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STUDIES ON THE CAUSE AND DEVELOPMENT OF RIDGES ON LIME FRUIT

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Ridges and excrescences on lime fruit were found not to be due to the citrus bud mite, *Aceria sheldoni* (Ewing), as had been suspected. The deformity results from incomplete separation of the stamens and pistil, or from fusion of the stamens and pistil, during the development of the flower. The origin and early development of the deformity are associated with moisture in the form of fog, dew, or rain, and with the fungi *Botrytis cinerea* Pers. and *Alternaria citri* Ellis and Pierce.

H I L G A R D I A

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STUDIES ON THE CAUSE AND DEVELOPMENT OF RIDGES ON LIME FRUIT[1]

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FOR SEVERAL YEARS, 5 to 10 per cent of the commercial lime crop has been rejected for shipment by packing houses in San Diego County, California, because of characteristic ridges on the fruit. These ridges differ in appearance from those caused by fumigation with hydrocyanic acid (Sinclair and Lindgren, 1943) and occur as commonly in nonfumigated as in fumigated groves. Similar deformities, however, have resulted from injury to lemon fruit buds from heavy infestations of citrus bud mite, *Aceria sheldoni* (Ewing) (Boyce, Korsmeier, and Persing, 1942). Because of this similarity the injury has been attributed to the feeding of citrus bud mite, and measures to reduce the percentage of deformed fruit have been directed toward control of that pest. Control attempts have been limited, however, as the proved materials for citrus bud mite control are relatively toxic to lime trees.

DESCRIPTION OF DEFORMED FRUIT

The deformed fruit differs from normal limes by having one or more ridges which arise from the stem end (figs. 1, 2, and 3). The ridges may be short or extend the entire length of the fruit. Most commonly the ridges end where there is a change in the curvature of the fruit, which is normally about one third the distance from the stem toward the tip. Often at the end of the ridge there is a blunt or hooklike excrescence (figs. 3 and 4).

Lime fruits with uniform ridges are usually packed and shipped with the normal fruits. However, fruits with excrescences are not suitable for regular shipment. The excrescences are readily broken or bruised during the packing and shipping process. The broken or bruised areas are subject to fungus attack, which favors decay of the fruit during shipment and storage.

[1] Received for publication January 29, 1951.

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RELATION OF LIME RIDGES TO CITRUS BUD MITE

As citrus bud mite is known to be a serious pest on lemon groves in the districts where limes are grown commercially in San Diego County, studies were initiated to ascertain the possible relation of this pest to the ridges found on limes. The population of citrus bud mite was evaluated at monthly intervals from February to November on a lime grove at Vista and one at Carlsbad. At no time during this interval were more than 1.0 per cent of the lime buds infested with bud mite. A section of each of these groves was sprayed thoroughly at monthly intervals from March to August with two pounds of 15 per cent wettable powder of 2-(*p*-tert. butylphenoxy) isopropyl 2-chloroethyl sulfite (Aramite) per 100 gallons of spray. No infested buds were found after treatment was commenced.

The influence of the spray treatment on the per cent of ridged fruit was evaluated by harvesting separately the treated and untreated sections of each grove. Counts of the ridged and normal fruit in each section of these groves showed that the percentage of ridged fruit was not reduced as a result of the treatment.

OBSERVATIONS OF DEVELOPMENT OF FRUIT RIDGES

Field observations indicate that the ridges are initiated during the early development of the fruit. Abnormal development was evident at the flowering stage. The stamen filaments had failed to separate or were fused to the pistil (figs. 5, 6, 7, and 8). Observations indicate that these abnormalities generally result from a lack of complete differentiation of the stamen and pistil rather than a fusion after the stamen and pistil have become completely separated.

The extent to which the stamen filaments are joined to the pistil varies considerably. The stamens occasionally become an integral part of the carpel; that is, they exhibit carpelloidy. More often, however, they are united to the external surface of the ovary for varying distances from their base. In figure 5, for example, one stamen is joined to the ovary for most of its length; whereas figure 6 shows a deformed stamen filament united with the ovary to illustrate how excrescences at the end of the ridge may originate. Figure 8 shows a stamen filament attached to the ovary at the base and again near its tip. Most commonly, however, the stamen filaments are joined to the ovary near its base (fig. 7).

As the ovary develops, the stamen filaments become a part of the fruit. They remain in evidence, however, as a ridge on the fruit (figs. 1, 2, and 3). The tips of the filaments which are free from the fruit tend to fold back. This often results in a hooklike excrescence (figs. 3, 9, and 10), which is readily broken as the fruit is handled in picking, packing, and shipping.

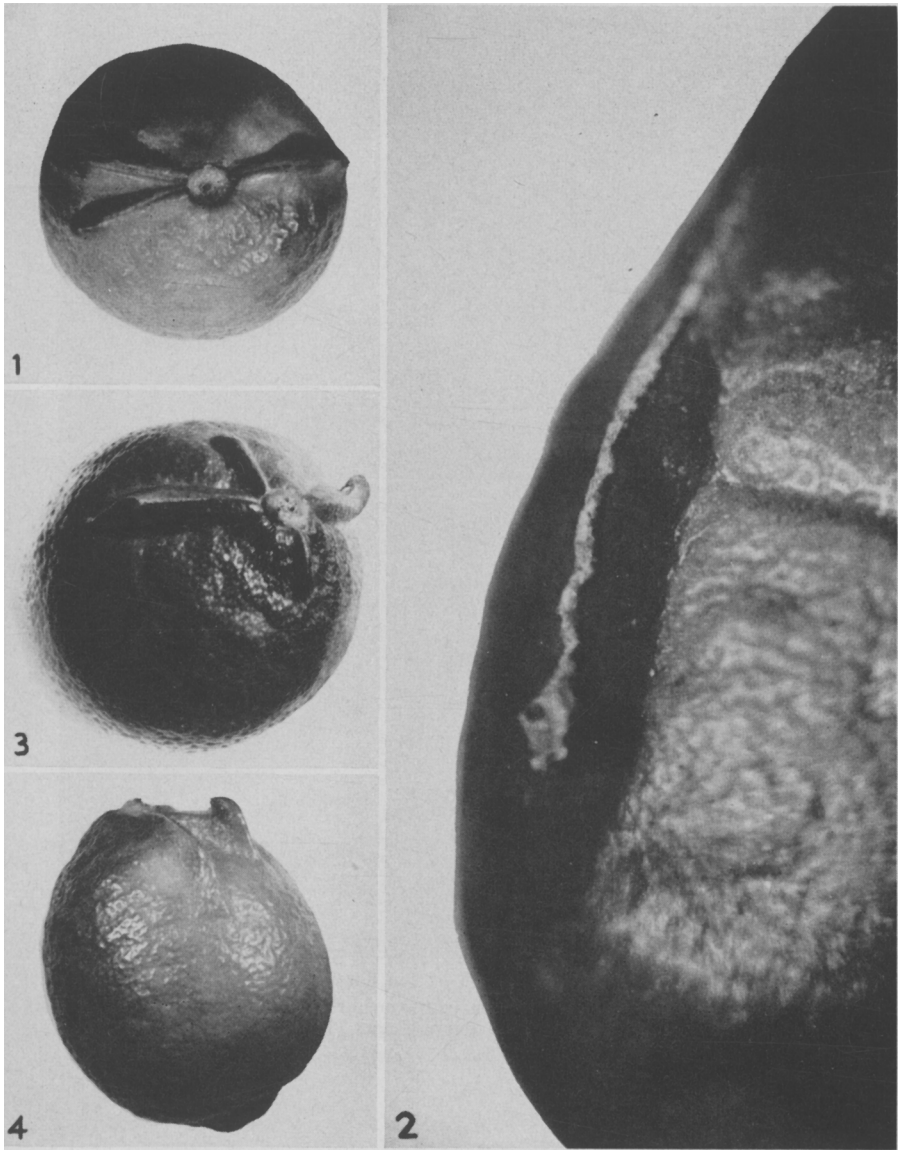

Fig. 1. Mature lime fruit showing ridges.
Fig. 2. Portion of mature lime fruit showing enlarged view of ridge. (Photomicrograph.)
Fig. 3. Mature lime fruit with ridges and hooklike excrescence.
Fig. 4. Mature lime fruit with blunt excrescence.

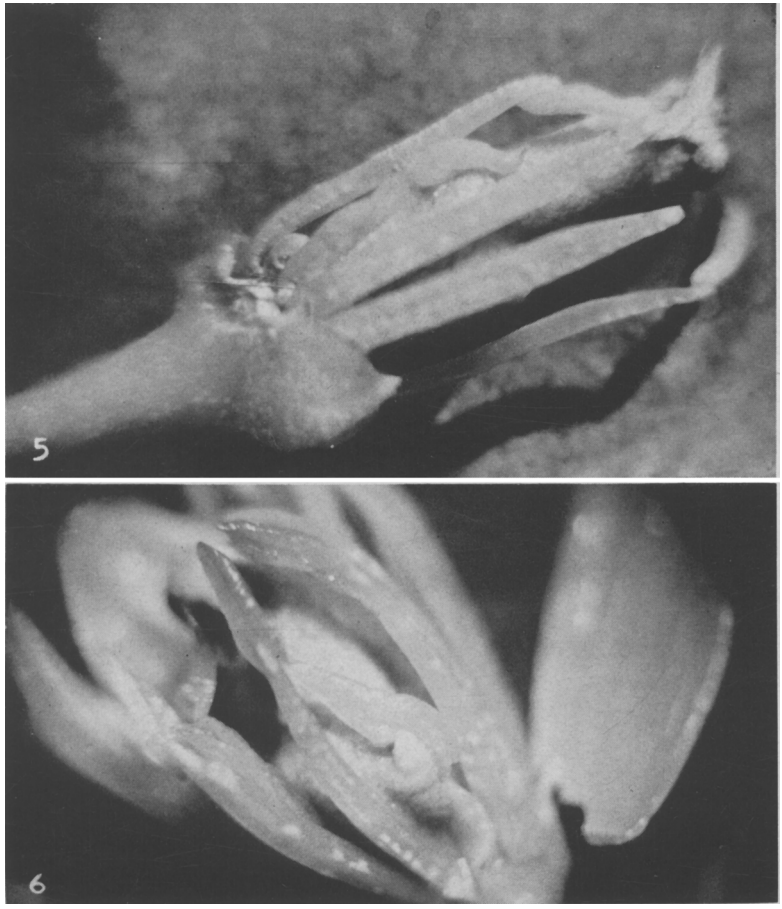

Fig. 5. Photomicrograph of lime flower (petals and most of the stamens removed) showing stamen filament incompletely differentiated from ovary for entire length of the filament.

Fig. 6. Incomplete differentiation of stamen from the ovary indicating early development of an excrescence. (Photomicrograph.)

Fig. 7. Stamen and ovary incompletely differentiated only at their base. (Photomicrograph.)

Fig. 8. Base of filament and anther of stamen incompletely differentiated or fused to ovary. (Photomicrograph.)

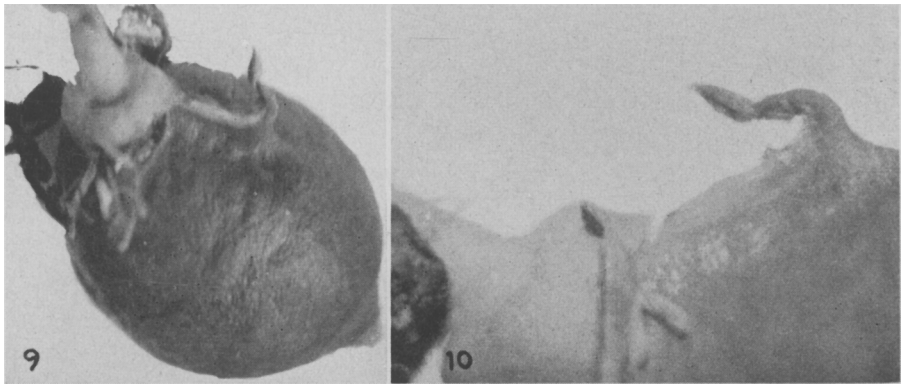

Fig. 9. Half-grown lime fruit showing ridge and hooklike excrescence on fruit resulting from incomplete differentiation of a stamen filament from young fruit.
Fig. 10. Similar to figure 9 enlarged. (Photomicrograph.)

DISCUSSION OF FACTORS RESPONSIBLE FOR RIDGES

Favorable conditions for development of deformed flowers occur during periods of damp weather. Observations made the past year indicate that the deformed flowers develop only during rainy periods or when foggy conditions or heavy dews occur. *Botrytis* and *Alternaria* fungi were found associated with these irregular flowers.[3] The fungi, *Botrytis cinerea* Pers. and *Alternaria citri* Ellis and Pierce, apparently caused heavy drop of the blossoms and young fruit. Most of the blossoms which showed the greatest irregularity turned black and dropped apparently as a result of the fungus infection. As excess blossoms were produced, this did not appear to be an important production factor.

Further study is necessary in order to ascertain the factors which initiate or influence this tendency toward incomplete differentiation of the stamens from the pistil of the lime flowers. The following possible responsible factors are suggested: (1) A natural tendency toward carpelloidy similar to that shown by papaya (Storey, 1941), which is stimulated by moisture or damp weather. (2) Moisture together with floral secretions may collect at the base of the flower sufficiently to provide favorable conditions for the incomplete differentiation of floral parts. (3) Fungus infection or products resulting from fungus activity may provide a suitable stimulus to initiate this tendency toward carpelloidy or furnish favorable conditions for the growth of the stamens to the external parts of the ovary. The separate effects of moist weather conditions and fungi could not be determined in the field because *Botrytis* and *Alternaria* were usually present on or near the deformed flowers.

SUMMARY

A characteristic deformity of lime fruit in the form of ridges and excrescences has been responsible for rejection of 5 to 10 per cent of the commercial lime crop in San Diego County, California. A description of several variations of the deformity is illustrated with photographs. Control of citrus bud mite, *Aceria sheldoni* (Ewing), by monthly treatments did not reduce the percentage of ridged fruit, which indicates that this mite was not the causative agent as had been suspected. The ridges and excrescences were observed to result from incomplete separation of the stamens and pistil, or from fusion of stamens and pistil, during the development of the flower. Moisture in the form of fog, dew, or rains, and the fungi *Botrytis cinerea* Pers. and *Alternaria citri* Ellis and Pierce, were associated with the origin and early development of these fruit deformities.

ACKNOWLEDGEMENTS

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[3] Fungi determined by L. J. Klotz and E. C. Calavan, Division of Plant Pathology, University of California, Citrus Experiment Station.

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