A HALF CENTURY OF RESEARCH ON PSOROSIS[1]

James M. Wallace[2]
University of California Citrus Experiment Station,
Riverside, California

INTRODUCTION

The name *psorosis* is now used to designate a related group of virus diseases of citrus that have certain characteristics in common, notably the symptoms they produce on young leaves. This name was used by Swingle and Webber (*14*) in 1896, when they first described the lesion-forming disease known at that time in Florida under the general name *gummosis* and in California as *scaly bark* or *scaly bark gum disease*. Later, in 1932, Fawcett (*2*) gave the name psorosis "A" to the commonly occurring form of the disease in order to distinguish it from a less common but more active type which he described as psorosis "B."

In addition to psorosis "A" and psorosis "B," Fawcett *et al.* (*2, 6, 9, 10, 11*) have described four other types or varieties of psorosis: these are *concave gum, blind pocket, crinkly leaf,* and *infectious variegation*. The bark-lesion-forming types are known to have been present in California as early as 1891 (*4*), and these and some of the other types are now distributed throughout the important citrus-growing sections of the world.

Psorosis "A" has been a particularly important factor in citrus production in the United States. The gradual reduction in yield of affected trees and the eventual need for replacing such trees have been costly to the citrus grower (*12, 15, 18*). However, losses from psorosis can be avoided in new plantings of citrus if intelligent use is made of the knowledge that has accumulated during the past half century, largely from the studies of the late Professor Howard S. Fawcett.

We know of no insects that transmit the psorosis viruses. The amount of seed transmission disclosed experimentally has been insignificant (*20*). There is only one chief source of infection, namely, the parent tree from which buds are taken. Bud perpetuation of the disease-causing agent has been known since long before the virus nature of these diseases was discovered. In fact, Fawcett (unpublished) actually produced the disease in healthy trees in 1916 by grafting pieces of lesion bark to them. However, it was not until he discovered the leaf symptoms in 1933 and established their relationship to the bark lesions that he proved psorosis to be a virus disease (*3*).

SYMPTOMATOLOGY

Leaf Symptoms

On citrus trees infected with any of the known strains of psorosis, young-leaf symptoms appear during the growth flushes and vary greatly in extent and degree on individual trees at a given time. Small elongated cleared places of lighter color than the rest of the leaf occur in the region of the veinlets (fig. 1, *A*). The clearing or flecking may be general over the entire leaf or may occur on only parts of the leaf. At times, most leaves of suitable growth show symptoms. At other times, relatively few leaves are affected.

[1] Paper No. 1102, University of California Citrus Experiment Station, Riverside, California.
[2] Plant Pathologist, Citrus Experiment Station, Riverside.

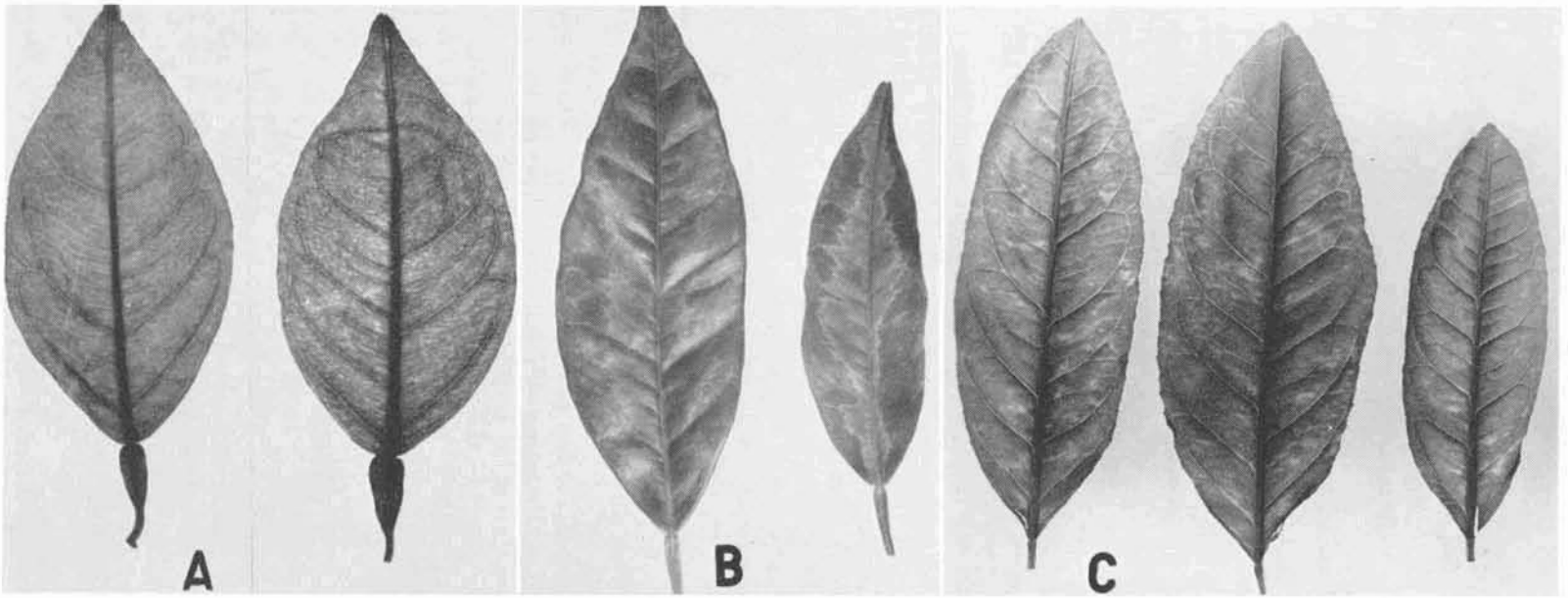

Fig. 1. Young-leaf symptoms of psorosis: A) typical veinal flecking on soft leaves of sweet orange; B) zonate or oak-leaf patterns of concave-gum psorosis on sweet orange leaves; C) young leaves of lemon with psorosis symptoms. Note the more spotted or blotchy effect on lemon leaves (C) than on sweet orange leaves (A).

Some of the small flecks are quite indistinct; others coalesce to form conspicuous blotches, especially on lemon leaves (fig. 1, *C*). The symptoms on the young leaves gradually disappear as the leaves mature. Symptoms are seen most readily when the leaf is shaded from the direct sun and viewed against the light of the sky.

With the exception of concave gum, the various types of psorosis cannot be identified on the basis of the symptoms produced on soft young leaves. In addition to the effects already described, young leaves of trees infected with the strain known as *concave gum* commonly display a zonate or oak-leaf pattern, particularly in the spring growth flush (fig. 1, *B*).

Other Symptoms

For the most part, the psorosis types are identified by other effects they induce. The psorosis-"A" and crinkly-leaf strains of the virus cause the bark lesions commonly known in California as *scaly bark*.

Sweet orange, grapefruit, and tangerine trees infected with either psorosis "A" or crinkly leaf commonly develop the typical bark lesions, but lemon and sour orange trees do not.

Psorosis "A" and psorosis "B" have been considered as being caused by closely related virus strains differing only in virulence (*2, 6, 9*). Psorosis-"B" type is not found often under natural conditions. Recent studies (*19*) indicate that the symptoms originally described for psorosis "B" are merely different manifestations of psorosis "A," resulting from infections from a particular kind of inoculum. Psorosis "B" is therefore no longer considered to be caused by a strain of virus distinct from psorosis "A."

Psorosis "A." Trees infected with psorosis "A" as a result of having originated from a bud from a diseased tree usually develop normally. They will periodically show transitory symptoms on young leaves, but bark lesions seldom appear until the trees are six years of age or older. The average age at time of the first lesion development is twelve to fifteen years. The virus is, of course, present in such trees at all times, and any progeny trees bud-propagated from them will likewise carry the virus and will eventually develop bark lesions. Prior to the discovery of the leaf symptoms (*3*), the absence of bark lesions on older trees was accepted as evidence that the trees were not infected. It is now known that many thousands of nursery trees were propagated from such carriers, and psorosis thus became widely distributed in California as well as in other citrus areas.

The histological aspects of psorosis "A" were studied in detail by Webber and Fawcett (*21*). Fawcett and Bitancourt (*6*) also studied the symptomatology of the bark-lesion-forming types of psorosis and described in detail the gum layers, accumulation of gum in the vessels, and the staining or discoloration in the wood beneath bark lesions. Bitancourt, Fawcett, and Wallace (*1*) studied the psorosis-induced wood alterations in relation to tree deterioration.

The bark lesions begin as pimples or small flakes of the outer bark, which loosen and break away from the live bark underneath (fig. 2, *A*). As the lesion advances, deeper layers of bark become disorganized and some of the tissues become impregnated with gum or gumlike materials. Scaling is more or less continuous, and the lesions increase in size. Portions of the bark die as a result of being cut off by phellogen layers which form below cells bearing the gumlike materials (*21*). As growth continues, the dead bark ruptures and eventually sloughs off in scales of various size and thickness (fig. 2, *B*), with the lesion area gradually increasing. Gum sometimes exudes from lesions, particularly from the margins of the affected area.

Soon after a bark lesion becomes visible, gum layers begin to form in the wood beneath. At intervals the embryonic layer of woody tissue immediately below the cambium is acted upon in some way so that the cells between the medullary rays are

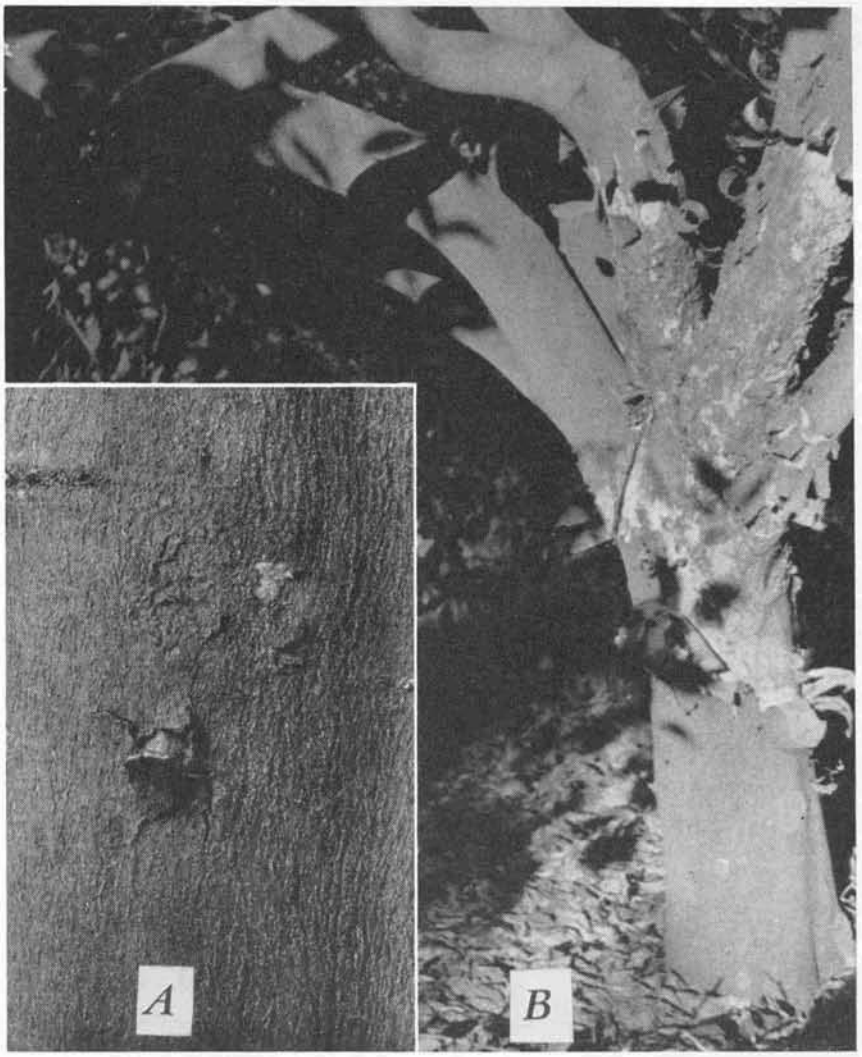

Fig. 2. Psorosis bark-lesion initiation and development on trees of sweet orange: A) initial stages of lesion; B) advanced stage of lesion after several years of activity.

forced apart and partially dissolved (fig. 3, *A*). The pockets become filled with a colorless gumlike substance. Normal wood is then laid down for some time before another gum layer is formed, but this does not follow a regular sequence. The process continues until there are many bands of normal wood alternating with thin layers of gum (fig. 3, *B*). The older layers of gum become buried deeper in the wood with each successive period of wood growth. The gum hardens as it ages and turns dark.

While the gum layers are being formed, gum appears in some of the xylem vessels and accumulates in the vicinity of the perforation plates of the vessels (fig. 3, *C*). In later stages, vessels, wood parenchyma, and medullary ray elements become impregnated with colored gum, and the wood-staining symptom of psorosis appears (fig. 3, *D*). At first, only small areas of stained wood are present, but in the wood under old and well-advanced lesions, staining becomes quite general. At this stage the number of

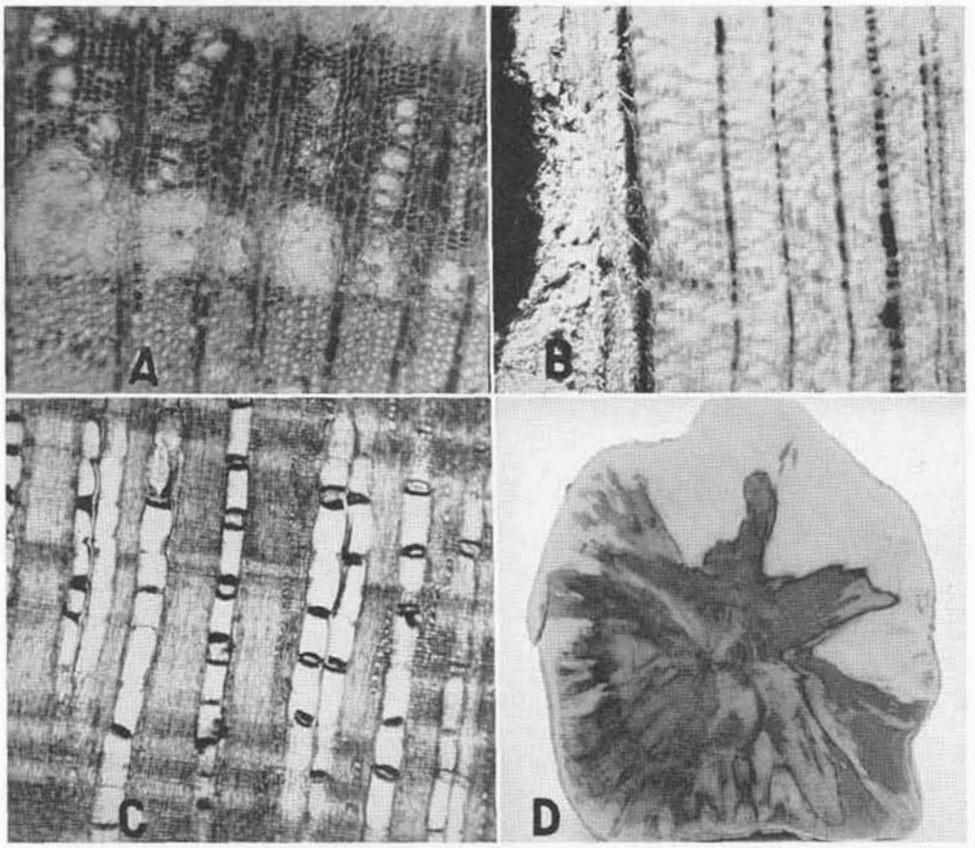

Fig. 3. Gum deposits and wood stain in xylem tissues of sweet orange beneath psorosis bark lesion: A) individual gum layer in transverse section, showing pockets of colorless gum between medullary rays; B) radial section showing series of dark-colored gum layers; C) accumulation of gum in vessels; D) transverse section through trunk of sweet orange tree (note extensive wood stain resulting from a bark lesion that had been active for many years).

functioning vessels is insufficient to supply water to the parts above, and the affected parts of the tree begin to deteriorate.

Concave Gum. In addition to the typical young-leaf symptoms and the oak-leaf pattern, the concave-gum strain of psorosis causes the formation of concavities of various sizes and numbers. The concavities remain open, and fairly normal bark covers the surface (fig. 4, *A*). Cracking of the bark often occurs in the central part or around the margins and gum appears on the surface. In the wood beneath the center of the concavities there is a somewhat limited region where growth has been almost entirely inhibited. Here thin bands of wood alternate with gum layers which can be traced from the center to the periphery of the concavity, where wood development has been normal (fig. 4, *B*).

Some of the xylem vessels in the vicinity of the concavities become plugged with gum, but not as extensively as in the case of psorosis "A." No general wood staining is present. Concavities may be few or many. Injurious effects usually appear slowly and are more pronounced when the concavities are numerous, but infected trees are sometimes stunted even though only a few concavities are present. This type of psorosis has been observed chiefly on sweet orange.

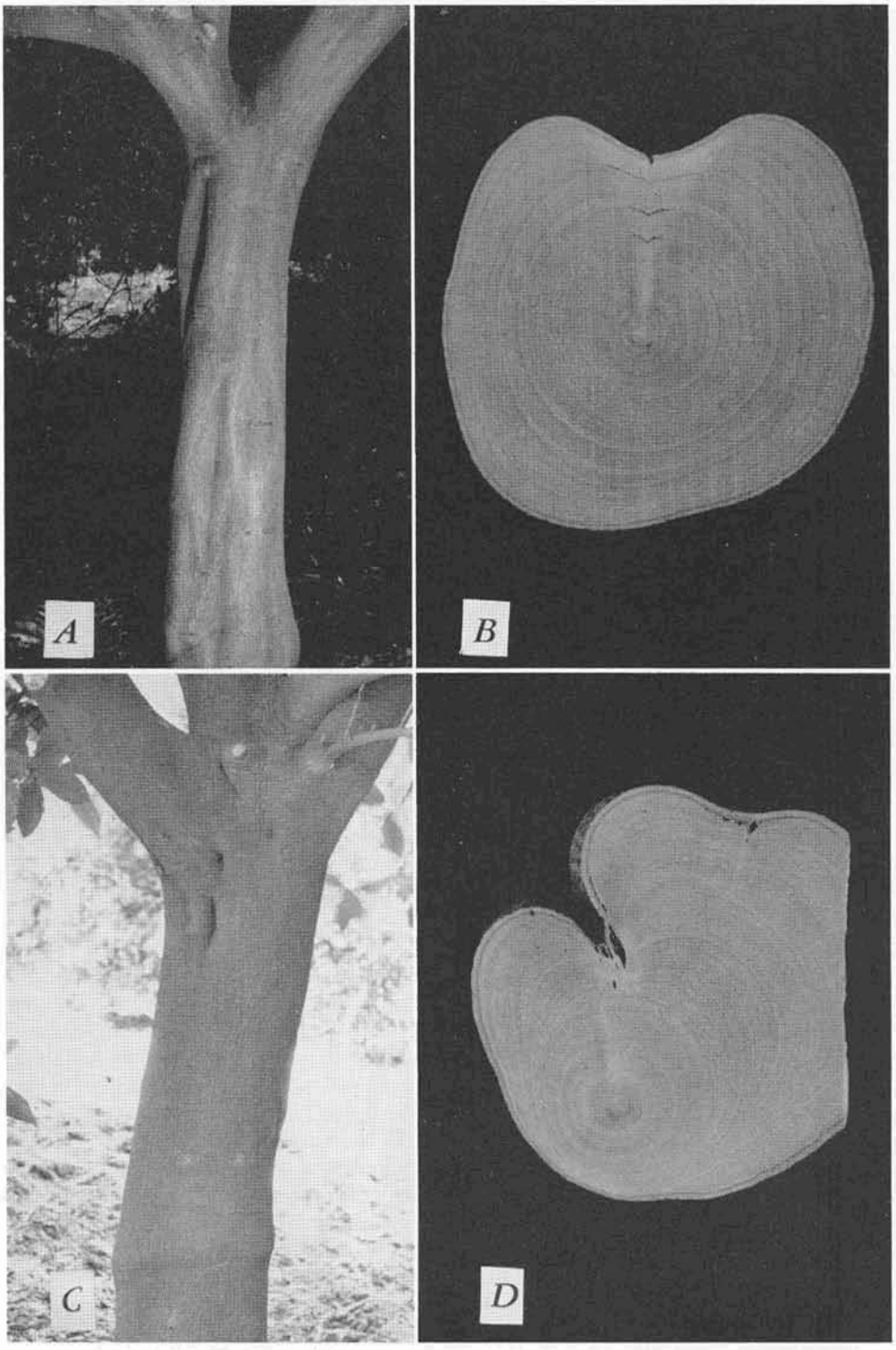

Fig. 4. Effects of concave-gum and blind-pocket strains of psorosis on bark and wood of sweet orange: A) tree trunk showing several large concave-gum concavities; B) wood section through concavity with three prominent gum layers; C) trunk of sweet orange tree with blind pockets; D) wood section showing two blind pockets in different stages of development.

Blind Pocket. Blind-pocket psorosis resembles concave-gum psorosis except that concavities of the former are more numerous and are deeper and narrower. A smaller area of wood is affected, so that as growth continues the depressions become very narrow (fig. 4, *C, D*). The point of origin is often found deep within the wood. There is usually more alteration of affected wood than is found in concave gum. Beneath the depressions one may find cores of tissue, ocherous salmon in color, and of a hard, gumlike consistency. It is not always possible to distinguish between the depresssions formed by concave gum and those formed by blind pocket, but they are considered to be caused by different virus strains because there are no oak-leaf-pattern symptoms associated with blind pocket. This strain of psorosis occurs chiefly on sweet orange but it also induces concavities on mandarin, grapefruit, and lemon.

Crinkly Leaf. Crinkly-leaf psorosis symptoms are seen chiefly on lemons, but this strain also infects other citrus. In addition to young-leaf symptoms, it causes a crinkling or blister effect, symptoms which are retained by the leaves after they become mature (fig. 5). Lemon fruits on diseased trees are often coarse and misshapen. There are no bark symptoms on lemon, but this strain of virus will cause lesions on sweet orange which are indistinguishable from those of psorosis "A."

Infectious Variegation. Infectious variegation, found principally on lemon, also induces symptoms on young leaves similar to those caused by the other psorosis strains. Symptoms resembling crinkly leaf are also found on old leaves of trees infected with infectious variegation (fig. 6). Some leaves on affected trees of lemon and sour orange are severely distorted; others are variegated. White to yellowish patterns of irregular distribution appear on some leaves. This type of psorosis, which may actually be

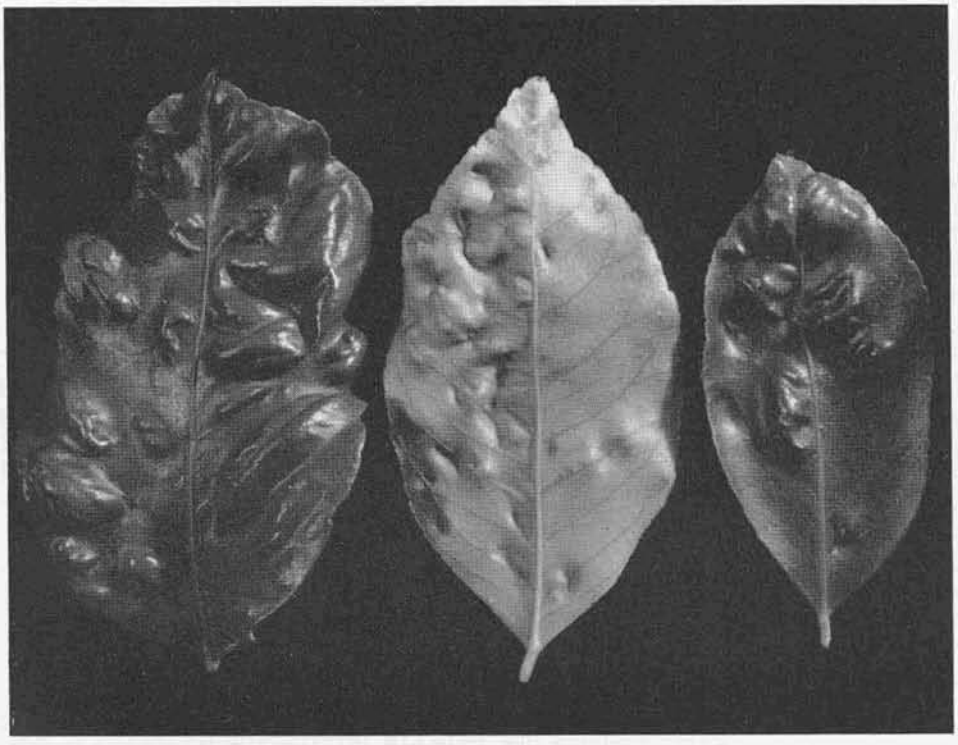

Fig. 5. Crinkly-leaf psorosis symptoms on mature leaves of lemon. The upper surfaces of the leaves have an uneven blistered appearance.