

are rarely found colonizing on papayas has little bearing on the problem, as was demonstrated by Dickson *et al.* (3) for cantaloupe mosaic. Winged adults which fly from plant to plant feeding en route are considered the primary means by which DRV spreads.

Efforts to control DR have been unsuccessful. Insecticides have been useless just as they have failed to control the aphid-borne, non-persistent virus diseases of vegetable crops such as the so-called squash mosaic and potato virus Y. Isolation of papaya plantings is of some value but in recent years nearly every planting has become almost 100% infected before it was a year old. Roguing is sometimes of considerable help but, as Harkness (4) points out, "Roguing, to be even partially successful, must be started while the proportion of diseased plants is very small, and is most effective in isolated plantings". At

the present time an effective control for DR is not known.

It is likely that DRV occurs naturally in weeds or cultivated crops and that these serve as reservoirs for the virus between papaya crops. The paper describing FMR and MM presents a discussion of this possibility (2), along with a discussion of the relationship of DRV to the other viruses affecting the papaya.

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MILD MOSAIC AND FAINT MOTTLE RINGSPOT, TWO PAPAYA VIRUS DISEASES OF MINOR IMPORTANCE IN FLORIDA

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Three viruses cause diseases of papaya in Florida. A previous paper dealt with distortion ringspot (DR), the most severe of the three virus diseases (6). This paper describes the other two diseases, mild mosaic (MM) and faint mottle ringspot (FMR), and also presents some characteristics of the causative viruses. Both diseases are of minor importance, being less severe than DR and probably less widely distributed.

MILD MOSAIC

The principal symptom of MM is a mild green mottle of the foliage which is most easily seen in the younger leaves (Fig. 1). No symptoms are produced on petioles, stems or fruit. Affected plants are slightly stunted and leaf size is somewhat reduced but this would hardly be noticed unless healthy plants were nearby for close comparison. MM has little effect on fruit size or yield.

The mild mosaic virus (MMV) is transmitted readily by rubbing the juice expressed from mottled foliage onto leaves of healthy plants. Symptoms usually appear from 10 to 14 days after inoculation of large plants in the field during hot weather. When small seedlings in the greenhouse are inoculated, symptoms appear in 4 to 5 days. Initial symptoms of MM on small seedlings are clearing of the minor leaf veins and downward cupping of the blade. A green mottle becomes evident as the disease progresses and this symptom is not affected appreciably by changes in temperature.

Physical Properties of the Virus. MMV was inactivated between 73 and 76 C during a 10-minute heating period. It was infectious after a dilution of 1 to 10,000 but was inactivated at a dilution of 1 to 20,000. MMV was infectious after 187 days of aging in vitro in expressed juice at room temperature.

MMV was not transmitted to several hundred seedlings through seed produced on naturally-infected and inoculated plants.

Host Range. Hosts of MMV, determined by mechanical inoculation, were found only in the Caricaceae and Cucurbitaceae. All strains of papaya tested were susceptible. Other hosts were *Carica cauliflora*, *C. goudotiana*, *C. monoica* and

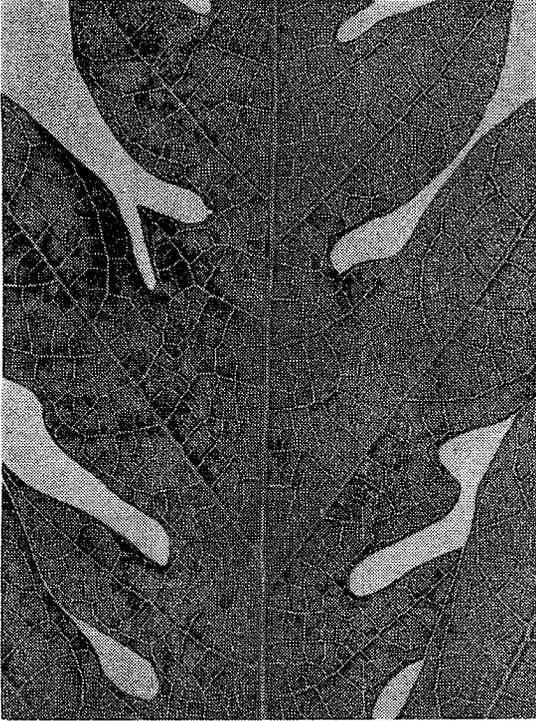


Figure 1.—Mottling of papaya leaf typical of mild mosaic.

C. canadamaricensis. MMV was lethal to *C. monoi-ca* and generally was more severe on other *Car-ica* spp. than on papaya. Of the cucurbits tested, only *Cyclanthera pedata* and *Melothria pendula* were susceptible. MMV was readily recovered

from these hosts. Cucumber, muskmelon, summer squash, watermelon, *Carica quercifolia*, *Jacaratia* spp., *Phaseolus vulgaris*, *Vigna sinensis*, *Nicotiana tabacum*, *N. glutinosa*, *Momordica charantia*, *Sicana odorifera* and *Passiflora edulis* f. *flavacarpa* were not susceptible and MMV was not recovered from them.

Aphid Transmission Tests. Repeated attempts to transmit MMV with several species of aphids were unsuccessful. The procedures used to demonstrate aphid transmission of the distortion ring-spot virus (6) were used in these tests.

FAINT MOTTLE RINGSPOT

There is much variation in symptomatology of FMR depending on plant vigor, how long the plant has been infected, temperature, and the plant to plant variation inherent within papaya types. There is considerable overlap in symptomatology of FMR and DR particularly with respect to mottling, and in petiole stem and fruit symptoms.

Initial symptoms of FMR include vein-clearing of young leaves and slight yellowing of the crown. This is followed by yellow mottle (Fig. 2) and greasy appearing streaks and rings on petioles, stems and fruit (Fig. 3). After several weeks affected plants gradually "recover" from the disease, especially during the summer months. However, a faint mottle can usually be detected upon close examination, and etching of the minor veins may be seen on the underside of the leaves. Occasionally white necrotic flecks or scattered

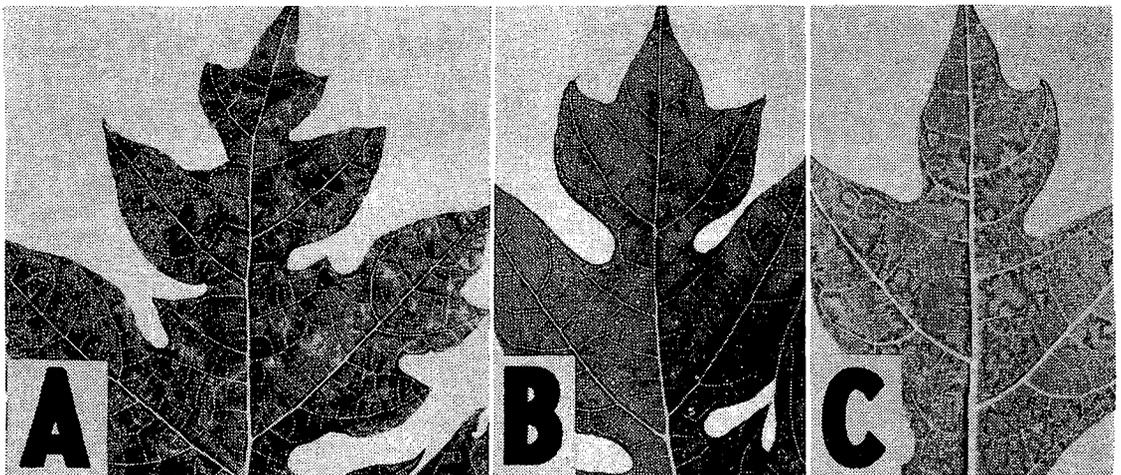


Figure 2.—Symptoms of faint mottle ringspot on papaya leaves: (A) Mottling; (B) white necrotic flecks and (C) etching seen in chronic stages of the disease.



Figure 3.—Symptoms of faint mottle ringspot on papaya fruits.

yellow spots may be seen in the blade (Fig. 2). Plants which show faint symptoms during the summer may develop yellow mottle with the return of cool weather. Symptoms on stems and fruit are usually present throughout the year but are somewhat less numerous in chronic stages of the disease. Affected plants are moderately stunted and fruit production is reduced, especially in acute stages of FMR.

Physical Properties of the Virus. FMRV was inactivated between 54 and 56 C during a 10-minute heating period. FMRV was infectious at a dilution of 1 to 500, but not after dilution of 1 to 1,000. The virus was inactivated after aging in vitro for eight hours at room temperature.

FMRV was not transmitted to several hundred seedlings through seed collected from inoculated and naturally infected plants.

Host Range. Hosts of FMRV, determined by mechanical inoculation of the virus, were found only in the Caricaceae and Cucurbitaceae. All strains of papaya tested were susceptible. Hosts in the Caricaceae were *Carica cauliflora*, *C. godotiana*, and *C. monoica*. Cucurbit hosts were muskmelon, cucumber, watermelon, summer squash, *Cyclanthera pedata* and *Melothria pendula*. The virus was readily recovered from all hosts. The following species were not susceptible and the virus was not recovered from them: *Carica canadamaricensis*, *C. quercifolia*, *Luffa cylindrica*, *Momordica charantia*, *Sicana odorifera*, *Nicotiana tabacum*, *N. glutinosa* x *tabacum*,

Phaseolus vulgaris, *Vigna sinensis*, and *Passiflora edulis* f. *flavacarpa*.

Aphid Transmission. FMRV was transmitted readily by the green peach aphid *Myzus persicae* (Sulz.). Efforts to transmit the virus with *Amphorophora sonchi* (Oestlund), *Macrosiphum ambrosiae* (Thos.) and *Aphis spiraecola* Patch were unsuccessful.* The methods used in demonstrating transmission were described previously (6).

MIXED INFECTIONS

MMV readily invaded plants previously infected with either FMRV or DRV, and both of the latter viruses invaded plants previously infected with MMV. The disease produced by either virus combination was far more severe than the disease produced by any single virus. In the field, onset of mixed infections was marked by yellowing of several leaves in the upper crown which soon abscised, leaving several inches of upper stem devoid of foliage. Plants infected with DRV + MMV usually ceased growing and died within a few weeks (Fig. 4). Infection with FMRV + MMV was less severe; new leaves were severely mottled and malformed, and petioles were only a few inches long. Such plants declined rapidly and usually succumbed within a few months. Both viruses in either mixture were readily recovered.

*The writer is grateful to Dr. A. N. Tissot for identifying the aphids.

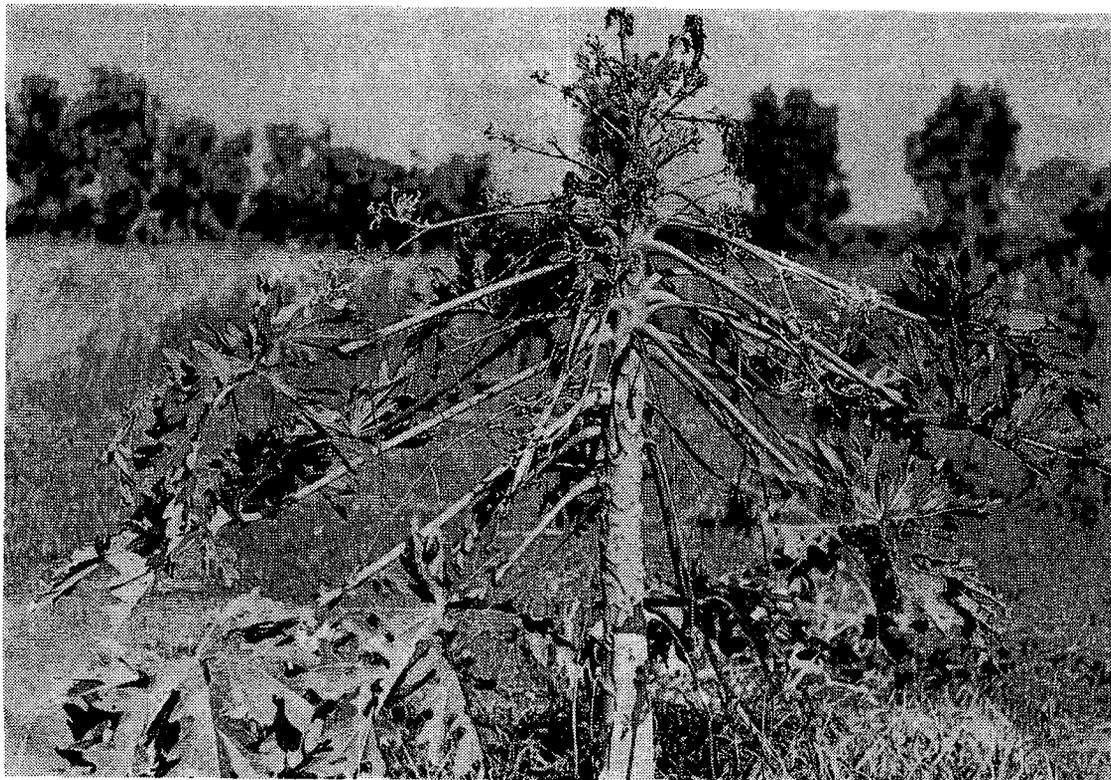


Figure 4.—Papaya showing effects of dual infection with distortion ringspot virus and mild mosaic virus.

Good evidence that mixed infections of DRV and FMRV resulted following mechanical inoculation was not obtained. Seedlings occasionally died following inoculations with DRV on one cotyledon and FMRV on the other. Since inoculation with either virus alone was not lethal, perhaps this represented an invasion of the seedling by both viruses, but evidence to prove this supposition was not secured. When older infected plants were inarched, characteristic DR symptoms eventually appeared in the top of the FMRV-infected plant, and DRV was recovered. No evidence was obtained showing that FMRV invaded plants infected with DRV when plants infected with these viruses were inarched.

DISCUSSION

FMR resembles DR in many respects and in certain stages cannot be differentiated from it. Initial symptoms are similar and infected plants pass through essentially the same sequence of symptoms during acute stages of the disease.

Differences between FMR and DR may not appear in the field for several months and then may not develop on all plants. In chronic stages of the disease DR may be identified by distorted foliage and crusty, gray-colored fruit symptoms whereas FMR tends to recover and to produce inconspicuous symptoms. FMR is most readily recognized in hot weather; DR produces its characteristic symptoms most often in cool weather.

Since FMRV and DRV are identical in host range, aphid transmission, physical properties, and in some aspects of symptomatology, it seems likely that they are closely related, but distinct strains of the same basic virus. Characteristic symptoms produced by these viruses have not varied during the twelve years they have been maintained in the greenhouse. The distinctive features of each disease have been duplicated several times by inoculating plants in the field. Differences in symptoms produced on alternate hosts indicate that these viruses are different. For example, FMRV affects *Carica monoica* more

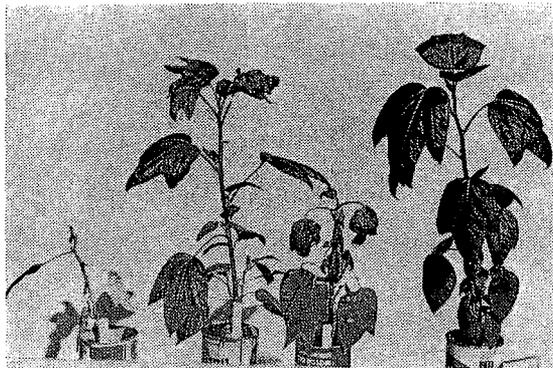


Figure 5.—Symptoms produced by papaya viruses on *Carica monoica* following inoculation, from left to right, with mild mosaic virus, distortion ringspot virus, and faint mottle ringspot virus. Healthy plant on right.

severely than does DRV (Fig. 5), a reversal of their effect on papaya.

DR and FMR are quite similar to papaya virus diseases described from other areas. They are difficult to classify because symptoms overlap and are often modified by the environment. Yet, marked similarity in symptomatology, in mechanical and aphid transmission of the causative viruses and host ranges strongly suggest that strains of one virus cause all these diseases. DR is probably identical with the papaya mosaic in Puerto Rico (2, 3, 4), and in Tanganyika (7), and the ringspot disease in Venezuela (8). Hawaiian ringspot (9), "Type B" mosaic in Cuba (1), and the mosaic from India (5) are quite similar to DR and FMR, and are very likely related to them.

MMV may be unique to Florida for it differs in essential details from papaya viruses described elsewhere. It is obviously not related to DR and FMRV since it readily invades plants previously infected with them, it is not transmitted by aphids, and differs significantly in physical properties and host range. No reference has been found to a similar disease from any other country.

The fact that the common weed, *Melothria pendula*, is susceptible to all three papaya viruses and cultivated cucurbits are susceptible to DRV and FMRV, suggests that alternate hosts may serve as reservoirs for the viruses. Observations suggest that this is the case. However, numerous weeds, many of which were symptomatic of virus infection, growing in and around infected papaya plantings have been assayed on papayas but no virus infectious to papayas was found. In one instance summer squash was interplanted with papayas with both crops showing a high incidence of virus infection. All inoculations of papaya from infected squash were negative, but DRV was readily recovered from the diseased papayas in the planting. In many inoculations the papaya has not been susceptible to any of the several viruses believed to occur naturally in cultivated cucurbits. It is unlikely that an inhibitor was involved in these failures for DRV and FMRV were readily recovered from squash and other cucurbits inoculated and infected with the papaya viruses. Thus there is no evidence that papaya viruses occur naturally on plants other than papaya but it is likely that they do.

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