the cuttings did; but many of the cuttings died.

a) Cuttings were planted in a cutting box in sand held at approximately 30° C. The cuttings were completely covered by the sand for initial periods of 11 and 26 days and then uncovered at the tip, followed in the latter case by an additional period of 53 days in the warm sand which dropped to about 28° C toward the end of the period.

b) Cuttings in moist sphagnum and wrapped in waxed paper were held for 9 and 14 days at 36° C.

c) Cuttings were immersed in water at 45° C for 15 and 30 minutes.

Cuttings exposed to an air temperature of 55° C for 30 and 60 minutes did not survive. The cut surfaces were covered by an asphalt emulsion during the treatment.

Virus 2 survived in cuttings completely covered for 11 days with moist sand at 30° C. Cuttings with the basal ends in water exposed for 15 and 30 minutes to an air temperature of 55° did not survive.

Cuttings affected by mosaic 3 immersed in water at 45° C for 45 and 90 minutes remained alive for as much as 4 weeks but all died without making any growth.

DISCUSSION

Since rose mosaic 1 seems to be the common disease of greenhouse roses capable of causing direct loss in yield of desirable flowers, and since the other diseases under discussion are sufficiently conspicuous to be more easily avoided in the selection of cuttings and budwood of both stocks and top varieties, the former is in particular need of further study. The stocks grown out of doors are soon marked, more or less, by the feeding of leafhoppers and other insects. This obscures largely or entirely the symptoms which are, at best, discernible with difficulty by any means except grafting with a known susceptible variety. More specifically, the determination of the identity and habits of the vector of mosaic 1 seems imperative for any program looking toward the maintenance of disease-free stocks.

In view of the number of distinct diseases which have emerged in the course of this work from a small number of collections, it seems probable that much is yet to be done in the separation of specific mosaic diseases of the rose and in the determination of their relation to diseases of other plants.

The adoption of the somewhat paradoxical procedure of selecting a more susceptible stock may prove advisable in order to facilitate the eradication of rose mosaic 1 by roguing. The resistance of certain species and varieties to particular diseases, however, suggests the possibility that rose stocks may eventually be found which are not even symptomless carriers of these diseases.

For the immediate future, a more careful selection of budwood seems to be the obvious way of greatly reducing mosaic 1 in roses to be grown in greenhouses. Since this disease seems to spread relatively slowly in greenhouses where insect control is consistently practiced, the roguing out of diseased plants during the first season in the greenhouse is indi-

cated. In a greenhouse where 50 per cent of the plants were infected originally, one worker has reported (1) the reduction of the disease to a minimum by roguing. Plants removed at an early stage can be replaced, or failing this the neighboring densely set plants will often occupy most of the available space or all of it.

SUMMARY

Three distinct mosaic diseases of the rose were found in central California. These are designated as rose mosaics 1, 2, and 3. Methods for distinguishing the diseases from each other are presented. In addition, roses were infected by inoculation with apple-mosaic virus and the virus of a disease of peach designated as "Winters peach mosaic."

The use of buds from diseased plants seems to be an important means of introducing the diseases.

The virus of rose mosaic 1 survived heat treatments which were near the limit of tolerance of the rose cuttings. Virus 2 withstood exposure at 30° C for 11 days.

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