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Morphological Modifications Induced by Stubborn Disease on Citrus Fruits

STUBBORN DISEASE causes characteristic modifications that seem to be specific for the disease. Nevertheless, so long as no unquestionable indicator plant is available, only the presence of acorn-shaped fruits, according to certain authors, is diagnostic. We think, however, that the acorn deformation can show up in a slightly modified way and still be specific for stubborn, and that, inversely, stubborn induces on citrus fruits other modifications just as typical.

Acorn Deformation

For a long time, in the Mediterranean area, acorn deformation remained, if not rare, at least not frequent, even on trees showing all the leaf and blooming symptoms. Recently, it has shown up more and more frequently, even on varieties, like Valencia orange, considered as producing typical acorn fruits scarcely ever. For instance, in the citrus collection of the Iskenderun Experiment Station (Turkey), of 17 varieties, 16 showed acorn fruits in February, 1960, on practically each of the 15 trees of the following 16 varieties: Marocchini sanguigno, Khalili red, Valencia Late (from California), Valencia Late (from Palestine), Valencia Late (from Egypt), Ovale calabrese, Hamlin, Tarocchino, Tarocco dal muso, Tarocco liscio, Sanguigno, Washington (from Florida), Shamouti, Ananas Signorelli, Tounsi, Akçay sekerlisi. In Morocco, typical acorn fruits were found on the following orange varieties: Washington, Surprise, Golden Buckeye, Hamlin, Petite Jaffa, Shamouti, Grosse Sanguine, Tarocco, Vernia, and an unnamed variety from Florida.

On the other hand, we have not found the acorn deformation on mandarin (especially Willow-Leaf and Clementine), or on grapefruit, or on sour orange, although these species, especially the first two, show all the other stubborn symptoms. Neither has acorn deformation been seen on lemon, but this species has never presented leaf or blooming symptoms. While looking at the citrus collection of the College of Agriculture in Athens (Greece), we observed acorn deformation on all the fruits from two small trees of an undetermined variety, probably an orange-lemon hybrid.

Acorn deformation is accompanied by a complete necrosis of the tissues corresponding to the stylar half. The cells die and the cuticle becomes wrinkled and whitish, probably due to the presence of air between the disorganized cells. The intensity of this whitish stain is increased by rubbing the fruit. The necrosis of the fruit's distal hemisphere can be observed rather early, and there are cases of very young fruits (size of a hazelnut) that show rotting from June on. All these fruits drop prematurely. During October-November from the aspect of the tissues of certain fruits when they are still green, it is possible to tell which ones will show the typical acorn modification when mature. This necrosis is directly related to the phenomena of color inversion (see below) and to pronounced modifications of the pulp.

Columella Curvature ("Lopsided Fruits")

All the cases of columella curvature, yielding lopsided fruits, have been observed on trees showing other stubborn symptoms, on branches, leaves, and blooms. These trees often produce acorn fruit also. Thus, one can assume that the curvature is a symptom of stubborn, particularly since we have observed in Morocco, all the transition stages between a typical acorn fruit and a lopsided fruit, especially one stage where the fruits show laterally the acorn deformation plus necrosis. Furthermore, on that part of the lopsided fruit where the meridian is shortest, a modification of the oil gland is noticeable, identical with the one on the acorn fruits. However, it should be noticed that only the lopsided fruits have a greyish stained albedo (see below).

The columella curvature is extremely frequent on mandarin (Willow-Leaf and Clementine) and on grapefruit, in contrast to the scarcity of the acorn modification. It is also frequent on oranges.

While in Morocco, J. B. Carpenter drew our attention to the fruit deformation of Sampson tangelo affected by internal breakdown. In

studying 5 trees in the Sidi Kacem district (Morocco), we observed fruit deformations consisting of the "sun burn" symptom of internal breakdown, but also acorn deformation, very typical of stubborn, with all the transitions between sun burn fruits and acorn fruits.

Decrease of the Fruit Size

One of the effects of stubborn is a decrease in size of fruit, particularly with Valencia orange. For some time, we have noted on stubborn-affected trees, fruits of a size much smaller than normal. These fruits do not come from an out-of-season blooming, but from the normal March-April blooming; thus, they have had a sufficient growing period.

Furthermore, the epidermis of these fruits is extremely rough and makes them resemble small sour oranges. On almost all these small-sized fruits, the albedo is stained either blue or grey. This phenomenon is extremely frequent on oranges, mandarins, and grapefruit. In Turkey, Dr. Adil Cengiz, of the Plant Protection Service in Adana, has observed it on seedlings of sour orange trees, more than 100 years old, planted in the public garden of Tarsus. Looking at those trees in February, 1960, we made the same observations; the trees seem to manifest very typical symptoms of stubborn. It is interesting to note that this disease affects seedlings and that these seedlings have had a normal behaviour up to a recent period.

Coloration of the Albedo

For a long period, the abnormal color of the albedo appeared not to exist in the Mediterranean countries. The reason for this is that one looked for it only on mature and normal-sized fruits. Even today, in Morocco, blue albedo is not found on mature and normal-sized fruits, not even on fruits harvested from trees showing other symptoms of stubborn.

Since J. B. Carpenter's observations (2) and especially since his demonstrations in the Moroccan groves in November, 1959, the facts appear differently; the abnormal albedo colorations have often been noticed, but only on immature fruits and on mature but small-sized fruits. These fruits show a rough epidermis.

These observations were made in groves where hormonal treatments were never carried out and in countries where they never are used

whatever the culture might be; thus we are faced here with a phenomenon due to stubborn and not to chemical treatments, such as those mentioned by J. B. Carpenter (1).

On the other hand, the blue staining of the albedo is much less frequent than in the stubborn cases noted in Arizona and in California, although one observes it more and more frequently in the Mediterranean area; the most widespread staining is a blue-greyish color, or more frequently, a clear-cut grey. This greyish stain can be found on the lopsided part of the fruit, the one corresponding to the shortest meridian; it is almost always accompanied by an abnormal abundance of fruit vessels, which contribute to a fibrous appearance in a cross section through the albedo.

Color Inversion

In a presumably healthy fruit, the orange color of the rind starts at the stylar scar and moves towards the peduncle in such a way that, at half maturity, the peduncular hemisphere is still green whereas the stylar end is perfectly orange. In a stubborn-affected fruit, the color pattern is just the opposite; the stylar end does not color up or remains orange-green, and the peduncular hemisphere is orange-colored. This phenomenon is very clear-cut, and very marked on navel oranges, and is accompanied by profound chemical modifications of the pulp. The color inversion is a regular fact on any fruit, mainly oranges, showing acorn deformation.

In connection with the color inversion, another phenomenon may be observed on stubborn-affected blood oranges; the normally red part of the rind and flesh remains uncolored (or the color has been destroyed). This lack of color is found on acorn fruit as well as on lopsided fruit; in acorn fruit the blood-orange color is lacking only from the affected stylar part; that is, the peduncular part is normally colored on the outside and shows red flesh. In lopsided fruit, only the affected lateral part is uncolored; the opposite one is colored and has red flesh. In this way, actually bicolored fruits are obtained.

This lack of anthocyanic pigments (or their destruction) is intimately connected with the other effects of the causal agent of the disease on the fruit: acorn shape, thinning down of the epidermis, necrosis of tissues, delayed maturity of the stylar part for the acorn fruit, deviation of columella, modifications of the shape and of the number of essential oil glands for the lopsided fruit.

Another symptom, probably connected with color inversion, is displayed by all the out-of-season fruits harvested from stubborn-affected trees: the stylar half of the fruit remains green, sometimes dark green. It was observed on oranges, grapefruits, and chiefly mandarins (Clementine, Willow-Leaf, and Wilking). Similar observations were made by J. F. L. Childs while examining in November, 1959, the Sanguine mandarin trees in the citrus collection of the Marrakech Experiment Station in Morocco. On all the fruits, the stylar hemisphere was completely green whereas the peduncular hemisphere was orange-red. The limit between the two colors was extremely marked. Such fruits were perfectly ripened, and from a regular blooming, not from an out-of-season period as for the fruits described above. At first sight, the trees did not show any other stubborn symptoms, whether on leaves, shoots, or flowers; however, they grow in an area heavily contaminated by this disease.

Thus, some similarities can be observed between this "green bottom" in the Mediterranean area, and the "greening" observed by P. C. J. Oberholzer in South Africa.

Literature Cited

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